Evaluation and Characterization of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir conditions

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Thesis

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"Grandparents"

Someone who encourages all our efforts
and appreciate us wholeheartedly

Someone who listens patiently to our
never-ending doubts

Some whose eyes shine with pride and
happiness at our every little achievement

Someone who helps us smile instead of

shedding a tear

I DEDICATE MY THESIS

TO

"MY BELOVED GRANDPARENTS"

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Vegetable Science

Certificate-I

This is to certify that the thesis entitled, **–Evaluation and Characterization of Knolkhol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir Conditions"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Vegetable Science)**, to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Raziya Sultana (Regd. No. MSH-2020-326)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

(Dr. Baseerat Afroza)
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We, the members of the Advisory Committee of **Ms. Raziya Sultana (Regd. No. MSH-2020-326)** a candidate for the degree of **Master of Science in Horticulture (Vegetable Science)** have gone through the manuscript of the thesis entitled, **"Evaluation and Characterization of Knolkhol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir Conditions"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **–Evaluation and Characterization of Knolkhol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir Conditions”** submitted by **Ms. Raziya Sultana (Regd. No. MSH-2020-326)** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Vegetable Science)** was examined and approved by the Advisory Committee and External Examiner on …………………

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ABSTRACT

The present investigation entitled –**Evaluation and characterization of Knol-khol (*Brassica oleracea* var. *gongylodes* L. under Kashmir conditions*)"*** was carried out at the Experimental field, Division of Vegetable Science, SKUAST-K, Shalimar during Rabi season 2021-22. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and plant spacing of 30 cm ×30 cm for thirty genotypes including three checks, Pusa Virat, Purple Vienna and White Vienna. Observations were recorded for various quantitative and quality traits. Based on descriptor traits indicated wide variability with respect to petiole attitude, leaf color, leaf shape, leaf waxiness, petiole crossing, stem shape and stem color. Analysis of variance revealed significant differences among genotypes for all the traits. The estimates of phenotypic coefficient of variance were slightly higher than the corresponding genotypic coefficient of variance for all the characters studied indicating little influence of environment in the expression of these traits. The highest phenotypic and genotypic coefficient of variation were observed for yield per hectare (q) (54.50, 54.27). High heritability coupled with high genetic gain was recorded for yield per hectare (q) (0.99 and 93.07), indicating that the heritability is most likely due to additive gene effects and thus the chances of fixing this trait by selection are more. The estimates of heritability in broad sense were high for all the traits. Correlation studies indicated that net stem weight followed by gross stem weight, petiole length, stem breadth, internode length and number of leaf whorls had significant positive correlation with yield per hectare. Path coefficient analysis showed that number of leaf whorls followed by plant height, net stem weight and stem length had highest direct effects on the yield per hectare. Based on Mahalanobis D^2 statistics, 30 genotypes were grouped into eleven clusters. Maximum number of 6 genotypes were included in cluster II followed by cluster I with 5 genotypes. Highest intra cluster distance was in cluster V and inter cluster distance (D^2) was maximum between cluster XI and cluster IV, indicating that the genotypes in these clusters are genetically very diverse hence, can be used as parents in any breeding programme to get higher heterotic effects. The maximum plant height was shown in genotype SK-KK-64 (63.96 cm), maximum gross stem weight per plant was shown in genotype SK-KK-14 (583.76 g), maximum yield per hectare was observed in genotype SK-KK-14 (246.04 q), maximum seed yield per hectare was observed in genotype SK-KK-90 (231.84 kg) and minimum days to 50% harvest was observed in genotype White Vienna (40.51 days) and minimum days to 50% flowering was observed in genotype SK-KK-23 (120.77 days). For quality attributing traits, the highest total chlorophyll content was recorded in White Vienna (146.94 mg/100g), the highest Vitamin C content in knob was recorded in genotype SK-KK-123 (74.71 mg/100g) and highest total soluble solid content in knob was recorded in genotype SK-KK-64 (8.46 ºB). Performance of the experimental material indicated that SK-KK-14, SK-KK-23, SK-KK-80, SK-KK-90 and SK-KK-64, Pusa Virat, Purple Vienna and White Vienna were important with respect to quantitative and quality traits.

Key words: Descriptor, Variance, Heritability, Genetic Advance, Correlation coefficient analysis, Path analysis, Diversity analysis, *Brassica oleracea* var. *gongylodes.*

Signature of Student | Signature of Major Advisor

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Chapter-1

INTRODUCTION

Knol-khol is a biennial cool season vegetable, originated from the wild cabbage (*Brassica oleracea* spp. *oleracea* L.). Knol-khol (*Brassica oleracea* var *gongylodes* L.) with chromosome no. 2n=2x=18, belongs to family *Brassicaceae* and is close relative of cabbage and cauliflower. Its primary Centre of origin is in Mediterranean region (Choudhary, 1967). Itis also known as kohlrabi (German word) i.e., cabbage turnip, since it resemblesan above ground turnip. Among the cole crops, it is comparatively hardy and short duration crop. The cultivation of knol-khol was practiced in Northern Europe in 15^{th} century (Boswell, 1949; Helm, 1963). It has been cultivated by Romans since 600 B.C. (Bose and Som, 1986). It was introduced in India during 18^{th} century and is now cultivated commonly during winter season in several parts of the country.

Knol-khol is a biennial plant takes two years to complete its life cycle but is grown as annual for consumption. In the first year, the plant grows and stores the food in their roots. In the second year, it is left in the ground or replanted and comes into flowering during spring and set seeds (Selsam and Jerome, 1971).

Knol-khol is a popular winter vegetable that gets its name from the knob (tuber) that forms when stem tissue above the cotyledons thickens. (Thamburaj and Singh, 2016). The formation of knob is best seen at the temperature between 15-18°C. The fleshy turnip-like enlargement of stem grows totally above the ground. This knob is harvested for human consumption as raw or cooked vegetable with young leaves being used in some areas. The stem expands and stores edible food, particularly starch and sugars, with a delicate flavor and texture (Singh, 1989). Knobs are either used as cooked or as boiled vegetable. It is also cut into small pieces and used as salad. Leaves are also used in the preparation of soup and pickle. Knob is green or violetin color and generally, round to flat round.

In India, Knol-khol is widely grown in Jammu & Kashmir, West Bengal and to a limited extent as a rare exotic vegetable in some parts of Maharashtra, Assam, Uttar Pradesh, and Punjab (Thamburaj and Singh, 2016). Of late, demand for Knol-khol has gained momentum in National Capital Region in Delhi and adjoining state because of its wholesome utility as fresh vegetable and value addition products which support the food needs of the people. In Jammu and Kashmir, it is a popular vegetable both among rich and poor; grown in almost all kitchen gardens and as a commercial crop around cities and towns. In Kashmir, it is cultivated on an area of 3456.6 ha with production of 103698.6 MT (Anonymous, 2022) and is in great demand throughout the year for its varied size of coloured knobs and leaves. In the eastern part of West Bengal and Bangladesh, it is called
ol kopi. In the Kashmir valley it is known as_'monj-hakh', 'monj' being the knob and 'hakh' being the leafy part. There is a tremendous scope of knol-khol production in Kashmir region particularly in the mid hills of Jammu and Kashmir due to highly favourable climatic conditions with mild agroclimatic conditions suited for its cultivation as well as seed production (Bhushan *et al*, 2010).

Knol-khol contains 21 kcal energy, 87 g moisture, 1.1 g protein, 3.8 g carbohydrate, 1.5 g dietary fibre, 35 mg phosphorous, 20 mg calcium, 1.54 mg iron, beta-carotene 21 mcg, 85 mg vitamin C, 33 mg magnesium, 112 mg sodium, potassium 37mg per 100 g of edible portion (Pathakamuri, 2020). Knol-khol has also gained popularity due to high ascorbic acid and potassium content combined with a high dietary fibre and low amount of lipid content (Cosic *et al.*, 2013). The consumption of Knol-khol has increased after the discovery of the presence of glucosinates and sulphoraphane, the compounds having strong anti-carcinogenic properties (Johnson, 2002). Knol-khol is also an important source of fibres (including pectin and cellulose) and phenolics (Harbaum *et al.*, 2007). Knol-khol juice extract is known to have hypoglycemic effect andantioxidant activity in Type 2 diabetic patients (Selvakumar *et al.,* 2017). The crop has tremendous medicinal properties against acidosis, asthma, cancer, cholesterol level, heart problems, indigestion, muscle and nerve malfunctions, prostate and colon cancer, skin problems and obesity etc. (Chauhan *et al*., 2016).

Knol-khol is a highly cross-pollinated crop which require cool climate for seed production. Genetic variability created either through natural processes or through crop breeding is essential for generating new gene complexes for realizing higher economic yield quality and resistance to biotic and abiotic stresses. Selection is perhaps the most important activity of all plant breeding programmes, the effectiveness of which in turn depends upon the range of genetic diversity existing already in the population in respect of economic characters. The presence of unique genetic characteristics distinguishes members of a given population from those of any other population. Genetic diversity is, therefore, a key component of conservation efforts associated with population management (Andayani *et al*., 2001).

Breeders can use the evaluation or characterization process to improve their crops. The key characteristics of the germplasm collected or assembled and introduced are determined by assessing it with morpho-agronomic descriptor. Breeders can benefit from the characterization and evaluation of genetic resources since it can provide them with vital knowledge on how to use genetic resources effectively in breeding programmes. The collection and evaluation of germplasm, especially land races, opens a lot of possibilities for selecting optimal kinds for any given region.

Genetic diversity is critical for identifying the best genotypes for making rapid progress in desirable traits and for selecting the most diverse parents for future breeding efforts. The analysis of a crop using many criteria might reveal the degree of variability present in the crop. The study of genetic variability exposes the variety in several quantitative and quality criteria. Genetic factors, environmental variables, mutation agents, or biological agents may all contribute to this diversity. As a result, it is critical to investigate the level of genetic variability available, as the success of selection is determined by the degree of genetic variability contained in the germplasm and its heritability.

The relative performance of genotypes often changes from one environment to another, resulting in the occurrence of Genotype × Environment interaction. A large Genotype × Environment effect poses a major problem of relating phenotypic performance to genetic constitution and makes it difficult to decide which genotypes should be selected. It is therefore important to understand the nature of G × E interaction for screening and selection of genotypes in an efficient manner. Genotypes × Environment interaction is expected to play an important role in the performance of genotypes under diverse environmental conditions besides their individual effects as reported by Samnotra *et al.* (2011) in chilli.

Yield is the most important parameter that a plant breeder must consider while trying to develop superior cultivars of any crop. However, yield is a polygenic feature that is heavily influenced by the environment. As it is a complicated trait that is dependent on multiple factors, genotyping based just on the yield parameter is unlikely to be effective. As a result, a plant breeder can ensure efficient selection by using genetic parameters such as genetic coefficient of variation, heritability, and genetic progress. Knowledge of the relationships between quantitative features, particularly yield and its attributes, is quite useful throughout the selection process.

Keeping in view the importance of the crop, lack of sufficient information on genetic diversity, variability, and correlation coefficient analysis in Knol-khol under the climatic conditions of Kashmir and in other parts of India, it becomes imperative to evaluate Knol-khol germplasm for its utilization in breeding programme, to generate information on genetic diversity and to identify superior parents with desirable yield and quality traits.

The present investigation was conducted to evaluate Knol-khol germplasm collected from diverse regions of Kashmir valley, with following objectives:

1. To evaluate and characterize Knol-khol genotypes using NBPGR descriptor.
2. To identify best performing genotypes among the population.

Chapter - 2

REVIEW OF LITERATURE

The understanding of magnitude and nature of variability, the extent to which a character is heritable and the indirect and direct effects of components on yield including their interrelationships, has been found very important for the improvement of yield and its components in vegetables. Some research work has been done in India and its related crops on genetic variability and divergence. However, the available literature pertaining to different aspects of the present study with respect to knol-khol and other cole crops has been reviewed in the present chapter under the following heads:

2.1 Variability

2.2 Heritability and genetic advance

2.3 Correlation and Path coefficient analysis

2.4 Genetic divergence

2.1 Variability

For any efficient plant improvement programme, the existence of sufficient genetic variability in the population is a prerequisite and selection are perhaps the most important activity which is made based on phenotype in all plant breeding programmes. The continuous variation exhibited by a quantitative trait includes the heritable and the non-heritable components, while the heritable may be the consequence of genotype, the non-heritable part is mostly due to environmental factors (Fisher, 1918). Partitioning of total variability into its heritable and non-heritable components is therefore, of paramount importance in understanding the genetic makeup of any breeding material under improvement and estimation of genetic diversity present in germplasm resources for their efficient utilization. Subsequently, several other workers have also discovered several techniques for the estimation of components of variance (Wright, 1921; Lush, 1940; Robinson *et al.*, 1951). Moreover, there is scanty of literature available regarding the variability present in knolkhol and related crops. It is therefore, important to assess the relative magnitude of components of variability in the present germplasm.

Kumar *et al*. (2011) studied genetic variability for quantitative and quality traits in early maturing Indian cauliflowers and observed that the highest estimates of GCV were observed for duration of curd availability whereas, the highest heritability was recorded for days to 50% curd formation. High heritability along with high genetic advance as per cent mean was estimated for curd compactness, net curd weight and vitamin C content.

Singh *et al.* (2011) studied the genetic variability for antioxidants and horticultural traits in cabbage and found that the phenotypic and genotypic coefficients of variation were high for carotenoids, stalk length, head compactness, gross plant weight, net head weight, dry matter, core length, plant height and equatorial diameter and low for days to 50% maturity, number of non-wrapper leaves, frame spread and ascorbic acid. Moderate to high heritability was evident for all the traits and was accompanied with high genetic advance for carotenoids, dry matter, plant height, gross plant weight, net head weight, stalk length, core length and head compactness which show the presence of additive gene action.

Khan *et al*. (2012) found tremendous variability for all the characters studied in forty kale genotypes. High heritability and high genetic advance revealed in plant height followed by leaf thickness, stem thickness, leaf number and leaf weight. It was due to additive gene effect. High heritability with moderate to low genetic advance in plant spread followed by leaf length, lamina length, leaf breadth and duration of picking. Hybridization followed by selection could be used for future breeding programmes.

Singh *et al*. (2013) evaluated sixteen genotypes of cauliflower to study the magnitude of genetic variability for growth, yield and quality traits. The estimate of high heritability (broad sense) was observed for two traits viz., curd weight without guard leaves and vitamin C while the moderate heritability was observed for stem diameter. The high genetic advance as per cent of mean was showed by curd weight with guard leaves while the lowest showed by leaves per plant. High heritability coupled with high genetic advance was observed for curd weight with guard leaves. The genotypes Pusa Snowball K-1 showed high genotypic co-efficient of variability for vitamin C followed by Pusa Sharad and Pusa Hybrid-2 while the genotype K-1 showed low genotypic and phenotypic co-efficient of variability for number of leaves per plant.

Mehra and Singh (2013) evaluated seven germplasm of cauliflower and the results revealed that the genotypic and phenotypic coefficient of variation was lowest in days to 50 per cent curd initiation. Low heritability and genetic advance were observed for curd depth. While, the plant diameter showed highest heritability with medium genetic advance and moderate genetic advance as percentage of mean.

Meena *et al.* (2014) evaluated thirty diverse cabbage genotypes and revealed that the highest estimates of PCV and GCV were recorded for stalk length followed by core length and low estimates of PCV and GCV were recorded for leaf width followed by polar length and days to maturity. A high estimate of heritability was noticed for yield followed by leaf length and equatorial length. High genetic gain (%) was observed for yield whereas it was low for days to maturity and polar length. Positive and significant association of yield was observed for all the characters except days to maturity and stalk length at both genotypic and phenotypic levels. The gross weight, leaf length, stalk length and head weight had maximum direct effect on yield followed by number of non-wrapper leaves and equatorial length.

Chittora and Singh (2015) investigated the genetic variability of forty early cauliflower genotypes for several features. PCF-95 produced the highest curd yield per acre (271.87 q), but PCF-101 matured earliest (115.33 days). For net curd weight, marketable curd weight, curd yield per hectare, harvest index, and gross plant weight, high levels of phenotypic and genotypic coefficients of variation (PCV and GCV), broad sense heritability, and genetic advance as a percent of mean were observed. Days to curd initiation and days to curd maturity, on the other hand, had the lowest coefficient of variation, heritability, and genetic advance.

Gaur and Singh (2016) noticed considerable variances among genotypes, while studying genetic variability in cauliflower indicated that sufficient variation for yield and quality traits. They discovered that overall PCV values were greater than GCV values, with highest GCV estimations for the curd size index (18.86) followed by marketable curd weight (15.64) and the highest heritability along with high genetic advance as per cent of mean was estimated for plant diameter, curd size index, marketable curd weight, net curd weight, and total yield.

In a study conducted by Manaware *et al.* (2017) for growth and yield traits in Cauliflower (*Brassica oleracea* var. *botrytis* L.) high genotypic coefficient of variation was noted for curd length, curd circumference, core length, curd width, net curd weight, curd yield per hectare, marketable curd yield, curd yield per plot, curd weight and total plant weight and low genotypic coefficients of variation was observed for characters like stalk length at 45 DAT, stalk length at 30 DAT, days to harvest and number of leaves per plant at 15 DAT. The high value of heritability (broad sense) was recorded for curd length, days to harvest, days to curd initiation, curd circumference, days to 50% curd formation, number of leaves per plant at 45 DAT, curd yield per hectare, marketable curd yield, curd yield per plot, core length, curd weight, total plant weight, number of leaves per plant at 30 DAT, curd width and net curd weight. Genetic advance as percentage of mean ranged between 13.84% for stalk length at 45 DAT to 103.65% for curd length. The highest estimate of genetic advance as percentage of mean was recorded for curd length followed by curd circumference, core length, curd width, curd yield per hectare, curd yield per plot, marketable curd yield, net curd weight, curd weight and total plant weight.

Chatterjee *et al*. (2018) evaluated twenty cauliflower genotypes from the mid-late and late groups for ten significant horticultural traits. For variability traits, phenotypic coefficients of variation were greater than corresponding genotypic coefficients of variation. Leaf number per plant (19.12 %), curd depth (15.76 %), plant height (20.85 %), leaf size index (19.44 %), curd size index (26.51 %), gross weight per plant (19.56 %), and marketable yield per plant all had GCV estimates in the moderate range. The curd size index had high heritability (>80%) and a high genetic gain (>50%), whereas traits like leaf number per plant, curd depth, leaf size index, gross weight per plant and marketable yield per plant had a high heritability and moderate genetic gain.

Dolkar *et al.* (2018) in another study conducted on Knol-khol that the analysis of variance depicted significant variation among the genotypes for all traits, indicating that there was enough genetic variation among the genotypes. SJKK04, G-40 and Green Gold recorded the yields which were comparable to Early Super White Vienna, which had the highest yield among the genotypes investigated. In terms of number of leaves per plant, net knob weight per plant and gross knob weight per plant, SJKK-04 proved to be one of the best performers. Early Super White Vienna had the largest marketable knob diameter and took the shortest time to reach commercial knob maturity, whereas Pusa Virat had the shortest stalk and petiole lengths.

Sharma *et al.* (2018) evaluated twenty-five genotypes of cauliflower including Madhuri as check for variability, heritability, and genetic advance in late maturing group of cauliflowers. High estimates of PCV and GCV were observed for curd solidity indicating that there is substantial variability ensuring ample scope for improvement of this trait through selection. High heritability coupled with high genetic advance was observed for ascorbic acid content and curd solidity.

Shruthy and Celine (2018) studied genetic variability in cauliflower varieties. It was reported that NS 60N outperformed G 45 in terms of curd yield, depth, diameter, and curd size index. Himshort was the earliest variety followed by NS 60N, with Himpriya-60 outperforming the others in terms of plant height, leaves per plant, gross plant weight, leaf length, leaf breadth and leaf size. Curd compactness and curd size index had high phenotypic and genotypic coefficients of variation, whereas gross plant weight had high heritability and genetic advance. NS 60N, G 45, White Snow, Himpriya 60 and Pusa Meghna were the top-ranking varieties based on the selection index.

Gariya *et al*. (2019) studied twenty-two Cauliflower genotypes to determine the nature and extent of variability, heritability, and genetic progress as a percentage of mean for a range of horticultural variables. Golden Agahani, Pusa Snowball, Pusa Deepali, Poosi, Haridwar Local, KT-9, Faizabad Local, Rajasthan Local, Pant Gobhi-3 had the largest curd weight and outperformed the check cultivar Pusa Himjyoti in terms of other horticultural traits. For all the traits studied, phenotypic coefficient of variation (PCV) was higher than corresponding genotypic coefficient of variation (GCV). For all the traits, high heritability (broad sense) and high genetic progress as percent of mean were observed.

Kumar *et al.* (2019) studied eight cauliflower genotypes for genetic variability, heritability and genetic advance for plant height at harvest (cm) followed by number of leaves per plant, stalk length (cm), gross curd weight (g), marketable curd weight (g), net curd weight (g), curd depth (cm), curd diameter (cm), curd size index (cm^2), days to 50% curd initiation, days to 50% curd maturity, days to 1st flowering, days to 50% flowering, harvest index (%) and curd yield (t/ha) and revealed that PCV was larger than corresponding GCV for all characteristics indicating the presence of an environmental effect on trait expression.

In another study conducted on cabbage, Shrestha (2019) reported that variety Wonder ball was highly uniform, vigorous, less susceptible to insect pests and disease and had significantly higher yield (71.7 t/ha), average head weight (1622 g), early maturity (95 days), freshness (4.0), and market preference (4.0) followed by widely grown cultivar Green Coronet with yield (57.91 t/ha), average head weight (1358 g), days to harvest (114 days), freshness (3.0), and market preference (4.0) and Green challenger with yield (57.77 t/ha), an average head weight (1387 g) an earlier harvestable period of 95 days, freshness of 4.0 and market preference (4.0).

Brito *et al*. (2020) studied genetic parameters, selection gains, and genotypic correlations in thirty-three kale half-siblings for various characters. The traits assessed included plant height, stem diameter, leaf length, petiole length, diameter of petiole base, diameter of petiole medium, number of shoots, fresh mass per leaf and leaf yield. Direct selection in the number of leaves yields the largest anticipated gains. The best indirect selection was found in leaf production, and higher correlations between number of leaves with the leaf yield and diameter of the stem were found.

Wudneh (2020) studied ethiopian kale accession for various traits. For all traits except days to second leaf picking, the analysis of variance revealed highly significant differences ($p<0.01$) among accessions. For the number of leaves per plant, fresh leaf weight, dry leaf matter content, fresh biomass and leaf yield, high genotypic and phenotypic coefficients of variation were estimated. The number of leaves per plant, fresh leaf weight, dry leaf matter content, leaf width, leaf petiole length, leaf petiole thickness, fresh biomass and leaf yield showed high broad sense heritability and high genetic advance as a percent of mean.

In a study conducted by Meena *et al*. (2021) in Knol-khol revealed that the highest plant height (17.59 cm and 29.60 cm), number of leaves (11.50 and 19.00), leaf length (12.50 cm and 24.43 cm) and leaf width (10.32 cm and 26.70 cm) were found in White Vienna at 30 DAT & at harvest respectively. The cultivar Palam Tender Knob had a plant spread of 29.80 cm and non-significant variations were found with respect to stem girth, days to knob initiation and knob harvest. The lowest values of growth characteristics were observed in Pusa Virat.

Pramila *et al*. (2021) studied fifteen cauliflower genotypes to determine the extent of genetic variability, heritability, and genetic advance regarding fourteen quantitative characters. According to the findings of this study, PCV was higher than GCV for all traits, indicating the presence of an environmental effect on trait expression. Additive gene was governed for number of leaves, leaf blade width, net curd weight, gross curd weight, curd width, harvest index, and total yield and can be effectively improved through selection and high heritability was observed in combination with high genetic advance.

Tiwari *et al*. (2022) evaluated the performance of locally available commercial cultivars of cabbage. Among the test cultivars, Green Express outperformed cultivar Royal Ball BC-51 and cultivar Blue Jayes in terms of growth parameters, marketable yield (2.62 kg/m^2), and biological yield (3.47 kg/m^2). The cultivar Royal Ball BC-86 was also found to be the second highest performing cultivar after the cultivar Green Express. In comparison to cultivar Blue Jayes (155.0 days), head of cultivar Green express reached harvest maturity (149.25 days) one week earlier.

2.2 Heritability and genetic advance

Heritability has been widely used in determining the extent to which a character may be passed on from parents to offspring. Heritability is a metric used to assess the genetic compatibility of parents and offspring. Lush (1940) introduced the idea of heritability and defined it broadly as the percentage of genetic variation to total or phenotypic variance. Heritability was defined by Robinson *et al.* (1949) as the additive genetic variance expressed as a percentage of the total variation. For making wise choices, high heritability and high genetic gain are essential. According to Johnson *et al.* (1955), genetic advance should be considered along with heritability when streamlining the coherent selection breeding programme even though estimates of heritability without genetic advance would not be of practical importance in selection based on phenotypic appearance.

Soni *et al*. (2013) evaluated heritability and genetic advance in sixteen genotypes of cabbage. High heritability in broad sense was observed for vitamin C, days to maturity, core length, head weight, yield, leaf width and leaf length and moderate heritability for plant height, equatorial length, head polar diameter, stalk length, plant spread and number of non-wrapper leaves. Genetic advance as percentage of mean varied from 6.04% - 50.09% for plant spread and vitamin C content, respectively.

Santhosha *et al*. (2015) similar effort was made to assess the early cauliflower (*Brassica oleracea* var. *botrytis* L.) germplasm under tropical conditions and observed that parameters such as plant height, leaf weight, curd size, net curd weight, net plot yield, yield per hectare, protein, vitamin C and marketable curd weight showed great variability and strong genetic advance, showing that these characters are controlled by additive gene action. Therefore, it was determined that direct selection may be used to improve early cauliflower for these traits.

Chura *et al.* (2016) studied heritability (broad sense) and genetic advancement in nine genotypes of cabbage and observed high heritability for yield, head width, days to 50% maturity, polar diameter, stalk length, head length, harvest index and biological yield. A high heritability (h^2) and genetic advancement was observed ranging from 16.74 % for harvest index to 0.58 % for net head weight.

Dolkar *et al*. (2018) studied heritability and genetic advance in knolkhol and observed that for all the quality parameters, high heritability (>70%) was predicted, but marketable knob weight per plant heritability was projected to be moderate. For beta carotene content of knob and marketable knob weight per plant strong genetic progress as a percentage of mean along with moderate to high heritability were obtained. For ascorbic acid content of knob and leaves and beta carotene content of leaves moderate to high heritability and moderate genetic advance were revealed.

2.3 Correlation and path coefficient analysis

Correlation studies are made mainly to measure the mutual relationship between various plant characters and to determine the component characters on which selection can be made for improvement in yield and coefficients are of three types viz., simple, or total, partial, and multiple correlations (Singh and Labana, 1990). In plant breeding, correlation co-efficient analysis measures the mutual relationship between various plant characters and determines the component character on which selection could be based for the genetic improvement in yield. The concept of correlation was given by Galton (1889) and later it was elaborated by Fisher (1936). The preliminary information on the nature and magnitude of genetic variation in the available material and association of characters with yield and among themselves is most important for a plant breeder for the development of good quality and high yielding varieties. Correlation studies between yield and its components are of great importance in planning and evaluating breeding populations. However, yield being the resultant of interaction between several factors i.e., inherent, and environmental. It is therefore, difficult to estimate or select for this complex character directly. Hence the association is usually determined by studying the correlations existing between different characters under study.

The study of simple correlation does not provide an exact picture of relative importance of direct and indirect influence of each of the component characters towards the desired characters. So, this can be overcome by path coefficient analysis technique by further partitioning the correlation coefficient into direct and indirect effects.

Rai *et al*. (2003) studied correlation and path coefficient analysis in nine hybrids of cabbage in four environments and demonstrated that genotypic correlation coefficients were greater than the phenotypic correlation coefficients for each character and that, with the exception of stalk length, the yield showed a positive and significant relationship with each yield component. A requirement for their simultaneous selection for the development of desirable traits was illustrated by the fact that leaf breadth had the highest direct impact on yield, followed by longitudinal head length and leaf length. Most of the yield component interrelationships among themselves were significant.

Kibar *et al*. (2014) studied fourteen inbred lines of cabbage and examined the associations between yield and several yield components and concluded that all yield components had highly significant and positive correlations with yield apart from days to maturity and core length. The most significant positive connection between yield and head weight was observed. Path coefficient analysis showed that head weight had the highest positive direct effect on yield followed by head length and plant diameter. Therefore, in the breeding programme of cabbage varieties with high yielding, head weight, head length, plant diameter, plant height, width of outer leaf, length of outer leaf, head diameter, and diameter of internal stem may be effectively used as selection criteria. These characteristics were the most significant yield factors determining cabbage yield.

Singh *et al*. (2014) studied correlation and path analysis in cauliflower and observed that all the characteristics, including curd weight, leaf number, leaf area, curd diameter, plant spread, plant height, and curd depth were revealed to be highly and significantly positively linked with yield. Each supporting character displayed a strong positive association with every other one. The results of the path coefficient analysis also showed that the number of leaves had the greatest positive direct influence followed by curd weight, plant height, and curd depth. Plant spread, leaf area, and curd diameter exhibited a direct negative impact.

In a study conducted by Santhosha *et al.* (2015) in cauliflower under tropical conditions, significant positive association of plant weight, leaf number, leaf length, leaf breadth, leaf weight, curd depth, curd diameter, curd size, net curd weight, net plot yield and yield per hectare was observed with marketable curd weight both at genotypic and phenotypic levels indicating that for the improvement in marketable curd weight of cauliflower, selection based on the above characters is desirable. Direct and indirect effects showed that during the selection of superior genotypes in early cauliflower emphasis should be given for plant and leaf parameters like, plant weight, leaf number, leaf length and curd parameters like, curd size and net curd weight.

Gaur and Singh (2016) evaluated early cauliflower and found that total yield had significant positive genotypic and phenotypic correlation with marketable curd weight, followed by net curd weight, curd depth. However, yield was negatively genotypically correlated with plant diameter. Path coefficient analysis revealed that marketable curd weight, days to curd initiation had the highest positive contribution towards the total yield.

Chittora and Singh (2017) studied correlation and path analysis on economic traits of early cauliflower and found that the marketable curd weight, net curd weight, curd diameter, number of leaves per plant, curd index, harvest index, curd depth, and gross plant weight had a highly positive correlation with the amount of curd produced per hectare. Days to curd initiation and days to curd maturity were found to have a negative and significant relationship with curd yield. Maximum positive direct impacts on curd yield were produced by marketable curd weight, leaf lamina length, and leaf stalk length, whereas negative direct effects were produced by leaf length and curd index.

Kannan *et al*. (2017) determined correlation for economic traits in sixty genotypes of cauliflower and revealed that the curd weight per plant had a significant and positive relationship with the curd length followed by number of leaves per plant, height of the plant, length of the petiole, days to curd formation and days to 50% maturity.

Kumar *et al.* (2017) studied fifty-seven genotypes of cauliflower, including five checks. The genotypic correlation coefficient was larger than the phenotypic correlation coefficient. Curd yield per hectare was found to positively correlated with marketable curd weight, net curd weight, curd diameter, number of leaves per plant and gross plant weight at both phenotypic and genotypic levels. Path coefficient analysis showed that net curd weight had a strong positive direct effect on total yield, while harvest index had a negative direct effect on curd yield per hectare.

In a study conducted by Chatterjee *et al.* (2018) in cauliflower, highest positive direct effect on marketable curd output per plant was shown by leaf number per plant (0.995), followed by curd size index (0.411), days to marketable curd maturity (0.376), plant height (0.371), leaf size index (0.363), curd depth (0.164) and curd solidity (0.164). On the other hand, gross weight per plant (-0.133) imparted the greatest negative direct effect, followed by stalk length (-0.908) on marketable curd output per plant stalk length via leaf number per plant (0.981) and plant height via days to marketable curd maturity (0.415) showed the most favourable indirect effects on marketable yield per plant.

In a study conducted by Kumar *et al.* (2020) in khol-knol, knob yield per plot was found to be positively significant correlated with fresh weight of knob followed by whole plant weight, fresh weight of leaves, plant height at harvest, knob length, knob diameter, dry weight of leaves and days taken to complete harvest at both genotypic and phenotypic levels, whereas days taken to knob initiation had a significant negative correlation with knob yield per plant at both genotypic and phenotypic levels. Plant height at harvest revealed a significant positive correlation with knob diameter, knob length, fresh weight of knob and fresh weight of leaves. Days taken to knob initiation had a highly significant positive correlation with days taken to first harvest only, whereas knob diameter, knob length and dry weight of leaves had a negative significant correlation with days taken to knob initiation. Knob diameter followed by knob length, fresh weight of knob, fresh weight of leaves and dry weight of knob had significant positive correlations with days taken to complete harvest. Fresh weight of knob had a positive significant association with fresh weight of leaves followed by whole plant weight and dried weight of leaves at both phenotypic and genotypic levels.

Pramila *et al.* (2020) studied fifteen genotypes of cauliflower for correlation and path coefficient analysis. The genotypic correlation coefficients were larger than the corresponding phenotypic correlation coefficient for all character. Total yield quintal per hectare was shown to be positively and significantly correlated with net curd weight followed by gross curd weight, curd length, curd breadth, and harvest index. Net curd weight and gross curd weight had a positive direct effect on total yield (q per ha) as per path coefficient analysis. Curd length, curd breadth, and harvest index recorded a negative direct influence on total yield. Curd length, leaf length and plant spread all had a high positive indirect effect, whereas net curd weight and gross curd weight had a significant negative indirect effect on total yield. It was concluded that the traits have a positive direct effect on total yield (q per ha) may be helpful in improving total yield of cauliflower.

Kumar *et al*. (2021) studied twenty-five cauliflower genotypes and found that highest positive significant association between net curd weight and curd yield and revealed that net curd weight is the best measure for selecting high yielding genotypes. Days to marketable maturity, on the other hand, had a non-significant negative connection with curd yield. Curd yield (kg per plot and q per ha) was higher in local genotypes Jachh CF-2, Jachh CF-7, and Jachh CF-17 than rest of the genotypes, indicating that these local varieties can be used in future breeding programmes.

Lakshmi *et al*. (2022) studied genetic variability, correlation and path coefficient analysis was studied in cauliflower (*Brassica oleracea* var. *botrytis* L.) genotypes and reported that plant height followed by plant spread, curd diameter, curd size, gross curd weight, net curd weight, curd compactness and yield per plot all exhibited a substantial positive association with yield per hectare. Therefore, selecting for these qualities assists in increasing yield. The results of the path analysis demonstrated a true association between the attributes with yield per plot followed by net curd weight, number of leaves per plant, curd diameter, plant spread and curd compactness exerting a positive direct effect on yield per hectare.

2.4 Genetic divergence

The concept of D2 statistics was originally developed by Mahalanobis (1928) in the study of Anthropometry and Psychometry. Rao (1952) suggested the application of this technique for the assessment of genetic diversity in plant breeding. The presence of unique genetic characteristics, distinguishes members of a given population from those of any other population. Large populations will usually have greater diversity of alleles compared to small populations. The diversity of alleles indicates a greater potential for the evolution of new combination of genes and subsequently a greater capacity for evolutionary adaptation to different environmental conditions. Genetic diversity is therefore, a key component for conservation efforts associated with population management. Genetic diversity existing in both the cultivated and wild species is essential for exploitation of new gene complexes for higher economic yield and resistance to biotic and abiotic stresses. Thus, the success of genetic improvement in any character depends upon the nature of variability present in the gene pool for that character.

Cartea *et al*. (2002) in a study of a population of kale was morphologically characterised at two sites with different planting dates. All the traits were significantly different. However, the genotypes × environment interaction was not significant for most of the traits. The phenogram displayed two groups that included most of the populations and three small independent groups with total five groups. The length of their vegetative phase and the morphological differences between the populations, particularly between the north and early population (cluster A) and the south and late population, were related with the group of landraces (cluster B). In comparison to inland populations, coastal populations had greater morphological diversity.

Quamruzzaman *et al*. (2007) studied twenty genetically diverged genotypes of cauliflower and classified them into five clusters. Cluster IV had the highest intra-cluster value and Cluster II had the lowest. The inter-cluster distance was greater than the intra-cluster distance, indicating greater genetic diversity among genotypes from different groups. The inter-cluster average D^2 values revealed the greatest distance between clusters I and IV, followed by I and III and I and V.

Khan *et al*. (2009) studied forty distinct genotypes of kale, including three commercial checks, Khanyari, Kawdari and Jumadari were tested for various yield and yield-attributing traits. Four significant clusters were created from the pooled analysis of the data across environments. The mean intra-cluster distance (D^2) estimate showed that cluster II had the highest value, followed by cluster III and cluster I. Cluster-IV, which has only one genotype, could be crossed in all possible combinations for increase in number of leaves and earliness; cluster-III genotypes for tall stature and earliness, cluster-I genotypes for dwarf stature and leaf weight and cluster-II genotypes for dwarf stature and winter hardiness. the highest inter-cluster distance (D^2) values were observed between cluster I and IV, followed by cluster I and cluster III.

Santhosha *et al*. (2011) conducted genetic divergence in 51 genotypes of cauliflower and grouped them into 14 clusters. Most of the genotypes were in Cluster XIV (14 genotypes), followed by Cluster XII (8 genotypes). Cluster VIII had the highest intra-cluster value, whereas Cluster II had the lowest. The greatest distance between clusters was found between Clusters VIII and X, then between

Clusters X and XII, and finally between Clusters VIII and XII. The genotypes included in Cluster X also had the highest mean values for plant weight, leaf number, curd diameter, curd size, net curd weight, net plot yield, yield per hectare, and marketable curd-weight, indicating that these genotypes are potential parents for hybridization programmes intended to increase cauliflower yields.

Meena *et al*. (2013) evaluated 30 diverse genotypes of cabbage for different growth and yield traits and formed three important clusters. Cluster II had the maximum intra-cluster distance, whereas cluster III had the minimum. Clusters I and II had the maximum inter-cluster distance, whereas clusters I and III had the shortest distance. Certain morphological and horticultural characteristics favored Cluster II. These five traits—days to maturity, number of non-wrapper leaves, core length, stalk length, and leaf width—contributed to divergence in this study.

Azevedo *et al.* (2014) studied the forty- four morphological characters of kale genotypes and reported that some genotypes showed high genetic divergence, such as the genotypes UFLA-6 and 24-UFVJM, which were the most divergent compared to the others. Most of the genotypes, however, were like each other.

Dolkar *et al*. (2020) determined the extent of genetic divergence in thirty genotypes of knolkhol. The genotypes were divided into six clusters, with cluster I containing 12 genotypes and clusters V and VI containing a single genotype. Cluster III had the maximum intra-cluster distance (122.44), followed by Cluster IV (104.23), and the maximum inter-cluster distance (1182.73) was observed between Cluster II and Cluster IV, followed by Cluster I and IV (723.99). During the main season, a significant genetic difference in cluster means of genotypes was observed between the groups. Cluster IV genotypes had the highest cluster mean value for the number of leaves per plant (11.18), marketable knob diameter (7.37 cm), marketable knob weight/plant (380.29 g/plant), and yield/plot (5.11 kg/plant).

Pramila *et al*. (2021) studied genetic divergence in cauliflower for fourteen quantitative characters. The genotypes were divided into four groups. Cluster 1 (with 12 genotypes) had the most genotypes, while the other clusters each had one genotype. Cluster 1 had the highest intra-cluster value. The highest inter-cluster distance was observed between clusters 4 and 2, followed by clusters 3 and 2 and cluster 4 and 1. As a result, the genotypes Sabour Agrim of cluster 4 and RCEF4 of cluster 2 are the ideal options for hybridization. Cluster 3 had the highest mean value of plant spread (cm), leaf length (cm), leaf blade width (cm), days to 50% curd initiation, net curd weight (g), gross curd weight, curd length, curd width, harvest duration, and total yield (q/ha).

Chapter 3

MATERIAL AND METHODS

The present investigation entitled as "**Evaluation and Characterization of Knol-khol (*Brassica oleracea var. gongylodes* L.) under Kashmir conditions**" was undertaken at Experimental Field of Division of Vegetable Science, SKUAST-Kashmir, Shalimar during Rabi 2021-22. The material and methods adopted during investigation have been described as under:

3.1 Site details

Experimental field of Division of Vegetable Science is situated at an altitude of 1685 meters above mean sea level lying between 34.15º North latitude and 74.89º East longitude. It grows well with a monthly average temperature of 15º-20ºC. The mean minimum and maximum temperatures are 4.5ºC and 24ºC recorded in months of January and June (respectively). The maximum rain fall is received during March to April.

3.2 Experimental Material

Thirty phenotypically diverse genotypes including three checks (Pusa Virat White Vienna and Purple Vienna) of knol-khol, collected from different agro climate of India and maintained in the Division of Vegetable Science were used for present study. The genotypes were sown on 09 August, 2021 at the Vegetable experimental field. The single factor experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. The plots of size 2 m × 1 m, consisted of three lines of each genotype in each replication at a spacing of 30 cm x 30 cm between rows and plants respectively. Recommended package of practices was followed to ensure healthy crop growth.

3.3 Characters studied and observational procedures

Observations were recorded on various descriptor, quantitative and quality traits in order to study the magnitude of genetic variability and to characterize the material under study as per the NBPGR descriptor (Mahajan *et al*., 2000).

Plate 1: View of experimental field

3.3.1 Descriptor traits as per Minimal descriptors of vegetable crops by NBPGR

3.3.1.1 Petiole attitude (PT_ATT)

Petiole altitude was recorded on visual basis of each tagged plant at the completion of vegetative stage and genotypes were categorized into following classes:

i. Erect (1)
ii. Semi-erect (2)
iii. Horizontal (5)

3.3.1.2 Leaf color (LF_CLR)

Leaf color was recorded on visual basis of each tagged plant on fully grown leaf and genotypes were classified as:

i. Light green (1)
ii. Dark green (2)
iii. Yellow green (3)
iv. Violet green (4)

3.3.1.3 Leaf shape (LF_SHP)

Leaf shape was recorded on visual basis of each tagged plant on afully grown leaf and genotypes were classified as:

i. Broad ovate (1)
ii. Narrow ovate (2)
iii. Ovate (3)

3.3.1.4 Leaf waxiness (LF_WXS)

Leaf waxiness was recorded on touch basis of each tagged plant on fully grown leaf and were classified as:

i. Weak (3)

Mulching stage

Nursery stage

Transplanted field for seed production

Siliqua

Seed

Plate 2: **View of different stage of production of Knol-khol (*Brassica oleracea* var. *gongylodes* L.)**

ii. Medium (5)

iii. Strong (7)

3.3.1.5 Petiole crossing (PT_CRS)

i. Absent (1)

ii. Present (9)

3.3.1.6 Stem color (STEM_CLR)

Stem color was recorded on visual basis of each tagged plant at the time of full heading stage and genotypes were classified as:

i. Light green (1)

ii. Green (2)

iii. Dark green (3)

iv. Purplish green (4)

v. Dark purple (5)

vi. Others (99)

3.3.1.7 Stem shape (STEM_SHP)

Stem shape was recorded on visual basis of each tagged plant at the time of full heading stage and genotypes were classified as:

i. Transverse narrow elliptic (1)

ii. Transverse elliptic (2)

iii. Transverse broad elliptic (3)

iv. Circular (4)

v. Broad elliptic (5)

vi. Others (99)

3.3.2 Quantitative traits

3.3.2.1 Number of leaf whorls

Number of leaf whorls was recorded as average of 5-10 random plants at marketable stage.

3.3.2.2 Internode length (cm)

Internode length was recorded as average length in between 4-5 nodes in the 5-10 plants at marketable stage.

3.3.2.3 Leaf length (cm)

The length of five leaves from each of the five tagged plants was measured in centimeters from the base to tip of the apical portion of leaf by scale and average was worked out.

3.3.2.4 Leaf width (cm)

Leaf width of randomly selected five leaves of each randomly selected 5-10 plants was measured in centimeters with the help of meter scale at the widest portion of the leaf and the average was worked out.

3.3.2.5 Petiole length (cm)

Petiole length of five leaves from each of the five random selected plants was measured from the base at the stem to the base of leaf and average was worked out.

3.3.2.6 Days to 50% stem swelling

Days to 50% stem swelling were recorded as number of days from date of transplanting to date when 50% plants show swelling of stem.

3.3.2.7 Days to 50% harvest

Days to 50% harvest were recorded as number of days from date of transplanting to the date when 50% plants develop marketable stem.

3.3.2.8 Stem length (cm)

The length of stem in five randomly selected plants was measured by vernier caliper in centimeters from crown to distal end of knob at marketable stage and the average was worked out.

3.3.2.9 Stem breadth (cm)

Stem breadth in randomly selected five plants was recorded just below crown with the help of vernier caliper in centimeters and average was worked out.

3.3.2.10 Gross stem weight (g)

The total plant weight (leaves as well as stem) of five randomly selected plants at marketable stage was recorded using a weighing balance and the average was calculated.

3.3.2.11 Net stem weight (g)

Stem weight of randomly selected five plants at marketable stage was recorded using a digital balance and the average was worked out.

3.3.2.12 Plant height (cm)

The height of five plants was measured in centimetres from the ground level to the highest tip and the average were worked out.

3.3.2.13 Plant spread (cm)

Plant spread of the tagged plants was measured in centimetres as the average spread from north to south and east to west direction and the average of five plants was worked out.

3.3.2.14 Number of leaves per plant

The number of leaves at harvesting stage from each tagged plants was pooled and total number of leaves per plant was noted and average was worked out.

3.3.2.15 Yield per hectare (q)

Total yield (knob and leaves) of each genotype in each plot from each replication was used to obtain yield per hectare.

3.3.2.16 Days to 50% flowering

The number of days taken from date of transplanting to the date when first flowers appeared in each genotype were recorded to get days to 50% flowering.

3.3.2.17 Days to seed maturity

Number of days to seed maturity were counted from the date of sowing to the date of fully matured yellow to dark brown pod.

3.3.2.18 Siliqua length (mm)

Siliqua length of the tagged plants was measured in mm from the base of the siliqua to the tip of the siliqua and average was worked out.

3.3.2.19 Siliqua width (mm)

Siliqua width of the tagged plants was recorded with help of vernier caliper in millimeters and average was worked out.

3.3.2.20 Number of seeds per siliqua

The number of seeds in a fully matured siliqua were counted from five tagged plants and the average was worked out.

3.3.2.21 Seed yield per plant (g)

The total seeds obtained from randomly selected plants were weighed on electric balance to calculate the mean seed yield per plant in grams.

3.3.2.22 Seed yield per hectare (kg)

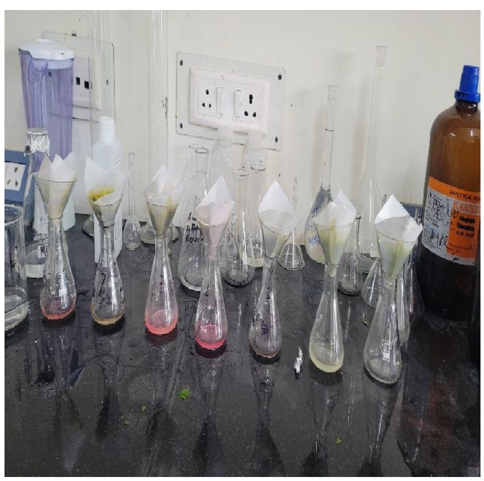
The seed yield per hectare was determined based on the seed yield per plot.

3.3.2.23 1000 seed weight (g)

The weight of 1000 seeds from each plant were taken with a digital weighing machine and its average was calculated.

Estimation of total chlorophyll content

Estimation of carbohydrate content



Estimation of Ascorbic Acid content

Plate 3: Quality traits analysis of Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

3.3.3 Quality traits

3.3.3.1 Total chlorophyll content (mg/100g)

The chlorophyll content was determined by the method given in Thimmaiah (1999). A known amount of sample was grounded with 20ml of 80% acetone. The grounded sample was centrifuged at 5000 rpm for 5 minutes and supernatant was transferred to a 100ml volumetric flask. The procedure was repeated until the residue was colourless. The volume was made to 100ml with 80% acetone. The absorbance of the solution was read at 645, 663 with the help of double beam UV-VIS spectrophotometer against the solvent (80% acetone) blank.

$$\text{Total Chlorophyll (mg/100g)} = 20.2(A_{645}) + 8.02\,(A_{663}) \times \frac{V}{1000 \times W}$$

Where,

A= Absorbance at specific wavelength,

V=Final volume of chlorophyll extract in 80% acetone

W=Fresh weight of tissue extracted

3.3.3.2 Moisture content (%)

Moisture content was determined by drying a known weight of the sample in an oven at 60 ± 5°C to a constant weight. The results were expressed as percent moisture content.

$$\text{Moisture percent: } \frac{\textit{Fresh weight-Final weight after drying}}{\textit{Fresh weight}} \times 100$$

3.3.3.3 Total soluble solids (Brix)

Total soluble solid content was determined using hand refractometer. 2-3 drops of juice obtained by crushing the sample were placed on the prism of refractometer and readings were taken. Five observations from each treatment were recorded and average was calculated. The results were expressed as ºBrix.

3.3.3.4 Ascorbic acid or Vitamin C content (mg/100g)

A known weight of sample was titrated with 6-dichloro phenol indophenol dye using metaphosphoric acid a stabilizing agent as per Association of Analytical Chemists (1975) method of titration.

Five grams of sample was grounded in a pestle and mortar with stabilizing medium (1:5). Homogenate was centrifuged. Supernatant was taken and volume was made up to 50 ml with stabilizing medium and filtered. 10 ml of the aliquot was titrated against 2, 6-dichloro phenol indophenol dye. The dye factor was calculated as:

Five ml of 3% HPO_4 was added to standard ascorbic acid and titrated with the dye solution to a pink colour. The dye factor i.e., mg of ascorbic acid per ml of dye was determined by using the formula:

$$\text{Dye factor} = \frac{0.5}{titre}$$

The vitamin C content of the sample was calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g} \quad \frac{\textit{Titre value} \times \textit{dye factor} \times \textit{volume made up}}{\textit{Total weight of sample} \times \textit{aliquot of sample}} \times 100$$

3.3.3.5 Carbohydrate content (%)

The total carbohydrate was estimated by Anthrone method (Hedge and Hofreiter, 1962).

Procedure: Total carbohydrate content in the sample was calculated by comparing the optical density of the sample with the calibration curve plotted by taking known dilutions of standard solution of pure glucose. Carbohydrate content present in investigated crop-samples was calculated as:

$$\text{Amount of carbohydrate (\%):} \frac{carbohydrate\ content}{aliquot\ sample\ used\ (1ml)} \times \frac{total\ volume\ of\ extract}{weight\ of\ sample\ (mg)} \times 100$$

3.3.3.6 Total carotenoids content (mg/100 g) (Mahadevan and Sridhar, 1986)

A known weight of sample (1g) was extracted with acetone and few crystals of sodium sulphate. The extractions were repeated and the extract was totaled in a beaker and to it added 10% KOH. The extract was heated on a water bath for 30 minutes and then transferred to a separating funnel. To this 50 ml of petroleum ether was added. The separating funnel was shaken and allowed to stand for at least 10 minutes till the layers got separated. The lower layer was drained and the upper layer of petroleum ether containing pigment was collected in a volumetric flask and the volume was made up to 50 ml with petroleum ether and O.D. was recorded at 452 nm against petroleum ether as blank. The total carotenoids were calculated as per the formula:

$$\text{Total carotenoids (mg/100 g)} = \frac{O.D. \times 13.9 \times 10^{4}\ volume\ made}{weight\ of\ sample\ \times 560 \times 100}$$

3.4 Statistical and biometrical analysis

All the data pertaining to quantitative and quality characters were analyzed as per the Randomized Complete Block Design and was subjected to following statistical andbiometrical analysis.

- Analysis of variance and estimation of variability components
- Estimation of heritability and expected genetic gain
- Estimation of phenotypic and genotypic correlation coefficient
- Component contribution of different traits to the yield per hectare (path analysis)
- Divergence analysis

3.4.1 Analysis of variance and estimation of variability components

3.4.1.1 Analysis of variance

Analysis of variance for all the characters was calculated as explained by Gomez and Gomez (1983). The treatment mean was tested at 5% and 1% level of significance. The analysis of variance table was setup as under:

Source of variation	Degrees of freedom	Sum of squares (SS)	Mean sum of squares (MSS)	Variance ratio (F-value)
Replication (r)	r - 1	SSr	MSr = SSr/r-1	MSr/MSe
Treatments (t)	t- 1	SSt	MSt = SSt/t-1	MSt/MSe
Error (e)	(r - 1) (t - 1)	SSe	MSe = SSe/(r-1) (t-1)	
Total	rt- 1			

Where,

r = number of replications

t = number of treatments

SS = Sum of squares

MSS = Mean sum of squares

SSr = Sum of squares due to replication

SSt = Sum of squares due to treatments (genotypes)

SSe = Sum of squares due to error

MSr = Mean sum of squares due to replication

MSt= Mean sum of squares due to treatments

MSe = Mean sum of squares due to error

The significance of varietal difference was tested by F-test by comparing the calculated F-value with the tabulated F-value.

3.4.1.2 Genotypic variance

Genotypic variance was worked out by using the method given by Johnson *et al.* (1955).

$$\sigma_g^2 = \frac{MSt - MSe}{r}$$

Where,

σ_g^2 = Genotypic variance

MSt = Mean sum of squares due to treatments

MSe = Mean sum of squares due to error

r = Number of replications

3.4.1.3 Phenotypic variance

Phenotypic variance was worked out by the method suggested by Johnson *et al.* (1955).

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2$$

Where,

σ_p^2 = Phenotypic variance

σ_g^2 = Genotypic variance

σ_e^2 = Error variance

3.4.1.4 Phenotypic and Genotypic co-efficient of variation

The magnitude of phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) existing in a trait was worked out by the formula given by Burton and De vane (1953):

$$\text{PCV} = \frac{\sqrt{\sigma_p^2}}{\bar{X}} \times 100$$

Where,

σ_p^2 =Phenotypic variance

$\bar{X}$ = Mean of traits studied

$$\text{GCV} = \sqrt{\frac{\sigma_g^2}{\bar{X}}} \times 100$$

Where,

$\sigma_g^2 =$ Genotypic variance

$\dot{X}$ = grand mean of traits studied

PCV and GCV were categorized into three classes as low, moderate, and high by following Sivasubramanian and Madhavamenon (1973) as follows:

0 - 10%	:	Low
10 - 20%	:	Moderate
Above 20%	:	High

3.4.2 Estimation of heritability, genetic advance, and genetic gain

3.4.2.1 Heritability (broad sense)

Heritability was estimated according to procedure presented by Burton and De-Vane (1953), Johnson *et al*. (1955) and Hanson *et al*. (1956).

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2}$$

Where,

h^2 = Estimate of heritability in broad sense

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

The heritability percentage was categorized into three classes as low. moderate and high as suggested by Robinson *et al*. (1949):

0 - 30%	:	Low
30 - 60%	:	Moderate
60% and above	:	High

3.4.2.2 Genetic advance

Genetic advance at 5% selection intensity was worked out by using the formula given by Lush (1940) and Johnson *et al.* (1955).

$$GA = \frac{\sigma_g^2}{\sigma_p^2} \times (\sigma_p^2)^{0.5} \times K$$

Where,

GA = Genetic advance of the trait

σ_g^2 = Genotypic variance of the trait

σ_p^2 = Phenotypic variance of the trait

K = Selection differential; (K = 2.06 at 5% selection intensity)

3.4.2.3 Expected genetic gain (Genetic advance as per cent of mean)

Genetic gain was calculated as per the method given by Johnson *et al.* (1955).

$$\text{Genetic gain} = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic advance of the trait

$\dot{X}$ = Mean of the trait

The GA as per cent of mean was categorised into three classes as low, moderate and high as proposed by Johnson *et al.* (1955).

0 - 10%	:	Low
10 - 20%	:	Moderate
Above 20%	:	High

3.4.2.4 Range

Range is the differences between the minimum value and the maximum value of a series of observation and thus provides the information about the variability present in the genotype.

3.4.2.5 Mean

Mean of the character was calculated by adding up of all the observation and dividing the sum by the number of observations.

$$(X) = \frac{\sum xi}{N}$$

Where,

$\sum Xi$ = Summation of all the observation,

N = Number of observations

3.4.3 Estimation of genotypic and phenotypic covariances and correlation coefficients

Covariance analysis was obtained in the same manner as the variance analysis. The genotypic and phenotypic covariances between two characters were obtained in the same fashion as corresponding variances. The genotypic and phenotypic variance values and covariances were substituted in the formula suggested by Panse and Sukhatme (1985) to calculate correlation co-efficient between all possible pairs of characters.

Genotypic correlation co-efficient

$$r_{xy}(g) = \frac{\sigma^2_{xy}(g)}{\sqrt{\sigma^2_x(g)\,\sigma^2_y(g)}}$$

Phenotypic correlation coefficient

$$r_{xy}(p) = \frac{\sigma^2_{xy}(p)}{\sqrt{\sigma^2_x(p)\,\sigma^2_y(p)}}$$

Where,

$r_{xy}(g)$, $r_{xy}(p)$ = Genotypic and phenotypic correlation coefficients, respectively, between a pair of characters x and y

$\hat{\sigma}_x^2(g)\hat{\sigma}_y^2(p)$ − Genotypic and phenotypic covariances, respectively, for a pair of characters x and y

$\hat{\sigma}_x^2\ (g)\ \hat{\sigma}_y^2\ (g)$ = Genotypic variance for characters x and y, respectively.

$\hat{\sigma}_x^2\ (p)\ \hat{c}_y^2\ (p)$ = Phenotypic variance for character x and y, respectively.

Test of significance

The significance of a correlation co-efficient was tested by the following formula

Where,

$$t = \frac{r\ (n-2)^{0.5}}{(1-r^2)^{0.5}}$$

r = Correlation coefficient

n = number of observations

Any value (±) exceeding the table value of t at n - 2 d.f is significant.

3.4.4 Path co-efficient analysis

The methodology suggested by Wright (1921) and Li (1956) was adopted while using the formula given by Dewey and Lu (1959) to carry out path coefficient analysis.

$$P_{y1} + P_{y2}\, r_{12} + P_{y3}\, r_{13} + \ldots\ldots\ldots\ldots P_{yn}\, r_{1n} = r_{y1}$$

$$P_{y1} + r_{12} + P_{y2} + P_{y3}\, r_{23} + \ldots\ldots\ldots\ldots P_{yn}\, r_{2n} = r_{y2}$$

$$P_{1n}\, r_{1n} + P_{y2}\, r_{2n} + P_{y3}\, r_{3n} + \ldots\ldots\ldots\ldots + P_{yn} = r_{yn}$$

Where,

P_{y1}, P_{y2}, P_{y3}, …………P_{ny} are the direct path effect of 1, 2, 3...................... n variable on the dependent variable y;

R_{12}, r_{13}, ……. r_{1n} ……………....$r(n^{-1})n$ are the possible coefficients of correlation between various independent variables and r_{y1} ,r_{y2} ………………….. r_{yn} are the coefficients of correlation of independent variables with the dependent variable y.

The residual factor (i.e., the variation in yield unaccounted for those associations) was calculated from the following formula:

$$\text{Residual factor (x)} = 1 - R^2$$

$$R^2 = P_{y1}r_{y1} + P_{y2}r_{y2} + \ldots\ldots\ldots\ldots\ldots\ldots + P_{yn}r_{yn}$$

R^2 the squared multiple correlation co-efficient and is the amount of variation in yield that can be accounted for by the yield component character.

3.4.5 Estimates of genetic divergence

The genetic divergence was computed using the procedure as described by Rao (1952) and Singh and Choudhary (1985). The details of analysis are described under the following heads:

1) Test of Wilk's criterion,
2) Transformation of correlated variables,
3) Computation of D^2 values,
4) Relative contribution of individual characters towards total divergence
5) Group constellation.

3.4.5.1 Test of Wilk's criterion

Variances and covariances were obtained from analysis of variance and covariance tables and the following analysis of dispersion table was constructed:

Analysis of dispersion

Dispersion due to	d.f.	Matrix due to			
		Sum of squares		Sum of products	
		X^2_1	X^2_2......	X_1 X_2	X_1 X_3.......
Replications	r-1	a	b	c	d......
Between treatments (Q)	q	a′	b′	c′	d′.....
Within treatments (W)	By subtraction	A- (a+a′)	B- (b+b′)	C- (c+c′)	D- (d+d′)....
Total	**n**	**A**	**B**	**C**	**D.....**

The determination of error and error + variety variance-covariance matrix was calculated by pivotal condensation method of using ‗V' statistics which, in turn, utilizes Wilk‗s criteria. A simultaneous test of differences between mean values of characters from all the genotypes in the present study was performed, as per the details given below:

The Wilk‗s test is:

$$V = -\ m\log e\ \lambda$$

Where,

$$\lambda = \frac{W}{W + Q}$$

$$= \frac{Determinant\ of\ error\ matrix}{Determinant\ of\ error +\ \text{variety matrix}}$$

and,

$$m = n - \frac{q\ + k + 1}{2}$$

Where,

n = Total number of observations minus one,

q = number of variables minus one, and

k = number of characters under study

‗V‘ Statistics so obtained was compared with the tabulated value of χ^2 for 2qk degrees of freedom.

3.4.5.2 Transformation of correlated variables

Plot means of the varieties corresponding to the characters studied were transformed to uncorrelated variables by Pivotal Condensation Method, which rendered the computation of D^2 values between any combinations of two varieties to simple summation of squares of differences in transformed values for various characters. The skeleton procedure of obtaining transformed variables by Pivotal Condensation Method is described below:

Let dispersion matrix of original variables $x_1, x_2 \ldots\ldots\ldots\ldots\ldots x_p$ be

$$\begin{array}{cccc}
\lambda_{11} & \lambda_{12} & \ldots\ldots\ldots\ldots\ldots & \lambda_{1p} \\
\lambda_{21} & \lambda_{22} & \ldots\ldots\ldots\ldots\ldots & \lambda_{2p} \\
\bullet & \bullet & \ldots\ldots\ldots\ldots\ldots & \bullet \\
\bullet & \bullet & \ldots\ldots\ldots\ldots\ldots & \bullet \\
\bullet & \bullet & \ldots\ldots\ldots\ldots\ldots & \bullet \\
\bullet & \bullet & \ldots\ldots\ldots\ldots\ldots & \bullet \\
\bullet & \bullet & \ldots\ldots\ldots\ldots\ldots & \bullet \\
\lambda_{p1} & \lambda_{p2} & \ldots\ldots\ldots\ldots\ldots & \lambda_{pp}
\end{array}$$

and consider the extended matrix

$$
\begin{array}{cccccc}
\lambda_{11} & \lambda_{12} & \ldots\ldots\ldots\ldots\ldots\ldots & \lambda_{1p\ x\ 1} & & \\
 & \lambda_{21} & \lambda_{22} & \ldots\ldots\ldots\ldots\ldots\ldots & \lambda_{2p\ x\ 2} & \\
 & \bullet & \bullet & \ldots\ldots\ldots\ldots\ldots\ldots & \bullet & \\
 & \bullet & \bullet & \ldots\ldots\ldots\ldots\ldots\ldots & \bullet & \\
 & \bullet & \bullet & \ldots\ldots\ldots\ldots\ldots\ldots & \bullet & \\
 & \bullet & \bullet & \ldots\ldots\ldots\ldots\ldots\ldots & \bullet & \\
 & \bullet & \bullet & \ldots\ldots\ldots\ldots\ldots\ldots & \bullet & \\
\lambda_{p1} & \lambda_{p2} & \ldots\ldots\ldots\ldots\ldots\ldots & \lambda_{pp\ x\ p} & &
\end{array}
$$

taking λ_{11} as the first pivotal element, the first row is replaced by

$$
1 \quad \frac{\lambda_{12}}{\lambda_{11}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \frac{\lambda_{1p}}{\lambda_{11}} \quad \frac{X\ 1}{\lambda_{11}}
$$

Sweeping out first column and using the first pivotal row, following reduced matrix is obtained

$$
\left.
\begin{array}{ccccc}
\lambda_{22'} & \ldots\ldots\ldots\ldots\ldots\ldots & \lambda_{2p'} & X_{2'} & \\
 & \bullet & & & \bullet \\
 & \bullet & & & \bullet \\
 & \bullet & & & \bullet \\
 & \bullet & & & \bullet \\
\lambda_{p2'} & \ldots\ldots\ldots\ldots\ldots\ldots & \lambda_{pp'} & x_{p'} &
\end{array}
\right)
\begin{array}{c} \\ \bullet \\ \bullet \\ \bullet \\ \bullet \\ \\ \end{array}
$$

Where,

$$\lambda_{ij} = - \frac{\lambda_{ij}}{\lambda_{11}} \lambda_{ij} x_i$$

$$x_i = - \frac{\lambda_{il}}{\lambda_{ll}} X_1$$

$$\text{Now, } = V_{(xi)} = V_{(xi)} - \frac{2\lambda_{il}}{\lambda_{ll}} \text{Cov.} (x_i x_1) + \frac{2\lambda_{il}}{\lambda_{ll}} V(X_1)$$

$$= \lambda_{ii} - \frac{\lambda_{il}^2}{\lambda_{ll}} X_{1i}$$

$$\text{Now, } V_{(xi')} = + \frac{\lambda_{il}}{\lambda_{ii}} V(xl)$$

Similarly, Cov. $(x'_{i1}\ x'j) = \lambda_{ij}'$

Similarly, Cov. $(x'_i{}'\ x'j') = \lambda_{ij}'$

$$\text{also, cov. } (x\ 1\ x'i) = \text{cov. } (xlxi) - \frac{\lambda il}{\lambda ll} v(xi)$$

$$= \lambda il - \lambda il = 0$$

So, the new variables are uncorrelated.

Considering the second pivotal row

$$\frac{\lambda 23}{\lambda 22'} \qquad \frac{\lambda 2p'}{\lambda 22'} \qquad \frac{x2'}{22'}$$

the further reduced matrix is

$$\left|\begin{matrix} \lambda 33'' & \ldots\ldots\ldots\ldots & \lambda 3p'' \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \lambda p3'' & & \lambda pp'' \end{matrix}\right| \quad \left|\begin{matrix} \lambda x3'' \\ \bullet \\ \bullet \\ \bullet \\ xp'' \end{matrix}\right|$$

resulting into variables

x1′ x 2′ x 3″...with variance

x1 1′ x λ22′ λ33″ ………………………..

They are all mutually uncorrelated as shown above and further x'_2, depends on x_1 and x_2', and x_3 on x_1', x_2 and x_3 only.

3.4.5.3 Computation of D^2 values

For each pair-wise combination of the varieties the differences in transformed values for various characters were computed and D^2-values were calculated according to the following formula:

$$D^2 = \sum_{i-1}^{p} (\overline{Y}_{ij} - Y_{ik})^2$$

Where,

P	=	number of characters studied, and
Y_{ij} and Y_{ik}	=	are two transformed variables of the i^{th} character for two genotypes

3.4.5.4 Relative contribution of individual characters towards total divergences

The ranking of differences in uncorrelated means between all the characters for all pair-wise combinations of varieties was carried out, with first rank being assigned to the highest differences. Finally relative contribution of a character towards total divergence was estimated by calculating the percentage of first rank in that character.

3.4.5.5 Group constellation

Tocher's method was used for assigning various varieties to different clusters. The two varieties having smallest distance from each other were considered first to which a third variety having smallest average D^2 value from the first two varieties was added. Next come the nearest fourth variety and the process continued till the average D^2 value increased. The remaining varieties were then considered for the next cluster and the process was continued till all varieties were included in various clusters.

The spatial distances between clusters were arrived at by taking square root of average intra and inter cluster D^2 values.

For each combination (pair of genotypes) the mean deviation (d^2i) i.e. Y_1-Y_1 with I = 1, 2, 3 ……… p was computed and D^2 values were calculated as sum of these deviations i.e. (y_i^1-y_i^2), where, y_i is the transformed variable from the original variable xi. According to D^2 values for all combinations were calculated. The D^2 values so obtained for each pair of population were treated as x^2 and were tested against the tabulated values of λ^2 for p degrees of freedom, where p is the number of traits considered.

In all combinations each character was ranked based on $d_i = y_{ij} - y_{ik}$ values. Rank I was given to the highest mean difference and rank p to the lowest mean difference, where p is the total number of characters. In this manner contribution of each character to the total divergence was computed.

Tocher method for grouping of varieties into various clusters was adopted. This method is detailed in a simplified way by Rao (1952) and Singh and Choudhary (1985).

All the above computations were carried out using the software Windostat at the Division of Genetics and Plant Breeding, SKUAST-Kashmir, Shalimar

Chapter-4

EXPERIMENTAL FINDINGS

The present investigation entitled –**Evaluation and Characterization of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir conditions**‖ was undertaken at Vegetable Experimental Farm, Division of Vegetable Science, Faculty of Horticulture, SKUAST-Kashmir during Rabi 2021-22. The experiment was laid in Randomized Complete Block design (RCBD) with three replications. The experimental material consisted of thirty genotypes including three checks (Pusa Virat, White Vienna and Purple Vienna) of Knol-khol and was evaluated on various descriptor, quantitative and quality traits. The data collected was analyzed as per standard statistical procedures to obtain results. The experimental results thus obtained are presented under following headings:

4.1 Mean performance and analysis of variance

4.2 Coefficient of variability, heritability and genetic gain

4.3 Correlation coefficient analysis

4.4 Path coefficient analysis

4.5 Estimation of genetic divergence

4.6 Descriptor traits as per Minimal descriptors of vegetable crops by NBPGR

4.1 Mean performance and Analysis of variance

The analysis of variance of all the traits under study is presented in Table-1(a-b). Significant mean sum of squares due to yield and attributing traits revealed existence of considerable variability in material studied for improvement of various traits. The mean values of different quantitative and quality traits for all the genotypes of knol-khol are presented in Annexure (I and II).

4.1.1 Number of leaf whorls

Number of leaf whorls ranged from 4.32-7.93 with an overall mean of 6.05. SK-KK-123 (4.32) recorded least number of leaf whorls followed by SK-KK-38 (4.45), SK-KK-22 (4.52), SK-KK-180 (4.62) and SK-KK-23 (4.72) while as SK-KK- 14 (7.93) recorded the maximum number of leaf whorls followed by SK-KK-154 (7.50), SK-KK-72(A) (7.34), SK-KK-65 (7.17) and SK-KK-197 (6.97). The phenotypic and genotypic variance this trait was 1.04 and 1.02 respectively. The phenotypic and genotypic coefficient of variation were 16.86 and 16.72 respectively. High heritability (98%) along with high genetic advance (30.04) wasobserved for this trait.

4.1.2 Internode length (cm)

Internode length ranged from 0.46 - 1.76 cm with an overall mean of 0.90 cm. The minimum internode length was observed for SK-KK-123 (0.46 cm) followed by SK-KK-38 (0.49 cm), SK-KK-90 (0.52 cm), SK-KK-IC-2 (0.53 cm) and SK-KK-175 (0.54 cm) while as the maximum internode length was observed in SK-KK-23 (1.76 cm), followed by SK-KK-65 (1.54 cm), SK-KK-88 (1.46 cm), SK-KK-154 (1.36 cm) and SK-KK-72(A) (1.27 cm). The phenotypic and genotypic variance of this trait were 0.09 and 0.08 respectively. The phenotypic and genotypic coefficient of variation were 34.10 and 32.71 respectively. High heritability (88%) along with high genetic advance (35.33) was observed for this trait.

4.1.3 Leaf length (cm)

Leaf length ranged from 15.52 - 35.02 cm with an overall mean of 27.06 cm. The minimum leaf length was observed for SK-KK-129 (15.52 cm) followed by SK-KK-IC-2 (17.75 cm), SK-KK-2 (18.87 cm), SK-KK-23 (20.52 cm) and SK-KK-88 (20.62 cm) while as the maximum leaf length was observed in SK-KK-14 (35.02 cm) followed by SK-KK-10 (34.15 cm), Purple Vienna (33.92 cm), SK-KK-197 (33.76 cm) and SK-KK-154 (32.36 cm). The phenotypic and genotypic variance for this trait were 42.07 and 41.07 respectively. The phenotypic and genotypic coefficient of variation were 23.96 and 23.68 respectively. High heritability (97%) along with high genetic advance (47.26) was observed for this trait.

4.1.4 Leaf width (cm)

Leaf width ranged from 12.38 - 26.16 cm with an overall mean of 18.83 cm. The minimum leaf width was observed for SK-KK-123 (12.38 cm) followed by SK-KK-IC-2 (13.00 cm), SK-KK-175 (14.42 cm), SK-KK-80 (14.43 cm) and SK-KK-9 (15.97 cm) while as the maximum leaf width was observed in SK-KK-14 (26.16 cm) followed by SK-KK-154 (25.80 cm), SK-KK-72(A) (24.09 cm), SK-KK-129 (23.89 cm) and SK-KK-2 (22.51 cm). The phenotypic and genotypic variance of this trait were 13.56 and 13.48 respectively. The phenotypic and genotypic coefficient of variation were 19.55 and 19.49 respectively. High heritability (99%) along with high genetic advance (40.03) was observed for this trait.

4.1.5 Petiole length (cm)

Petiole length ranged from 7.88 - 18.22 cm with an overall mean of 13.59 cm. The minimum petiole length was observed for Pusa Virat (7.88 cm) followed by SK-KK-IC-6 (8.24 cm), SK-KK-3 (8.95 cm), SK-KK-197 (9.41 cm) and SK-KK-88 (9.63 cm) while as the maximum petiole length was observed in SK-KK-32 (18.22 cm) followed by SK-KK-175 (18.01 cm), SK-KK-72(A) (17.01 cm), White Vienna (16.98 cm) and SK-KK-90 (16.55 cm). The phenotypic and genotypic variance in this trait were 6.22 and 6.13 respectively. The phenotypic and genotypic coefficient of variation were 18.36 and 18.22 respectively. High heritability (98%) along with high genetic advance (36.31) was observed for this trait.

Table 1(a): Analysis of variance with respect to MSS for various quantitative traits in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S. No.	Source of variation	d.f.	Mean sum of squares										
			No. of leaf whorls	Internode length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Days to 50% stem swelling	Days to 50% harvest	Stem length (cm)	Stem breadth (cm)	Gross stem weight (g)	Net stem weight (g)
1	Replicate	2	0.07	0.02	0.96	0.09	0.72	0.5	0.65	0.35	0.12	22.91	21.2
2	Genotypes	29	2.66**	0.19**	124.22**	40.54**	39.52**	87.50**	54.81**	1.11**	2.77**	28706.28**	22668.78**
3	Error	58	0.23	0.04	1.00	0.08	0.18	0.29	1.02	0.18	0.11	0.09	0.23

Contd..

S. No.	Source of variation	d.f.	Mean sum of squares											
			Plant height (cm)	Plant spread (cm)	No. of leaves per plant	Yield per hectare (q)	Days to 50% flowering	Days to seed maturity	Siliqua length (mm)	Siliqua width (mm)	No. of seeds per siliqua	Seed yield per plant (g)	Seed yield per hectare (Kg)	1000 seed weight (g)
1	Replicate	2	0.12	0.28	0.05	37.6	0.05	24.01	10.15	0.01	0.23	6.14	18.48	0.01
2	Genotypes	29	246.60**	202.36**	15.10**	3911.60**	432.47**	531.86**	776.46**	0.25**	91.25**	39.45**	5260.11*	1.28**
3	Error	58	0.09	0.18	0.56	2.43	0.65	4.80	4.35	0.02	0.16	0.11	5.03	0.01

*, **- Significant at 5% and 1% level of significance respectively

Contd..

Table 1(b): Analysis of variance with respect to MSS for various quality traits in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S.no.	Source of Variation	d. f.	Mean sum of squares										
			Total chlorophyll content (mg/100g)	Moisture content in leaf (%)	Moisture content in knob (%)	TSS content in leaf (ºB)	TSS content in knob (ºB)	Vitamin C content in leaf (mg/100g)	Vitamin C content in knob (mg/100g)	Carbohydrate content in leaf (%)	Carbohydrate content in knob (%)	Total carotenoids content in leaf (mg/100g)	Total carotenoids content in knob (mg/100g)
1	Replicate	2	115.14	0.65	0.03	1.06	1.7	0.03	0.4	0.72	0.06	0.77	1.11
2	Genotype	29	1710.59**	78.26*	129.51*	2.01**	2.00**	272.27**	187.20**	4.36**	3.84**	21.68**	5.72**
3	Error	58	72.12	0.09	0.11	0.06	0.07	0.09	0.19	0.08	0.09	0.06	0.04

*, **- Significant at 5% and 1% level of significance respectively

4.1.6 Days to 50% stem swelling

Days to 50% stem swelling ranged between 21.99 – 41.71 days with an overall mean of 33.06 days. The genotypes which took minimum days to 50% stem swelling were White Vienna (21.99) followed by SK-KK-154 (23.32), SK-KK-180 (25.81), SK-KK-197 (25.99) and SK-KK-90 (26.04) while as SK-KK-23 (41.71) took the maximum days for 50% swelling followed by SK-KK-1 (41.15), SK-KK-72(A) (40.65), SK-KK-14 (38.91) and SK-KK-9 (38.88). The phenotypic and genotypic variance of this trait were 29.36 and 29.06 respectively. The phenotypic and genotypic coefficient of variation were 16.39 and 16.30 respectively. High heritability (99%) along with high genetic advance (33.41) was observed for this trait.

4.1.7 Days to 50% harvest

Days to 50% harvest ranged between 40.51 - 62.09 days with an overall mean of 51.01 days. The genotypes which took minimum days to 50% harvest were White Vienna (40.51) followed by SK-KK-197 (41.57), SK-KK-38 (42.31), SK-KK-90 (42.33) and SK-KK-32 (43.15) while as SK-KK-23 (62.09) took the maximum days for 50% harvest followed by SK-KK-1 (61.22), SK-KK- 72(A) (60.12), SK-KK-72(B) (58.50) and SK-KK-9 (58.42). The phenotypic and genotypic variance this trait was 18.95 and 17.92 respectively. The phenotypic and genotypic coefficient of variation were 8.53 and 8.30 respectively. High heritability (94%) along with medium genetic advance (16.62) was observed for this trait.

4.1.8 Stem length (cm)

Stem length ranged from 3.60 - 5.89 cm with an average of 4.62 cm. Least stem length was recorded in SK-KK-123 (3.60 cm) followed by SK-KK-51 (3.62 cm), SK-KK-22 (3.66 cm), SK-KK-23 (3.71 cm) and SK-KK-38 (3.79 cm) while as SK-KK-14 followed by White Vienna, SK-KK-88, SK-KK-65, and SK-KK-72(B) recorded highest stem length values of 5.89 cm, 5.82 cm, 5.79 cm, 5.71 cm,

Table 2(a): Estimates of range, phenotypic variance, genotypic variance, phenotypic and genotypic coefficient of variation, heritability(bs) and genetic advance (as % of mean) for different quantitative traits in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S. No.	Parameter	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability (bs)	Genetic advance (as % of mean
1.	Number of leaf whorls	6.05	4.32 - 7.93	1.04	1.02	16.86	16.72	0.98	30.04
2.	Internode length (cm)	0.90	0.46 - 1.76	0.09	0.08	34.10	32.71	0.88	35.33
3.	Leaf length (cm)	27.06	15.52 - 35.02	42.07	41.07	23.96	23.68	0.97	47.26
4.	Leaf width (cm)	18.83	12.38 - 26.16	13.56	13.48	19.55	19.49	0.99	40.03
5.	Petiole length (cm)	13.59	7.88 - 18.22	6.22	6.13	18.36	18.22	0.98	36.31
6.	Days to 50% stem swelling	33.06	21.99 - 41.71	29.36	29.06	16.39	16.30	0.99	33.41
7.	Days to 50% harvest	51.01	40.51 - 62.09	18.95	17.92	8.53	8.30	0.94	16.62
8.	Stem length (cm)	4.62	3.60 - 5.89	0.49	0.48	15.24	15.12	0.97	24.53
9.	Stem breadth (cm)	6.88	5.24 - 9.46	0.99	0.88	14.50	13.68	0.88	26.57
10.	Gross stem weight (g)	399.72	222.89 – 583.76	7005.91	6780.25	20.94	20.60	0.99	42.45
11.	Net stem weight (g)	300.52	174.83 – 478.09	2762.65	2759.49	17.49	17.48	0.99	36.03

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S.No.	Parameter	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability (bs)	Genetic advance (as % of mean
1.	Plant height (cm)	48.40	31.41 - 63.96	82.26	82.17	18.73	18.72	0.99	38.55
2.	Plant spread (cm)	55.34	40.52 - 72.17	67.57	66.39	14.85	14.83	0.99	30.51
3.	Number of leaves per plant	12.60	8.84 - 17.57	5.41	4.84	18.45	17.46	0.89	34.04
4.	Yield per hectare (q)	175.06	116.13 – 246.04	9104.28	9026.21	54.50	54.27	0.99	93.07
5.	Days to 50% flowering	137.32	120.77 - 164.05	151.96	151.25	8.97	8.95	0.99	18.40
6.	Days to seed maturity	193.03	168.03 - 217.73	180.49	175.68	6.96	6.86	0.97	13.95
7.	Siliqua length (mm)	76.29	49.53 - 106.23	164.79	163.13	16.82	16.74	0.98	62.95
8.	Siliqua width (mm)	0.84	0.52 - 1.65	0.09	0.08	37.40	35.70	0.88	50.73
9.	Number of seed per siliqua	14.20	4.62 - 24.96	30.52	30.36	38.89	38.70	0.99	79.70
10.	Seed yield per plant (g)	11.91	5.95 - 19.82	28.60	28.52	44.91	44.84	0.99	92.23
11.	Seed yield per hectare (kg)	142.96	71.4 – 231.84	4122.06	4110.57	44.92	44.85	0.99	92.26
12.	1000 seed weight (g)	5.17	4.02 – 6.59	0.82	0.77	17.55	17.02	0.93	38.85

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Table 2(b): Estimates of range, phenotypic variance, genotypic variance, phenotypic and genotypic coefficient of variation, heritability(bs) and genetic advance (as % of mean) for different quality traits in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S. No.	Parameter	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability (bs)	Genetic advance (as % of mean
1.	Total chlorophyll content (mg/100g)	98.35	70.56 - 146.94	618.28	546.15	25.28	23.76	0.88	46.00
2.	Moisture content in leaf (%)	73.19	62.77 - 84.73	26.14	25.05	6.98	6.97	0.99	14.34
3.	Moisture content in knob (%)	56.06	41.12 - 69.22	43.24	43.13	11.73	11.71	0.99	24.10
4.	TSS content in leaf (ºB)	5.50	4.10 - 6.95	0.71	0.65	15.36	14.66	0.91	28.85
5.	TSS content in knob (ºB)	6.91	5.50 - 8.46	0.71	0.64	12.24	11.59	0.89	22.63
6.	Vitamin C content in leaf (mg/100g)	94.82	85.73 - 109.81	90.02	90.72	9.74	9.73	0.99	20.04
7.	Vitamin C content in knob (mg/100g)	58.53	45.97 - 74.71	62.53	62.33	13.50	13.48	0.99	27.74
8.	Carbohydrate content in leaf (%)	5.39	3.46 - 7.52	1.51	1.42	22.79	22.15	0.94	44.37
9.	Carbohydrate content in knob (%)	8.94	7.12 - 10.96	1.34	1.24	12.95	12.49	0.93	24.81
10.	Total carotenoids content in leaf (mg/100g)	8.34	5.94 - 9.69	7.27	7.20	32.32	32.17	0.99	65.97
11.	Total carotenoids content in knob (mg/100g)	3.51	1.86 - 6.07	1.93	1.89	39.55	39.12	0.97	79.71

and 5.68 cm respectively. The phenotypic and genotypic variance of this trait were 0.49 and 0.48 respectively. The phenotypic and genotypic coefficient of variation were 15.24 and 15.12 respectively. High heritability (97%) along with high genetic advance 24.53) was observed for this trait.

4.1.9 Stem breadth (cm)

Stem breadth ranged from 5.24 - 9.46 cm with an average of 6.88 cm. Least stem breadth was also recorded in SK-KK-IC-6 (5.24 cm) followed by SK-KK-123 (5.35 cm), SK-KK- 23 (5.46 cm), SK-KK-180 (5.56 cm) and SK-KK-IC-2 (5.86 cm) while as SK-KK-14, SK-KK-3, SK-KK-154, SK-KK-72(A) and SK-KK-129 recorded highest stem breadth values of 9.46 cm, 8.59 cm, 8.33 cm, 7.90 cm, and 7.86 cm respectively. The phenotypic and genotypic variance of this trait were 0.99 and 0.88 respectively. The phenotypic and genotypic coefficient of variation were 14.50 and 13.68 respectively. High heritability (88%) along with high genetic advance (26.57) was observed for this trait.

4.1.10 Gross stem weight (g)

Gross stem weight ranges from 222.8–583.76 g with an average of 399.72 g. The lowest gross stem weight was recorded in SK-KK-123 (222.89 g) followed by SK-KK-80 (272.81 g), SK-KK-32 (312.84 g), SK-KK-9 (316.64 g) and SK-KK-22 (323.81 g). Highest gross stem weight was recorded in SK-KK-14 (583.76 g), SK-KK-197 (572.81 g), SK-KK-10 (562.80 g), Purple Vienna (561.86 g), SK-KK-175 (547.96 g). The phenotypic and genotypic variance of this trait were 7005.91 and 6780.25 respectively. The phenotypic and genotypic coefficient of variation were 20.94 and 20.60 respectively. High heritability (99%) along with high genetic advance (42.45) was observed for this trait.

4.1.11 Net stem weight (g)

Net stem weight ranges from 174.83 - 478.09 g with an average of 300.52 g. Lowest net stem weight was recorded in SK-KK-123 (174.83 g) followed by SK-KK-80 (183.65 g), SK-KK-175 (199.78 g), SK-KK-IC-2 (223.87 g) and SK-

KK-65 (234.96 g). The highest net stem weight was recorded in SK-KK-14 (478.09 g) followed by SK-KK-154 (460.60 g), SK-KK-72(A) (445.65 g), SK-KK-129 (439.84 g) and SK-KK-2 (423.82 g). The phenotypic and genotypic variance of this trait were 2762.65 and 2759.49 respectively. The phenotypic and genotypic coefficient of variation were 17.49 and 17.48 respectively. High heritability (99%) along with high genetic advance (36.03) was observed for this trait.

4.1.12 Plant height (cm)

Plant height ranged from 31.41 - 63.96 cm with an overall mean of 48.40 cm. The minimum plant height was observed for SK-KK-23 (31.41 cm) followed by SK-KK-IC-2 (33.41 cm), SK-KK-180 (34.09 cm), White Vienna (36.60 cm) and SK-KK-IC-6 (38.06 cm) while as the maximum plant height was observed in SK-KK-64 (63.96 cm), Purple Vienna (61.56 cm), SK-KK-72(A) (60.28 cm), SK-KK-1 (59.36 cm) and SK-KK-14 (58.32 cm). The phenotypic and genotypic variance in this trait were 82.26 and 82.17 respectively. The phenotypic and genotypic coefficient of variation were 18.73 and 18.72 respectively. High heritability (99%) along with high genetic advance (38.55) was observed for this trait.

4.1.13 Plant spread (cm)

Plant spread ranged from 40.52 - 72.17 cm with an overall mean of 55.34 cm. The minimum plant spread was observed for SK-KK-32 (40.52 cm) followed by SK-KK-IC-2 (41.16 cm), SK-KK-80 (43.50 cm), SK-KK-23 (44.17 cm) and SK-KK-65 (46.33 cm) while as the maximum plant spread was observed in SK-KK-180 (72.17 cm), SK-KK-154 (67.71 cm), SK-KK-72(A) (66.15 cm), SK-KK-129 (65.77 cm) and Purple Vienna (64.52 cm). The phenotypic and genotypic variance of this trait were 67.57 and 66.39 respectively. The phenotypic and genotypic coefficient of variation were 14.85 and 14.83 respectively. High heritability (99%) along with high genetic advance (30.51) was observed for this trait.

4.1.14 Number of leaves per plant

Number of leaves per plant ranged from 8.84 - 17.57 with an overall mean of 12.60. SK-KK-123 (8.84) recorded least number of leaves per plant by SK-KK-IC-2 (9.58), SK-KK-23 (10.02), SK-KK-80 (10.32) and SK-KK-197 (10.52) while as SK-KK-14 (17.57) recorded the maximum number of leaves per plant followed by Purple Vienna (16.80), SK-KK-129 (16.33), SK-KK-2 (15.86) and SK-KK-175 (14.72). The phenotypic and genotypic variance were 5.41 and 4.84 respectively. The phenotypic and genotypic coefficient of variation were of number of leaves per plant 18.45 and 17.46 respectively. High heritability (89%) along with high genetic advance (34.04) was observed for this trait.

4.1.15 Yield per hectare (q)

Yield per hectare range from 116.00 – 246.04 q with an average of 175.06 q. Lowest yield per hectare was recorded in SK-KK-123 (116.00 q) followed by SK-KK-197 (119.60 q), SK-KK-IC-6 (124.00 q), SK-KK-51 (134.40 q) and SK-KK-65 (135.20 q). The highest yield per hectare was recorded in SK-KK-14 (246.04 q), SK-KK-154 (238.31 q), SK-KK-72(A) (226.80 q), SK-KK-129 (221.22 q), SK- KK-2 (216.01 q). The phenotypic and genotypic variance of this trait were 9104.28 and 9026.21 respectively. The phenotypic and genotypic coefficient of variation were 54.50 and 54.27 respectively. High heritability (99%) along with high genetic advance (93.07) was observed for this trait.

4.1.16 Days to 50% flowering

Days to 50% flowering ranged between 120.77 - 164.05 days with an overall mean of 137.32 days. The genotypes which took minimum days to 50% flowering were SK-KK-23 (120.77), SK-KK-IC-2 (120.94), SK-KK-180 (121.97), SK-KK-154 (122.55) and SK-KK-197 (125.16) while as SK-KK-80 (164.05) took the maximum days for 50% flowering followed by SK-KK-14

(160.05), SK-KK-72(A) (157.93), SK-KK-90 (156.55) and SK-KK-65 (153.69). The phenotypic and genotypic variance of this trait were 151.96 and 151.25 respectively. The phenotypic and genotypic coefficient of variation were 8.97 and 8.95 respectively. High heritability (99%) along with medium genetic advance (18.40) was observed for this trait.

4.1.17 Days to seed maturity

Days to seed maturity ranged between 168.03 - 217.73 days with an overall mean of 193.03 days. The genotypes which took minimum days to seed maturity were SK-KK-23 (168.03) followed by SK-KK-180 (173.16), SK-KK-3 (176.19), SK-KK-32 (177.29) and SK-KK-1 (179.21) while as SK-KK-80 (217.73) took the maximum days for seed maturity followed by SK-KK-14 (214.50), SK-KK-72(A) (212.14), SK-KK-38 (210.77) and Pusa Virat (207.03). The phenotypic and genotypic variance were 180.49 and 175.68 respectively. The phenotypic and genotypic coefficient of variation were 6.96 and 6.86 respectively. High heritability (97%) along with medium genetic advance (13.95) was observed for this trait.

4.1.18 Siliqua length (mm)

Siliqua length (mm) ranged between 49.53 - 106.23 mm with an overall mean of 76.29 mm. The genotypes which took minimum siliqua length were SK-KK-3 (49.53 mm) followed by SK-KK-1 (51.04 mm), SK-KK-51 (51.60 mm), SK-KK-180 (52.16 mm) and SK-KK-14 (54.92 mm) while as SK-KK-90 (106.23 mm) took the maximum siliqua length followed by SK-KK-64 (101.32 mm), SK-KK-72(B) (98.78 mm), White Vienna (95.49 mm) and SK-KK-2 (94.20 mm). The phenotypic and genotypic variance were 164.79 and 163.13 respectively. The phenotypic and genotypic coefficient of variation were 16.82 and 16.74 respectively. High heritability (98%) along with high genetic advance (62.95) was observed for this trait.

4.1.19 Siliqua width (mm)

Siliqua width (mm) ranged between 0.52 - 1.65 mm with an overall mean of 0.84 mm. The genotypes which took minimum siliqua width were SK-KK-1 (0.52 mm) followed by SK-KK-45 (0.54 mm), SK-KK-22 (0.55 mm) and SK-KK-3 (0.55 mm), SK-KK-154 (0.56 mm) and SK-KK-14 (0.57 mm) while as SK-KK-64 (1.65 mm) took the maximum siliqua width followed by SK-KK-90 (1.52 mm), SK-KK-72(B) (1.26 mm), SK-KK-175 (1.25 mm) and SK-KK-32 (1.19 mm). The phenotypic and genotypic variance of siliqua width were 0.09 and 0.08 respectively. The phenotypic and genotypic coefficient of variation were 37.40 and 35.70 respectively. High heritability (88%) along with high genetic advance (50.73) was observed for this trait.

4.1.20 Number of seeds per siliqua

Number of seeds per siliqua ranged from 4.62 - 24.96 with an overall mean of 14.20. SK-KK-3 (4.62) recorded minimum number of seeds per siliqua followed by SK-KK-1 (5.61), SK-KK-51 (6.11), SK-KK-154 (7.23) and SK-KK-38 (7.73) while as SK-KK-90 (24.96) recorded the maximum number of seeds per siliqua followed by SK-KK-64 (23.43), SK-KK-72(B) (22.77), SK-KK-32 (20.84) and White Vienna (20.48). The phenotypic and genotypic variance of number of seed per siliqua were 30.52 and 30.36 respectively. The phenotypic and genotypic coefficient of variation were 38.89 and 38.70 respectively. High heritability (99%)along with high genetic advance (79.70) was observed for this trait.

4.1.21 Seed yield per plant (g)

Seed yield per plant (g) range from 5.95 - 19.82 g with an average of 11.91 g. The lowest seed yield per plant was recorded in SK-K-3 (5.95 g) followed by SK-KK-129 (6.04 g), SK-KK-1 (6.95 g), SK-KK-51 (7.12 g) and ISK-KK-IC-2 (7.91 g). The highest seed yield per plant was recorded in SK-KK-90 (19.82 g), SK-KK-2 (18.09 g), SK-KK-23 (17.10 g), White Vienna (16.35 g), Purple Vienna (15.52 g). The phenotypic and genotypic variance of seed yield per plant were

28.60 and 28.52 respectively. The phenotypic and genotypic coefficient of variation were 44.91 and 44.84 respectively. High heritability (99%) along with high geneticadvance (92.23) was observed for this trait.

4.1.22 Seed yield per hectare (kg)

Seed yield per hectare (kg) range from 71.40 – 231.84 kg with an average of 142.96 kg. The lowest seed yield per hectare was recorded in SK-K-3 (71.40 kg) followed by SK-KK-129 (72.48 kg), SK-KK-1 (83.40 kg), SK-KK-51 (85.44 kg) and SK-KK-IC-2 (94.92 kg). The highest seed yield per hectare was recorded in SK-KK-90 (231.84 kg), SK-KK-2 (205.20 kg), SK-KK-23 (196.20 kg), White Vienna (193.08 kg), Purple Vienna (186.24 kg). The phenotypic and genotypic variance of seed yield per hectare were 4122.06 and 4110.57 respectively. The phenotypic and genotypic coefficient of variation were 44.92 and 44.85 respectively. High heritability (99%) along with high genetic advance (92.26) was observed for this trait.

4.1.23 1000 seed weight (g)

1000 seed weight (g) range from 4.02 to 6.59 g with an average of 5.17 g. The lowest 1000 seed weight was recorded in SK-K-129 (4.02 g) followed by SK-KK-80 (4.21 g), SK-KK-3 (4.32 g), SK-KK-32 (4.34 g) and SK-KK-1 (4.43 g). The highest 1000 seed weight was recorded in Purple Vienna (6.59 g) followed by SK-KK-23 (6.22 g), White Vienna (5.96 g), SK-KK-2 (5.93 g) and SK-KK-14 (5.84 g). The phenotypic and genotypic variance of 1000 seed weight were 0.82 and 0.77 respectively. The phenotypic and genotypic coefficient of variation were 17.55 and 17.02 respectively. High heritability (93%) along with high genetic advance (38.85) was observed for this trait.

4.1.24 Total chlorophyll content (mg/100g)

Total chlorophyll content (mg/100g) range from 70.62 -146.94 mg/100g with an average of 98.35 mg/100g. The lowest total chlorophyll content was recorded in Purple Vienna (70.56 mg/100g) followed by SK-KK-2 (70.62 mg/100g), SK-KK-22 (70.82 mg/100g), SK-KK-123

(71.92 mg/100g) and SK-KK-88 (72.25 mg/100g). The highest total chlorophyll content was recorded in White Vienna (146.94 mg/100g) followed by SK-KK-175 (143.35 mg/100g), Pusa Virat (132.51 mg/100g), SK-KK-90 (130.41 mg/100g) and SK-KK-88 (126.48 mg/100g). The phenotypic and genotypic variance were 618.28 and 546.15 respectively. The phenotypic and genotypic coefficient of variation were 25.28 and 23.76 respectively. High heritability (88%) along with high genetic advance (46.00) was observed for this trait.

4.1.25 Moisture content in leaf (%)

Moisture content in leaf (%) range from 62.77 - 84.73% with an average of 73.19. The lowest moisture content in leaf was recorded in SK-K-9 (62.77 %) followed by SK-KK-3 (65.79%), SK-KK-88 (68.10%), Purple Vienna (68.93%) and SK-KK-10 (69.00%). The highest moisture content in leaf was recorded in SK-KK-14 (84.73%) followed by White Vienna (81.51%), SK-KK-72(A) (81.04%), SK-KK-23 (80.38%) and SK-KK-22 (79.70%). The phenotypic and genotypic variance were 26.14 and 25.05 respectively. The phenotypic and genotypic coefficient of variation were 6.98 and 6.97 respectively. High heritability (99%) along with high genetic advance (14.34) was observed for this trait.

4.1.26 Moisture content in knob (%)

Moisture content in knob (%) range from 41.12 - 69.22 with an average of 56.06%. The lowest moisture content in knob was recorded in SK-K-23 (41.12%) followed by SK-KK-65 (41.82%), SK-KK-32 (46.28%), SK-KK-51 (47.96%) and SK- KK-9 (48.22%). The highest moisture content in knob was recorded in SK-KK-14 (69.22%) followed by SK-KK-154 (67.77%), SK-KK-IC-6 (66.09%), SK-KK- 180 (64.76%) and SK-KK-1 (63.36%). The phenotypic and genotypic variance were 43.24 and 43.13 respectively. The phenotypic and genotypic coefficient of variation were 11.73 and 11.71 respectively. High heritability (99%) along with high genetic advance (24.10) was observed for this trait.

4.1.27 TSS content in leaf (ºB)

TSS in leaf (ºB) range from 4.10 - 6.95 with an average of 5.50 ºB. The lowest TSS content in leaf was recorded in SK-K-10 (4.10 ºB) followed by SK-KK-1 (4.25 ºB), SK-KK-51 (4.44 ºB), SK-KK-38 (4.52 ºB) and SK-KK-65 (4.53). The highest TSS content in leaf was recorded in SK-KK-80 (6.95 ºB) followed by SK- KK-72(A) (6.93 ºB), SK-KK-3 (6.86 ºB), SK-KK-72(B) (6.50) and SK-KK-154 (6.49 ºB). The phenotypic and genotypic variance were 0.71 and 0.65 respectively. The phenotypic and genotypic coefficient of variation were 15.36 and 14.66 respectively. High heritability (91%) along with high genetic advance (28.85) wasobserved for this trait.

4.1.28 TSS content in knob (ºB)

TSS in knob (ºB) range from 5.50 - 8.46 with an average of 6.91 ºB. The lowest TSS content in knob was recorded in SK-K-32 (5.50) followed by SK-KK-123 (5.78 ºB), SK-KK-38 (5.84 ºB), SK-KK-23 (5.97 ºB) and White Vienna (6.03 ºB). The highest TSS content in knob was recorded in SK-KK-64 (8.46 ºB) followed by SK- KK-197 (8.32 ºB), SK-KK-180 (8.31 ºB), SK-KK-88 (8.08 ºB) and SK-KK-45 (7.94 ºB). The phenotypic and genotypic variance were 0.71 and 0.64 respectively. The phenotypic and genotypic coefficient of variation were 12.24 and 11.59 respectively. High heritability (89%) along with high genetic advance (22.63) wasobserved for this trait.

4.1.29 Vitamin C content in leaf (mg/100g)

Vitamin C content in leaf (mg/100g) range from 85.73 - 109.81 with an average of 94.82 mg/100g. The lowest vitamin C content in leaf was recorded in SK-K- 64 (85.73 mg/100g) followed by SK-KK-88 (86.77 mg/100g), SK-KK-51 (87.53 mg/100g), SK-KK-23 (88.12 mg/100g) and SK-KK-9 (88.17 mg/100g). The highest Vitamin C content in leaf was recorded in SK-KK-129 (109.81 mg/100g) followed by Pusa Virat (108.01 mg/100g), SK-KK-123 (107.28 mg/100g), SK-KK-72(B) (106.88 mg/100g) and SK-KK-80 (105.44 mg/100g). The phenotypic and genotypic variance were 90.02 and 90.72 respectively. The phenotypic and genotypic coefficient of variation was 9.74 and 9.73 respectively. High heritability (99%) along with high genetic advance (20.04) was observed for this trait.

4.1.30 Vitamin C content in knob (mg/100g)

Vitamin C content in knob (mg/100g) range from 45.97 - 74.71 with an average of 58.53 mg/100g. The lowest vitamin content in knob was recorded in SK-K-10 (45.97 mg/100g) followed by SK-KK-72(A) (47.54 mg/100g), SK-KK-23 (47.88 mg/100g), SK-KK-154 (49.46 mg/100g) and SK-KK-3 (50.92 mg/100g). The highest Vitamin C content in knob was recorded in SK-KK-123 (74.71 mg/100g) followed by SK-KK-88 (73.52 mg/100g), SK-KK-IC-6 (72.22 mg/100g), SK-KK-180 (70.11 mg/100g) and Pusa Virat (69.29 mg/100g). The phenotypic and genotypic variance were 62.53 and 62.33 respectively. The phenotypic and genotypic coefficient of variation were 13.50 and 13.48 respectively. High heritability (99%) along with high genetic advance (27.74) was observed for this trait.

4.1.31 Carbohydrate content in leaf (%)

Carbohydrate content in leaf (%) range from 3.46 - 7.52 with an average of 5.39. The lowest carbohydrate content in leaf was recorded in SK-K-123 (3.46%) followed by SK-KK-64 (3.49%), SK-KK-180 (3.50%), SK-KK-3 (3.55%) and SK-KK-197 (4.00%). The highest carbohydrate content in leaf was recorded in White Vienna (7.52) followed by SK-KK-23 (7.03%), SK-KK-IC-2 (6.93%), SK-KK-154 (6.72%) and SK-KK-32 (6.70%). The phenotypic and genotypic variance were 1.51 and 1.42 respectively. The phenotypic and genotypic coefficient of variation were 22.79 and 22.15 respectively. High heritability (94%) along with high genetic advance (44.37) was observed for this trait.

4.1.32 Carbohydrate content in knob (%)

Carbohydrate content in knob (%) range from 7.12 - 10.96 with an average of 8.94. The lowest carbohydrate content in knob was recorded in SK-K-72(A) (7.12%) followed by SK-KK-1 (7.32%), SK-KK-65 (7.41%), SK-KK-64 (7.42%)

and SK-KK-3 (7.47%). The highest carbohydrate content in knob was recorded in SK-KK- 80 (10.96%) followed by SK-KK-72(A) (10.87%), SK-KK-14 (10.79%), S K - K K - 7 5 (10.56%) and SK-KK-23 (10.37%). The phenotypic and genotypic variance were 1.34 and 1.24 respectively. The phenotypic and genotypic coefficient of variation were 12.95 and 12.49 respectively. High heritability (93%) along with high genetic advance (24.81) was observed for this trait.

4.1.33 Total carotenoids content in leaf (mg/100g)

Total carotenoids content in leaf (mg/100g) range from 5.94 – 9.69 with an average of 8.34. The lowest total carotenoids content in leaf was recorded in SK-K-9 (5.94) followed by SK-KK-22 (6.06 mg/100g), SK-KK-10 (6.07 mg/100g), SK-KK-2 (7.01 mg/100g) and SK-KK-197 (7.02 mg/100g). The highest total carotenoids content in leaf was recorded in SK-KK-65 (9.69) followed by SK-KK-180 (9.56 mg/100g), SK-KK-45 (9.37 mg/100g), SK-KK-32 (9.05 mg/100g) and Pusa Virat (8.42 mg/100g). The phenotypic and genotypic variance were 7.27 and 7.20 respectively. The phenotypic and genotypic coefficient of variation were 32.32 and 32.17 respectively. High heritability (99%) along with high genetic advance (65.97) was observed for this trait.

4.1.34 Total carotenoids content in knob (mg/100g)

Total carotenoids content in knob (mg/100g) range from 1.86 - 6.07 with an average of 3.51 mg/100g. The lowest total carotenoids content in knob was recorded in SK- K-IC-6 (1.86 mg/100g) followed by Purple Vienna (1.93 mg/100g), SK-KK-80 (1.95 mg/100g), SK-KK-3 (1.99 mg/100g) and SK-KK-1 (2.03 mg/100g). The highest total carotenoids content in knob was recorded in SK-KK-197 (6.07 mg/100g) followed by SK-KK-14 (5.94 mg/100g), SK-KK-51 (5.59 mg/100g), SK-KK-72(A) (5.48 mg/100g) and Pusa Virat (5.42 mg/100g). The phenotypic and genotypic variance were 1.93 and 1.89 respectively. The phenotypic and genotypic coefficient of variation were 39.55 and 39.12 respectively. High heritability (97%) along with high genetic advance (79.71) was observed for this trait.

SK-KK-14

SK-KK-90

SK-KK-80

SK-KK-64

Plate 4: Variability observed among different genotypes

Contd..

Plate 4: contd…..

Pusa Virat

Purple Vienna

White Vienna

4.2 Coefficient of variability, heritability, and genetic gain

The perusal of Table-2(a-b) revealed that the range was high for almost all the traits under study indicating that wide variation existed in the population. However, low range was observed for number of leaf whorls, internode length, stem length, stem breadth, siliqua width, 1000 seed weight, TSS in leaves and knob, carbohydrate in leaves and knob, total carotenoids in leaf and knob.

4.2.1 Coefficient of variability

Genotypic and phenotypic coefficients of variation are simple measures of variability, these measures are commonly used for the assessment of variability. The relative value of these types of coefficients gives an idea about the magnitude of variability present in a genetic population. Thus, the component of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed. The phenotypic coefficients of variation were slightly higher than the corresponding genotypic coefficient of variation indicating the little influence of environment in the expression of the character under study. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) as suggested by Sivasubramanian and Madhavamenon (1973). The highest PCV was observed for yield per hectare (54.50), seed yield per hectare (44.92) followed by seed yield per plant (44.91), total carotenoid content in knob (39.55), number of seeds per siliqua (38.89) and siliqua width (37.40). Lowest estimate of PCV was obtained in case of days to seed maturity (6.96), moisture content in leaf (6.98), days to 50% harvest (8.53) and days to 50% flowering (8.97). GCV also showed the same trend. Highest GCV was observed for yield per hectare (54.27), seed yield per hectare (44.85) followed by seed yield per plant(44.84), total carotenoid content in knob (39.12), number of seeds per siliqua (38.70) and siliqua width (35.70). Days to seed maturity (6.86) recorded lowest GCV followed by moisture content in leaf (6.97), days to 50% harvest (8.30) and days to 50% flowering (8.95).

4.2.2 Heritability and genetic gain

Heritability in broad sense was found to be high for all the traits under study. Its value ranged from 88% in stem breadth, internode length and siliqua width to as high as 99% in leaf width, plant height, plant spread, days to 50% stem swelling, gross stem weight, net stem weight, yield per hectare, days to 50% flowering, number of seeds per siliqua, seed yield per plant, seed yield per hectare, vitamin C content in leaf and knob, total carotenoids in leaf and moisture content in leaf and knob. Other characters also recorded high heritability viz. petiole length (98%) followed by number of leaf whorls (98%) and siliqua length (98%), leaf length (97%), stem length (97%) and total carotenoids content in knob (97%), days to 50% harvest (94%) and carbohydrate content in leaf (94%), 1000 seed weight (93%) and carbohydrate content in knob (93%), TSS content in leaf (91%), number of leaves per plant (89%) and TSS content in knob (89%), stem breadth (88%) followed by internode length (88%), siliqua width (88%) and total chlorophyll content (88%).

Highest genetic advance as percentage of mean was recorded in yield per hectare (93.07) followed by seed yield per hectare (92.26), seed yield per plant (92.23), total carotenoids content in knob (79.71), number of seeds per siliqua (79.70), total carotenoids content in leaf (65.97) and siliqua length (62.95). Lowest genetic advance as percentage of mean was recorded in days to seed maturity (13.95) followed by moisture content in leaf (14.34), days to 50% harvest (16.62), daysto 50% flowering (18.40) and vitamin C content in leaf (20.04). A careful study of results indicates that genotypic coefficients of variation and genetic advance as percentage of mean show a similar trend. Both GCV and genetic advance as percentage of mean are lowest for days to seed maturity and highest for seed yield per hectare and almost complete correspondence was observed between the two parameters for most of the characters although heritability was high in all cases and showed a different trend.

4.3 Correlation coefficient

The correlation coefficients were determined using variances and co-variances to obtain relationship among various characters and their relationship with yield per hectare, at both genotypic and phenotypic levels. The genotypic (r_g) and phenotypic (r_p) correlation coefficients among various characters are presented in Table-3.

4.3.1 Number of leaf whorls

Number of leaf whorls exhibited significant and positively corelated with internode length (r_g = 0.98, r_p= 0.96), leaf length (r_g = 0.57, r_p = 0.52), leaf width (r_g = 0.38, r_p = 0.36), petiole length (r_g = 0.86, r_p = 0.84), stem length (r_g = 0.72, r_p = 0.70), stem breadth (r_g = 0.78, r_p = 0.76), gross stem weight (r_g = 0.88, r_p = 0.84), net stem weight (r_g = 0.77, r_p = 0.75), plant height (r_g = 0.84, r_p = 0.80), plant spread (r_g = 0.56, r_p = 0.52), number of leaves per plant (r_g= 0.79, r_p = 0.78), siliqua length (r_g = 0.36, r_p = 0.34), siliqua width (r_g = 0.39, r_p = 0.38), number of seeds per siliqua (r_g = 0.46, r_p = 0.44), seed yield per plant (r_g = 0.35, r_p = 0.31) and yield per hectare (r_g = 0.85, r_p = 0.84). However, Number of leaf whorls exhibited non-significant and negative correlation with days to 50% stem swelling (r_g = -0.27, r_p = -0.23), days to 50% harvest (r_g = -0.37, r_p = -0.32), days to 50% flowering (r_g = -0.20, r_p = -0.18), days to seed maturity (r_g = -0.17, r_p = -0.16).

4.3.2 Internode length (cm)

Internode length was significant and positively corelated with number of leaf whorls (r_g =0.98, r_p= 0.96), leaf length (r_g = 0.56, r_p = 0.52), leaf width (r_g= 0.38, r_p = 0.34), petiole length (r_g = 0.87, r_p = 0.85), stem length (r_g= 0.77, r_p = 0.74), stem breadth (r_g = 0.81, r_p = 0.80), gross stem weight (r_g = 0.89, r_p = 0.87), net stem weight (r_g = 0.88, r_p = 0.86), plant height (r_g = 0.89, r_p = 0.88), plant spread (r_g = 0.60, r_p = 0.58), number of leaves per plant (r_g = 0.83, r_p = 0.82), siliqua length (r_g = 0.40, r_p = 0.38), siliqua width (r_g = 0.43, r_p = 0.42), number of seeds per siliqua (r_g = 0.48, r_p = 0.42), seed yield per plant (r_g = 0.36, r_p = 0.32) and yield per hectare (r_g = 0.87, r_p = 0.85). However, it exhibited non-significant and negative correlation with days to 50% stem swelling (r_g = -0.11, r_p = -0.09), days to50% harvest (r_g = -0.26, r_p = -0.21), days to 50% flowering (r_g = -0.21, r_p = -0.19), days to seed maturity (r_g = -0.17, r_p = -0.15).

4.3.3 Leaf length (cm)

Leaf length was significant and positively corelated with number of leaf whorls (r_g = 0.57, r_p = 0.52), internode length (r_g = 0.56, r_p = 0.52), leaf width (r_g = 0.59, r_p = 0.53), petiole length (r_g = 0.73, r_p = 0.70), stem length (r_g= 0.61, r_p = 0.59), stem breadth (r_g = 0.68, r_p = 0.64), gross stem weight (r_g = 0.64, r_p = 0.62), net stem weight (r_g = 0.68, r_p = 0.66), plant height (r_g = 0.59, r_p = 0.56), plant spread (r_g = 0.45, r_p = 0.43), number of leaves per plant (r_g = 0.45, r_p = 0.44), siliqua length (r_g = 0.18, r_p = 0.16), siliqua width (r_g = 0.20, r_p = 0.19), number of seeds per siliqua (r_g = 0.33, r_p = 0.31), seed yield per plant (r_g = 0.33, r_p = 0.32) andyield per hectare (r_g = 0.77, r_p = 0.75). However, it exhibited non-significant and negative correlation with days to 50% stem swelling (r_g = -0.05, r_p = -0.02), days to 50% harvest (r_g = -0.13, r_p = -0.10), days to 50% flowering (r_g = -0.11, r_p = -0.09) and days to seed maturity (r_g = -0.09, r_p = -0.08).

4.3.4 Leaf width (cm)

Leaf width was significant and positively corelated with number of leaf whorls (r_g =0.38, r_p= 0.36), internode length (r_g = 0.38, r_p = 0.34), leaf length (r_g = 0.59, r_p = 0.53), petiole length (r_g = 0.39, r_p = 0.33), stem length (r_g= 0.48, r_p = 0.44), stem breadth (r_g = 0.35, r_p = 0.32), gross stem weight (r_g = 0.39, r_p = 0.37), net stem weight (r_g = 0.37, r_p = 0.36), plant height (r_g = 0.42, r_p = 0.39), plant spread (r_g = 0.52, r_p = 0.50), number of leaves per plant (r_g = 0.43, r_p = 0.41), siliqua length (r_g = 0.29, r_p = 0.28), siliqua width (r_g = 0.20, r_p = 0.19), number of seeds per siliqua (r_g = 0.37, r_p = 0.35), seed yield per plant (r_g = 0.31, r_p = 0.30) andyield per hectare (r_g = 0.44, r_p = 0.42). However, it exhibited non-significant and negative correlation with days to 50% stem swelling (r_g = -0.09, r_p = -0.08), days to 50% harvest (r_g = -0.07, r_p = -0.05), days to 50% flowering (r_g = -0.12, r_p = -0.11)and days to seed maturity (r_g = -0.08, r_p = -0.06).

Table 3: Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among different traits in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

Parameters	NLW	IL	LL	LW	PL	DSS	DH	SL	SB	GSW	NSW	PH	PS	NLP	DF	DSM	SqL	SqW	NSS	SYP
No. of leaf whorls	**1.00**	0.98**	0.57**	0.38*	0.86**	-0.27^{ns}	-0.37^{ns}	0.72**	0.78**	0.88**	0.77**	0.84**	0.56**	0.79**	-0.20^{ns}	-0.17^{ns}	0.36*	0.39*	0.46*	0.35*
Internode length (cm)	0.96**	**1.00**	0.56**	0.38*	0.87**	-0.11^{ns}	-0.26^{ns}	0.77**	0.81**	0.89**	0.88**	0.89**	0.60**	0.83**	-0.21^{ns}	-0.17^{ns}	0.40*	0.43*	0.48*	0.36*
Leaf length (cm)	0.52**	0.52*	**1.00**	0.59*	0.73**	-0.05^{ns}	-0.13^{ns}	0.61*	0.68*	0.64*	0.68**	0.59**	0.45*	0.45*	-0.11^{ns}	-0.09^{ns}	0.18	0.20	0.33	0.33*
Leaf width (cm)	0.36*	0.34*	0.53*	**1.00**	0.39*	-0.09^{ns}	-0.07	0.48*	0.35*	0.39*	0.37*	0.42*	0.52*	0.43*	-0.12^{ns}	-0.08^{ns}	0.29	0.20	0.37*	0.31*
Petiole length (cm)	0.84**	0.85**	0.70**	0.33*	**1.00**	-0.18^{ns}	-0.09	0.80**	0.86*	0.85**	0.85**	0.85**	0.51*	0.83**	-0.16^{ns}	-0.13^{ns}	0.20	0.15	0.37*	0.35*
Days to 50% stem swelling	-0.23^{ns}	-0.09^{ns}	-0.02^{ns}	-0.08^{ns}	-0.16^{ns}	**1.00**	-0.14^{ns}	0.17	0.14	-0.03^{ns}	0.16	-0.04^{ns}	-0.02^{ns}	-0.05^{ns}	-0.03^{ns}	-0.02^{ns}	-0.19^{ns}	-0.02^{ns}	-0.05^{ns}	-0.17^{ns}
Days to 50% harvest	-0.32^{ns}	-0.21^{ns}	-0.10^{ns}	-0.05	-0.08	-0.13^{ns}	**1.00**	0.11	0.12	-0.04^{ns}	0.17	-0.02^{ns}	-0.11^{ns}	-0.06^{ns}	-0.12^{ns}	-0.10^{ns}	-0.11^{ns}	-0.13^{ns}	-0.06^{ns}	-0.11^{ns}
Stem length (cm)	0.70**	0.74**	0.59*	0.44*	0.78*	0.16	0.09	**1.00**	0.73**	0.76**	0.75**	0.85**	0.67**	0.66**	-0.27^{ns}	-0.20^{ns}	0.19	0.24	0.37*	0.36*
Stem breadth (cm)	0.76**	0.80**	0.64**	0.32*	0.84**	0.13	0.11	0.71**	**1.00**	0.82**	0.85**	0.82**	0.53*	0.77**	-0.06^{ns}	-0.04^{ns}	0.36*	0.35*	0.28	0.33*
Gross stem weight (g)	0.84**	0.87**	0.62*	0.37*	0.83**	-0.02^{ns}	-0.03^{ns}	0.74**	0.80**	**1.00**	0.94**	0.83**	0.55*	0.87**	-0.21^{ns}	-0.15^{ns}	0.38*	0.39*	0.45*	0.32*
Net stem weight (g)	0.75**	0.86**	0.66*	0.36*	0.83**	0.15	0.16	0.74**	0.84**	0.92**	**1.00**	0.83**	0.52*	0.83**	-0.12^{ns}	-0.08^{ns}	0.14	0.18	0.40*	0.35*
Plant height (cm)	0.80**	0.88**	0.56**	0.39*	0.81**	-0.03^{ns}	-0.01^{ns}	0.84**	0.81**	0.81**	0.80**	**1.00**	0.69**	0.67**	-0.14^{ns}	-0.07^{ns}	0.20	0.13	0.50*	0.33*
Plant spread (cm)	0.52**	0.58**	0.43*	0.50**	0.49*	-0.01^{ns}	-0.10^{ns}	0.66**	0.51**	0.53*	0.50**	0.68**	**1.00**	0.13	-0.13^{ns}	-0.03^{ns}	0.10	0.14	-0.06^{ns}	0.20
No. of leaves per plant	0.78**	0.82**	0.44*	0.41*	0.81**	-0.04^{ns}	-0.05^{ns}	0.65*	0.75**	0.85**	0.81**	0.66*	0.11	**1.00**	-0.30^{ns}	-0.18^{ns}	0.28	0.25	-0.04^{ns}	0.23
Days to 50% flowering	-0.18^{ns}	-0.19^{ns}	-0.09^{ns}	-0.11^{ns}	-0.14^{ns}	-0.02^{ns}	-0.10^{ns}	-0.26^{ns}	-0.04^{ns}	-0.19^{ns}	-0.11^{ns}	-0.12^{ns}	-0.11^{ns}	-0.28^{ns}	**1.00**	-0.21^{ns}	-0.02^{ns}	-0.11^{ns}	-0.09^{ns}	-0.11^{ns}
Days to seed maturity	-0.16^{ns}	-0.15^{ns}	-0.08^{ns}	-0.06^{ns}	-0.12^{ns}	-0.01^{ns}	-0.09^{ns}	-0.19^{ns}	-0.03^{ns}	-0.14^{ns}	-0.07^{ns}	-0.06^{ns}	-0.02^{ns}	-0.16^{ns}	-0.20^{ns}	**1.00**	-0.07^{ns}	-0.04^{ns}	-0.28^{ns}	-0.17^{ns}
Siliqua length (mm)	0.34*	0.38*	0.16	0.28	0.18	-0.16^{ns}	-0.10^{ns}	0.18	0.35*	0.37*	0.12	0.18	0.09	0.25	-0.01^{ns}	-0.06^{ns}	**1.00**	0.26	0.34*	0.39*
Siliqua width (mm)	0.38*	0.42*	0.19	0.19	0.13	-0.01^{ns}	-0.12^{ns}	0.23	0.34*	0.38*	0.17	0.11	0.12	0.22	-0.09^{ns}	-0.03^{ns}	0.24	**1.00**	0.36*	0.36*
No. of seeds per siliqua	0.44*	0.42*	0.31*	0.35*	0.35*	-0.04^{ns}	-0.04^{ns}	0.36*	0.26	0.42*	0.37*	0.49*	ˉ0.05^{ns}	-0.03^{ns}	-0.08^{ns}	-0.26^{ns}	0.32*	0.34*	**1.00**	0.37*
Seed yield per plant (g)	0.31*	0.32*	0.32*	0.30*	0.34*	-0.15^{ns}	-0.09^{ns}	0.35*	0.32	0.30	0.33*	0.30*	0.18	0.22	-0.10^{ns}	-0.16^{ns}	0.38*	0.35*	0.36*	**1.00**
Yield per hectare (q)	**0.85****	**0.87****	**0.77****	**0.44***	**0.88****	**-0.06^{NS}**	**-0.03^{NS}**	**0.79****	**0.87****	**0.89****	**0.95****	**0.84****	**0.57***	**0.75****	**-0.09^{NS}**	**-0.06^{NS}**	**0.31***	**0.37***	**0.46***	**0.49***

*, **= Significant at 5% and 1% respectively

NLW : Number of leaf whorls
IL : Internode length (cm)
LL: Leaf length (cm)
LW: Leaf width (cm)
PL : Petiole length (cm)
DSS : Days to 50% stem swelling
DH : Days to 50% harvest
SL : Stem length (cm)
SB : Stem breadth (cm)
GSW : Gross stem weight (g)
NSW : Net stem weight (g)
PH : Plant height (cm)
PS: Plant spread (cm)
NLP : Number of leaves per plant
DF: Days to 50% flowering
DSM : Days to seed maturity
SqL : Siliqua length (mm)
SqW: Siliqua width (mm)
NSS: No. of seeds per siliqua
SYP : Seed yield per plant (g)
YH: Yield per hectare (q)

4.3.5 Petiole length (cm)

Petiole length was significant and positively corelated with number of leaf whorls (r_g =0.86, r_p= 0.84), internode length (r_g =0.87, r_p= 0.85), leaf length (r_g = 0.73, r_p = 0.70), leaf width (r_g = 0.39, r_p = 0.33), stem length (r_g= 0.80, r_p = 0.78), stem breadth (r_g = 0.86, r_p = 0.84) gross stem weight (r_g = 0.85, r_p = 0.83), net stem weight (r_g = 0.85, r_p = 0.83), plant height (r_g = 0.85, r_p = 0.81), plant spread (r_g = 0.51, r_p = 0.49), number of leaves per plant (r_g = 0.83, r_p = 0.81), siliqua length (r_g = 0.20, r_p = 0.18), siliqua width (r_g = 0.15, r_p = 0.13), number of seeds per siliqua (r_g = 0.37, r_p = 0.35), seed yield per plant (r_g = 0.35, r_p = 0.34) and yield per hectare (r_g = 0.88, r_p = 0.86). However, it exhibited non- significant and negative correlation with days to 50% stem swelling (r_g = -0.18, r_p = -0.16), days to50% harvest (r_g = -0.09, r_p = -0.08), days to 50% flowering (r_g = -0.16, r_p = -0.14) and days to seed maturity (r_g = -0.13, r_p = -0.12).

4.3.6 Days to 50% stem swelling

Days to 50% stem swelling was non-significant and negatively corelated with number of leaf whorls (r_g =-0.27, r_p= -0.23), internode length (r_g = -0.11, r_p= -0.09), leaf length (r_g = -0.05, r_p = -0.02), leaf width (r_g = -0.09, r_p = -0.08), petiole length (r_g = -0.18, r_p = -0.16), days to 50% harvest (r_g = -0.14, r_p = -0.13), gross stem weight (r_g = -0.02, r_p = -0.02), plant height (r_g = -0.04, r_p = -0.03), plant spread (r_g = -0.02, r_p = -0.01), number of leaves per plant (r_g = -0.05, r_p = -0.04), days to 50% flowering (r_g = -0.03, r_p = -0.02), days to seed maturity (r_g = -0.02, r_p = -0.01), siliqua length (r_g = -0.19, r_p = -0.16), siliqua width (r_g = -0.02, r_p = -0.01), number of seeds per siliqua (r_g = -0.05, r_p = -0.04), seed yield per plant (r_g = -0.17, r_p = -0.15) and yield per hectare (r_g = -0.06, r_p = -0.05). It was non-significant and positive with stem length (r_g = 0.17, r_p = 0.16), stem breadth (r_g = 0.14, r_p = 0.13) and net stem weight (r_g = 0.16, r_p = 0.15).

4.3.7 Days to 50% harvest

Days to 50% harvest was non-significant and negatively corelated with number of leaf whorls (r_g = -0.37, r_p= -0.32), internode length (r_g = -0.26, r_p= -0.21), leaf length (r_g = -0.13, r_p = -0.10), leaf width (r_g = -0.07, r_p = -0.05), petiole length (r_g = -0.09, r_p = -0.08), days to 50% stem swelling (r_g = -0.14, r_p = -0.13), gross stem weight (r_g = -0.04, r_p = -0.03), plant height (r_g = -0.02, r_p = -0.01), plant spread (r_g = -0.11, r_p = -0.10), number of leaves per plant (r_g = -0.06, r_p = -0.05), days to 50% flowering (r_g = -0.12, r_p = -0.10), days to seed maturity (r_g = -0.10, r_p = -0.09), siliqua length (r_g = -0.11, r_p = -0.10), siliqua width (r_g = -0.13, r_p = -0.12), number of seeds per siliqua (r_g = -0.06, r_p = -0.05), seed yield per plant (r_g = -0.11, r_p = -0.09) and yield per hectare (r_g = -0.03, r_p = -0.02). It was non-significant and positive with stem length (r_g = 0.11, r_p = 0.09), stem breadth (r_g = 0.12, r_p = 0.11) and net stem weight (r_g = 0.17, r_p = 0.16).

4.3.8 Stem length (cm)

Stem length was significant and positively corelated with number of leaf whorls (r_g =0.72, r_p= 0.70), internode length (r_g =0.77, r_p= 0.74), leaf length (r_g = 0.61, r_p = 0.59), leaf width (r_g = 0.48, r_p = 0.44), petiole length (r_g = 0.80, r_p = 0.78), stem breadth (r_g = 0.73, r_p = 0.71), gross stem weight (r_g = 0.76, r_p = 0.74), net stem weight (r_g = 0.75, r_p = 0.74), plant height (r_g = 0.85, r_p = 0.84), plant spread (r_g = 0.67, r_p = 0.66), number of leaves per plant (r_g = 0.66, r_p = 0.65), siliqua length (r_g = 0.19, r_p = 0.18), siliqua width (r_g = 0.24, r_p = 0.23), number of seeds per siliqua (r_g = 0.37, r_p = 0.36), seed yield per plant (r_g = 0.36, r_p = 0.35) andyield per hectare (r_g = 0.79, r_p = 0.77). However, it exhibited non-significant and positive corelated with days to 50% stem swelling (r_g = 0.17, r_p = 0.16), days to 50% harvest (r_g = 0.11, r_p = 0.09).and it exhibited non-significant and negative corelated with days to 50% flowering (r_g = -0.27, r_p = -0.26) and days to seed maturity (r_g = -0.20, r_p = -0.19).

4.3.9 Stem breadth (cm)

Stem breadth was positive and significantly corelated with number of leaf whorls (r_g = 0.78, r_p = 0.76), internode length (r_g = 0.81, r_p = 0.80), leaf length (r_g = 0.68, r_p = 0.64), leaf width (r_g = 0.35, r_p = 0.32), petiole length (r_g = 0.86, r_p = 0.84), stem length (r_g = 0.73, r_p = 0.71), gross stem weight (r_g = 0.82, r_p = 0.80), net stem weight (r_g = 0.85, r_p = 0.84), plant height (r_g = 0.82, r_p = 0.81), plant spread (r_g = 0.53, r_p = 0.51), number of leaves per plant (r_g = 0.77, r_p = 0.75), siliqua length (r_g = 0.36, r_p = 0.35), siliqua width (r_g = 0.35, r_p = 0.34), number of seeds per siliqua (r_g = 0.28, r_p = 0.26), seed yield per plant (r_g = 0.33, r_p = 0.32) andyield per hectare (r_g = 0.87, r_p = 0.86). However, it exhibited non-significant and positive corelated with days to 50% stem swelling (r_g = 0.14, r_p = 0.13), days to 50% harvest (r_g = 0.12, r_p = 0.11) and it exhibited non-significant and negative corelated with days to 50% flowering (r_g = -0.06, r_p = -0.04) and days to seed maturity (r_g = -0.04, r_p = -0.03).

4.3.10 Gross stem weight (g)

Gross stem weight was positive and significantly corelated with number of leaf whorls (r_g =0.88, r_p= 0.84), internode length (r_g = 0.89, r_p = 0.87), leaf length (r_g = 0.64, r_p = 0.62), leaf width (r_g = 0.39, r_p = 0.32), petiole length (r_g = 0.85, r_p = 0.84), stem length (r_g = 0.76, r_p = 0.74), stem breadth (r_g = 0.82, r_p = 0.80), net stem weight (r_g = 0.94, r_p = 0.92), plant height (r_g = 0.83, r_p = 0.81), plant spread (r_g = 0.53, r_p = 0.51), number of leaves per plant (r_g = 0.77, r_p = 0.75), siliqua length (r_g = 0.38, r_p = 0.37), siliqua width (r_g = 0.39, r_p = 0.38), number of seeds per siliqua (r_g = 0.45, r_p = 0.42), seed yield per plant (r_g = 0.32, r_p = 0.30) and yield per hectare (r_g = 0.89, r_p = 0.88). However, it exhibited non-significant and negative corelated with days to 50% stem swelling (r_g = -0.03, r_p = -0.02), days to 50% harvest (r_g = -0.04, r_p = -0.03), days to 50% flowering (r_g = -0.21, r_p = -0.19) and days to seed maturity (r_g = -0.15, r_p = -0.14).

4.3.11 Net stem weight (g)

Net stem weight was positive and significantly corelated with number of leaf whorls (r_g = 0.77, r_p = 0.75), internode length (r_g = 0.88, r_p = 0.87), leaf length (r_g = 0.68, r_p = 0.66), leaf width (r_g = 0.37, r_p = 0.36), petiole length (r_g = 0.85, r_p = 0.83), stem length (r_g = 0.75, r_p = 0.74), stem breadth (r_g = 0.85, r_p = 0.84), gross stem weight (r_g = 0.94, r_p = 0.92), plant height (r_g = 0.83, r_p = 0.80), plant spread (r_g = 0.52, r_p = 0.50), number of leaves per plant (r_g = 0.83, r_p = 0.81), siliqua length (r_g = 0.14, r_p = 0.12), siliqua width (r_g = 0.18, r_p = 0.17), number of seeds per siliqua (r_g = 0.40, r_p = 0.37), seed yield per plant (r_g = 0.35, r_p = 0.33) and yield per hectare (r_g = 0.95, r_p = 0.94). However, it exhibited non-significant and positive corelated with days to 50% stem swelling (r_g = 0.16, r_p = 0.15), days to 50% harvest (r_g = 0.17, r_p = 0.16) and it exhibited non-significant and negative corelated with days to 50% flowering (r_g = -0.12, r_p = -0.11) and days to seed maturity (r_g = -0.08, r_p = -0.07).

4.3.12 Plant height (cm)

Plant height was positive and significantly corelated with number of leaf whorls (r_g = 0.84, r_p = 0.82), internode length (r_g = 0.89, r_p = 0.88), leaf length (r_g = 0.59, r_p = 0.56), leaf width (r_g = 0.42, r_p = 0.39), petiole length (r_g = 0.85, r_p = 0.81), stem length (r_g = 0.85, r_p = 0.80), stem breadth (r_g = 0.82, r_p = 0.85), gross stem weight (r_g = 0.85, r_p = 0.82), net stem weight (r_g = 0.83, r_p = 0.81), plant spread (r_g = 0.69, r_p = 0.68), number of leaves per plant (r_g = 0.67, r_p = 0.66), number of seeds per siliqua (r_g = 0.50, r_p = 0.49), seed yield per plant (r_g = 0.33, r_p = 0.30) and yield per hectare (r_g= 0.84, r_p = 0.82). However, it exhibited non-significant and negative corelated with days to 50% stem swelling (r_g = -0.04, r_p = -0.03), days to 50% harvest (r_g = -0.02, r_p = -0.01), days to 50% flowering (r_g = -0.14, r_p = -0.12), days to seed maturity (r_g = -0.07, r_p = -0.06) and it exhibited non-significant and positive corelated with siliqua length (r_g = 0.20, r_p = 0.18) and siliqua width (r_g = 0.13, r_p = 0.11).

4.3.13 Plant spread (cm)

Plant spread was positive and significantly corelated with number of leaf whorls ($r_g = 0.56$, $r_p = 0.52$), internode length ($r_g = 0.60$, $r_p = 0.58$), leaf length ($r_g = 0.45$, $r_p = 0.43$), leaf width ($r_g = 0.52$, $r_p = 0.50$), petiole length ($r_g = 0.51$, $r_p = 0.49$), stem length ($r_g = 0.67$, $r_p = 0.66$), stem breadth ($r_g = 0.53$, $r_p = 0.51$), gross stem weight ($r_g = 0.55$, $r_p = 0.53$), net stem weight ($r_g = 0.52$, $r_p = 0.50$), plant height ($r_g = 0.69$, $r_p = 0.68$) and it exhibited non-significant and positive corelated with number of leaves per plant ($r_g = 0.13$, $r_p = 0.11$), siliqua length ($r_g = 0.10$, $r_p = 0.09$), siliqua width ($r_g = 0.14$, $r_p = 0.12$), seed yield per plant ($r_g = 0.20$, $r_p = 0.18$) and yield per hectare ($r_g = 0.57$, $r_p = 0.56$). However, it exhibited negative and non-significantly corelated with days to 50% stem swelling ($r_g = -0.02$, $r_p = -0.01$), days to 50% harvest ($r_g = -0.11$, $r_p = -0.10$). days to 50% flowering ($r_g = -0.13$, $r_p = -0.11$), days to seed maturity ($r_g = -0.03$, $r_p = -0.02$) and number of seed per siliqua ($r_g = -0.06$, $r_p = -0.05$).

4.3.14 Number of leaves per plant

Number of leaves per plant was positive and significantly corelated with number of leaf whorls ($r_g = 0.79$, $r_p = 0.78$), internode length ($r_g = 0.83$, $r_p = 0.82$), leaf length ($r_g = 0.45$, $r_p = 0.44$), leaf width ($r_g = 0.43$, $r_p = 0.41$), petiole length ($r_g = 0.83$, $r_p = 0.81$), stem length ($r_g = 0.66$, $r_p = 0.65$), stem breadth ($r_g = 0.77$, $r_p = 0.75$), gross stem weight ($r_g = 0.87$, $r_p = 0.85$), net stem weight ($r_g = 0.83$, $r_p = 0.81$), plant height ($r_g = 0.67$, $r_p = 0.66$), plant spread ($r_g = 0.13$, $r_p = 0.11$), siliqua length ($r_g = 0.28$, $r_p = 0.25$), siliqua width ($r_g = 0.25$, $r_p = 0.22$), seed yield per plant ($r_g = 0.23$, $r_p = 0.22$) and yield per hectare ($r_g = 0.75$, $r_p = 0.74$). However, it exhibited negative and non-significantly corelated with days to 50% stem swelling ($r_g = -0.05$, $r_p = -0.04$), days to 50% harvest ($r_g = -0.06$, $r_p = -0.05$), days to 50% flowering ($r_g = -0.30$, $r_p = -0.28$), days to seed maturity ($r_g = -0.18$, $r_p = -0.16$) and number of seed per siliqua ($r_g = -0.04$, $r_p = -0.02$).

4.3.15 Days to 50% flowering

Days to 50% flowering was negative and non-significantly corelated with number of leaf whorls (r_g = -0.20, r_p= -0.18), internode length (r_g = -0.21, r_p= -0.19), leaf length (r_g = -0.11, r_p = -0.09), leaf width (r_g = -0.12, r_p = -0.11), petiole length (r_g = -0.16, r_p = -0.14), days to 50% stem swelling (r_g = -0.03, r_p = -0.02), days to 50% harvest (r_g = -0.12, r_p = -0.10), stem length (r_g = -0.27, r_p = -0.26), stem breadth (r_g = -0.06, r_p = -0.04), gross stem weight (r_g = -0.21, r_p = -0.19), net stem weight (r_g = -0.12, r_p = -0.11), plant height (r_g = -0.14, r_p = -0.12), plant spread (r_g = -0.13, r_p = -0.11), number of leaves per plant (r_g = -0.30, r_p = -0.28), days to seed maturity (r_g = -0.21, r_p = -0.20), siliqua length (r_g = -0.02, r_p = -0.01), siliqua width (r_g = -0.11, r_p = -0.09), number of seeds per siliqua (r_g = -0.09, r_p = -0.08), seed yield per plant (r_g = -0.11, r_p = -0.10) and yield per hectare (r_g = -0.09, r_p = -0.08).

4.3.16 Days to seed maturity

Days to seed maturity was negative and non-significantly corelated with number of leaf whorls (r_g = -0.17, r_p= -0.16), internode length (r_g = -0.17, r_p= -0.15), leaf length (r_g = -0.09, r_p = -0.08), leaf width (r_g = -0.08, r_p = -0.06), petiole length (r_g = -0.13, r_p = -0.12), days to 50% stem swelling (r_g = -0.02, r_p = -0.01), days to 50% harvest (r_g = -0.10, r_p = -0.09), stem length (r_g = -0.20, r_p = -0.19), stem breadth (r_g = -0.04, r_p = -0.03), gross stem weight (r_g = -0.15, r_p = -0.14), net stem weight (r_g = -0.08, r_p = -0.05), plant height (r_g = -0.07, r_p = -0.06), plant spread (r_g = -0.03, r_p = -0.02), number of leaves per plant (r_g = -0.18, r_p = -0.16), days to 50% flowering (r_g = -0.21, r_p = -0.20), siliqua length (r_g = -0.07, r_p = -0.06), siliqua width (r_g = -0.04, r_p = -0.03), number of seeds per siliqua (r_g = -0.28, r_p = -0.26), seed yield per plant (r_g = -0.17, r_p = -0.16) and yield per hectare (r_g = -0.06, r_p = -0.05).

4.3.17 Siliqua length (mm)

Siliqua length was positive and significantly corelated with number of leaf whorls (r_g = 0.36, r_p= 0.34), internode length (r_g = 0.40, r_p= 0.38), leaf length (r_g = 0.18, r_p = 0.16), leaf width (r_g = 0.29, r_p = 0.28), petiole length (r_g = 0.20, r_p = 0.18), stem length (r_g = 0.19, r_p = 0.18), stem breadth (r_g = 0.36, r_p = 0.35), gross stem weight (r_g = 0.38, r_p = 0.37), net stem weight (r_g = 0.14, r_p = 0.12), plant height (r_g = 0.20, r_p = 0.18), plant spread (r_g = 0.10, r_p = 0.09), number of leaves per plant (r_g = 0.28, r_p = 0.25), siliqua width (r_g = 0.26, r_p = 0.24), number of seeds per siliqua (r_g = 0.34, r_p = 0.32), seed yield per plant (r_g = 0.39, r_p = 0.38) and yield per hectare (r_g = 0.31, r_p = 0.30) . However, it exhibited negative and non-significantly corelated with days to 50% stem swelling (r_g = -0.19, r_p = -0.16), days to 50% harvest (r_g = -0.11, r_p = -0.10), days to 50% flowering (r_g = -0.02, r_p = -0.01), days to seed maturity (r_g = -0.07, r_p = -0.06).

4.3.18 Siliqua width (mm)

Siliqua width was positive and significantly corelated with number of leaf whorls (r_g = 0.39, r_p= 0.38), internode length (r_g = 0.43, r_p= 0.42), leaf length (r_g = 0.20, r_p = 0.19), leaf width (r_g = 0.20, r_p = 0.19), petiole length (r_g = 0.15, r_p = 0.13), stem length (r_g = 0.24, r_p = 0.23), stem breadth (r_g = 0.35, r_p = 0.34), gross stem weight (r_g = 0.39, r_p = 0.38), net stem weight (r_g = 0.18, r_p = 0.17), plant height (r_g = 0.13, r_p = 0.11), plant spread (r_g = 0.14, r_p = 0.12), number of leaves per plant (r_g = 0.25, r_p = 0.22), siliqua length (r_g = 0.26, r_p = 0.24), number of seeds per siliqua (r_g = 0.36, r_p = 0.34), seed yield per plant (r_g = 0.36, r_p = 0.35) and yield per hectare (r_g = 0.37, r_p = 0.36). However, it exhibited negative and non- significantly corelated with days to 50% stem swelling (r_g = -0.02, r_p = 0.01), daysto 50% harvest (r_g = -0.13, r_p = -0.12), days to 50% flowering (r_g = -0.11, r_p = - 0.09), days to seed maturity (r_g = -0.04, r_p = -0.03).

4.3.19 Number of seeds per siliqua

Number of seeds per siliqua was positive and significantly corelated with number of leaf whorls (r_g = 0.46, r_p = 0.44), internode length (r_g = 0.48, r_p = 0.42), leaf length (r_g = 0.33, r_p = 0.31), leaf width (r_g = 0.37, r_p = 0.35), petiole length (r_g = 0.37, r_p = 0.32), stem length (r_g = 0.37, r_p = 0.36), stem breadth (r_g = 0.28, r_p = 0.26), gross stem weight (r_g = 0.45, r_p = 0.42), net stem weight (r_g = 0.40, r_p = 0.37), plant height (r_g = 0.50, r_p = 0.49), siliqua length (r_g = 0.34, r_p = 0.32), siliqua width (r_g = 0.36, r_p = 0.34), seed yield per plant (r = 0.37, r = 0.36) and yield per hectare (r_g = 0.46, r_p = 0.45). It was negative with days to 50% stem swelling (r_g = -0.05, r_p = -0.04), days to 50% harvest (r_g = -0.05, r_p = -0.04), plant spread (r_g = -0.06, r_p = -0.05), number of leaves per plant (r_g = -0.04, r_p = -0.03), days to 50% flowering (r_g = -0.09, r_p = -0.08) and days to seed maturity (r_g = -0.28, r_p = -0.26).

4.3.20 Seed yield per plant (g)

Seed yield per plant was positive and significantly corelated with number of leaf whorls (r_g = 0.35, r_p = 0.31), internode length (r_g = 0.36, r_p = 0.32), leaf length (r_g = 0.33, r_p = 0.32), leaf width (r_g = 0.31, r_p = 0.30), petiole length (r_g = 0.35, r_p = 0.34), stem length (r_g = 0.36, r_p = 0.35), stem breadth (r_g = 0.33, r_p = 0.32), gross stem weight (r_g = 0.32, r_p = 0.30), net stem weight (r_g = 0.35, r_p = 0.33), plant height (r_g = 0.33, r_p = 0.30), plant spread (r_g = 0.20, r_p = 0.18), number of leaves per plant (r_g = 0.23, r_p = 0.22), siliqua length (r_g = 0.39, r_p = 0.38), siliqua width (r_g = 0.36, r_p = 0.35), number of seeds per siliqua (r_g = 0.37, r_p = 0.36) and yield per hectare (r_g = 0.49, r_p = 0.48). It was negative and non-significantly corelated with days to 50% stem swelling (r_g = -0.17, r_p = -0.15), days to 50% harvest (r_g = -0.11, r_p = -0.09), days to 50% flowering (r_g = -0.11, r_p = -0.10) and days to seed maturity (r_g = -0.17, r_p = -0.16).

4.3.21 Yield per hectare (q)

Yield per hectare was positive and significantly corelated with number of leaf whorls (r_g = 0.85, r_p = 0.84), internode length (r_g =0.87, r_p= 0.86), leaf length (r_g = 0.77, r_p = 0.76), leaf width (r_g= 0.44, r_p = 0.43), petiole length (r_g = 0.88, r_p = 0.87), stem length (r_g = 0.79, r_p = 0.78, stem breadth (r_g = 0.87, r_p = 0.86) gross stem weight (r_g = 0.89, r_p = 0.88), net stem weight (r_g = 0.95, r_p = 0.94), plant height (r_g = 0.84, r_p = 0.83), plant spread (r_g = 0.57, r_p = 0.56), number of leaves per plant (r_g = 0.75, r_p = 0.74), siliqua length (r_g = 0.31, r_p = 0.30), siliqua width (r_g = 0.37, r_p = 0.36), number of seed per siliqua (r_g = 0.46, r_p = 0.45) and seed yield per plant (r_g = 0.49, r_p = 0.48). However, it exhibited non-significant and negative correlation with days to 50% stem swelling (r_g = -0.06, r_p = -0.05), days to50% harvest (r_g = -0.03, r_p = -0.02), days to 50% flowering (r_g = -0.09, r_p = -0.08) and days to seed maturity (r_g = -0.06, r_p = -0.05).

4.4 Path coefficient analysis

The path coefficient analysis was computed to find out relative direct and indirect contribution of component traits towards yield per hectare. The genotypic correlation coefficients were partitioned into direct and indirect effects of component traits on yield and the results are presented in Table-4.

4.4.1 Number of leaf whorls

Number of leaf whorls showed significant positive correlation with yield per hectare (0.85) and its direct effect on yield was positive (0.79). Indirect effects of number of leaf whorls on yield per hectare via leaf length, leaf width, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity and number of seeds per siliqua were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, plant spread, days to 50% flowering, siliqua length, siliqua width and seed yield per plant were negative.

4.4.2 Internode length (cm)

Internode length recorded significant positive correlation with yield per hectare (0.87) and its direct effect on yield was negative (-0.65). Indirect effects of internode length on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity and number of seeds per siliqua were positive and those through days to 50% stem swelling, days to 50% harvest, plant spread, days to 50% flowering, siliqua length, siliqua width and seed yield per plant were negative.

4.4.3 Leaf length (cm)

Leaf length recorded significant positive correlation with yield per hectare (0.77) and its direct effect on yield was positive (0.07). Indirect effects of leaf length on yield per hectare via number of leaf whorls, leaf width, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity and number of seeds per siliqua were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, plant spread, days to 50% flowering, siliqua length, siliqua width and seed yield per plant were negative.

4.4.4 Leaf width (cm)

Leaf width recorded significant positive correlation with yield per hectare (0.44) and its direct effect on yield was also positive (0.08). Indirect effects of leaf width on yield per hectare via number of leaf whorls, leaf length, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity and number of seeds per siliqua were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length, siliqua width and seed yield per plant were negative.

4.4.5 Petiole length (cm)

Petiole length recorded significant positive correlation with yield per hectare (0.88) and its direct effect on yield was also positive (0.32). Indirect effects of petiole length on yield per hectare via number of leaf whorls, leaf length, leaf width, stem length, stem breadth, gross stem weight, net stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.6 Days to 50% stem swelling

Days to 50% stem swelling recorded non-significant negative correlation with yield per hectare (-0.06) and its direct effect on yield was also negative (-0.23). Indirect effects of days to 50% stem swelling on yield per hectare via number of leaf whorls, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internodelength, leaf length, leaf width, petiole length, days to 50% harvest, plant spread, days to 50% flowering, siliqua length and siliqua width were negative.

Table 4: Path matrix showing direct (diagonal) and indirect (off diagonal) effects of different traits on yield per hectare in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

Parameters	NLW	IL	LL	LW	PL	DSS	DH	SL	SB	GSW	NSW	PH	PS	NLP	DF	DSM	SqL	SqW	NSS	SYP
No. of leaf whorl	**0.79**	0.78	0.45	0.30	0.68	0.40	0.15	0.57	0.62	0.69	0.69	0.66	-0.36	0.28	-0.16	-0.13	-0.13	-0.15	0.32	-0.28
Internode length (cm)	-0.65	**-0.65**	-0.37	-0.25	-0.57	-0.34	-0.11	-0.51	-0.53	-0.58	-0.58	-0.58	-0.09	-0.04	-0.31	-0.23	0.11	-0.13	-0.14	-0.11
Leaf length (cm)	0.04	0.04	**0.07**	0.04	0.05	-0.04	-0.04	0.04	0.05	0.04	0.05	0.04	-0.03	0.03	0.02	0.04	-0.06	-0.08	0.05	-0.06
Leaf width (cm)	0.03	0.03	0.05	**0.08**	0.03	-0.05	-0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.05	0.04	-0.01	-0.09	0.01	-0.07
Petiole length (cm)	0.28	0.28	0.23	0.12	**0.32**	-0.17	-0.18	0.26	0.28	0.31	0.31	0.27	0.16	0.27	0.12	0.11	-0.03	-0.05	0.05	0.04
Days to 50% stem swelling	-0.12	-0.12	-0.13	-0.13	-0.12	**-0.23**	-0.16	-0.15	-0.15	-0.11	-0.12	-0.16	-0.13	-0.08	-0.08	-0.09	0.04	-0.01	-0.08	0.04
Days to 50% harvest	-0.11	-0.11	-0.15	-0.13	-0.13	-0.16	**-0.24**	-0.16	-0.15	-0.12	-0.13	-0.15	-0.18	0.10	0.12	0.15	-0.02	-0.03	-0.03	0.02
Stem length (cm)	0.25	0.27	0.21	0.16	0.28	0.27	0.31	**0.35**	0.25	0.26	0.22	-0.23	0.23	0.13	0.13	0.12	0.06	0.08	0.19	0.17
Stem breadth (cm)	0.15	0.16	0.13	0.07	0.17	0.18	0.17	0.14	**0.20**	0.16	0.12	-0.12	0.10	0.15	0.05	0.08	0.01	-0.01	0.11	0.10
Gross stem weight (g)	0.27	0.28	0.20	0.12	0.29	0.29	0.26	0.24	0.25	**0.31**	0.15	-0.15	0.17	0.27	0.14	0.10	0.03	-0.06	0.06	0.04
Net stem weight (g)	0.50	0.50	0.39	0.21	0.54	-0.30	-0.10	0.44	0.51	0.54	**0.57**	0.47	0.30	0.18	0.23	0.20	-0.02	-0.04	0.06	0.04
Plant height (cm)	0.59	0.62	0.42	0.30	0.60	-0.47	-0.12	0.62	0.60	0.59	0.58	**0.70**	0.19	0.17	0.35	0.23	-0.06	-0.09	0.10	0.05
Plant spread (cm)	-0.34	-0.03	-0.02	0.03	0.03	-0.03	-0.04	0.04	0.03	0.03	0.32	0.04	**-0.06**	0.02	-0.04	-0.02	-0.04	-0.09	-0.09	0.01
No. of leaves per plant	0.26	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.22	0.01	0.09	**0.02**	0.01	0.02	-0.09	-0.07	0.00	0.08
Days to 50% flowering	-0.13	-0.14	-0.09	-0.16	-0.11	-0.10	-0.15	-0.11	-0.08	-0.13	-0.11	-0.14	-0.18	-0.13	**-0.29**	-0.16	-0.02	0.01	-0.01	0.07
Days to seed maturity	0.08	0.08	0.12	0.12	0.08	0.09	0.14	0.08	0.10	0.07	0.08	0.07	0.09	0.07	0.13	**0.23**	-0.04	-0.01	0.01	0.10
Siliqua length (mm)	-0.01	-0.01	-0.01	-0.02	-0.07	-0.01	-0.08	-0.01	-0.01	-0.07	-0.03	-0.05	0.01	-0.02	0.01	-0.01	**-0.07**	0.06	0.06	0.07
Siliqua width (mm)	-0.26	-0.26	-0.14	-0.14	-0.20	-0.10	-0.17	-0.32	-0.07	-0.26	0.11	-0.17	-0.19	-0.34	-0.03	-0.05	-0.05	**-1.13**	-1.31	0.26
No. of seeds per siliqua	0.43	0.45	0.25	0.27	0.36	-0.07	-0.27	0.58	0.13	0.46	0.24	0.31	-0.29	0.64	-0.12	0.16	-0.08	--0.28	**-2.12**	-2.06
Seed yield per plant (g)	-0.13	-0.13	-0.06	-0.06	0.10	0.01	0.07	0.15	0.03	0.12	0.06	0.61	0.02	0.21	0.05	0.09	0.03	0.13	0.12	**0.16**
Genotypic Corelated with yield(q/ha)	**0.85****	**0.87****	**0.77****	**0.44***	**0.88****	**-0.06^{ns}**	**-0.13^{ns}**	**0.79****	**0.87****	**0.89****	**0.95****	**0.84****	**0.57***	**0.75****	**-0.09^{ns}**	**-0.06^{ns}**	**0.31**	**0.37**	**0.46***	**0.49***

Residual effect = 0.1860

NLW : Number of leaf whorls
IL : Internode length (cm)
LL: Leaf length (cm)
LW: Leaf width (cm)
PL : Petiole length (cm)
DSS : Days to 50% stem swelling
DH : Days to 50% harvest
SL : Stem length (cm)
SB : Stem breadth (cm)
GSW : Gross stem weight (g)
NSW : Net stem weight (g)
PH : Plant height (cm)
PS: Plant spread (cm)
NLP : Number of leaves per plant
DF: Days to 50% flowering
DSM : Days to seed maturity
SqL : Siliqua length (mm)
SqW: Siliqua width (mm)
NSS: No. of seeds per siliqua
SYP : Seed yield per plant (g)
YH: Yield per hectare (q)

4.4.7 Days to 50% harvest

Days to 50% harvest recorded non-significant negative correlation with yield per hectare (-0.13) and its direct effect on yield was also negative (-0.24). Indirect effects of days to 50% harvest on yield per hectare via Indirect effects of days to 50% stem swelling on yield per hectare via number of leaf whorls, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, leaf length, leaf width, petiole length, days to 50% stem swelling, days to 50% harvest, plant spread, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.8 Stem length (cm)

Stem length recorded significant positive correlation with yield per hectare (0.79) and its direct effect on yield was also positive (0.35). Indirect effects of stem length on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem breadth, gross stem weight, net stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.9 Stem breadth (cm)

Stem breadth recorded significant positive correlation with yield per hectare (0.87) and its direct effect on yield was also positive (0.20). Indirect effects of stem breadth on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem length, gross stem weight, net stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.10 Gross stem weight (g)

Gross stem weight recorded significant positive correlation with yield per hectare (0.89) and its direct effect on yield was also positive (0.31). Indirect effects of gross stem weight on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem length, stem breadth, net stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.11 Net stem weight (g)

Net stem weight recorded significant positive correlation with yield per hectare (0.95) and its direct effect on yield was also positive (0.57). Indirect effects of net stem weight on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem length, stem breadth, gross stem weight, plant height, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.12 Plant height (cm)

Plant height recorded significant positive correlation with yield per hectare (0.84) and its direct effect on yield was also positive (0.70). Indirect effects of plant height on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, net stem weight, plant spread, number of leaves per plant, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, stem length, stem breadth, gross stem weight, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.13 Plant spread (cm)

Plant spread recorded significant positive correlation with yield per hectare (0.57) and its direct effect on yield was also negative (-0.06). Indirect effects of plant spread on yield per hectare via leaf width, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity, siliqua length, number of seeds per siliqua and seed yield per plant were positive and those through number of leaf whorls, internode length, leaf length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering and siliqua width were negative.

4.4.14 Number of leaves per plant

Number of leaves per plant recorded significant positive correlation with yield per hectare (0.75) and its direct effect on yield was also positive (0.02). Indirect effects of number of leaves per plant on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, days to 50% harvest, stem length, stem breadth, gross stem weight, net stem weight, plant height, plant spread, days to seed maturity, number of seeds per siliqua and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.15 Days to 50% flowering

Days to 50% flowering recorded negative correlation with yield per hectare (-0.09) and its direct effect on yield was also negative (-0.29). Indirect effects of days to 50% flowering on yield per hectare via leaf length, leaf width, petiole length, days to 50% harvest, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, days to seed maturity, siliqua length, number of seeds per siliqua and seed yield per plant were positive and those through number of leaf whorls, internode length, days to 50% stem swelling, plant spread and siliqua width were negative.

4.4.16 Days to seed maturity

Days to seed maturity recorded negative correlation with yield per hectare (-0.06) and its direct effect on yield was also positive (0.23). Indirect effects of days to seed maturity on yield per hectare via leaf length, leaf width, petiole length, days to 50% harvest, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant, number of seeds per siliqua and seed yield per plant were positive and those through number of leaf whorls, internode length, days to 50% stem swelling, plant spread, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.17 Siliqua length (mm)

Siliqua length recorded positive correlation with yield per hectare (0.31) and its direct effect on yield was also positive (0.07). Indirect effects of siliqua width on yield per hectare via internode length, days to 50% stem swelling, stem length, stem breadth, gross stem weight, number of seeds per siliqua and seed yieldper plant were positive and those through number of leaf whorls, leaf length, leaf width, petiole length, days to 50% harvest, net stem weight, plant height, plant spread, days to seed maturity, days to 50% flowering and siliqua width were negative.

4.4.18 Siliqua width (mm)

Siliqua width recorded negative correlation with yield per hectare (0.37) and its direct effect on yield was also negative (-1.33). Indirect effects of siliqua width on yield hectare via, stem length, stem breadth and seed yield per plant were positive and those through number of leaf whorls, internode length, leaf length, leaf width, petiole length, days to 50% stem swelling, days to 50% harvest, gross stem weight, net stem weight, plant height, plant spread, days to seed maturity, days to 50% flowering, siliqua length and number of seeds per siliqua were negative.

4.4.19 Number of seeds per siliqua

Number of seeds per siliqua recorded positive correlation with yield per hectare (0.46) and its direct effect on yield was also negative (-2.12). Indirect effects of number of seed per siliqua on yield per hectare via number of leaf whorls, leaf length, leaf width, petiole length, stem length, stem breadth, gross stem weight, net stem weight, plant height, number of leaves per plant and days to seed maturity and seed yield per plant were positive and those through internode length, days to 50% stem swelling, days to 50% harvest, plant spread, days to 50% flowering, siliqua length and siliqua width were negative.

4.4.20 Seed yield per plant (g)

Seed yield per plant recorded positive correlation with yield per hectare (0.49) and its direct effect on yield was also positive (0.16). Indirect effects of seed yield per plant on yield per hectare via, petiole length, stem length, stem breadth, days to 50% stem swelling, days to 50% harvest, gross stem weight, net stem weight, plant height, plant spread, number of leaves per plant, days to 50% flowering, days to seed maturity, siliqua length, siliqua width and number of seeds per siliqua were positive and those through number of leaf whorls, internode length, leaf length and leaf width were negative.

4.5 Estimation of genetic divergence

The genetic divergence analysis among thirty genotypes of knol-khol was carried out by Mahalanobis D^2 statistics.

Thirty genotypes of knol-khol were distributed into eleven non-overlapping clusters (table 5). Maximum number of genotypes were present in cluster II (6 genotypes) viz., SK-KK-1, SK-KK-32, SK-KK-64, SK-KK-65, SK-KK-180, SK-KK-175 followed by cluster I (5 genotypes) viz., SK-KK-3, SK-KK-38, SK-KK-72(B), Purple Vienna, Pusa Virat followed by cluster III (5 genotypes) viz., SK-KK-9, SK-KK-22, SK-KK-23, SK-KK-80, White Vienna followed by cluster IV (4 genotypes) viz., SK-KK-2, SK-KK-10, SK-KK-129, SK-KK-IC-6 followed by cluster V (4 genotypes) viz., SK-KK-14, SK-KK-72(A), SK-KK-154, SK-KK-197 and cluster VI, VII, VIII, IX, X and XI with one genotype each viz., SK-KK-90, SK-KK-88, SK-KK-123, ISK-KK-C-2, SK-KK-45 and SK-KK-51 respectively. (fig.1)

The intra and inter-cluster distance obtained by D^2 statistics are presented in table 6. The minimum intra-cluster was found in cluster I (149931.00) and maximum intra-cluster distance was found in cluster V (475570.30). The cluster VI, VII, VIII, IX, X and XI showed intra-cluster distance of 0.00 because of being mono-genotypic. The maximum inter-cluster distance was observed between cluster IV and cluster XI (4849918.00) followed by cluster X and XI (4051389.00) and cluster IV and cluster VI (3824375.00).(fig.2)

Table 5: Distribution of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) genotypes into clusters based on D^2 Statistics

Cluster	No of genotypes in the cluster	Name of genotypes
I	5	SK-KK-3, SK-KK-38, SK-KK-72(B), Purple Vienna, Pusa Virat
II	6	SK-KK-1, SK-KK-32, SK-KK-64, SK-KK-65, SK-KK-180, SK-KK-175
III	5	SK-KK-9, SK-KK-22, SK-KK-23, SK-KK-80, White Vienna
IV	4	SK-KK-2, SK-KK-10, SK-KK-129, SK-KK-IC-6
V	4	SK-KK-14, SK-KK-72(A), SK-KK-154, SK-KK-197
VI	1	SK-KK-90
VII	1	SK-KK-88
VIII	1	SK-KK-123
IX	1	SK-KK- IC-2
X	1	SK-KK-45
XI	1	SK-KK-51

Table 6: Average intra-cluster (Diagonal) and inter-cluster (Above diagonal) distance values in Knol-khol

S.No.	Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1.	**I**	**149931.00**	725708.30	423755.20	257410.00	593087.30	872037.60	493073.80	711273.10	574714.90	1210443.00	412787.00
2.	**II**		**180522.30**	348560.00	3000983.00	948541.30	473559.90	537955.20	552666.40	315924.80	2162679.00	431580.30
3.	**III**			**221743.20**	663205.80	970150.20	1896108.00	356032.00	659622.40	894765.90	534859.00	2546522.00
4.	**IV**				**283734.90**	541991.00	3824375.00	2596490.00	1961909.00	499782.00	476465.50	4849918.00
5.	**V**					**475570.30**	1567997.00	765422.10	123385.00	1121527.00	227373.00	1869609.00
6.	**VI**						**0.00**	344264.50	353060.00	697671.80	3463256.00	233871.80
7.	**VII**							**0.00**	371324.00	938529.60	2426872.00	802400.40
8.	**VIII**								**0.00**	186311.70	1058281.00	366076.00
9.	**IX**									**0.00**	1782108.00	672064.70
10.	**X**										**0.00**	4051389.00
11.	**XI**											**0.00**

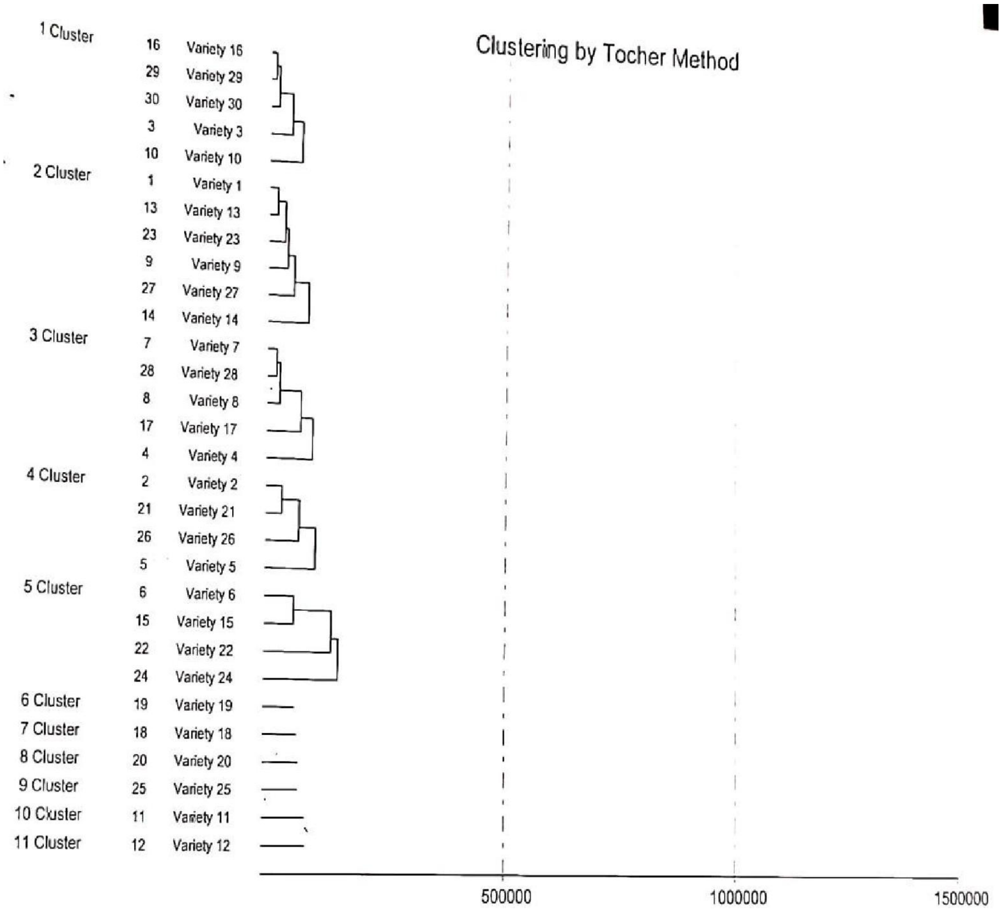

Fig. 1: Clustering of genotypes by Tocher method (Dendrogram)

1= SK-KK-1, 2= SK-KK-2, 3= SK-KK-3, 4= SK-KK-9, 5= SK-KK-10, 6= SK-KK-14, 7= SK-KK-22, 8= SK-KK-23, 9= SK-KK-32, 10= SK-KK-38, 11= SK-KK-45, 12= SK-KK-51, 13= SK-KK-64, 14= SK-KK-65, 15= SK-KK-72(A), 16= SK-KK-72(B), 17= SK-KK-80, 18= SK-KK-88, 19= SK-KK-90, 20= SK-KK-123, 21= SK-KK-129, 22= SK-KK-154, 23= SK-KK-175, 24= SK-KK-180, 25= SK-KK-197, 26= SK-KK-IC-2, 27= SK-KK-IC-6, 28= Purple Vienna, 29= Pusa Virat, 30= White Vienna.

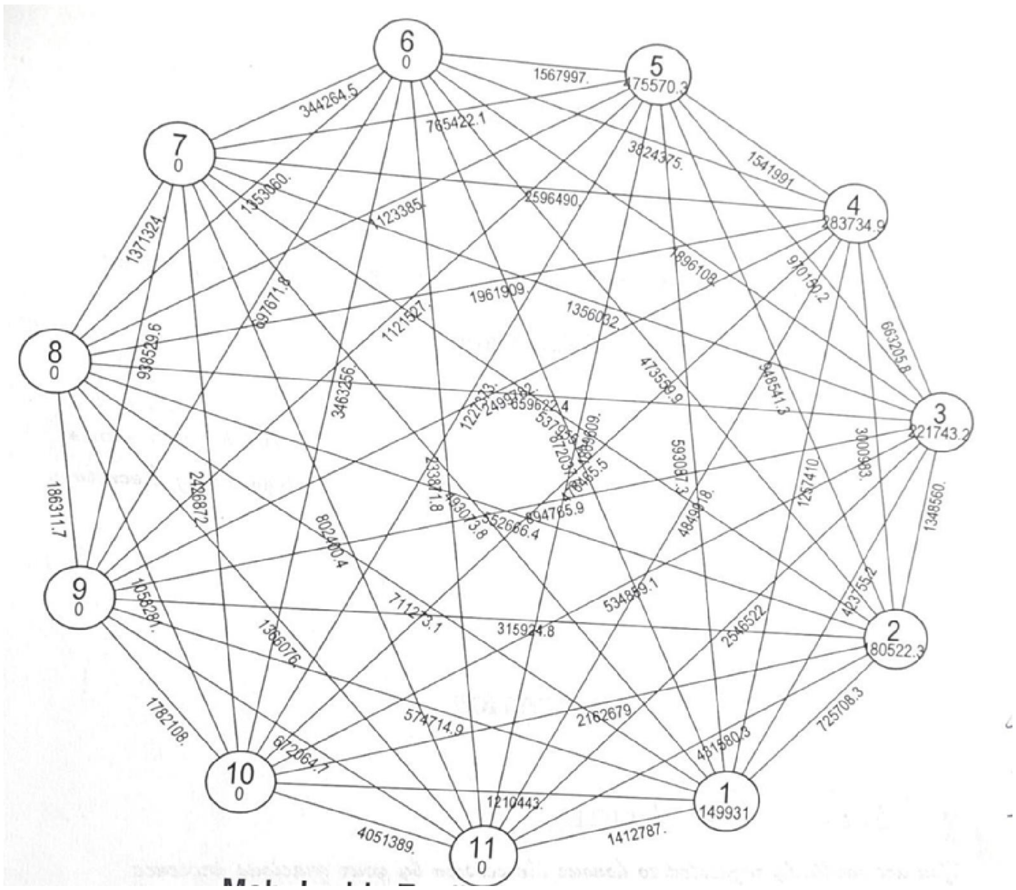

Fig. 2: Mahalanobis Euclidean distance within and between clusters

Table 7(a): Cluster means for various quantitative traits in different clusters of Knol-khol genotypes (Tocher method)

S. No.	Parameters	Cluster										
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1.	Number of leaf whorls	6.17	5.93	5.36	5.73	7.44	6.73	6.48	5.21	4.72	5.92	6.61
2.	Internode length (cm)	0.99	0.74	0.89	1.08	1.23	0.52	0.80	0.52	0.46	0.82	0.93
3.	Leaf Length (cm)	28.00	25.84	23.61	34.97	36.97	22.70	24.71	15.52	17.75	28.84	21.13
4.	Leaf width(cm)	18.71	17.13	16.73	22.20	24.63	15.67	18.63	12.39	13.00	20.04	15.46
5.	Petiole length (cm)	17.34	23.46	15.68	20.13	21.32	16.55	18.63	17.71	13.22	20.66	15.36
6.	Days to 50% stem swelling	33.92	33.23	37.38	33.88	32.46	26.04	38.84	28.91	27.46	33.07	22.00
7.	Days to 50% harvest	53.53	49.73	57.31	48.62	49.21	49.33	49.47	48.36	44.64	52.61	50.74
8.	Stem length (cm)	4.53	4.55	4.21	5.01	5.55	4.63	4.79	4.06	3.60	4.63	3.62
9.	Stem breadth (cm)	7.45	6.18	6.42	7.33	8.04	6.26	7.34	5.86	5.40	7.48	6.38
10.	Net stem weight (g)	274.74	266.60	257.34	423.82	478.09	249.94	268.59	174.83	297.05	285.00	245.92
11.	Gross stem weight (g)	370.92	352.60	323.81	500.98	583.76	398.83	379.72	222.89	330.72	394.91	373.69

Contd…

S. No.	Parameters	Cluster										
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**
1.	**Plant height (cm)**	47.36	57.59	47.66	45.00	53.21	40.76	41.77	53.60	33.41	38.52	45.18
2.	**Plant spread (cm)**	58.19	67.14	49.30	51.16	63.74	49.17	54.15	40.52	41.16	58.67	48.82
3.	**Number of leaves per plant**	13.12	11.23	11.16	15.12	15.95	11.14	11.86	8.84	9.58	12.71	10.98
4.	**Yield per hectare (q)**	197.22	162.82	152.42	202.43	246.04	143.20	206.10	116.13	190.87	178.07	134.27
5.	**Days to 50% flowering**	132.96	131.97	151.81	137.99	135.26	156.55	128.45	136.78	120.95	131.35	150.13
6.	**Days seed maturity**	195.62	183.70	210.83	192.19	188.19	195.57	207.04	206.41	179.71	181.32	187.74
7.	**Siliqua length (mm)**	75.17	74.80	82.49	106.23	66.24	80.58	87.01	86.31	68.40	64.92	51.60
8.	**Siliqua width (mm)**	0.82	0.86	0.80	1.65	0.71	0.88	0.88	0.86	0.64	0.54	0.96
9.	**Number of seeds per siliqua**	13.70	14.29	16.27	24.96	10.60	15.14	17.22	16.83	11.81	10.66	6.11
10.	**Seed yield per plant(g)**	13.18	16.35	17.10	19.82	10.68	14.71	18.09	15.52	10.26	8.41	7.12
11.	**Seed yield per hectare (kg)**	181.16	193.08	205.20	231.84	136.20	186.24	226.68	196.20	128.48	100.92	71.40
12.	**1000 seed weight (g)**	4.48	5.10	5.66	4.02	5.84	5.26	5.78	5.26	6.59	5.02	4.98

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Table 7(b): Cluster means for various quality traits in different clusters of Knol-khol genotypes (Tocher method)

S. No.	Parameters	Cluster										
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1.	**Total Chlorophyll content (mg/100g)**	169.17	98.28	151.55	148.91	154.08	113.09	92.93	136.43	200.63	71.86	163.42
2.	**Moisture content in leaf (%)**	69.55	73.86	72.52	73.14	76.99	74.53	68.10	71.46	71.91	78.45	77.53
3.	**Moisture content in knob (%)**	55.11	55.21	53.85	59.76	58.37	49.53	57.56	62.60	59.06	56.52	47.96
4.	**TSS in leaf (ºB)**	5.64	5.07	5.90	4.98	6.24	4.93	5.97	4.94	5.51	6.38	4.44
5.	**TSS in knob (ºB)**	6.39	7.28	6.58	6.71	7.28	6.58	8.09	5.79	7.19	7.94	7.38
6.	**Vitamin C content in leaf (mg/100g)**	107.23	93.93	94.45	104.85	94.51	90.47	86.78	108.28	103.29	89.04	87.53
7.	**Vitamin C content in knob (mg/100g)**	58.49	58.30	55.36	59.15	50.81	63.98	73.52	74.71	61.47	65.87	57.64
8.	**Carbohydrate content in leaf (%)**	5.30	5.03	6.05	5.79	5.30	5.44	4.16	3.47	6.93	4.90	5.62
9.	**Carbohydrate content in knob (%)**	9.32	8.25	9.37	8.65	8.85	9.91	8.96	8.48	9.87	8.60	9.59
10.	**Total carotenoids content in leaf (mg/100g)**	7.63	11.33	6.92	7.00	7.51	7.39	7.14	7.51	7.59	14.38	7.53
11.	**Total carotenoids content in knob (mg/100g)**	3.30	2.78	3.40	3.65	4.89	2.23	3.48	5.59	4.97	2.45	2.48

The data presented in table-7 (a-b) showed that cluster means for different traits had considerable differences between the clusters. All the eleven clusters had in general medium mean performance for most of the characters, exhibiting extreme cluster means for none of the characters under study.

Cluster means for different traits revealed that cluster-I expressed a mean number of leaf whorls and internode length of 6.17 and 0.99 cm respectively with leaf length, leaf width and petiole length of 28.00 cm, 18.71 cm, 17.34 cm, respectively and took 33.92 and 53.53 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.53 cm, 7.45 cm, 274.74 and 370.92 g respectively. The plant height, plant spread, numberof leaves per plant of 47.36 cm, 58.19 cm, 13.12 with yield per hectare of 197.22 qper ha. It took 132.96 and 195.62 days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 75.17 mm, 0.82 mm, 13.70, 13.18 g, 181.16 kg and 4.48 g respectively. The total chlorophyll content was 169.17 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 69.55% and 55.11% and 5.64 and 6.39ºB respectively. The Vitamin C content in leaf and knob was 107.23 mg/100g and 58.49 mg /100g and carbohydrate content in leaf and knob were 5.30% and, 9.32% respectively. The total carotenoids content in leaf and knob was 7.63 mg/100g and 3.30 mg/100g respectively.

Cluster-II expressed a mean number of leaf whorls and internode length of 5.93 and 0.74 cm respectively with leaf length, leaf width and petiole length of 25.84 cm, 17.13 cm and 23.46 cm respectively and took 33.23 and 49.73 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.55 cm, 6.18 cm, 266.60 and 352.60 g respectively. The plant height, plant spread and number of leaves per plant of 57.59 cm, 67.14 cm and 11.23 with yield per hectare of 162.82 q per ha. It took 131.97 and 183.70 days for days to 50%

flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 74.80 mm, 0.86 mm, 14.29, 16.35 g, 193.08 kg and 5.10 g respectively. The total chlorophyll content was 98.28 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 73.86% and 55.21% and 5.07 and 7.28 ºB respectively. The Vitamin C content in leaf and knob was 93.93 mg/100g and 58.30 mg/100g and carbohydrate content in leaf and knob were 5.03 % and 8.25 % respectively. The total carotenoids content in leaf and knob was 11.33 mg/100g and 2.78 mg/100g respectively.

Cluster-III expressed a mean number of leaf whorls and internode length of 5.36 and 0.89 cm respectively with leaf length, leaf width and petiole length of 23.61 cm, 16.73 cm and 15.68 cm respectively and took 37.38 and 57.31 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.21 cm, 6.42 cm, 257.34 and 323.81 g respectively. The plant height, plant spread, number of leaves per plant of 47.66 cm, 49.30 cm, 11.16 with yield per hectare of 152.42 q per ha. It took 151.81 and 210.82 days fordays to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 82.49 mm, 0.80 mm, 16.27, 17.10 g, 205.20 kg and 5.66 g respectively. The total chlorophyll content was 151.55 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 72.52% and 53.85% and 5.90 and 6.58ºB respectively. The Vitamin C content in leaf and knob was 94.45 mg/100g and 55.36 mg/100g and carbohydrate content in leaf and knob were 6.05 % and 9.37 % respectively. The total carotenoids content in leaf and knob was 6.92 mg/100g and 3.40 mg/100g respectively.

Cluster-IV expressed a mean number of leaf whorls and internode length of 5.73 and 1.08 cm respectively with leaf length, leaf width and petiole length of 34.97 cm, 22.20 cm and 20.13 cm respectively and took 33.88 and 48.62 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 5.01 cm, 7.33 cm, 423.82 and 500.98 g respectively. The plant height, plant spread and number of leaves per plant of 45.00 cm, 51.16 cm and 15.12 with yield per hectare of 202.43 q per ha. It took 137.99 and 192.19 days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 106.23 mm, 1.65 mm, 24.96, 19.82 g, 231.84 kg and 4.02 g respectively. The total chlorophyll content was 148.91 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 73.14 % and 59.76 % and 4.98 and 6.71 ºB respectively. The Vitamin C content in leaf and knob was 104.85 mg/100g and 59.15 mg/100g and carbohydrate content in leaf and knob were 5.79 % and, 8.65 % respectively. The total carotenoids content in leaf and knob was 7.00 mg/100g and 3.65 mg/100g respectively.

Cluster-V expressed a mean number of leaf whorls and internode length of 7.44 and 1.23 cm respectively with leaf length, leaf width and petiole length of 36.97 cm, 24.63 cm and 21.32 cm respectively. It took 32.46 and 49.21 days for daysto 50% stem swelling and days to 50% harvest from the date of transplanting respectively with stem length, stem breadth, net stem weight and gross stem weight of 5.55 cm, 8.04 cm, 478.09 and 583.76 g respectively. The plant height, plant spread and number of leaves per plant of 53.21 cm, 63.74 cm and 15.95 with yield per hectare of 246.04 q per ha. It took 135.26 and 188.19 days fordays to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 66.24 mm, 0.71 mm, 10.60, 10.68 g, 136.20 kg and 5.84 g respectively. The total chlorophyll content was 154.08 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 76.99 % and 58.37 % and 6.24 and 7.28 ºB respectively. The Vitamin C content in leaf and knob was 94.51 mg/100g and 50.81 mg/100g and carbohydrate content in leaf and knob were 5.30 % and, 8.85 % respectively. The total carotenoids content in leaf and knob was 7.51 mg/100g and 4.89 mg/100g respectively.

Cluster-VI expressed a mean number of leaf whorls and internode length of 6.73 and 0.52 cm respectively with leaf length, leaf width and petiole length of 22.70 cm, 15.67 cm and 16.55 cm respectively and took 26.04 and 49.33 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.63 cm, 6.26 cm, 249.94 and 398.83 g respectively. The plant height, plant spread and number of leaves per plant of 40.76 cm, 49.17 cm and 11.14 with yield per hectare of 143.20 q per ha. It took 156.55 and 195.57 days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 80.58 mm, 0.88 mm, 15.14, 14.71 g, 186.24 kg, and 5.26 g respectively. The total chlorophyll content was 113.09 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 74.53 % and 49.53 % and 4.93 and 6.58 ºB respectively. The Vitamin C content in leaf and knob was 90.47 mg/100g and 63.98 mg/100g and carbohydrate content in leaf and knob were 5.44 % and, 9.91 % respectively. The total carotenoids content in leaf and knob was 7.39 mg/100g and 2.23 mg/100g respectively.

Cluster-VII expressed a mean number of leaf whorls and internode length of 6.48 and 0.80 cm respectively with leaf length, leaf width and petiole length of 24.71 cm, 18.63 cm and 18.63 cm respectively and took 38.84 and 49.47 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.79 cm, 7.34 cm, 268.59 and 379.72 g respectively. The plant height, plant spread and number of leaves per plant of 41.77 cm, 54.15 cm and 11.86 with yield per hectare of 206.10 q per ha. It took 128.45 and 207.04 days fordays to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 87.01 mm, 0.88 mm, 17.22, 18.09 g, 226.68 kg, and 5.78 g respectively. The total chlorophyll content was 92.93 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 68.10 % and 57.56 % and 5.97 and 8.09 ºB respectively. The Vitamin C content in leaf and knob was 86.78 mg/100g and 73.52 mg/100g and carbohydrate content in leaf and knob were 4.16 % and, 8.96 % respectively. The total carotenoids content in leaf and knob was 7.14 mg/100g and 3.48 mg/100g respectively.

Cluster-VIII expressed a mean number of leaf whorls and internode length of 5.21 and 0.52 cm respectively with leaf length, leaf width and petiole length of 15.52 cm, 12.39 cm and 17.71 cm respectively and took 28.91 and 48.36 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.06 cm, 5.86 cm, 174.83 and 222.89 g respectively. The plant height, plant spread and number of leaves per plant of 53.60 cm, 40.52 cm and 8.84 with yield per hectare of 116.13 q per ha. It took 136.78 and 206.41 days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 86.31 mm, 0.86 mm, 16.83, 15.52 g, 196.20 kg, and 5.26 g respectively. The total chlorophyll content was 136.43 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 71.46 % and 62.60 % and 4.94 and

5.79 ºB respectively. The Vitamin C content in leaf and knob was 108.28 mg/100g and 74.71 mg/100g and carbohydrate content in leaf and knob were 3.47 % and, 8.48 % respectively. The total carotenoids content in leaf and knob was 7.51 mg/100g and 5.59 mg/100g respectively.

Cluster-IX expressed a mean number of leaf whorls and internode length of 4.72 and 0.46 cm respectively with leaf length, leaf width and petiole length of 17.75 cm, 13.00 cm, 13.22 cm respectively and took 27.46 and 44.64 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 3.60 cm, 5.40 cm, 297.05 and 330.72 g respectively. The plant height, plant spread, number of leaves per plant of 33.41 cm, 41.16 cm, 9.58 with yield per hectare of 190.87 q per ha. It took 120.95 and 179.71 days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 68.40 mm, 0.64 mm, 11.81, 10.26 g, 128.48 kg and 6.59 g respectively. The total chlorophyll content was 200.63 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 71.91 % and 59.06 % and 5.51 and 7.19 ºB respectively. The Vitamin C content in leaf and knob was 103.29 mg/100g and 61.47 mg/100g and carbohydrate content in leaf and knob were 6.93 % and, 9.87 % respectively. The total carotenoids content in leaf and knob was 7.59 mg/100g and 4.97 mg/100g respectively.

Cluster-X expressed a mean number of leaf whorls and internode length of 5.92 and 0.82 cm respectively with leaf length, leaf width and petiole length of 28.84 cm, 20.04 cm and 20.66 cm respectively and took 33.07 and 52.61 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 4.63 cm, 7.48 cm, 285.00 and 394.91 g respectively. The plant height, plant spread and number of leaves per plant of 38.52 cm, 58.67 cm and 12.71 with yield per hectare of 178.07 q per ha. It took 131.35 and 181.32

days for days to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 64.92 mm, 0.54 mm, 10.66, 8.41 g, 100.62 kg, and 5.02 g respectively. The total chlorophyll content was 71.86 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 78.45 % and 56.52 % and 6.38 and 7.94 ºB respectively. The Vitamin C content in leaf and knob was 89.04 mg/100g and 65.87 mg/100g and carbohydrate content in leaf and knob were 4.90 % and, 8.60 % respectively. The total carotenoids content in leaf and knob was 14.38 mg/100g and 2.45 mg/100g respectively.

Cluster-XI expressed a mean number of leaf whorls and internode length of 6.61 and 0.93 cm respectively with leaf length, leaf width and petiole length of 21.13 cm, 15.46 cm, 15.36 cm, respectively and took 22.00 and 50.74 days for days to 50% stem swelling and days to 50% harvest from the date of transplanting with stem length, stem breadth, net stem weight and gross stem weight of 3.62 cm, 6.38 cm, 245.92 and 373.69 g respectively. The plant height, plant spread, number of leaves per plant of 45.18 cm, 48.82 cm, 10.98 with yield per hectare of 134.27 q per ha. It took 150.13 and 187.74 days fordays to 50% flowering and days to seed maturity. The siliqua length, siliqua breadth, number of seeds per siliqua, seed yield per plant, seed yield per hectare and 1000 seed weight were 51.60 mm, 0.96 mm, 6.11, 7.12 g, 71.40 kg and 4.98 g respectively. The total chlorophyll content was 163.42 mg/100g respectively. The moisture content (%) and TSS content (ºB) in leaf and knob was 77.53 % and 47.96 % and 4.44 and 7.38 ºB respectively. The Vitamin C content in leaf and knob was 87.53 mg/100g and 57.64 mg/100g and carbohydrate content in leaf and knob were 5.62 % and, 9.59 % respectively. The total carotenoids content in leaf and knob was 7.53 mg/100g and 2.48 mg/100g respectively.

Table 8: Percent contribution of thirty-four traits towards total genetic divergence in knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S. No.	Traits	Percent contribution
1.	Yield per hectare (q)	20.30%
2.	Gross stem weight (g)	12.10%
3.	Net stem weight (g)	10.93%
4.	Number of leaves per plant	8.69%
5.	Stem breadth (cm)	7.78%
6.	Stem length (cm)	7.40%
7.	Leaf length (cm)	6.04%
8.	Leaf width (cm)	5.43%
9.	Plant height (cm)	4.40%
10.	Plant spread (cm)	2.84%
11.	Petiole length (cm)	2.20%
12.	Seed yield per plant (g)	1.34%
13.	Seed yield per hectare (kg)	1.15%
14.	Number of seeds per siliqua	1.14%
15.	1000 seed weight (g)	1.12%
16.	Number of leaf whorls	0.99%
17.	Internode length (cm)	0.90%
18.	Siliqua length (mm)	0.76%
19.	Siliqua width (mm)	0.52%
20.	Days to 50% stem swelling	0.51%
21.	Days to 50% harvest	0.47%
22.	Days to 50% flowering	0.46%
23.	Days to seed maturity	0.45%
24.	Total chlorophyll content (mg/100g)	0.36%
25.	Vitamin C content in knob (mg/100g)	0.35%
26.	Vitamin C content in leaf (mg/100g)	0.25%
27.	Total carotenoids content in knob (mg/100g)	0.20%
28.	Total carotenoids content in leaf (mg/100g)	0.17%
29.	Carbohydrate content in knob (%)	0.15%
30	Carbohydrate content in leaf (%)	0.14%
31.	TSS content in leaf (ºB)	0.13%
32.	TSS content in knob (ºB)	0.12%
33.	Moisture content in leaf (%)	0.11%
34.	Moisture content in knob (%)	0.10%
	Total	100.00

4.5.1 Per cent contribution of the traits

The per cent contribution of the traits towards total genetic divergence (table 8) revealed that the yield per hectare (q) was the main factor contributing to divergence accounting for 20.30% followed by gross stem weight (g) 12.10%, net stem weight (g) 10.93%, number of leaves per plant 8.69%, stem breadth (cm) 7.78%, stem length (cm) 7.40% and leaf length (cm) 6.04%. For the character moisture content in knob 0.10% followed by moisture content in leaf 0.11%, TSS content in knob (ºB) (0.12%) and TSS content in leaf (ºB) (0.13%) per cent contribution towards divergence was observed very low.

4.6 Descriptor traits as per Minimal descriptors of vegetable crops by NBPGR

4.6.1 Petiole attitude (PT_ATT)

All the genotypes were of erect petiole attitude except SK-KK-2, SK-KK-22, SK-KK-38, SK-KK-45, SK-KK-64, SK-KK-80, SK-KK-88, SK-KK-90, SK-KK-123, SK-KK-180 and SK-KK-IC-2 which showed semi-erect petiole attitude and SK-KK-23, SK-KK-32 and SK-KK-IC-6 showed horizontal petiole attitude.

4.6.2 Leaf color (LF_CLR)

Leaf color showed a wide range of variation. SK-KK-1, SK-KK-32, SK-KK-72(A) and SK-KK-123 showed light green leaf color. SK-KK-3, SK-KK-10, SK-KK-14, SK-KK-23, SK-KK-45, SK-KK-51, SK-KK-64, SK-KK-65, SK-KK-72(B), SK-KK-129, SK-KK-175, SK-KK-180, SK-KK-IC-2 and Pusa Virat showed dark green leaf color. SK-KK-38, SK-KK-80, SK-KK-90, SK-KK-154, SK-KK-IC-6 and White Vienna showed yellow green leaf color. SK-KK-2, SK-KK-9, SK-KK-22, SK-KK-88, SK-KK-197 and Purple Vienna showed violet green leaf color.

4.6.3 Leaf shape (LF_SHP)

A wide range of variation was observed with respect to leaf shape. SK-KK-1, SK-KK-3, SK-KK-9, SK-KK-14, SK-KK-45, SK-KK-65, SK-KK-72(A),

SK-KK-90, SK-KK-129, SK-KK-180, SK-KK-IC-2 and White Vienna showed broad ovate leaf shape. SK-KK-2, SK-KK-10, SK-KK-22, SK-KK-23, SK-KK-51, SK-KK-72(B), SK-KK-80, SK-KK-88, SK-KK-123, SK-KK-154, SK-KK-175, SK-KK-197, SK-KK-IC-6, Pusa Virat and Purple Vienna showed narrow ovate leaf shape. SK-KK-32, SK-KK-38 and SK-KK-65 showed ovate leaf shape.

4.6.4 Leaf waxiness (LF_WXS)

Strong leaf waxiness showed in SK-KK-1, SK-KK-2, SK-KK-22, SK-KK-23, SK-KK-51, SK-KK-64, SK-KK-65, SK-KK-72(A), SK-KK-129, SK-KK-154, SK-KK-175, SK-KK-180, Purple Vienna and Pusa Virat. SK-KK-3, SK-KK-9, SK-KK-10, SK-KK-14, SK-KK-72(B), SK-KK-80, SK-KK-88, SK-KK-197, SK-KK-IC-6 and White Vienna showed medium leaf waxiness. SK-KK-32, SK-KK-38, SK-KK-45, SK-KK-90 and SK-KK-123 showed weak leaf waxiness.

4.6.5 Petiole crossing (PT_CRS)

Petiole crossing were present in all the genotypes except SK-KK-38, SK-KK-45, SK-KK-80 and SK-KK-197 showed absent petiole crossing.

4.6.6 Stem color (STEM_CLR)

Wide range of variation was found among genotypes for stem color. SK-KK-3, SK-KK-23, SK-KK-32, SK-KK-38, SK-KK-80, SK-KK-90, SK-KK-129, SK-KK-IC-6, Pusa Virat and White Vienna had light green stem color. SK- KK-10, SK-KK-14, SK-KK-45, SK-KK-64, SK-KK-123, SK-KK-175 and SK- KK-180 had green stem color. SK-KK-1, SK-KK-51, SK-KK-65, SK-KK-72(B), SK-KK-154 and SK-KK-IC-2 had dark green stem color. SK-KK-9 and SK-KK-72(A) had purplish green stem color. SK-KK-2, SK-KK-22, SK-KK-88, SK- KK-197 and Purple Vienna had dark purple stem color.

4.6.7 Stem shape (STEM_SHP)

Wide range of variation among genotypes with respect to stem shape. SK-KK-2, SK-KK-22, SK-KK-23, SK-KK-32, SK-KK-38, SK-KK-64, SK-KK-197, SK-KK-IC-2 and Purple Vienna had transverse narrow elliptic stem shape. Other genotypes like SK-KK-64, SK-KK-80, SK-KK-88, SK-KK-90 and SK-KK-123 had transverse narrow elliptic stem shape. Whereas as genotype as SK-KK-14, SK-KK-45, SK-KK-65, SK-KK- 72(A), SK-KK-72(B), SK-KK-129, SK-KK-180, SK-KK-IC-6 and Pusa Virat had circular stem shape. Genotypes SK-KK-51, SK-KK-154, SK-KK-175 and White Vienna had broad elliptic stem shape and genotypes SK-KK-1, SK-KK-3, SK-KK-9 and SK-KK-10 had transverse elliptic stem shape.

Table 9: Descriptor traits for various genotypes in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

S. No.	Genotype	Petiole attitude	Leaf color	Leaf shape	Leaf waxiness	Petiole crossing	Stem color	Stem shape
1.	**SK-KK-1**	Erect	Light green (142A)	Broad ovate	Strong	Present	Dark green (145A)	Transverse elliptic
2.	**SK-KK-2**	Semi-erect	Violet green (N71A)	Narrow ovate	Strong	Present	Dark purple (N74A)	Transverse narrow elliptic
3.	**SK-KK-3**	Erect	Dark green (145A)	Broad ovate	Medium	Present	Light green (142A)	Transverse elliptic
4.	**SK-KK-9**	Erect	Violet green (N71A)	Broad ovate	Medium	Present	Purplish green (N71A)	Transverse elliptic
5.	**SK-KK-10**	Erect	Dark green (145A)	Narrow ovate	Medium	Present	Green (143A)	Transverse elliptic
6.	**SK-KK-14**	Erect	Dark green (145A)	Broad ovate	Medium	Present	Green (143A)	Circular
7.	**SK-KK-22**	Semi-erect	Violet green (N71A)	Narrow ovate	Strong	Present	Dark purple (N74A)	Transverse narrow elliptic
8.	**SK-KK-23**	Horizontal	Dark green (145A)	Narrow ovate	Strong	Present	Light green (142A)	Transverse narrow elliptic
9.	**SK-KK-32**	Horizontal	Light green (142A)	Ovate	Weak	Present	Light green (142A)	Transverse narrow elliptic
10.	**SK-KK-38**	Semi-erect	Yellow green (144B)	Ovate	Weak	Absent	Light green (142A)	Transverse narrow elliptic
11.	**SK-KK-45**	Semi-erect	Dark green (145A)	Broad ovate	Weak	Absent	Green (143A)	Circular
12	**SK-KK-51**	Erect	Dark green (145A)	Narrow ovate	Strong	Present	Dark green (145A)	Broad elliptic
13.	**SK-KK-64**	Semi-erect	Dark green (145A)	Ovate	Strong	Present	Green (143A)	Transverse broad elliptic
14.	**SK-KK-65**	Erect	Dark green (145A)	Broad ovate	Strong	Present	Dark green (145A)	Circular
15.	**SK-KK-72(A)**	Erect	Light green (142A)	Broad ovate	Strong	Present	Purplish green (N71A)	Circular

Contd…

S. No.	Genotype	Petiole altitude	Leaf color	Leaf shape	Leaf waxiness	Petiole crossing	Stem color	Stem shape
16.	**SK-KK-72(B)**	Erect	Dark green (145A)	Narrow ovate	Medium	Present	Dark green (145A)	Circular
17.	**SK-KK-80**	Semi-erect	Yellow green (144B)	Narrow ovate	Medium	Absent	Light green (142A)	Transverse Broad elliptic
18.	**SK-KK-88**	Semi-erect	Violet green (N71A)	Narrow ovate	Medium	Present	Dark purple (N74A)	Transverse broad elliptic
19.	**SK-KK-90**	Semi-erect	Yellow green (144B)	Broad ovate	Weak	Present	Light green (142A)	Transverse broad elliptic
20.	**SK-KK-123**	Semi-erect	Light green (142A)	Narrow ovate	Weak	Present	Green (143A)	Transverse broad elliptic
21.	**SK-KK-129**	Erect	Dark green (145A)	Broad ovate	Strong	Present	Light green (142A)	Circular
22.	**SK-KK-154**	Erect	Yellow green (144B)	Narrow ovate	Strong	Present	Dark green (145A)	Broad elliptic
23.	**SK-KK-175**	Erect	Dark green (145A)	Narrow ovate	Strong	Present	Green (143A)	Broad elliptic
24.	**SK-KK-180**	Semi-erect	Dark green (145A)	Broad ovate	Strong	Present	Green (143A)	Circular
25.	**SK-KK-197**	Erect	Violet green (N71A)	Narrow ovate	Medium	Absent	Dark purple (N74A)	Transverse narrow elliptic
26.	**SK-KK-IC-2**	Semi-erect	Dark green (145A)	Broad ovate	Strong	Present	Dark green (145A)	Transverse narrow elliptic
27.	**SK-KK-IC-6**	Horizontal	Yellow green (145A)	Narrow ovate	Medium	Present	Light green (142A)	Circular
28.	**Purple Vienna**	Erect	Violet green (N71A)	Narrow ovate	Strong	Present	Dark purple (N74A)	Transverse narrow elliptic
29.	**Pusa Virat**	Erect	Dark green (145A)	Narrow ovate	Strong	Present	Light green (142A)	Circular
30.	**White Vienna**	Erect	Yellow green (144B)	Broad ovate	Medium	Present	Light green (142A)	Broad elliptic

Erect

Semi-erect

Horizontal

Plate 5(a): **Descriptor traits for Petiole attitude in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)**

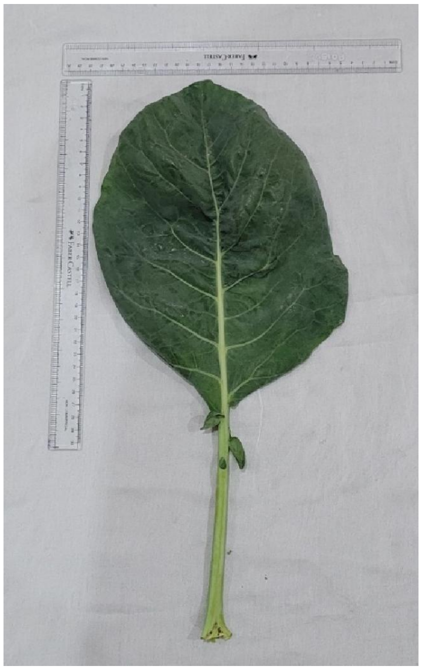
Yellow green

Light green

Dark green

Violet green

Plate 5(b): Descriptor traits for Leaf color in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)



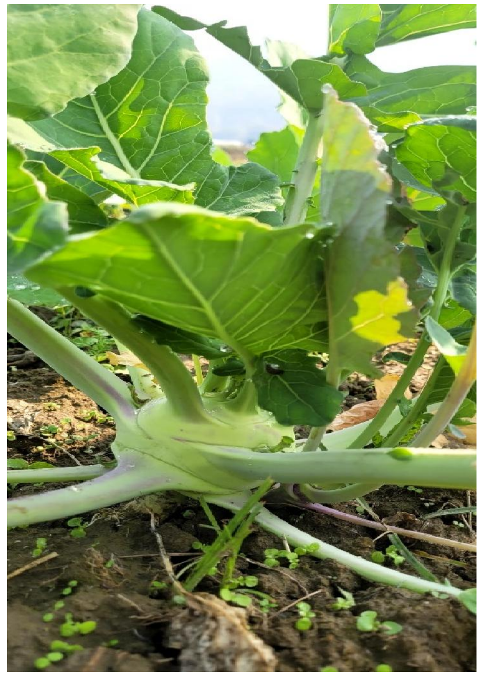
Broad ovate

Narrow ovate

Ovate

Plate 5(c): Descriptor traits for Leaf shape in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

Light green



Dark green

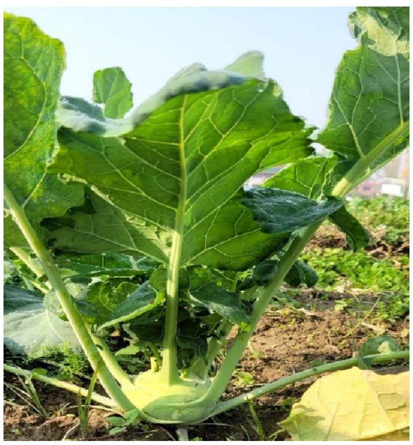
Purplish green

Dark purple

Plate 5(d): Descriptor traits for Stem color in Knol-khol (*Brassica oleracea* var. *gongylodes* L.)

Transverse broad elliptic

Transverse narrow elliptic



Transverse elliptic

Broad elliptic

Circular

Plate 5(e): **Descriptor traits for stem shape in Knol-khol (*Brassica oleracea* var. *gongylodes* LS)**

Chapter-5

DISCUSSION

Knol-khol (*Brassica oleracea* var. *gongylodes* L.) is an important crop grown particularly in Kashmir and northern parts of India. The main objective of plant breeding is to increase the productivity or yield and quality of the crops to meet the requirements of farmer and consumer. Crop improvement largely depends on the existence of variability and its exploitation by the plant breeder. For this plant breeder needs to identify sourcesof favourable genes, incorporate them into breeding populations/lines and select for a combination of desirable traits that might result in the isolation of productivegenotypes. To achieve these goals, plant breeder needs to know the extent of variability present in a population. Effective evaluation and identification of potentially useful germplasm forms the first and foremost step in a crop improvement programme. The high yielding genotypes with good adaptation and desirable attributes could be directly utilized for general massive hybridization programme.

This improvement in any crop is based on the extent of genetic variation and magnitude of available genetic variability. The proportion of genotypic, environmental variance and their interaction (G x E) can be determined by employing useful biometrical and genetical methods. Some of these parameters include genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). High value of these coefficients indicates wider diversity. Similarly narrow differences between GCV and PCV reveals low sensitivity to the environmental effects. Another indicator of variability is heritability, which is the ratio of genetic variance to total variance. This is broad sense heritability and gives an idea about that portion of observed variability which is attributable to genetic differences. Heritability estimates supplemented by genetic variance are more meaningful. Heritability is a component in the computation of expected progress which is most meaningful when accompanied by genetic advance.

Genotypic, phenotypic correlations reveal the degree of association between different characters. Thus, it helps to base selection procedure to a required balance when two opposite desirable characters affecting principle character are being selected. It also helps to improve different characters simultaneously (Falconer, 1981). The other genetic parameter commonly used is the path analysis as given by Dewey and Lu (1959). Path analysis gives the cause-and-effect relationship. It critically breaks up different direct and indirect effects which finally make up correlation coefficient.

The D^2 statistics assesses a vast number of germplasm resources for genetic diversity and provides accurate and trustworthy information on the kind, degree, and identification of divergent parents for use in a hybridization programme. Since, hybrids between lines of different ancestry typically exhibit more heterosis than those between parents who are closely related, genetic divergence is crucial.

All these factors help in selection of better parents for the development of commercial variety or hybrid. The results derived from the present investigation are discussed as follows:

5.1 Mean performance of genotypes

In this study genotypes showed wide range of variability for most of the descriptor, quantitative and quality traits (Annexure-I and II). The estimates of mean values revealed that no genotype was superior for all the characters under consideration. However, for number of leaf whorls SK-KK-14 (7.93) followed by SK-KK-154 (7.50), SK-KK-72(A) (7.34), SK-KK-65 (7.17) and SK-KK-197 (6.97); for internode length SK-KK-23 (1.76 cm) followed by SK-KK-65 (1.54 cm), SK-KK-88 (1.46 cm), SK-KK-154 (1.36 cm) and SK-KK-72(A) (1.27 cm), for leaf length SK-KK-14 (35.02 cm) followed by SK-KK-10 (34.15 cm), Purple Vienna (33.92 cm), SK-KK-197 (33.76 cm) and SK-KK-154 (32.36 cm); for leaf width SK-KK-14 (26.16 cm) followed by SK-KK-154 (25.80 cm), SK-KK-72(A) (24.09 cm), SK-KK-129 (23.89 cm) and SK-KK-2 (22.51 cm); for petiole length

SK-KK-32 (18.22 cm) followed by SK-KK-175 (18.01 cm), SK-KK-72(A) (17.01 cm), White Vienna (16.98 cm), SK-KK-90 (16.55 cm); For days to 50% swelling SK-KK-23 (41.71) followed by SK-KK-1 (41.15), SK-KK-72(A) (40.65), SK-KK-14 (38.91) and SK-KK-9 (38.88); for days to 50% harvest SK-KK-23 (62.09) followed by SK-KK-1 (61.22), SK-KK-72(A) (60.12), SK-KK-72(B) (58.50) and SK-KK-9 (58.42); for stem length SK-KK-14 (5.84 cm) followed by White Vienna (5.82 cm), SK-KK-88 (5.79 cm), SK-KK-65 (5.71 cm) and SK- KK-72(B) (5.68 cm); for stem breadth SK-KK-14 (9.46 cm) followed by SK-KK-3 (8.59 cm), SK-KK-154 (8.33 cm), SK-KK-72(A) (7.90 cm) and SK-KK-129 (7.86 cm); for gross stem weight SK-KK-14 (583.76 g) followed by SK-KK-197 (572.81 g), SK-KK-10 (562.80 g), Purple Vienna (561.86 g) and SK-KK-175 (547.96 g); for net stem weight SK-KK-14 (478.09 g) followed by SK-KK-154 (460.60 g), SK-KK-72(A) (445.65 g), SK-KK-129 (439.84 g) and SK-KK-2 (423.82 g); for plant height SK-KK-64 (63.96 cm) followed by Purple Vienna (61.56 cm), SK-KK-72(A) (60.28 cm), SK-KK-1 (59.36 cm) and SK-KK-14 (58.32 cm); for plant spread SK-KK-180 (72.17 cm) followed by SK-KK-154 (66.71 cm), Purple Vienna (64.52 cm), SK-KK-197 (63.52 cm) and SK-KK-10 (62.86 cm); for number of leaves per plant SK-KK-14 (17.57) followed by Purple Vienna (16.80), SK-KK-129 (16.33), SK-KK-2 (15.86) and SK-KK-175 (14.72); for days for 50% flowering SK-KK-80 (164.05) followed by SK-KK-14 (160.05), SK-KK-72(A) (157.93), SK-KK-90 (156.55) and SK-KK-65 (153.69); for days for seed maturity SK-KK-80 (217.73) followed by SK-KK-14 (214.50), SK-KK-72(A) (212.14), SK-KK-38 (210.77) and Pusa Virat (207.03); for siliqua length SK-KK-90 (106.23 mm) followed by SK-KK-64 (101.32 mm), SK-KK-72(B) (98.78 mm), White Vienna (95.49 mm) and SK-KK-2 (94.20 mm); for siliqua width SK-KK-64 (1.65 mm) followed by SK-KK-90 (1.52 mm), SK-KK-72(B) (1.26 mm), SK-KK-175 (1.25 mm) and SK-KK-32 (1.19 mm); for number of seeds per siliqua SK-KK-90 (24.96) followed by SK-KK-64 (23.43), SK-KK-72(B) (22.77), SK-KK-32 (20.84) and White Vienna (20.78); for seed yield per plant SK- KK-90 (19.82 g) followed by SK-KK-2 (18.09 g), SK-KK-23 (17.10 g), White Vienna (16.35) and Purple Vienna (15.52); For seed yield per hectare SK-KK-90 (231.84 kg) followed by SK-KK-2 (205.20 kg), SK-KK-23 (196.20 kg), White Vienna (193.08 kg) and Purple Vienna (186.24 kg); for 1000 seed weight Purple Vienna (6.59 g) followed by SK-KK-23 (6.22 g), White Vienna (5.96 g), SK-KK-2 (5.93 g) and SK-KK-14 (5.84 g). For total chlorophyll content (mg/100g) White Vienna (146.94) followed by SK-KK-175 (143.35), Pusa Virat (132.51), SK-KK- 90 (130.41) and SK-KK-88 (126.48); for moisture content in leaf (%) SK-KK-14 (84.73) followed by White Vienna (81.51), SK-KK-72(A) (81.04), SK-KK-23 (80.38) and SK-KK-22 (79.70); for moisture content in knob (%) SK-KK-14 (69.22) followed by SK-KK-154 (67.77), SK-KK-IC-6 (66.09), SK-KK-180 (64.76) and SK-KK-1 (63.36); for TSS content in leaf (ºB) was recorded in SK- KK-80 (6.95) followed by SK-KK-72(A) (6.93), SK-KK-3 (6.86), SK-KK-72(B) (6.50) and SK-KK-154 (6.49); for TSS content in knob (ºB) was recorded in SK- KK-64 (8.46) followed by SK-KK-197 (8.32), SK-KK-180 (8.31), SK-KK-88 (8.08) and SK-KK-45 (7.94); for Vitamin C content in leaf (mg/100g) SK-KK- 129 (109.81) followed by Pusa Virat (108.40), SK-KK-123 (107.28), SK-KK-72(B) (106.88) and SK-KK-80 (105.44); for Vitamin C content in knob (mg/100g) SK-KK-123 (74.71) followed by SK-KK-88 (73.52), SK-KK-IC-6 (72.22), SK-KK-180 (70.11) and Pusa Virat (69.29); for carbohydrate content in leaf (%) White Vienna (7.52) followed by SK-KK-23 (7.03), SK-KK-IC-2 (6.93), SK-KK-154 (6.72) and SK-KK-32 (6.70); for carbohydrate content in knob (%) SK-KK-80 (10.96) followed by SK-KK-72(A) (10.87), SK-KK-14 (10.79), SK-KK-175 (10.56) and SK-KK-23 (10.37); for total carotenoids content in leaf(mg/100g) SK-KK-65 (9.69) followed by SK-KK-180 (9.56), SK-KK-45 (9.37), SK-KK-32 (9.05) and Pusa Virat (8.42); for total carotenoid content in knob (mg/100g) SK-KK-197 (6.07) followed by SK-KK-14 (5.94), SK-KK-51 (5.59), SK-KK-72(B) (5.48) and Pusa Virat (5.42) were found superior.

For yield per hectare (q) SK-KK-14 (246.04 q) followed by SK-KK-154 (238.31 q), SK-KK-72(A) (226.80 q), SK-KK-129 (221.22 q) and SK-KK-2 (216.01 q) were found superior.

The perusal of Table 10(a-b) revealed the superior performance of SK-KK-14 for number of leaf whorls, leaf length, leaf width, stem length, stem breadth, gross stem weight, net stem weight, number of leaves per plant, yield per hectare and moisture content in leaves and knob, SK-KK-23 for internode length, days to 50% stem swelling and days to 50% harvest, SK-KK-64 for plant height and siliqua width, SK-KK-80 for days to 50% flowering, days to seed maturity, TSS content in leaf and carbohydrate content in knob, SK-KK-90 for siliqua length, number of seeds per siliqua, seed yield per plant, seed yield per hectare and White Vienna for total chlorophyll content and carbohydrate content in leaf. Similar findings have also been reported by other workers such as Khan *et al*. (2012) in kale, Mehra and Singh (2013) for leaf length, leaf width, gross weight per plant and marketable yield per plant in cauliflower, Chittora and Singh (2015) for ascorbic acid content in cauliflower, Manaware *et al*. (2017) in cauliflower for number of leaves per plant, gross head weight per plant and yield per plot, Dolkar *et al*. (2018) for number of leaves per plant, gross stem weight per plant and net stem weight per plant in knolkhol, Gariya *et al*. (2019) for curd weight in cauliflower, Wudneh (2020) for plant height and fresh leaf weight in kale.

Since no genotype could be identified to have superior performance for all the characters, the genotype with diverse characteristics could be used in a well-planned hybridization programme to select superior performing lines in the successive segregating lines.

Table 10(a): Best genotypes with respect to different quantitative traits based on *per se* performances

S.No.	Traits	Best genotypes
1.	Number of leaf whorls	SK-KK- 14 (7.93), SK-KK-154 (7.50), SK-KK-72(A) (7.34), SK-KK-65 (7.17), SK-KK-197 (6.97)
2.	Internode length (cm)	SK-KK-23 (1.76 cm), SK-KK-65 (1.54 cm), SK-KK-88 (1.46 cm), SK-KK-154 (1.36 cm), SK-KK-72(A) (1.27 cm)
3.	Leaf length (cm)	SK-KK-14 (35.02 cm), SK-KK-10 (34.15 cm), Purple Vienna (33.92 cm), SK-KK-197 (33.76 cm), SK-KK-154 (32.36 cm)
4.	Leaf width (cm)	SK-KK-14 (26.16 cm), SK-KK-154 (25.80 cm), SK-KK-72(A) (24.09 cm), SK-KK-129 (23.89 cm), SK-KK-2 (22.51 cm)
5.	Petiole length (cm)	SK-KK-32 (18.22 cm), SK-KK-175(18.01 cm), SK-KK-72(A) (17.01 cm), White Vienna (16.98 cm), SK-KK-90 (16.55 cm)
6.	Days to 50% stem swelling	SK-KK-23 (41.71), SK-KK-1 (41.15), SK-KK-72(A) (40.65), SK-KK-14 (38.91), SK-KK-9 (38.88)
7.	Days to 50% harvest	SK-KK-23 (62.09), SK-KK-1 (61.22) SK-KK-72(A) (60.12), SK-KK-72(B) (58.50), SK-KK-9 (58.42)
8.	Stem length (cm)	SK-KK-14 (5.84), White Vienna (5.82), SK-KK-88 (5.79 cm) SK-KK-65 (5.71 cm), SK-KK-72(B) (5.68 cm)
9.	Stem breadth (cm)	SK-KK-14 (9.46 cm), SK-KK-3 (8.59 cm), S-KK-154 (8.33 cm), SK-KK-72(A) (7.90 cm), SK-KK- 129 (7.86 cm)
10.	Gross stem weight (g)	SK-KK-14 (583.76 g), SK-KK-197 (572.81 g), SK-KK-10 (562.80 g), Purple Vienna (561.86 g), SK-KK-175 (547.96 g)
11	Net stem weight (g)	SK-KK-14 (478.09 g), SK-KK-154 (460.60 g), SK-KK-72(A) (445.65 g), SK-KK-129 (439.84 g), SK-KK-2 (423.82 g)

Contd..

S.No.	Traits	Best genotypes
12.	Plant height (cm)	SK-KK-64 (63.96 cm), Purple Vienna (61.56 cm), SK-KK-72(A) (60.28 cm), SK-KK-1 (59.36 cm), SK-KK-14 (58.32 cm)
13.	Plant spread (cm)	SK-KK-180 (72.17 cm), SK-KK-154 (67.71 cm), SK-KK-72(A) (66.15 cm), SK-KK-129 (65.77 cm) and Purple Vienna (64.52 cm)
14.	No. of leaves per plant	SK-KK-14 (17.57), Purple Vienna (16.80), SK-KK-129 (16.33), SK-KK-2 (15.86), SK-KK-175 (14.72)
15.	Yield per hectare (q)	SK-KK-14 (246.04 q), SK-KK-154 (238.31 q), SK-KK-72(A) (226.80 q), SK-KK-129 (221.22 q), SK-KK-2 (216.01 q)
16.	Days to 50% flowering	SK-KK-80 (164.05), SK-KK-14 (160.05), SK-KK-72(A) (157.93), SK-KK-90 (156.55), SK-KK-65 (153.69)
17.	Days to seed maturity	SK-KK-80 (217.73), SK-KK-14 (214.50), SK-KK-72(A) (212.14), SK-KK-38 (210.77), Pusa Virat (207.03)
18.	Siliqua length (mm)	SK-KK-90 (106.23 mm), SK-KK-64 (101.32 mm), SK-KK-72(B) (98.78 mm), White Vienna (95.49 mm), SK-KK-2 (94.20 mm)
19.	Siliqua width (mm)	SK-KK-64 (1.65 mm), SK-KK-90 (1.52 mm), SK-KK-72(B) (1.26 mm), SK-KK-175 (1.25 mm), SK-KK-32 (1.19 mm)
20.	No. of seeds per siliqua	SK-KK-90 (24.96), SK-KK-64 (23.43), SK-KK-72(B) (22.77), SK-KK-32 (20.84), White Vienna (20.48)
21.	Seed yield per plant (g)	SK-KK-90 (19.82 g), SK-KK-2 (18.09 g), SK-KK-23 (17.10 g), White Vienna (16.35 g), Purple Vienna (15.52)
22.	Seed yield per hectare (kg)	SK-KK-90 (231.84 kg), SK-KK-2 (205.20 kg), SK-KK-23 (196.20 kg), White Vienna (193.08 kg), Purple Vienna (186.24 kg)
23.	1000 seed weight (g)	Purple Vienna (6.59 g), SK-KK-23 (6.22 g), White Vienna (5.96 g), SK-KK-2 (5.93 g), SK-KK-14 (5.84 g)

Table 10(b): Best genotypes with respect to different quality traits as *per se* performances

S.No.	Traits	Best genotypes
1.	Total chlorophyll content (mg/100g)	White Vienna (146.94), SK-KK-175 (143.35), Pusa Virat (132.51), SK-KK-90 (130.41), SK-KK-88 (126.48)
2.	Moisture content in leaf (%)	SK-KK-14 (84.73), White Vienna (81.51), SK-KK-72(A) (81.04), SK-KK-23 (80.38), SK-KK-22 (79.70)
3.	Moisture content in knob (%)	SK-KK-14 (69.22), SK-KK-154 (67.77), SK-KK-IC-6 (66.09), SK-KK-180 (64.76), SK-KK-1 (63.36)
4.	TSS content in leaf (ºB)	SK-KK-80 (6.95), SK-KK-72(A) (6.93), SK-KK-3 (6.86), SK-KK-72(B) (6.50), SK-KK-154 (6.49)
5.	TSS content in knob (ºB)	SK-KK-64 (8.46), SK-KK-197 (8.32), SK-KK-180 (8.31), SK-KK-88 (8.08), SK-KK-45 (7.94)
6.	Vitamin C content in leaf (mg/100g)	SK-KK-129 (109.81), Pusa Virat (108.40), SK-KK-123 (107.28), SK-KK-72(B) (106.88), SK-KK-80 (105.44)
7.	Vitamin C content in knob (mg/100g)	SK-KK-123 (74.71), SK-KK-88 (73.52), SK-KK-IC-6 (72.22), SK-KK-180 (70.11), Pusa Virat (69.29)
8.	Carbohydrate content in leaf (%)	White Vienna (7.52), SK-KK-23 (7.03), SK-KK-IC-2 (6.93), SK-KK-154 (6.72), SK-KK-32 (6.70)
9.	Carbohydrate content in knob (%)	SK-KK-80 (10.96), SK-KK-72(A) (10.87), SK-KK-14 (10.79), SK-KK-175 (10.56), SK-KK-23 (10.37)
10.	Total carotenoids content in leaf (mg/100g)	SK-KK-65 (9.69), SK-KK-180 (9.56), SK-KK-45 (9.37), SK-KK-32 (9.05), Pusa Virat (8.42)
11.	Total carotenoid content in knob (mg/100g)	SK-KK-197 (6.07), SK-KK-14 (5.94), SK-KK-51 (5.59), SK-KK-72(B) (5.48), Pusa Virat (5.42)

5.2 Genetic variability, heritability and genetic advance (as per cent of mean)

The analysis of variance revealed that all the genotypes exhibited highly significant differences for all the traits under study (Table 4). Range values for various characters, 4.32 – 7.93 for number of leaf whorls, 0.46 - 1.76 for internode length (cm), 15.52 - 35.02 for leaf length (cm), 12.38 - 26.16 for leaf width, 7.88 – 18.22 for petiole length (cm), 21.99 – 41.71 for days to 50% stem swelling, 40.51 – 62.09 for days to 50% harvest, 3.60 - 5.89 for stem length (cm), 5.24 - 9.46 for stem breadth (cm), 222.89 – 583.76 for gross stem weight (g), 174.83 - 478.09 for net stem weight (g), 31.41 - 63.96 for plant height (cm), 40.52 - 72.17 for plant spread (cm), 8.84 - 17.57 for number of leaves per plant, 116.13 – 246.04 for yield per hectare (q), 120.77 - 164.05 for days to 50% flowering, 168.03 – 217.73 for days to seed maturity, 49.53 – 106.23 for siliqua length (cm), 0.52 – 1.65 for siliqua width (cm), 4.62 - 24.96 for number of seeds per siliqua, 5.95 - 19.82 for seed yield per plant (g), 71.40 – 231.84 for seed yield per hectare (kg), 4.02 – 6.59 for 1000 seed weight (g), 70.56 – 146.94 for total chlorophyll content (mg/100g), 62.77 – 84.73 for moisture content in leaf (%), 41.12 – 69.22 for moisture content in knob (%), 4.10 – 6.95 for TSS content in leaf (ºB), 5.50 – 8.46 for TSS content in knob (ºB), 85.73 – 109.81 for vitamin C content in leaf (mg/100g), 45.97 – 74.71 for vitamin C content in knob (mg/100g), 3.46 – 7.52 for carbohydrate content in leaf (%), 7.12 –10.96 for carbohydrate content in knob (%), 5.94 – 9.69 for total carotenoids content in leaf (mg/100g), 1.86 – 6.07 for total carotenoids in knob (mg/100g), indicated presence of sufficient genetic variability for all the characters, which is prerequisite for making improvement through selection. This was in conformity with the finding of Soni *et al*. (2013) in cabbage, Kumar *et al*. (2019) and Pramila *et al*. (2021) in cauliflower, Meena *et al*. (2021) in knolkhol.

The values of range represent the degree of phenotypic variability, which is not very trustworthy because it includes genotype, environment and genotype-environment interaction and does not specify which character is illustrating a higher level of variability. Additionally, the phenotype of a crop is influenced by the additive gene influence (heritable), dominance (non- heritable), and epistasis (non-allelic interaction). In order to determine the level ofvariability present for different traits, it is necessary to separate the observed variability into phenotypic coefficient of variation and genotypic coefficient of variation.

The estimates of phenotypic and genotypic coefficients of variation of all the characters studied are presented in (Table 2{a-b}). The possibility for improvement through selection is higher for traits with moderate to high coefficients of variation. High estimates of the phenotypic and genotypic coefficients of variation, together with a wide range of variability, further suggest that these traitswould be responsive to selection. Despite a small difference in the values, phenotypic coefficients of variation were larger than the comparable genotypic coefficients of variation. This demonstrated that the variation was mostly attributable to genetic variations and that the environment had little impact on the expression of the observed features. Similar findings were reported by Khan *et al*. (2012) for leaf area, width of leaf, petiole length, leaf length and plant height in kale. These results are in close agreement with those reported by Kumar *et al.* (2011), Singh *et al*. (2013), Chatterjee *et al*. (2018) and Sharma *et al*. (2018) in cauliflower. and Brito *et al*. (2020) for plant height, stem diameter, leaf length andleaf yield in kale.

It is evident from the data presented in Table 2(a-b) that for yield per hectare (54.50% and 54.27%) followed by seed yield per hectare (44.92% and 44.85%), seed yield per plant (44.91% and 44.84%), total carotenoids content in knob (39.55 % and 39.12%), number of seed per siliqua (38.89% and 38.70%), siliqua width (37.40% and 35.70%), internode length (34.10% and 32.71%) and carotenoids content in leaf (32.32% and 32.17%) recorded high phenotypic and genotypic coefficients of variation, respectively, indicating that genotypes had broad genetic base for these characters. Rest of traits such as days to seed maturity (6.96% and 6.86%) followed by moisture content in leaf (6.98% and 6.97%), days to 50% harvest (8.53% and 8.30%), days to 50% flowering (8.97% and 8.95%) and vitamin C content in leaf (9.74% and 9.73%) demonstrated moderate to low genotypic and phenotypic coefficients of variation. These traits could therefore be improved by selection less easily. Similar findings have also been reported by Singh *et al*. (2013) for days to marketable maturity and leaf width in cauliflower, Meena *et al*. (2014) for stalk length and core length in cabbage, Dolkar *et al.* (2018) for number of leaves per plant and gross weight per plant in knolkhol, Shruthy *et al*. (2018) for curd compactness and curd size index for in cauliflower, Pramila *et al*. (2021) for number of leaves, leaf blade width and net curd weight cauliflower. Thus, these traits were less amenable for improvement through selection.

Even phenotypic and genotypic coefficients of variation are not reliable indicators of the degree of heritability. Breeders can rely on a trait's heritability as a result it gives them the freedom to decide how much selection pressure to apply in a specific situation, separating the impacts of the environment from overall variability. The estimation of heritability has a greater impact on determining the efficacy of character selection, as suggested by Panse and Sukhatme (1985) and Johnson *et al*. (1955), and given that heritability is influenced by bio-metrical method, hybrid generation, sample size of experimental material, and environment. Additionally, the quantity of genetic gain is strongly correlated with the process of selection. The results are in conformation with the findings of earlier workers namely Singh *et al*. (2011) for net head weight and gross weight per plant in cabbage, Khan *et al*. (2012) for plant height, leaf thickness, stem thickness, leaf number and leaf weight in kale, Chittora and Singh (2015) for leaf length, leaf width and plant height in cauliflower, Singh *et al.* (2013) and Manaware *et al*. (2017) for leaf length and ascorbic acid content in cauliflower, Kumar *et al*. (2019) for plant height and days to marketable maturity in cauliflower, Dolkar *et al*. (2018) for ascorbic acid content of knob and leaves and beta carotene content of leaves in knol-khol was reported as moderate to high heritability for above traits.

It is an indication that selection and additive gene effects may be active when high heritability is accompanied by high genetic gain (Genetic advance as a percentage of mean). When high heritability is demonstrated due to a favourable influence of environment rather than genotype, rather than when it is due to high heritability being due to genotype, it highlights the relevance of non-additive gene action and may not be advantageous to select for such traits. Additive gene effects control low heritability with high genetic gain, where low heritability is demonstrated due to high environmental effects, and selection may be successful in such circumstances. Low genetic gain and heritability suggest that traits are strongly impacted by environmental factors and therefore selection would be unsuccessful.

High heritability alone is not enough to make sufficient improvement through selection generally in advance generations, unless accompanied by substantial amount of genetic advance (Bhargava *et al*., 2003). The efficacy of heritability is increased with the estimation of genetic advance, which indicates the degree of gain in a trait obtained under a particular selection pressure. The estimates of genetic advance as percentage of mean along with the heritability values are more useful because it provides better response during selection than either of the parameters alone, whereas, Burton (1952) believed the genetic coefficient of variation along with heritability give the best picture of the genetic advance to be expected from selection. The expected genetic advance expressed as percentage of mean varied from 14.34 % (moisture content of leaf) to 93.07 % (yield per hectare).

High genetic advance as percentage of mean coupled with moderate to high heritability were obtained for seed yield per hectare, seed yield per plant, yield per hectare, number of seed per siliqua, siliqua length, total carotenoids content in leaf and knob, siliqua width, leaf length, gross stem weight, leaf width and net stem weight indicating thereby that the selection based on phenotypic performance could be effectively utilized for isolation of superior genotypes for these traits as these are controlled by additive gene action (Panse, 1957). Moderate to high heritability and high genetic advance have also been obtained by Mehra and Singh (2013) for plant height and leaf length, Singh *et al*. (2013) for leaf length and plant height; Chittora and Singh (2015) for plant height, Chura *et al*. (2016) for harvest index and net head weight, Dolkar *et al*. (2018) for beta carotene content of knob and marketable knob weight per plant, Kumar *et al*. (2019) for plant height at harvest and number of leaves per plant indicating that these traits could be substantially considered for making selections as these traits are mainly influenced by the major effects of additive gene action.

High estimate of heritability along with genetic gain (genetic advance as per cent of mean) is more reliable than heritability alone for predicting the effect of selection (Johnson *et al*., 1955). The characters *viz.,* yield per hectare, siliqua width, siliqua length, number of seeds per siliqua, seed yield per plant, seed yield per hectare, total carotenoids content in leaf and knob, leaf length and leaf width showed high estimates of heritability coupled with high genetic gain (genetic advance as per cent of mean), indicating the preponderance of additive gene action for control of these traits. The traits like stem length, stem breadth, days to 50% harvest, days to 50% flowering, days to seed maturity, TSS content in leaf and knob, vitamin C content in leaf and knob, carbohydrate content in knob and moisture content in leaf had moderate to high heritability along with moderate to low genetic gain and genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). Moderate heritability and moderate genetic advance have also been observed by Santhosha *et al.* (2015) leaf length and plant height in cauliflower and Manaware *et al*. (2017) for number of leaves per plant in cauliflower. High heritability along with low to moderate genetic gain were observed for most of the quality traits which clearly shows the major role of non-additive gene action in the transmission of these traits from parents to offspring as reported earlier by Buhroy *et al.* (2017) and therefore cannot be improved by selection.

A crucial factor that determines the variety's commercial viability is yield. Therefore, the characteristic should be given top importance in any breeding effort. High genetic advance as a percentage of the mean for this feature and high heritability both highlighted the possibility of choosing high yielding cultivars from the current collection.

5.3 Correlation coefficients

The ultimate criterion for developing improved cultivars of any crop that a plant breeder must constantly keep in mind is yield. Yield is a polygenic trait, nevertheless, and is greatly impacted by the environment. When selecting, understanding the relationship between quantitative aspects and the yield and its characteristics is useful. Variability studies reveal how much improvement is feasible in many qualities, but they do not reveal the extent or nature of the association between various contributing traits and economically significant traits. Therefore, in order to make indirect selection for the enhancement of economic traits, knowledge of the associations between various attributes and economic traits is required. Studies of correlation help us understand the relationships that exist between highly heritable traits and the economic traits and how each trait contributes to the genetic make-up of a crop. The degree of the association between two traits that has been detected is shown by the phenotypic correlations. This suggests both heritability and environmental impacts, which obscures the actual genetic picture of the relationship. Genotypic correlations give a rough idea of the genetic relationships between any two regulating genes. As a result, it is more important and might be used to create a good selection process. Perusal (Table-3) indicated that in the present investigation, the magnitude of the genotypic correlation coefficients in the current study were higher than the phenotypic coefficients, proving the predominance of heritable components and demonstrating the additive nature of gene action for these traits. These results are in conformity with the findings of Rai *et al*. (2003), Singh *et al*. (2014), Santhosha *et al*. (2015), Kumar *et al*. (2017), Chittora and Singh (2017), Kumar *et al*. (2020), Pramila *et al*. (2020), Kumar *et al*. (2021) reported that higher magnitude of genotypic correlation than phenotypic correlation in *Brassica oleracea*.

The most economically important traits (table 3) i.e., yield per hectare showed significant and positive association with net stem weight ($r_g = 0.95$, $r_p = 0.94$), gross stem weight ($r_g = 0.89$, $r_p = 0.88$), petiole length ($r_g = 0.88$, $r_p = 0.87$), stem breadth ($r_g = 0.87$, $r_p = 0.86$), internode length ($r_g = 0.87$, $r_p = 0.86$), number of leaf whorls ($r_g = 0.85$, $r_p = 0.84$), plant height ($r_g = 0.84$, $r_p = 0.83$), stem length ($r_g = 0.79$, $r_p = 0.78$), number of leaves per plant ($r_g = 0.75$, $r_p = 0.74$), plant spread ($r_g = 0.57$, $r_p = 0.56$), and seed yield per plant ($r_g = 0.49$, $r_p = 0.48$), number of seeds per siliqua ($r_g = 0.46$, $r_p = 0.45$), leaf width ($r_g = 0.44$, $r_p = 0.43$), siliqua width ($r_g = 0.37$, $r_p = 0.36$), siliqua length ($r_g = 0.31$, $r_p = 0.30$). This result is suggested that selection for these characters is useful for improvement upon yield.

Similar findings were noticed by Santhosha *et al*. (2015), Chittro and Singh (2017), Kumar *et al*. (2017) and Kumar *et al*. (2021) in cauliflower. Plant height and plantspread were positively and significantly correlated with yield per hectare both at phenotypic and genotypic levels and these results corroborate the work of Kibar *etal*. (2014) for plant height and Singh *et al*. (2014) and Gaur and Singh (2016) for plant height and plant frame in cauliflower indicating that yield per hectare is associated with highest plant height and plant spread. Yield per hectare showed negative and non-significant with days to 50% stem swelling (r_g = -0.06, r_p = - 0.05), days to 50% harvest (r_g = -0.03, r_p = -0.02), days to 50% flowering (r_g = -0.09, r_p = -0.08) and days to seed maturity (r_g = -0.06, r_p = -0.05). These results agree with the findings of Chittora and Singh (2017) and Kumar *et al*. (2020) revealing that as earliness in maturity results in increased gross knob weight per plant and so do affect the yield per hectare. Leaf length was found to exhibit significantly positive relationship with yield per hectare (r_g = 0.77, r_p = 0.75), number of leaf whorls (r_g = 0.57, r_p = 0.52), internode length (r_g = 0.56, r_p = 0.52), leaf width (r_g = 0.59, r_p = 0.53), petiole length (r_g = 0.73, r_p = 0.70), stem length (r_g= 0.61, r_p = 0.59), stem breadth (r_g = 0.68, r_p = 0.64), gross stem weight (r_g = 0.64, r_p = 0.60), net stem weight (r_g = 0.68, r_p = 0.66), plant height (r_g = 0.59, r_p = 0.56), plant spread (r_g = 0.45, r_p = 0.43), number of leaves per plant (r_g = 0.45, r_p =0.44), siliqua length (r_g = 0.18, r_p = 0.16), siliqua width (r_g = 0.20, r_p = 0.19), number of seeds per siliqua (r_g = 0.33, r_p = 0.31) and seed yield per plant (r_g = 0.33, r_p = 0.32). These results are in conformity with earlier workers namely Rai *et al*. (2003) and Kumar *et al*. (2017) in cabbage. Gross stem weight showed positive and significant corelated with yield per hectare (r_g = 0.89, r_p = 0.88), number of leaf whorls (r_g =0.88, r_p= 0.84), internode length (r_g = 0.89, r_p = 0.87), leaf length (r_g = 0.64, r_p = 0.62), leaf width (r_g = 0.39, r_p = 0.32), petiole length (r_g = 0.85, r_p = 0.84), stem length (r_g = 0.76, r_p = 0.74), stem breadth (r_g = 0.82, r_p = 0.80), net stem weight (r_g = 0.94, r_p = 0.92), plant height (r_g = 0.83, r_p = 0.81), plant spread (r_g = 0.53, r_p = 0.51), number of leaves per plant (r_g = 0.77, r_p = 0.75), siliqua length (r_g = 0.38, r_p = 0.37), siliqua width (r_g = 0.39, r_p = 0.38), number of seeds per siliqua (r_g = 0.45, r_p = 0.42) and seed yield per plant (r_g = 0.32, r_p = 0.30). Kibar *et al*. (2014) in cabbage and Kumar *et al*. (2017) in cauliflower, reportedthat increase in head or curd diameter, number of leaves per plant and net head weight or net curd weight will result in to higher gross weight per plant. Similar results were reported by Kumar *et al.* (2020) in knol-khol. The association ofseeds and the degree of their association showed that, the number of seeds per siliqua and the seed yield per plant except for the days to 50% flowering and the days to seed maturity had a significantly positive correlation with one another. It is possible to conclude that the genotypes with higher seed yield would benefit from selection based on either these seed parameters alone or in combination. However, at the genotypic level, there was a direct relationship between thenumber of leaf whorls and the internode length content and yield per hectare. According to the findings, breeding for knol-khol should prioritise the selection ofsmaller knob sizes in order to preserve the higher seed yield content.

5.4 Path coefficient analysis

Correlation analysis indicates the association pattern of component traits with yield, it simply represents the overall association of a particular trait with yield rather than providing cause and effect relationship. The technique of path coefficient analysis developed by Wright (1921) and demonstrated by Dewey and Lu (1959) facilitates in partitioning the correlation coefficients into direct and indirect contribution of various traits on yield. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify important component traits of yield and utilise the genetic stock for improvement in a planned way.

In current study the path coefficient analysis (Table-4) revealed that number of leaf whorls (0.79) had maximum positive direct effect on yield per hectare at genotypic level followed by plant height (0.70), net stem weight (0.57), stem length (0.35), petiole length (0.32), gross stem weight (0.31), days to seed maturity (0.23) and stem breadth (0.20) indicating that direct selection of these traits will be effective in realizing improvements in yield of knol-khol while maximum negative direct effect was recorded for number of seeds per siliqua (-2.12) followed by siliqua width (-1.13), internode length (-0.65), days to 50% flowering (-0.29), days to 50% harvest (-0.24) and days to 50% stem swelling (-

0.23) that while improving the yield per hectare. The results are in the agreement with the earlier findings of Rai *et al*. (2003) for leaf length and leaf breath in cabbage; Singh *et al*., (2014) for number of leaves and curd weight in cauliflower, Chittora and Singh (2015) for curd diameter and plant height, Kumar *et al.* (2017) for net curd weight in cauliflower and Maximum indirect effect for curd length and leaf length by Pramila *et al*. (2020) in cauliflower. Similar findings were also observed by Lakshmi *et al*. (2022) for number of leaves and plant spread in cauliflower,

The residual effect value in the current study was 0.1860, indicating that the characters selected for the study are the primary contributors to yield and that the characters selected for the current study account for the variability in yield. Similarly, Chittora and Singh *et al*. (2015), Kumar *et al*. (2017), Pramila *et al.* (2020) and Lakshmi *et al*. (2022) observed very fewer residual effects while working on the similar traits in *Brassica* spp.

5.5 Estimation of genetic divergence

Due to the lack of literature on the genetic diversity of knol-khol, it is crucial to identify the diversity and enforce a breeding programme for the scientific utilisation of allelic resources present in the elite gene pool of knol-khol through hybridization and subsequent selection of recombinants possessing high yield potential as well as abiotic resistance and quality. Estimating genetic divergence in the available germplasm resources for yield and yield attributing traits is essential in order to identify potential parents for such programmes. From the perspective of protecting plant biodiversity and utilising it in crop development programmes, it is now crucial to conserve and characterise the knolkhol germplasm that is now available.

In plant breeding, the technique of categorizing genetic stocks based on genetic divergence assessed by D2 is already well-established (Murthy and Pavate, 1962). D^2 statistics of Mahalanobis (1928) have been widely employed to assess population divergence in terms of generalized group distance in order to group a vast number of possible genotypes into a small number of homozygous clusters. One effective method for determining genetic divergence is this one. It is widely known that the likelihood of producing high heterotic hybrids and a wide range of diversity in segregating generations increases with the number of genetically different parents utilised in a hybridization operation (Murthy and Arunachalam, 1966). Geographic diversification is one of several factors that contribute to genetic diversity.

Based on D^2 values, the genetic constellation pattern of thirty knolkhol genotypes showed that there is sufficient genetic diversity to choose superior and diverse parents that can be used for any crop development programme. The distribution of genotypes various clusters often followed a random pattern. Geographic diversification is one of several factors that contribute to genetic diversity. Given that the genotypes were divided up into several clusters in the current study, it was concluded that geographic distribution was not a necessary component for clustering the genotypes. The presence of factors other than geographic origin, such as genetic stock exchange, drift, and natural and artificial selection, may be the cause of genetic diversity. Therefore, selection of genotypes for hybridization should have genetic diversity rather than geographical diversity as reported by Quamruzzaman *et al*. (2007) in cauliflower; Khan *et al*. (2009) in kale, Santhosha *et al*. (2011) and Meena *et al*. (2013) in cabbage, Dolkar *et al.* (2020) in Knolkhol and Pramila *et al*. (2021) in cauliflower. The perusal of table 5 using Mahalanobis D^2 statistics clustered thirty genotypes of knolkhol in 11 clusters with cluster II had maximum number of genotypes (6); followed by cluster I (5) and cluster III (5); cluster IV (4) and cluster V (4); cluster VI (1), cluster VII (1), cluster VIII (1), cluster IX (1), cluster X (1) and cluster XI (1) (Table 5). Using Mahalanobis D^2 clustering Quamruzzaman *et al*. (2007) grouped twenty genotypes of cauliflower into six clusters; Khan *et al*. (2009) grouped forty genotypes of kale into four clusters; Santhosha *et al.* (2011) reported fourteen clusters in fifty-one genotypes of cauliflower, Meena *et al*. (2013) reported three clusters in thirty accessions of cabbage and Dolkar *et al.* (2020) grouped thirty genotypes of knol-khol into six clusters; Pramila *et al*. (2021) grouped fourteen genotypes of cauliflower into four clusters.

5.4.1 Inter and intra cluster distance

As per Mahalanobis D^2 statistics, maximum intra cluster distance was recorded for cluster V (475570.30) followed by cluster IV (283734.90), cluster III (221743.20), cluster II (180522.30) and cluster I (149931.00) suggesting sufficient genetic diversity among the genotypes of the cluster during main season. The maximum inter cluster distance was observed between cluster XI and cluster IV (4849918.00) followed by cluster XI and X (4051389.00) (table 6). The maximum intra-cluster distance (D^2) (cluster V) indicated high heterogeneity in genetic constitution of genotypes in that cluster while minimum intra-cluster distance (D^2) (cluster I) indicated homogeneity in genetic constitution of genotypes in that cluster. As well as the highest value of inter-cluster distance (cluster XI and IV) indicated also more heterogeneous genetic constitution of genotypes included in both clusters. In contrast, minimum inter-cluster distance (cluster VIII and V) indicated closer relationship among the genotypes included. Parent selection from highly divergent cluster is expected to manifest high heterosis in hybridization. Genotypes belonging to clusters separated by maximum genetic distance may be used in hybridization programme to obtain a wide spectrum of variation among the segregants (Doddabhimappa *et al*., 2010). Genotypically distant parents can exert high heterosis (Farhad *et al*., 2010) and (Dar *et al*., 2010). It is also mentioned that crossing involving parents belonging to the medium divergent cluster may also exhibited significant and positive heterosis (Mian and Bahl, 1989).

5.4.2 Cluster mean analysis

Genetic constellation means of different clusters helps to identify the clusters to be chosen for hybridization. Cluster means and co-efficient of variation present an interesting picture of the nature of diversity (Sardana *et al*., 1997). Although the mean values obtained for the various genotype counts in each cluster cannot be statistically compared, they are compared in order to provide a general understanding of the diversity within the clusters. It is possible to identify the characteristics driving the divergence based on the range of means for each character. Perusal of the results representing cluster means (Table-7{a-b}) for different growth characters revealed that cluster V registered the maximum mean value for number of leaf whorls (7.44), internode length (1.23 cm), leaf length (36.97 cm), leaf width (24.63 cm), stem length (5.55 cm), stem breadth (8.04 cm), gross stem weight (583.76 g), net stem weight (478.09 g), number of leaves per plant (15.95), yield per hectare (246.04 q); cluster IV for siliqua length (106.23 cm), siliqua width (1.65 cm), number of seeds per siliqua (24.96), seed yield per plant (19.82 g) and seed yield per hectare (231.84 kg), cluster IX for 1000 seed weight (6.59 g), total chlorophyll content (200.63), carbohydrate content in leaf (6.93) and total carotenoid content in knob (4.97), cluster II for petiole length (23.46 cm), plant height (57.59 cm) and plant spread (67.14 cm); cluster VIII for vitamin C content in leaf (108.28), moisture content in knob (62.60) and vitamin C content in knob (74.71), cluster X for total carotenoids content in leaf (14.38), TSS content in leaf (6.38) and TSS content in knob (7.94), cluster III for days to 50% harvest (57.31 days) and days to seed maturity (210.83 days), cluster VI for days to 50% flowering (156.55 days) and carbohydrate content in knob (9.91), cluster VII for days to 50% stem swelling (38.84 days), cluster XI for moisture content in leaf (77.53). Hence, crosses between genotypes selected from these clusters may be used to generate Knol-khol genotypes with good yield and quality traits. Similar comparison of clusters based on the range of mean value of each character had been done by Quamruzzaman *et al.* (2007), Khan *et al.* (2009), Santhosha *et al.* (2011), Meena *et al.* (2013), Dolkar *et al.* (2020) and Pramila *et al.* (2021).

5.4.3 Percent contribution towards divergence

The selection and choice of parents mainly depends on contribution of traits towards divergence Ramya and Kumar (2004). The present investigation in Table 8 depicted that the traits contributing maximum (up to 90%) towards divergence yield per hectare were followed by gross knob weight, net knob weight, number of leaves per plant, stem breadth, stem length, leaf length, leaf width, plant height, plant spread, petiole length, seed yield per plant, seed yield per hectare, number of seeds per siliqua, 1000 seed weight, number of leaf whorls, internode length, siliqua width, siliqua length, days to 50% stem swelling, days to 50% harvest, days to 50% flowering, days to seed maturity, total chlorophyll content, vitamin C content in leaf and knob, total carotenoids in leaf and knob, carbohydrate content in leaf and knob, TSS content in leaf and knob and moisture content in leaf and knob. The traits contributing maximum towards the divergence should be given great emphasis for deciding the clusters to be chosen for hybridization and the subsequent selection of the parents from the clusters be based on their *per se* performance. In Knol-khol, maximum contribution from traits towards divergence has been reported to be different for different sets of materials used in experimentation depending upon the genotypes under study which is in conformity to the findings of and Khan *et al*. (2009), Dolkar *et al*. (2020) in knol- khol.

While selecting genotypes from distant cluster the mean values for different trait should be given importance to generate promising breeding material (Hazara *et al*., 2002). The findings of the current investigation into genetic variability and genetic constellation suggested that there was a significant amount of genetic diversity and variability available to take advantage of the superior allelic resources present in the genotypes through deliberate breeding and selection techniques in order to recover high yielding segregants that also possessed high-quality traits. Plant breeding is a constant process of improvement over current varieties. Any varietal improvement programme mainly depends on the selection of parents with high genetic variability so that desirable character combinations could be selected for the target traits to be improved upon. Maurya and Singh (1977) suggested that more diverse the parents within overall limits of fitness, the greater are the chances of obtaining higher magnitude of heterotic F1"s and subsequently result in the release of broad spectrum of genetic variability in the segregating generations (Joshi and Dawan, 1966; Panday and Ghorai,1987). Singh *et al*. (1996) suggested, the selection of parents should be done from different clusters having wide inter cluster distance and the parents should have high mean performance for traits that are contributing maximum towards divergence.

5.6 Descriptor traits as per Minimal descriptors of vegetable crops by NBPGR

Observations were recorded on seven descriptor traits (Table 11) viz., petiole attitude, leaf color, leaf shape, leaf waxiness, petiole crossing, stem color and stem shape. An erect petiole attitude was shown by most of the genotypes with a few showing semi-erect and horizontal petiole attitude. Leaf color exhibited a wide range of variation with dark green and violet green as predominant classes. Others genotypes had light green and yellow green leaves. Leaf shape was broad ovate and narrow ovate for most genotypes with a few having ovate leaf shape. Most ofthe genotypes exhibited strong leaf waxiness with a few exceptions exhibiting medium and weak leaf waxiness. All the genotypes under study had petiole crossing. However, a few with no petiole crossing. Stem color exhibited four classes for the genotypes under study viz., light green, green, dark green, purplish green and dark purple. Wide range of variation among genotypes with respect to stem shape. Shape of the stem was transverse narrow elliptic, transverse broad elliptic, broad elliptic, transverse elliptic and circular for most of the genotypes with some stumping stem shapes (table 9).

Chapter - 6

SUMMARY AND CONCLUSION

The present investigation entitled **"Evaluation and Characterization of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir conditions"** was undertaken to estimate the coefficients of variability, heritability, genetic gain, correlation coefficients, path coefficients and genetic divergence in thirty genotypes of Knol-khol.

The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole experimental area was divided into three blocks each of which was then divided into thirty lines to represent the thirty treatments.

Observations were also recorded on thirty-four quantitative and quality traits viz., number of leaf whorls, internode length (cm), leaf length (cm), leaf breadth (cm), petiole length (cm), days to 50% stem swelling, days to 50% harvest, stem length (cm), stem breadth (cm), gross stem weight (g), net stem weight (g), plant height (cm), plant spread (cm), number of leaves per plant, yield per hectare (q), days to 50% flowering, days to seed maturity, siliqua length (cm), siliqua width (cm), number of seeds per siliqua, seed yield per plant (g), seed yield per hectare (q), 1000 seed weight (g), total chlorophyll content (mg/100g), moisture content in leaf and knob (%), TSS content in leaf and knob (ºB), vitamin C in leaf and knob (mg/100g), carbohydrate content in leaf and knob (%), total carotenoids content in leaf and knob (mg/100g). The data collected on these characters were subjected to statistical analysis and the results obtained from the investigation are summarized as follows:

Wide range was observed for most of the traits under study. Based on mean performance of the genotypes, it was observed that lowest yield per hectare was recorded in SK-KK-123 (116.13) followed by SK-KK-197 (119.60), SK-KK-IC-6 (124.01), SK-KK-51 (134.27) and SK-KK-23 (134.41). The highest yield per hectare was recorded in SK-KK-14 (246.04 q) followed by SK-KK-154 (238.31 q), SK-KK-72(A) (226.80 q), SK-KK-129 (221.22 q) and SK-KK-2 (216.01 q).

Analysis of variance revealed significant differences among genotypes for all the traits studied. The highest and lowest phenotypic and genotypic coefficients of variability ranged from 6.96 – 54.50 and 6.86 – 54.27 respectively. The highest phenotypic and genotypic coefficients of variability was observed for yield per hectare (54.50, 54.27), seed yield per hectare (44.92, 44.85) followed by seed yield per plant (44.91, 44.84), total carotenoids content in knob (39.55, 39.12) and number of seeds per siliqua (38.89, 38.70). In general, the phenotypic and genotypic coefficients of variation were slightly higher than the corresponding phenotypic coefficients of variation, which indicates the minor role of environment in the expression of traits under observation. The difference between the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was found to be narrow for number of leaf whorls, internode length (cm), leaf length (cm), leaf breadth (cm), petiole length (cm), days to 50% stem swelling, days to 50% harvest, stem length (cm), stem breadth (cm), gross stem weight (g), net stem weight (g), plant height (cm), plant spread (cm), number of leaves per plant, yield per hectare (q), days to 50% flowering, days to seed maturity, siliqua length (cm), siliqua width (cm), number of seeds per siliqua, seed yield per plant (g) and seed yield per hectare (q) suggesting that these traits were leastaffected by the environment and selection for these traits based on phenotypic would be rewarding. The difference between phenotypic and genotypic coefficient of variation was found to be high for total chlorophyll content indicating that the apparent variation was not only due to genotypes but also due to influence of environment.

Heritability (b. s.) was high for all the characters and ranged from 88 to 99 per cent indicating that the characters are less influenced by environmental effects and that characters are effectively transmitted to the progeny. All the characters showed the high of heritability coupled with high genetic advance as per cent of mean, indicating the preponderance of additive gene action for control of these traits. The present investigation indicates a great scope of fast improvement in all the traits as these characters in general possessed high estimates of heritability coupled with high genetic advancement. High heritability coupled with high genetic gain was recorded for yield per hectare (q) followed by seed yield per hectare (kg), seed yield per plant (g), total carotenoids content in knob (mg/100g), number of seed per siliqua, and siliqua length (mm) indicating that most likely the heritability is due to additive gene effects and thus the chances of fixing by selection are more to improve such traits through pure line selection, mass selection, progeny selection, hybridization and selection through pedigree breeding.

In the present investigation, the estimates of genotypic correlation coefficients were in general slightly higher than phenotypic correlation coefficients showing that masking effects of the environment was little indicating the presence of inherent association between various characters. Correlation coefficients revealed that the economically important trait i.e., yield per hectare (q) exhibited significant and positive association with number of leaf whorls, internode length (cm), leaf length (cm), leaf width (cm), petiole length (cm), stem length (cm), stem breadth (cm), gross stem weight (g), net stem weight (g), plant height (cm), plant spread (cm), number of leaves per plant, siliqua length (mm), siliqua width (mm), number of seeds per siliqua and seed yield per plant (g) both at genotypic and phenotypic levels. Days to 50% stem swelling, days to 50% harvest, days to 50% flowering and days to seed maturity showed negative but non-significant association with yield per hectare (q).

The path coefficient analysis made it apparent that the highest amount of direct positive effect on yield per hectare was recorded via., number of leaf whorls followed by plant height (cm), net stem weight (g), stem length (cm), petiole length (cm), gross stem weight (g), days to seed maturity and stem breadth (g).

D^2 statistics grouped thirty genotypes of Knol-khol in eleven clusters. Cluster II had maximum number of genotypes (6); followed by cluster I (5) and cluster III (5); cluster IV (4) and cluster V (4); cluster VI (1), cluster VII (1), cluster VIII (1), cluster IX (1), cluster X (1) and cluster XI (1). The maximum inter-cluster distance was observed between cluster IV and cluster XI (4849918.00) followed by cluster X and XI (4051389.00) and cluster IV and cluster VI (3824375.00). The minimum intra-cluster was found in cluster I (149931.00) and maximum intra-cluster distance was found in cluster V (475570.30). Cluster means for different traits exhibited substantial variability. Selection of parents from cluster IV and XI followed by cluster X and XI for hybridization programmes would help in achieving novel recombinants.

Maximum per cent contribution of the traits towards total genetic divergence was observed from yield per hectare (q) (20.30%) followed by gross stem weight (g) (12.10%), net stem weight (g) (10.93%) and number of leaves per plant(8.69%) suggesting that selection of one or two elite genotypes from such divergent clusters based on the above characters and crossing would result in more heterosis.

These descriptor traits revealed a wide range of variability. Petiole attitude ranged as erect, semi-erect and horizontal. Leaf color exhibited four classes ranged from light green, dark green, yellow green and violet green. Leaf shape ranged from broad ovate, narrow ovate and ovate. Leaf waxiness varied from strong, medium to weak. All the genotypes under study had petiole crossing. However, a few with no petiole crossing. Stem color exhibited four classes for the genotypes under study viz., light green, green, dark green, purplish green, dark purple. Shape of the stem was transverse broad elliptic, broad elliptic, circular and transverse elliptic for most of the genotypes with some transverse narrow elliptic, stem shapes.

Based on the findings of present investigation the following conclusions can be drawn:

i. Analysis of variance indicated that a significant variation existed for various characters under study.
ii. High heritability coupled with high genetic gain (genetic advance as per

cent of mean) was observed for yield per hectare followed by seed yield per hectare, seed yield per plant, total carotenoids content in knob, number of seeds per siliqua and siliqua length indicating the preponderance of additive gene action.

iii. Correlation studies indicated that characters for net stem weight followed by gross stem weight, petiole length, stem breadth, internode length, number of leaf whorls, plant height, stem length, number of leaves per plant, plant spread and seed yield per plant, number of seeds per siliqua, leaf width, siliqua width and siliqua length should be considered important for improving quantitative traits in Knol-khol.

iv. Path coefficient analysis further suggested that number of leaf whorls followed by plant height, net stem weight, stem length, petiole length, gross stem weight, days to seed maturity and stem breadth should be given due importance by selection for breeding of new cultivars.

v. Per se performance of the experimental material indicated that SK-KK-14, SK-KK-23, SK-KK-80, SK-KK-90, SK-KK-64, SK-KK-129, Pusa Virat, White Vienna and Purple Vienna were important with respect to quantitative and quality traits.

vi. The inter cluster distance (D^2) was maximum between cluster XI and cluster IV indicated that the genotypes in these clusters are genetically very diverse with each other hence, can be used as parents in any breeding programme to get higher heterotic effects.

vii. Descriptor traits as per Minimal descriptors of vegetable crops by NBPGR indicated wide variability with respect to petiole attitude, leaf color, leaf shape, leaf waxiness, petiole crossing, stem color and stem shape.

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APPENDIX -I

Mean performance of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) genotypes with respect to different quantitative traits

S. No.	Genotypes	No. of leaf whorls	Internode length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Days to 50% stem swelling	Days to 50% harvest	Stem length (cm)	Stem breadth (cm)	Gross stem weight (g)	Net stem weight (g)
1	SK-KK-1	6.48	0.55	26.82	18.03	16.32	41.15	61.22	4.68	6.40	352.60	266.60
2	SK-KK-2	6.64	0.62	18.87	22.51	15.04	34.97	46.16	4.54	6.41	500.98	423.82
3	SK-KK-3	6.77	0.96	28.92	20.04	8.95	35.30	52.71	4.31	8.59	388.76	278.98
4	SK-KK-9	6.84	0.84	23.47	15.97	14.83	38.88	58.42	4.55	6.78	316.64	255.94
5	SK-KK-10	6.02	0.84	34.15	21.42	15.06	34.51	46.34	5.08	6.83	562.80	400.62
6	SK-KK-14	7.93	1.76	35.02	26.16	12.66	38.91	58.03	5.89	9.46	583.76	478.09
7	SK-KK-22	4.52	0.58	26.12	16.86	10.64	32.69	45.36	3.66	6.58	323.81	257.34
8	SK-KK-23	4.72	0.57	20.52	15.34	12.54	41.71	62.09	3.71	5.46	373.69	234.19
9	SK-KK-32	5.88	0.81	28.15	19.70	18.22	29.26	43.15	4.56	6.31	312.84	251.77
10	SK-KK-38	4.45	0.49	26.19	16.84	11.91	28.41	42.31	3.79	6.46	334.11	252.49
11	SK-KK-45	5.92	0.82	25.92	20.04	16.43	33.07	45.22	4.63	7.47	394.91	285.00
12	SK-KK-51	6.61	0.56	30.92	15.46	15.36	34.99	50.23	3.62	6.37	373.69	245.92
13	SK-KK-64	5.98	0.70	28.84	15.93	12.32	33.84	45.28	4.67	6.53	365.51	272.63
14	SK-KK-65	7.17	1.54	23.56	20.39	13.48	36.81	56.40	5.71	6.39	375.85	234.96
15	SK-KK-72(A)	7.34	1.27	31.83	24.09	17.01	40.65	60.12	5.48	7.90	530.70	445.65
16	SK-KK-72(B)	6.72	1.00	20.86	21.03	14.52	38.79	58.50	5.68	7.38	370.92	274.74
17	SK-KK-80	5.78	0.66	25.22	14.43	11.46	36.24	52.02	4.35	6.02	272.81	183.65
18	SK-KK-88	6.47	1.46	20.62	18.63	9.63	38.84	57.46	5.79	7.34	379.72	268.59
19	SK-KK-90	6.73	0.52	28.21	15.67	16.53	26.04	42.33	4.63	6.26	398.83	249.94
20	SK-KK-123	4.32	0.46	25.11	12.38	13.71	28.91	46.06	3.60	5.35	222.89	174.83
21	SK-KK-129	6.27	1.12	15.52	20.89	15.44	33.87	50.33	5.50	7.86	514.80	439.84
22	SK-KK-154	7.50	1.36	32.36	25.80	13.98	23.32	43.57	5.66	8.33	358.83	295.72
23	SK-KK-175	5.32	0.54	31.12	14.42	18.01	30.20	49.12	4.02	5.98	344.85	199.78
24	SK-KK-180	4.62	0.84	26.78	17.87	13.22	25.81	45.02	4.70	5.56	345.63	265.83
25	SK-KK-197	6.97	0.97	33.76	22.45	9.41	25.99	41.37	5.22	7.33	572.81	411.03
26	SK-KK-IC-2	5.21	0.53	17.75	13.00	13.29	27.46	48.12	4.06	5.86	332.67	223.87
27	SK-KK-IC-6	4.98	0.88	32.17	20.99	8.24	32.16	51.18	4.92	5.24	330.72	297.05
28	Purple Vienna	6.63	1.20	33.92	15.6	14.18	35.84	55.32	5.62	7.04	561.86	460.60
29	Pusa Virat	6.75	1.12	30.85	20.05	7.88	31.26	47.22	5.22	6.93	346.94	285.68
30	White Vienna	6.34	1.06	28.06	20.04	16.76	21.99	40.51	5.82	6.47	547.96	400.71
	Mean	**6.05**	**0.9**	**27.06**	**18.83**	**18.83**	**33.86**	**51.01**	**4.62**	**6.88**	**399.72**	**300.52**
	CD($P\leq0.05$)	**0.78**	**0.34**	**1.52**	**0.47**	**0.71**	**0.89**	**1.65**	**0.70**	**0.54**	**2.51**	**2.52**

Contd…

S.no.	Genotypes	Plant height (cm)	Plant spread (cm)	No. of leaves per plant	Yield per hectare (q)	Days to 50% flowering	Days to Seed maturity	Siliqua length (mm)	Siliqua width (mm)	No. of Seed per siliqua	Seed yield per plant (g)	Seed yield per hectare (kg)	1000 seed weight (g)
1	SK-KK-1	59.36	53.42	11.90	162.82	129.27	179.21	51.04	0.52	5.61	6.95	83.40	4.43
2	SK-KK-2	46.14	60.91	15.86	216.01	130.52	184.47	94.20	0.61	20.48	18.09	205.20	5.93
3	SK-KK-3	51.02	57.59	12.85	175.61	138.15	176.19	49.53	0.55	4.62	5.95	71.4	4.32
4	SK-KK-9	56.22	51.17	11.06	149.69	141.75	182.78	76.94	0.73	13.78	12.38	148.56	5.78
5	SK-KK-10	52.22	62.86	14.68	202.43	146.74	180.91	80.63	0.98	14.64	13.80	165.60	5.44
6	SK-KK-14	58.32	52.33	17.57	246.04	160.05	214.50	54.92	0.57	7.73	8.22	98.64	5.84
7	SK-KK-22	49.12	51.75	11.33	152.42	134.53	203.36	67.19	0.55	11.12	9.91	118.92	5.66
8	SK-KK-23	31.41	44.17	10.32	134.41	120.77	168.03	87.15	0.87	16.61	17.10	193.08	6.22
9	SK-KK-32	57.12	49.77	10.75	148.48	145.90	177.29	91.34	1.19	20.84	12.52	150.24	4.34
10	SK-KK-38	49.14	51.83	11.23	156.05	132.64	210.77	66.50	0.67	12.01	10.96	131.52	5.11
11	SK-KK-45	38.52	58.67	12.71	178.07	131.34	181.32	64.91	0.54	10.66	8.06	96.72	5.02
12	SK-KK-51	45.18	48.82	10.98	134.27	150.13	187.74	51.60	0.96	6.11	7.12	85.44	4.98
13	SK-KK-64	63.96	55.36	12.53	167.24	130.14	180.05	101.32	1.65	23.43	10.80	129.60	4.80
14	SK-KK-65	47.82	46.33	10.80	135.20	153.69	203.24	76.67	0.73	13.49	13.18	158.16	5.10
15	SK-KK-72(A)	60.28	66.15	13.34	226.80	157.93	212.14	81.43	0.81	14.89	14.71	176.52	4.86
16	SK-KK-72(B)	45.52	61.92	14.26	197.30	132.37	185.34	98.78	1.26	22.77	11.08	133.96	4.48
17	SK-KK-80	44.43	43.50	10.02	206.09	164.05	217.73	89.82	0.92	19.88	13.24	158.88	4.21
18	SK-KK-88	41.77	54.15	11.85	206.10	128.45	205.42	87.01	0.87	17.22	14.19	170.28	5.78
19	SK-KK-90	40.76	49.17	11.14	143.20	156.55	195.56	106.23	1.52	24.96	19.82	231.84	5.26
20	SK-KK-123	53.60	55.92	8.84	116.13	136.78	206.41	86.31	0.86	16.83	15.16	181.26	5.35
21	SK-KK-129	43.59	65.77	16.33	221.22	144.13	193.64	66.53	0.59	10.11	6.04	72.48	4.02
22	SK-KK-154	55.53	67.71	13.24	238.31	122.55	194.53	56.71	0.56	7.23	8.41	100.92	5.13
23	SK-KK-175	57.67	49.77	14.72	160.48	130.58	189.25	72.07	1.25	13.13	11.90	142.80	5.15
24	SK-KK-180	34.09	72.17	11.28	206.54	121.97	173.16	52.16	0.60	8.24	10.04	120.48	4.76
25	SK-KK-197	44.54	63.52	10.52	119.60	125.16	198.94	71.90	0.90	12.55	11.35	136.20	4.54
26	SK-KK-IC-2	33.41	41.16	9.58	190.87	120.94	179.71	68.40	0.64	11.81	7.91	94.92	5.80
27	SK-KK-IC-6	38.06	61.82	13.62	124.01	130.55	199.67	81.27	0.77	15.03	14.14	169.68	4.59
28	Purple Vienna	61.56	64.52	16.80	169.56	126.13	200.38	85.70	0.90	15.34	15.52	186.24	6.59
29	Pusa Virat	55.62	58.68	13.42	182.47	135.48	207.03	75.32	0.72	13.74	12.44	149.28	5.72
30	White Vienna	36.60	40.52	12.74	186.83	140.24	192.22	95.49	0.93	19.95	16.35	196.20	5.96
	Mean	**48.4**	**55.34**	**12.6**	**175.06**	**137.32**	**193.03**	**76.29**	**0.83**	**14.20**	**11.91**	**142.96**	**5.17**
	CD(P≤0.05)	**0.49**	**0.70**	**1.22**	**3.63**	**1.37**	**3.58**	**3.41**	**0.24**	**0.65**	**0.58**	**4.57**	**0.22**

APPENDIX -II

Mean performance of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) genotypes with respect to different quality traits

S.no.	Genotypes	Total Chlorophyll content (mg/100g)	Moisture content in leaf (%)	Moisture content in knob (%)	TSS content in leaf (°B)	TSS Content in knob (°B)	Vitamin C content in leaf (mg/100g)	Vitamin C content in knob (mg/100g)	Carbohydrate content in leaf (%)	Carbohydrate content in knob (%)	Total carotenoids content in leaf (mg/100g)	Total carotenoids Content in knob (mg/100g)
1	SK-KK-1	82.54	76.46	63.36	4.25	6.21	94.11	54.54	4.70	7.32	7.50	2.03
2	SK-KK-2	70.62	69.07	53.14	5.05	6.50	97.04	58.41	6.52	7.67	7.01	5.48
3	SK-KK-3	80.96	65.79	51.02	6.86	6.59	96.42	50.92	3.55	7.47	7.24	1.99
4	SK-KK-9	94.86	62.77	48.22	5.96	6.40	88.17	64.94	4.48	8.60	5.94	3.06
5	SK-KK-10	82.24	69.00	58.13	4.10	6.29	92.85	45.97	5.47	9.17	6.07	2.35
6	SK-KK-14	91.47	84.73	69.22	5.40	6.94	91.59	54.40	4.56	10.79	7.97	5.94
7	SK-KK-22	70.82	79.7	60.12	5.74	6.98	98.44	53.32	6.46	8.42	6.06	4.50
8	SK-KK-23	101.48	80.38	41.12	5.31	5.97	88.12	47.88	7.03	8.3	7.07	4.92
9	SK-KK-32	96.39	70.85	46.28	5.12	5.50	99.13	55.22	6.70	10.37	9.05	2.94
10	SK-KK-38	98.72	73.11	54.32	4.52	5.84	102.44	54.18	4.87	8.68	7.03	3.42
11	SK-KK-45	84.76	78.45	56.52	6.38	7.94	89.04	65.87	4.90	8.59	9.37	2.45
12	SK-KK-51	74.82	77.52	47.96	4.44	7.38	87.53	57.64	5.61	9.59	7.53	2.48
13	SK-KK-64	91.34	74.48	61.14	6.45	8.46	85.73	53.24	3.49	7.42	7.42	2.45
14	SK-KK-65	93.71	75.87	41.82	4.53	7.48	93.77	56.52	6.18	7.41	9.69	3.16
15	SK-KK-72(A)	88.21	81.04	52.18	6.93	7.05	100.42	47.54	5.90	7.12	7.04	2.50
16	SK-KK-72(B)	118.44	69.39	54.52	6.50	6.90	106.88	55.91	4.33	10.87	8.28	3.71
17	SK-KK-80	104.40	70.65	59.43	6.95	7.51	105.44	53.36	5.27	10.96	7.89	1.95
18	SK-KK-88	72.25	68.10	57.56	5.97	8.08	86.77	73.52	4.15	8.96	7.14	3.48
19	SK-KK-90	126.48	74.53	49.53	4.93	6.57	90.47	63.98	5.43	9.91	7.39	2.23
20	SK-KK-123	86.49	71.46	62.60	4.93	5.78	107.28	74.71	3.46	8.48	7.50	5.59
21	SK-KK-129	121.96	72.03	55.59	5.53	6.52	109.81	59.98	6.58	8.47	7.23	4.90
22	SK-KK-154	124.92	72.46	67.77	6.49	6.80	91.89	49.46	6.72	8.82	8.01	5.03
23	SK-KK-175	143.35	69.11	50.91	4.53	7.72	98.95	60.13	6.12	7.81	8.34	2.79
24	SK-KK-180	130.41	76.36	64.76	5.54	8.31	95.94	70.11	3.50	9.16	9.56	3.29
25	SK-KK-197	71.92	69.71	61.41	6.13	8.32	90.09	51.83	4.00	9.24	7.02	6.07
26	SK-KK-IC-2	121.22	71.91	59.06	5.50	7.18	103.29	61.47	6.93	9.86	7.59	4.97
27	SK-KK-IC-6	78.79	70.02	66.09	5.22	7.51	104.69	72.22	4.59	9.26	7.67	1.86
28	Purple Vienna	70.56	68.93	58.25	5.35	6.45	91.40	62.14	6.17	8.79	7.16	1.93
29	Pusa Virat	132.51	70.51	49.42	4.93	6.15	108.01	69.29	6.49	10.22	8.42	5.42
30	White Vienna	146.94	81.51	60.37	5.50	6.03	92.04	57.28	7.52	10.56	7.60	2.54
	Mean	**98.35**	**73.19**	**56.06**	**5.50**	**6.91**	**94.82**	**58.53**	**5.39**	**8.94**	**8.34**	**3.51**
	CD(P≤0.05)	**13.89**	**0.49**	**0.55**	**0.41**	**0.44**	**0.51**	**0.71**	**0.47**	**0.50**	**0.42**	**0.33**

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C E R T I F I C A T E

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Geetika Malik**, Scientist (ARS) and I/c Head, Division of Vegetable Science and Floriculture, ICAR, CITH, Srinagar during Viva-Voce examination held on **07-03-2023** have been incorporated in the manuscript entitled "**Evaluation and Characterization of Knol-khol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir conditions**" submitted by **Ms. Raziya Sultana (Regd. No. MSH-2020-326).**

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