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Genetic variability, heritability, correlation and path coefficient analysis in kale (*Brassica oleracea* var. *acephala* L.)

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Abstract

The goal of the current study was to estimate variability among different kale genotypes for various yield and yield attributing traits, seventeen growth and yield characteristics were examined in total across 29 different Kale germplasm samples. Significant differences between the 29 genotypes Kale were identified by analysis of variance. For all characters, high heritability and genetic advance as a percentage of the mean were found. Studies on correlation coefficients revealed that for the majority of the characters, genotypic correlation coefficient was higher than phenotypic correlation coefficients, indicating a strong inherent association between various characters. Leaf yield showed highly significant and positive correlation with leaf length, leaf width, plant spread, leaf area, number of leaves, duration of picking and total number of pickings. This suggests that these traits were the primary determinants of leaf yield. The highest positive direct effect, according to path coefficient analysis, was of leaf length, plant spread, leaf area, petiole thickness, number of leaves, duration of picking and total number of picking. These characters might benefit from improvement.

Keywords: Kale, genetic variability, leaf yield

Introduction

Kale (*Brassica oleracea* var. *acephala* L.) belonging to the family Brassicaceae, is one of the earliest form of the cabbage family with its origin in Mediterranean region. It is comparable to wild cabbage and was possibly one of the first brassicas to be farmed. Kale leaves are typically marketed in fresh, canned, and frozen varieties and are typically eaten raw or cooked in salads (Fahey, 2003) [7]. The crops of Brassicaceae family have drawn particular interest because they contain phytonutrients that are rich in sulphur. In addition to reducing gastrointestinal tract cancer, kale has favourable cardiovascular protective properties (Raiola *et al.*, 2018) [17]. Antioxidant and free radical scavenging properties are attributed to glucosinolates, flavonoids (glycosylated flavanols), and phenolic substances (Cartea *et al.*, 2010 [5]; Lin and Harnly, 2009) [15]. Kale is rich in vitamins and minerals, vitamin C, pro- vitamin (β - carotene & lutein) and minerals and antioxidants (Cao *et al.*, 1996) [4].

All plant breeding programmes aim to increase yield, but because yield has a low heritability and direct selection is ineffective, it is preferable to select for increased yield indirectly. Methods like correlation benefit plant breeders during selection by improving their understanding of yield components (Robinson, 1951) [18]. Path coefficient analysis makes it possible to examine both the direct effects of different characters on yield as well as their indirect effects through other component features. The yield components are thus determined using the calculations of the direct and indirect effects.

Material and Methods

The variability studies in kale were carried out at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar. Twenty-nine genotypes were evaluated along with three standard checks (G.M. Dari), (Khanyari) and (Kawdari) during 2021-2022, for various quantitative traits in RCBD. The seeds of all the genotypes were first sown in nursery and then transplanted to the main field at a spacing of 30×10 cm between rows and plants respectively. Recommended package of practices was followed to raise a healthy crop. On a few selected plants, the following observations were recorded *viz.*, leaf length (cm), leaf

width (cm), petiole length (cm), plant height (cm), plant spread (cm), leaf area (cm²) petiole thickness (mm), number of leaves plant⁻¹, total number of picking, days to first leaf picking, duration of picking (days), leaf yield plant⁻¹ (g), leaf yield hectare⁻¹ (q), days to first flowering, duration of flowering (days), seed yield plant⁻¹ (g) and 1000 seed weight (mg).

Results and Discussions

The variance analysis indicated very substantial variations among all 29 genotypes of Kale for all 17 characters suggesting there is a lot of genetic variation in the population. (Table 1.) For each trait, the phenotypic coefficient of variation (PCV) exceeded the corresponding genotypic coefficient of variation (GCV). All seventeen characters showed high heritability. The highest heritability was showed by leaf yield hectare⁻¹ (99.8%) while lowest was showed by 1000 seed weight (77.4%). Leaf yield per hectare with a high heritability may be due to the stronger additive genetic contribution to the inheritance of these traits. Similar outcomes were also found by Brito *et al.* (2020) [3], Rout *et al.* (2019) [19] and Dhatt and Garg (2008) [6] in various crops (Table 2).

The heritable variation can be found with the help of heritability estimates and genetic gain; the present investigation heritability could be estimated in only broad sense. Although high heritability denotes high proportion of genetic effects in the determination of these characters and can be adopted for improving leaf yield per ha. Leaf yield per ha character showing high heritability, could be owing to greater contribution of additive genetic components in the inheritance of these attributes. Similar results also found earlier by Wudneh A.Y. (2020), [22], Rout *et al.*, (2019) [19], Akabari *et al.*, (2015) [1], Khan *et al.*, (2012) [9] in various crops.

The high percent of genotypic co-efficient of variation (>20%) was observed for seed yield per plant (157.47), leaf yield per hectare (49.16), petiole thickness (46.41), number of leaves (39.27) and total number of picking (36.19). Leaf width, plant spread, plant height, leaf length, duration of flowering and leaf area, observed moderate genotypic coefficient of variation (10%-20%). Low coefficient of variation was seen for the remaining characters. (Table 2,).

As per Table 5, there is a vast difference for the 17 characters

among the 29 genotypes of Kale. SK-Kale-52 found best performer for Leaf length (25.36), Leaf width (17.08), number of leaves (72.68) and Leaf yield per hectare (1710.93). SK-Kale-54 showed best results for petiole length (13.14) and SK-Kale-KL-8 for Plant height (62.38).SK-Kale -KL-32 showed best results for days to first picking.SK-Kale-KL-22 were found best for duration of flowering (86.88),SK-Kale-21 were found best for days to Ist flowering (107.38) and Seed yield per plant (29.89). Several workers have also reported a wide range of variations for different quantitative characters. like Brito *et al.*, (2020) [3], Singh *et al.*, (2017) [20], Azevedo *et al.*, (2012) [2], Knezovic *et al.*, (2012) [11] and Khan *et al.*, (2012) [9] in kale.

Leaf yield per ha expressed highly significant and positive correlation with leaf length, leaf width, plant spread, leaf area, number of leaves, duration of picking and total number of pickings. Positive and non-significant correlation with plant height and days to first leaf picking. While it showed non-significant and negative correlation with petiole length and petiole thickness. Therefore, it can be concluded that strains with high yields will be identified through selection based on any one of these traits, either individually or in combination. Khan *et al.* (2009) [10] Meena *et al.* (2009) [16] and Habib *et al.* (2013) [8] were found similar trends in their investigation.

When compared to the comparable phenotypic direct and indirect effects, the genotypic direct and indirect effects were slightly greater in terms of magnitude. The positive and high direct effect on leaf yield per ha was observed for leaf length, plant spread, leaf area, petiole thickness, number of leaves, duration of picking and total number of picking was observed very high, which indicates that these characters play the significant role to increase the leaf yield per ha. High but negative direct effect showed by leaf width, petiole length, plant height and days to first leaf picking on leaf yield per ha at genotypic level, therefore these characters may be selected for kale crop improvement (Table 4). At the phenotypic level, also the estimates of direct and indirect were generally similar to those shown at genotypic level with less variation in magnitude. Both at phenotypic and genotypic level the magnitude of residual effects was found to be low (Table 4). These results are in agreement with Khan *et al.* (2009) [10], Lakshmi *et al.* (2022) [13], Kutty *et al.* (2017) [12] and Soni *et al.* (2013) [21].

Table 1: Analysis of variance for genotypes with respect to MSS for various characters in Kale (*Brassica oleracea* var. *acephala* L.)

S. No.	Source of variation	d.f	Mean sum of Squares									
			Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Plant height (cm)	Plant spread (cm)	Leaf area (cm ²)	Petiole thickness (cm)	No. of leaves	Days to ist leaf picking	Duration of picking (days)
1.	Replicate	2	12.18	10.06	10.06	20.64	29.51	18.01	0.008	27.12	38.52	29.56
2.	Genotypes	28	28.003**	18.90**	15.88**	196.73**	231.14**	1195.90**	0.23**	624.63**	100.97**	87.54**
3.	Error	56	0.83	0.94	0.89	2.009	1.19	1.80	0.001	3.20	1.86	2.41

**Significant at 1% probability level

* Significant at 5% probability level

S. No.	Source of variation	d.f	Mean sum of Squares						
			Average leaf yield per plant (g)	Leaf yield hectare ⁻¹ (q)	Total no of picking	Days to ist flowering	Duration of flowering (days)	Seed yield per plant (g)	1000 seed weight (mg)
1.	Replicate	2	14.94	10.96	13.36	17.26	10.58	13.99	33.54
2.	Genotypes	28	30022.21**	332479.27**	44.99**	126.17**	302.56**	740.59**	19.55**
3.	Error	56	2.29	1.21	0.83	0.78	1.03	0.92	1.73

**Significant at 1% probability level

* Significant at 5% probability level

Table 2: Estimates of mean, range, phenotypic variance, genotypic variance, phenotypic and genotypic coefficients of variation, heritability (bs) and genetic advance (as% of mean) for different growth characters in Kale (*Brassica oleracea* var *acephala* L.)

S.no.	Growth Parameters	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability h ² (broad sense)	Genetic gain (Genetic advance as% mean)
1.	Leaf length (cm)	17.38	13.59-25.36	9.89	9.05	18.09	17.31	91.6	34.14
2.	Leaf Width (cm)	11.93	8.32-17.08	6.93	5.98	22.07	20.50	86.3	39.25
3.	Petiole length (cm)	8.36	3.86-13.14	5.88	4.99	29.01	26.73	84.9	50.73
4.	Plant height (cm)	46.40	29.78-62.38	66.91	64.90	17.62	17.36	97.0	35.22
5.	Plant spread (cm)	45.43	32.92-64.15	77.84	76.65	19.42	19.27	98.5	39.39
6.	Leaf area (cm)	146.51	99.66-185.78	399.83	398.03	13.64	13.61	99.5	27.98
7.	Petiole thickness (cm)	0.60	0.24-1.42	0.08	0.07	46.76	46.41	98.5	94.90
8.	Number of leaves	36.64	14.45-72.68	210.34	207.14	39.57	39.27	98.5	80.28
9.	Days to ist picking	22.02	12.20-30.75	34.90	33.03	26.82	26.09	94.6	52.29
10.	Duration of picking (days)	111.59	102.89-120.85	30.79	28.37	4.97	4.77	92.1	9.43
11.	Average yield plant ⁻¹ (g)	203.55	91.13-513.28	10008.94	10006.64	49.16	49.14	99.8	101.22
12.	Leaf yield hn ⁻¹ (q)	679.13	303.75-1710.93	110827.20	110826.00	49.01	49.16	99.8	100.97
13.	Total no of picking	10.60	3.65-16.45	15.55	14.72	37.20	36.19	94.6	72.51
14.	Days to Ist flowering	119.22	105.80-131.20	42.58	41.79	5.47	5.42	98.2	11.06
15.	Duration of flowering (days)	67.12	44.81-86.88	101.54	100.59	15.01	14.93	99.0	30.61
16.	Seed yield plant ⁻¹ (g)	9.97	2.01-72.07	247.48	246.55	157.76	157.47	99.6	323.78
17.	1000 seed weight	12.40	5.50-16.83	7.69	5.94	22.32	19.64	77.4	35.61

Table 3: Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among different growth traits in Kale (*Brassica oleracea* var. *acephala* L.)

	Leaf length	Leaf width	Petiole length	Plant height	Plant spread	Leaf area	Petiole thickness	Number of leaves	Days to ist leaf picking	Duration of picking	Total number of picking	Leaf yield per hectare
LL	1	0.940**	-0.043NS	0.106NS	0.783**	0.915**	-0.075NS	0.948**	0.056NS	0.749**	0.722**	0.943**
LW	0.948**	1	-0.087NS	0.251*	0.745**	0.916**	-0.062NS	0.938**	0.143NS	0.735**	0.741**	0.888**
PL	-0.052NS	-0.052NS	1	-0.030NS	0.131NS	-0.123NS	0.537**	-0.068NS	-0.213*	-0.005NS	-0.036NS	-0.067NS
PH	0.105NS	0.542*	-0.032NS	1	0.173NS	0.237*	0.337**	0.192NS	0.186NS	0.229*	0.386**	0.085NS
PS	0.691**	0.842**	0.231NS	0.182NS	1	0.803**	0.079NS	0.853**	0.062NS	0.816**	0.654**	0.819**
LA	0.923**	0.938**	-0.121NS	0.256*	0.802**	1	-0.116NS	0.967**	0.188NS	0.794**	0.745**	0.928**
PT	-0.071NS	-0.052NS	0.427**	0.325**	0.068NS	-0.117NS	1	-0.087NS	-0.129NS	-0.037NS	0.021NS	-0.080NS
NoL	0.914**	0.936**	-0.057NS	0.173NS	0.833**	0.963**	-0.097NS	1	0.178NS	0.798**	0.723**	0.965**
DFLP	0.055NS	0.151 NS	-0.213*	0.296NS	0.061NS	0.198NS	-0.139NS	0.167NS	1	0.067NS	-0.009NS	0.051NS
DoP	0.658**	0.923**	-0.005NS	0.217*	0.814**	0.783**	-0.038NS	0.743**	0.046NS	1	0.787**	0.780**
TNoP	0.792**	0.762**	-0.036NS	0.386**	0.654**	0.745**	0.021NS	0.723**	-0.009NS	0.787**	1	0.702**
LYH	0.921**	0.898**	-0.067NS	0.085NS	0.819**	0.928**	-0.080NS	0.965**	0.051NS	0.776**	0.702**	1

Table 4: Path Matrix showing direct (diagonal) and indirect (off diagonal) effects of different yield parameters on yield in Kale

S. no	Parameters	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Plant height (cm)	Plant spread (cm)	Leaf area (cm ²)	Petiole thickness (cm)	No of leaves	Days to first picking	Duration of picking (days)	Total no of picking
1.	Leaf length (cm)	0.238	-0.228	0.003	-0.009	0.004	0.007	-0.004	0.914	-0.005	0.005	0.017
2.	Leaf width (cm)	0.223	-0.243	0.005	-0.020	0.0042	0.007	-0.003	0.905	-0.013	0.005	0.018
3.	Petiole length (cm)	-0.010	0.021	-0.064	0.002	0.00075	-0.00095	0.030	-0.066	0.019	-0.00003	-0.0009
4.	Plant height (cm)	0.0252	-0.060	-0.0019	-0.082	0.001	0.0018	0.019	0.185	-0.017	0.0015	0.0095
5.	Plant spread (cm)	0.186	-0.180	-0.0083	-0.0142	0.006	0.00617	0.0044	0.803	-0.0058	0.0054	0.0161
6.	Leaf area (cm ²)	0.2174	-0.2225	0.0078	-0.0193	0.0046	0.008	-0.0065	0.933	-0.017	0.0053	0.018
7.	Petiole thickness (cm)	-0.017	0.015	-0.034	-0.027	0.00046	-0.00089	0.0565	-0.0839	0.0120	-0.00025	0.00053
8.	No of leaves	0.2252	-0.2279	0.00436	-0.0156	0.0047	0.0074	-0.0049	0.965	-0.0166	0.0053	0.0178
9.	Days to first leaf picking	0.0134	-0.0347	0.0135	-0.0152	0.00036	0.0014	-0.0072	0.1720	-0.0932	0.0004	0.0002
10.	Duration of picking (days)	0.1779	-0.1786	0.0003	-0.0187	0.0046	0.0061	-0.0020	0.7700	-0.0062	0.007	0.0194
11.	Total no of picking	0.1716	-0.18	0.0023	-0.0315	0.0037	0.0057	0.0012	0.6980	0.0008	0.0052	0.025
	Genotypic coorelation with yield ha ⁻¹	0.921**	0.898**	-0.067NS	0.085NS	0.819**	0.928**	-0.080NS	0.965**	0.051NS	0.776**	0.702**

Residual effect: 0.03793

Table 5: Mean performance of Kale (*Brassica oleracea* var. *acephala*) genotypes for various growth and yield attributing characters

S. no	genotypes	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Plant height (cm)	Plant spread (cm)	Leaf area (cm ²)	Petiole thickness (cm)	No of leaves	Days to ist leaf picking	Duration of picking	Average yield plant ¹	Leaf yield hectare ¹
1.	SK-Kale-1	16.42	11.52	7.24	50.92	46.91	137.88	0.46	30.42	26.39	108.61	162.26	540.30
2.	SK-Kale-2	14.84	9.76	8.16	53.68	44.67	132.64	1.42	25.29	28.67	106.35	127.65	425.50
3.	SK-Kale-3	14.38	8.68	9.36	34.68	36.12	126.24	0.42	20.47	24.53	109.31	115.65	385.52
4.	SK-Kale-8	16.34	11.86	11.94	48.02	47.96	144.52	0.86	32.49	21.62	111.59	179.35	597.89
5.	SK-Kale-23	19.72	13.82	7.88	52.48	58.37	168.16	0.42	50.49	30.75	118.47	266.43	888.15
6.	SK-Kale-25	18.06	13.22	10.44	49.52	45.55	157.94	0.66	46.28	27.52	107.76	247.76	825.86
7.	SK-Kale-27	15.62	9.88	7.22	51.36	45.22	134.52	0.46	28.29	21.35	112.86	139.25	464.18
8.	SK-Kale-52	25.36	17.08	9.78	42.98	64.15	185.78	0.72	72.68	18.23	120.85	513.28	1710.93
9.	SK-Kale-Sel 52(1)	20.40	14.38	8.48	52.36	54.60	168.64	0.54	51.69	20.15	116.87	276.45	921.50
10.	SK-Kale-Sel 52(2)	15.36	9.60	11.42	50.98	44.23	134.84	0.75	27.87	22.43	106.84	132.79	442.65
11.	SK-Kale-54	16.92	12.76	13.14	49.58	47.31	145.68	0.98	37.89	23.65	110.39	190.65	635.54
12.	SK-Kale-55	24.14	16.76	6.86	37.96	60.53	180.76	0.42	66.45	26.45	120.72	415.72	1385.73
13.	SK-Kale-KL-7	22.08	15.38	10.54	46.84	50.99	170.72	0.94	52.27	16.23	117.92	297.58	991.90
14.	SK-Kale-KL-8	16.64	12.08	9.26	62.38	48.93	142.96	1.28	34.27	14.82	118.23	190.60	635.33
15.	SK-Kale-KL-12	16.84	12.58	6.68	53.24	46.16	151.56	0.34	38.49	23.86	110.63	191.52	638.49
16.	SK-Kale-KL-15	22.84	15.78	6.08	40.82	57.79	180.36	0.36	54.39	14.69	117.41	376.48	1254.93
17.	SK-Kale-KL-18	16.28	11.88	7.34	50.96	38.91	143.36	0.40	31.46	15.48	111.42	173.47	578.23

S. no	genotypes	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Plant height (cm)	Plant spread (cm)	Leaf area (cm ²)	Petiole thickness (cm)	No of leaves	Days to ist leaf picking	Duration of picking	Average yield plant ¹	Leaf yield hectare ¹
18.	SK-Kale-KL-21	15.84	10.83	10.74	38.32	48.87	138.66	0.48	30.82	17.42	115.28	116.18	553.61
19.	SK-Kale-KL-22	17.34	13.18	4.42	56.76	39.16	151.89	0.64	39.26	28.48	112.69	218.45	728.16
20.	SK-Kale-KL-25	13.92	8.32	10.36	39.46	34.56	99.66	0.68	14.45	13.59	104.52	91.13	303.75
21.	SK-Kale-KL-31	18.72	13.32	7.28	48.74	52.51	160.96	0.38	49.26	25.74	119.46	256.60	855.33
22.	SK-Kale-KL-32	14.86	9.08	9.34	38.16	38.07	131.68	0.62	23.47	12.20	105.68	113.73	397.11
23.	SK-Kale Bla	15.91	10.64	8.66	31.28	32.92	137.38	0.52	29.26	30.13	107.83	148.38	494.73
24.	SK-Kale-New	15.61	10.41	7.96	45.76	39.16	135.58	0.49	28.63	25.62	105.75	140.35	467.83
25.	SK-Kale-Sel-5	18.46	13.28	7.76	45.18	53.96	156.39	0.58	45.86	26.32	114.46	235.20	784.20
26.	SK-Kale-Kawdari-2	14.78	9.74	4.16	37.42	35.71	131.48	0.28	24.83	29.56	108.52	122.83	409.43
27.	G.M. Dari ©	14.62	8.52	10.34	46.78	33.02	123.92	0.82	18.96	15.75	103.59	99.25	330.83
28.	Kawdari ©	18.12	13.26	3.86	59.28	34.23	155.99	0.24	40.27	24.84	109.42	220.72	735.73
29.	Khanyari ©	13.59	8.38	5.83	29.78	36.98	118.68	0.39	16.47	12.29	102.89	93.46	311.53
	Mean	17.38	11.93	8.36	46.40	45.43	146.51	0.60	36.64	22.02	111.59	203.55	679.13
	CD 5%	1.49	1.59	1.54	2.31	1.78	2.19	0.05	2.92	2.23	2.54	2.47	1.79

S. no.	Genotypes	Total no of picking	Days to Ist flowering	Duration of flowering (days)	Seed yield plant ¹ (g)	1000 seed weight (mg)
1.	SK-Kale-1	8.96	120.63	70.63	2.12	11.59
2.	SK-Kale-2	7.63	116.42	60.42	2.01	12.54
3.	SK-Kale-3	9.48	112.65	53.62	3.30	14.82
4.	SK-Kale-8	9.82	105.80	44.81	4.26	13.64
5.	SK-Kale-23	14.73	122.79	69.79	5.79	12.35
6.	SK-Kale-25	7.45	109.58	62.43	8.65	13.51
7.	SK-Kale-27	12.57	119.40	54.42	9.05	14.56
8.	SK-Kale-52	16.45	121.83	58.83	2.88	13.82
9.	SK-Kale-Sel 52(1)	14.47	123.25	59.25	2.82	15.63
10.	SK-Kale-Sel 52(2)	10.28	128.31	68.31	3.71	10.56
11.	SK-Kale-54	9.52	124.42	69.49	7.47	16.77
12.	SK-Kale-55	15.84	117.20	63.20	2.64	12.46
13.	SK-Kale-KL-7	16.32	115.76	80.76	4.39	10.50
14.	SK-Kale-KL-8	15.62	116.83	63.83	7.32	12.68
15.	SK-Kale-KL-12	10.36	110.92	60.92	3.70	14.29
16.	SK-Kale-KL-15	14.75	125.52	75.52	21.94	11.74
17.	SK-Kale-KL-18	15.26	113.61	67.69	5.39	10.90
18.	SK-Kale-KL-21	11.56	107.38	77.38	29.89	10.50
19.	SK-Kale-KL-22	12.39	126.88	86.88	3.13	6.75
20.	SK-Kale-KL-25	5.39	120.24	67.24	72.07	9.84

S. no.	Genotypes	Total no of picking	Days to Ist flowering	Duration of flowering (days)	Seed yield plant ¹ (g)	1000 seed weight (mg)
21.	SK-Kale-KL-31	8.35	118.72	58.72	5.02	13.29
22.	SK-Kale-KL-32	6.52	117.67	65.65	4.47	11.99
23.	SK-Kale Bla	8.63	124.61	76.71	51.11	12.26
24.	SK-Kale-New	6.79	127.51	69.51	4.01	15.22
25.	SK-Kale-Sel-5	11.92	131.20	86.20	6.05	16.83
26.	SK-Kale-Kawdari-2	4.95	111.72	52.72	3.27	11.96
27.	G.M. Dari ©	4.32	125.29	77.28	6.24	5.50
28.	Kawdari ©	13.45	119.35	67.35	3.52	10.26
29.	Khanyari ©	3.65	121.93	76.93	2.95	12.98
	Mean	10.60	119.22	67.12	9.97	12.40
	CD 5%	1.49	1.45	1.66	1.57	2.15

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