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Genetic studies in Knol Khol (*Brassica oleracea* var. *gongylodes* L.) under Kashmir valley conditions

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Abstract
The present investigation 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 *viz*. Pusa Virat, Purple Vienna and White Vienna. Observations were recorded for various yield and yield attributing traits. 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 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.

Keywords: Knol Khol, variability, genetic advance, correlation, path analysis

Introduction
Knol-khol (*Brassica oleracea* var. *gongylodes* L.) is a popular winter vegetable that gets its name from the knob (tuber) formed when stem tissue above the cotyledons thickens. (Thamburaj and Singh, 2016) [29]. The formation of knob is best seen at the temperature between 15-18 °C. Knobs are either used as cooked or as boiled vegetable. 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) [29]. 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) [1] and is in great demand throughout the year for its varied size of coloured knobs and leaves. 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) [2].
Knol-khol has 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) [6]. 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) [9]. Knol-khol is also an important source of fibres (including pectin and cellulose) and phenolics (Harbaum *et al.*, 2007) [8].
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. 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. Knowledge of the relationships between quantitative features, particularly yield and its attributes, is also useful for an effective 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 variability and to identify superior genotypes with desirable yield and quality traits.

Materials and Methods

The present investigation was undertaken at Experimental Field of Division of Vegetable Science, SKUAST-Kashmir, Shalimar during Rabi 2021-22. Thirty phenotypically diverse genotypes including three checks (Pusa Virat White Vienna and Purple Vienna) of knol-khol, collected from different agro climates of India and maintained in the Division of Vegetable Science were used for present study. The single factor experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. The spacing of 30 cm x 30 cm between rows and plants was maintained. Recommended package of practices was followed to ensure healthy crop growth. 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 standard statistical analysis.

Results and Discussion

Wide range was observed for most of the traits under study. Analysis of variance (Table 1) revealed significant differences among genotypes for all the traits studied. This was in conformity with the finding of Soni *et al*. (2013) [28] in cabbage, Kumar *et al*. (2019) [12] and Pramila *et al*. (2021) [21] in cauliflower, Meena *et al*. (2021) [18] in knolkhol.

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 least affected 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. Similar findings have also been reported by Singh *et al*. (2013) [26] for days to marketable maturity and leaf width in cauliflower, Meena *et al*. (2014) [17] for stalk length and core length in cabbage, Dolkar *et al.* (2018) [7] for number of leaves per plant and gross weight per plant in knolkhol, Shruthy *et al*. (2018) [24] for curd compactness and curd size index for in cauliflower, Pramila *et al*. (2021) [21] for number of leaves, leaf blade width and net curd weight cauliflower.

Heritability (b. s.) was high for all the characters and ranged from 88 to 99 percent indicating that the characters are less influenced by environmental effects and that characters are effectively transmitted to the progeny. The results are in conformation with the findings of earlier workers namely Singh *et al*. (2011) [25] for net head weight and gross weight per plant in cabbage, Khan *et al*. (2012) [10] for plant height, leaf thickness, stem thickness, leaf number and leaf weight in kale, Chittora and Singh (2015) [3] for leaf length, leaf width and plant height in cauliflower, Singh *et al*. (2013) [26] and Manaware *et al*. (2017) [16] for leaf length and ascorbic acid content in cauliflower, Kumar *et al*. (2019) [12] for plant height and days to marketable maturity in cauliflower, Dolkar *et al*. (2018) [7] for ascorbic acid content of knob and leaves and beta carotene content of leaves in knol-khol.

All the characters showed the high of heritability coupled with high genetic advance as percent of mean, indicating the preponderance of additive gene action for control of these traits. 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. 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) [26] for leaf length and plant height; Chittora and Singh (2015) [3] for plant height, Chura *et al*. (2016) [5] for harvest index and net head weight, Dolkar *et al*. (2018) [7] for beta carotene content of knob and marketable knob weight per plant, Kumar *et al*. (2019) [12] 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.

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. These results are in conformity with the findings of Rai *et al*. (2003) [22], Singh *et al*. (2014) [27], Santhosha *et al*. (2015) [23], Kumar *et al*. (2017), Chittora and Singh (2017) [4], Kumar *et al*. (2020) [13], Pramila *et al*.

(2020) [20] and Kumar *et al.* (2021) [14]. The most economically important trait 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 suggested that selection for these characters is useful for improvement upon yield. Similar findings were noticed by Santhosha *et al.* (2015) [23], Chittro and Singh (2017) [4], Kumar *et al.* (2017) [11] and Kumar *et al.* (2021) [14] in cauliflower.

In current study the path coefficient analysis 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) [22] for leaf length and leaf breath in cabbage; Singh *et al.*, (2014) [27] for number of leaves and curd weight in cauliflower, Chittora and Singh (2015) [3] for curd diameter and plant height, Kumar *et al.* (2017) [11] for net curd weight in cauliflower; for curd length and leaf length by Pramila *et al.* (2020) [20] in cauliflower and for number of leaves and plant spread in cauliflower by Lakshmi *et al.* (2022) [15].

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) [3], Kumar *et al.* (2017) [11], Pramila *et al.* (2020) [20] and Lakshmi *et al.* (2022) [15] observed very fewer residual effects while working on the similar traits in *Brassica* spp.

Table 1: 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

S. No.	Source of variation	d.f.	Mean sum of squares: Plant height (cm)	Plant spread (cm)	No. of leaves plant^{-1}	Yield hectare^{-1} (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

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

Table 2a: 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
12.	Plant height (cm)	48.40	31.41 - 63.96	82.26	82.17	18.73	18.72	0.99	38.55
13.	Plant spread (cm)	55.34	40.52 - 72.17	67.57	66.39	14.85	14.83	0.99	30.51
14.	Number of leaves per plant	12.60	8.84 - 17.57	5.41	4.84	18.45	17.46	0.89	34.04
15.	Yield per hectare (q)	175.06	116.13 – 246.04	9104.28	9026.21	54.50	54.27	0.99	93.07
16.	Days to 50% flowering	137.32	120.77 - 164.05	151.96	151.25	8.97	8.95	0.99	18.40
17.	Days to seed maturity	193.03	168.03 - 217.73	180.49	175.68	6.96	6.86	0.97	13.95
18.	Siliqua length (mm)	76.29	49.53 - 106.23	164.79	163.13	16.82	16.74	0.98	62.95
19.	Siliqua width (mm)	0.84	0.52 - 1.65	0.09	0.08	37.40	35.70	0.88	50.73
20.	Number of seed per siliqua	14.20	4.62 - 24.96	30.52	30.36	38.89	38.70	0.99	79.70
21.	Seed yield per plant (g)	11.91	5.95 - 19.82	28.60	28.52	44.91	44.84	0.99	92.23
22.	Seed yield per hectare (kg)	142.96	71.4 – 231.84	4122.06	4110.57	44.92	44.85	0.99	92.26
23.	1000 seed weight (g)	5.17	4.02 – 6.59	0.82	0.77	17.55	17.02	0.93	38.85

Table 2b: 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

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	-0.37	0.72**	0.78**	0.88**	0.77**	0.84**	0.56**	0.79**	-0.20	-0.17	0.36*	0.39*	0.46*	0.35*
Internode length (cm)	0.96**	1.00	0.56**	0.38*	0.87**	-0.11	-0.26	0.77**	0.81**	0.89**	0.88**	0.89**	0.60**	0.83**	-0.21	-0.17	0.40*	0.43*	0.48*	0.36*
Leaf length (cm)	0.52**	0.52*	1.00	0.59*	0.73**	-0.05	-0.13	0.61*	0.68*	0.64*	0.68**	0.59**	0.45*	0.45*	-0.11	-0.09	0.18	0.20	0.33	0.33*
Leaf width (cm)	0.36*	0.34*	0.53*	1.00	0.39*	-0.09	-0.07	0.48*	0.35*	0.39*	0.37*	0.42*	0.52*	0.43*	-0.12	-0.08	0.29	0.20	0.37*	0.31*
Petiole length (cm)	0.84**	0.85**	0.70**	0.33*	1.00	-0.18	-0.09	0.80**	0.86*	0.85**	0.85**	0.85**	0.51*	0.83**	-0.16	-0.13	0.20	0.15	0.37*	0.35*
Days to 50% stem swelling	-0.23	-0.09	-0.02	-0.08	-0.16	1.00	-0.14	0.17	0.14	-0.03	0.16	-0.04	-0.02	-0.05	-0.03	-0.02	-0.19	-0.02	-0.05	-0.17
Days to 50% harvest	-0.32	-0.21	-0.10	-0.05	-0.08	-0.13	1.00	0.11	0.12	-0.04	0.17	-0.02	-0.11	-0.06	-0.12	-0.10	-0.11	-0.13	-0.06	-0.11
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	-0.20	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	-0.04	0.36*	0.35*	0.28	0.33*
Gross stem weight (g)	0.84**	0.87**	0.62*	0.37*	0.83**	-0.02	-0.03	0.74**	0.80**	1.00	0.94**	0.83**	0.55*	0.87**	-0.21	-0.15	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	-0.08	0.14	0.18	0.40*	0.35*
Plant height (cm)	0.80**	0.88**	0.56**	0.39*	0.81**	-0.03	-0.01	0.84**	0.81**	0.81**	0.80**	1.00	0.69**	0.67**	-0.14	-0.07	0.20	0.13	0.50*	0.33*

Plant spread (cm)	0.52**	0.58**	0.43*	0.50**	0.49*	-0.01	-0.10	0.66**	0.51**	0.53*	0.50**	0.68**	1.00	0.13	-0.13	-0.03	0.10	0.14	-0.06	0.20
No. of leaves per plant	0.78**	0.82**	0.44*	0.41*	0.81**	-0.04	-0.05	0.65*	0.75**	0.85**	0.81**	0.66*	0.11	1.00	-0.30	-0.18	0.28	0.25	-0.04	0.23
Days to 50% flowering	-0.18	-0.19	-0.09	-0.11	-0.14	-0.02	-0.10	-0.26	-0.04	-0.19	-0.11	-0.12	-0.11	-0.28	1.00	-0.21	-0.02	-0.11	-0.09	-0.11
Days to seed maturity	-0.16	-0.15	-0.08	-0.06	-0.12	-0.01	-0.09	-0.19	-0.03	-0.14	-0.07	-0.06	-0.02	-0.16	-0.20	1.00	-0.07	-0.04	-0.28	-0.17
Siliqua length (mm)	0.34*	0.38*	0.16	0.28	0.18	-0.16	-0.10	0.18	0.35*	0.37*	0.12	0.18	0.09	0.25	-0.01	-0.06	1.00	0.26	0.34*	0.39*
Siliqua width (mm)	0.38*	0.42*	0.19	0.19	0.13	-0.01	-0.12	0.23	0.34*	0.38*	0.17	0.11	0.12	0.22	-0.09	-0.03	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	-0.04	0.36*	0.26	0.42*	0.37*	0.49*	-0.05	-0.03	-0.08	-0.26	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	-0.09	0.35*	0.32	0.30	0.33*	0.30*	0.18	0.22	-0.10	-0.16	0.38*	0.35*	0.36*	1.00
Yield per hectare (q)	0.85**	0.87**	0.77**	0.44*	0.88**	-0.06	-0.03	0.79**	0.87**	0.89**	0.95**	0.84**	0.57*	0.75**	-0.09	-0.06	0.31*	0.37*	0.46*	0.49*

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

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

Table 4: Path matrix showing direct (diagonal) and indirect (off diagonal) effects of different traits on yield per hectare in Knol-hol (*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	**LW:** Leaf width (cm)	**DH:** Days to 50% harvest	**GSW:** Gross stem weight (g)	**PS:** Plant spread (cm)	**DSM:** Days to seed maturity			
NSS: No. of seeds per siliqua	**IL:** Internode length (cm)	**PL:** Petiole length (cm)	**SL**: Stem length (cm)	**NSW:** Net stem weight (g)	**NLP:** Number of leaves per plant			
SqL: Siliqua length (mm)	**SYP:** Seed yield per plant (g)	**LL:** Leaf length (cm)	**DSS:** Days to 50% stem swelling	**SB:** Stem breadth (cm)	**PH:** Plant height (cm)	**DF:** Days to 50% flowering	**SqW**: Siliqua width (mm)	**YH**: Yield per hectare (q)

Table 5: 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% stemswelling	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 (561.86g), 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)
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), WhiteVienna (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 (16.35g), 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)
24.	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)
25.	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)
26.	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)
27.	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)
28.	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)
29.	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)
30.	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)
31.	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)

	(%)	
32.	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)
33.	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), PusaVirat (8.42)
34.	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), PusaVirat (5.42)

Conclusion

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

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