International Journal of Plant & Soil Science

Volume 36, Issue 8, Page 413-421, 2024; Article no.IJPSS.110950
ISSN: 2320-7035

Character Association and Path Coefficient Analysis of Morphological Quantitative Traits in Ethiopian Kale (*Brassica Carinata* A.)

Yenenesh Asfaw [a*], Techale Birhan [b] and Getachew Tabor [a]

[a] *Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia.*
[b] *Jimma university college of Agriculture and Veterinary Medicine, Jimma, Ethiopia.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i84870

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/110950

Original Research Article

Received: 30/10/2023
Accepted: 01/01/2024
Published: 31/07/2024

ABSTRACT

The present study was conducted at Debre zeit Agricultural Research Center to determine the extent of association among yield and its related traits of 49 accessions and to assess the direct and indirect effects of yield component traits on leaf yield of Ethiopian Kale. The accession were studied for fourteen quantitative traits using 7 × 7 simple lattice design in 2018 cropping season. The accessions were collected from diverse agro ecological area. The research findings indicated that leaf yield per plant exhibited positive and significant phenotypic and genotypic association with all factors except for leaf width and leaf petiole thickness. The result revealed that days to first leaf

**Corresponding author: E-mail: yenutasfaw@gmail.com;*

***Cite as:** Asfaw, Yenenesh, Techale Birhan, and Getachew Tabor. 2024. "Character Association and Path Coefficient Analysis of Morphological Quantitative Traits in Ethiopian Kale (Brassica Carinata A.)". International Journal of Plant & Soil Science 36 (8):413-21. https://doi.org/10.9734/ijpss/2024/v36i84870.*

picking, leaf fresh weight per plant, leaf dry matter content and number of leaves per plant were the most important yield components as they exerted positive direct effect on leaf yield as well as positive genotypic and phenotypic association with each other explaining the existence of significant association. This highlighting their importance in improving Ethiopian kale yield.

Keywords: Leaf yield; correlation; path co-efficient; Brassica; genotypic and phenotypic level association.

1. INTRODUCTION

"Ethiopian Kale (*Brassica carinata*) is one of six economically important species that belong to the family Brassicaceae. It arose as a natural cross between *B. nigra* and *B. oleracea* in north-eastern Africa, in all probability in the Ethiopian plateau, where wild forms of *B. nigra* co-exist with cultivated forms of *B. oleracea* since ancient times" [1]. "It is an annual vegetable growing to 1.6 m at fast rate with hermaphrodite flowers which are pollinated by bees. The plant is self-pollinated with about 30 – 50 % outcrossing" [2]. "When grown with adequate moisture it produces seeds in 5-6 months" [3,4]. "The vegetables chosen for cultivation are typically strong and sturdy, with thick stems and large leaves. They are also known to either flower very late or not at all" [5].

"It is found exclusively in Ethiopia but, recently it has been cultivated in different parts (corners) of the world. It produces the greatest number of leaves and in plant height clearly exceeded both parental species and others" [6]. "In its area of adoption, it possesses acceptable yield levels as well as resistance to diverse biotic and abiotic stresses" [7]. "Under semi-arid conditions, it has several desirable agronomic characteristics compared to other Brassica crops: the root system is more highly developed and forceful, the plant is resistant to drought and wide range of diseases and pests" [8,9,10].

"Peoples in Ethiopia produce the crop for different uses, they eat the leaf at its earlier stages either by thinning or topping and also harvest the seed for oil extraction" [11]. "Furthermore, in native Ethiopia the ground seeds are used to lubricate Enjera and bread baking traditional clay-pan. Moreover, the powder of the seed is used to prepare beverages and cure certain illness like stomach upsets. In some areas, the crop is used as a green manure. It also benefits in traditional farming system for crop rotation. It serves as the break crop for the cultivation of cereals with comparative ecological amplitude" [12].

"Ethiopian Kale is locally grown in most parts of the country situated above 1700 meters above sea level but, cultivation is mostly exercised by small farmers in more fertile and well drained fields, usually around homesteads" [13]. "Records of *B. carinata are* scarce here in Ethiopia or elsewhere, probably because it is rarely grown outside of Africa" [4]. "Which make the crop among the underutilized crop species" [14].

"Yield is a complex character which is highly influenced by the environment and is the result of interrelationships of its various yield components" [15]. "Thus, information on genotypic and phenotypic correlation coefficients among various plant traits help to ascertain the degree to which these are associated with economic productivity. Correlation studies are useful in disclosing the magnitude and direction of the relationships between different characters and yield as well as characters among themselves" [16]. "The association between two characters that can be directly observed is phenotypic correlation. Genetic correlation is the association of the two characters. Path coefficient analysis calculates the correlations between yield and its contributing components, taking account of the cross correlation, either positive or negative. It is useful to partition the total correlation into direct and indirect effects on different components" [17]. The present study, therefore, in order to assess interrelationship and path coefficient analysis of yield and yield related traits within collected accessions for further breeding works.

2. MATERIALS AND METHODS

For these study, Forty-nine Ethiopian kale accessions, of which a local control were obtained and evaluated in a simple lattice design at Debre zeit Agricultural Research Center (Table 1). The experiment was conducted during 2018 under rain feed condition. Mean annual maximum temperatures is 26.5° C and minimum being 11.6 and receives 821 mm annual rainfall. The experiment were conducted on soil at the

Table 1. Passport data of the test Ethiopian kale Accessions

No	Accessions	Status	No	Accessions	Status
1	EK-002	Pipeline	26	EK-046	Pipeline
2	EK-003	Pipeline	27	EK-047	Pipeline
3	EK-004	Pipeline	28	EK-048	Pipeline
4	EK-005	Pipeline	29	EK-051	Pipeline
5	EK-006	Pipeline	30	EK-052	Pipeline
6	EK-007	Pipeline	31	EK-053	Pipeline
7	EK-012	Pipeline	32	EK-054	Pipeline
8	EK-018	Pipeline	33	EK-056	Pipeline
9	EK-020	Pipeline	34	EK-057	Pipeline
10	EK-021	Pipeline	35	EK-058	Pipeline
11	EK-022	Pipeline	36	EK-059	Pipeline
12	EK-024	Pipeline	37	EK-060	Pipeline
13	EK-027	Pipeline	38	EK-061	Pipeline
14	EK-028	Pipeline	39	EK-062	Pipeline
15	EK-033	Pipeline	40	EK-063	Pipeline
16	EK-034	Pipeline	41	EK-064	Pipeline
17	EK-035	Pipeline	42	EK-066	Pipeline
18	EK-036	Pipeline	43	EK-067	Pipeline
19	EK-038	Pipeline	44	EK-069	Pipeline
20	EK-039	Pipeline	45	EK-070	Pipeline
21	EK-040	Pipeline	46	EK-074	Pipeline
22	EK-041	Pipeline	47	EK-075	Pipeline
23	EK-042	Pipeline	48	EK-076	Pipeline
24	EK-043	Pipeline	49	EK-081	Local control
25	EK-044	Pipeline			

center which is classified as both black (Vertisol) soil. Each accessions was transplanted in a plot size of 2 m × 2 m length in each block of replication. All the cultural practices were practiced according to necessity. Observation for data on plant height, plant canopy width, leaf fresh weight, leaf dry matter content, fresh biomass, number of leaves per plant, leaf length, leaf width, leaf petiole length, leaf petiole thickness, leaf area, days to first leaf picking, days to second leaf picking, and leaf yield per hectare were recorded on a plot and plant basis. Phenotypic and genotypic correlation coefficients was subjected by the data obtained among different characters by the method [18] and Path coefficient analysis were calculated by the method suggested by [19].

2.1 Phenotypic and genotypic correlation coefficient analysis

Phenotypic and genotypic correlations among traits were assessed using the suggested formula by [18].

$$r_p = \frac{\mathrm{Pcov}xy}{\sqrt{V_{\mathrm{p}X} . V_{\mathrm{p}Y}}}$$

$$\mathrm{rg} = \frac{Gcovxy}{\sqrt{V_{gX} . V_{gY}}}$$

Where, $r_{p\,=}$ phenotypic correlation coefficient
r_g = Genotypic correlation coefficient
$Pcov_{xy}$ =Phenotypic covariance among character x and y,
$Gcov_{xy}$ = Genotypic covariance among character x and y,
V_px = Phenotypic variance of variable x
V_py = Phenotypic variance of variable y.
V_gx= Genotypic variance of variable x
V_gy = Genotypic variance of variable y.

Level of genotypic correlation coefficient was tested for significance with the following formula discribed by [20].

$$\mathrm{t} = \frac{rg_{xy}}{SEg_{xy}}$$

2.2 Path Coefficient Analysis

Path coefficient analysis was conducted as recommended by [19] using the phenotypic and genotypic correlation coefficient governed the direct and indirect effect of yield components based on the following relationship:

$$r_{ij} = p_{ij} + \sum r_{ik} * pk_j$$

Where;

r_{ij} = Mutual association between the independent character (i) and dependent character, (j) as measured by the genotypic correlation coefficients.
P_{ij} = Components of direct effects of the independent character (i) as measured by the Path coefficients and
$\sum r_{ik} pk_j$ = summation of components of indirect effect of a given independent character i on a given dependent character (j) via all other independent characters (k). whereas, the contribution of the remaining unknown character measured residual effect estimated as follows:

$$\text{The residual effect (h)} = \sqrt{1 - R^2}$$

Where;

$$R^2 = \sum r_{ij} p_{ij}$$

Where p_{ij} = the direct effect of yield by i^{th} characters, and rij is the correlation of yield with the i^{th} characters.

3. RESULTS AND DISCUSSION

3.1 Genotypic and Phenotypic Correlation

The estimates of genotypic and phenotypic correlation coefficients between leaf yield and yield attributes are given in Table 2. Leaf yield per hectare showed positive and significant association with all factors except for leaf width and leaf petiole thickness at both levels of genotypic and phenotypic. In addition there was a highly significant and positive correlation at those traits at genotypic level. Which suggests that using those characteristics as selection criteria might be a useful strategy for raising leaf yield. "The observed significant positive correlation could be either due to the strong coupling linkage between the genes or was the result of pleiotropic genes that controlled these characters in the same direction" [21]. However highly significant and positive correlation at phenotypic level were obtained from leaf fresh weight and leaf dry matter content with the leaf yield per hectare. For the majority of traits, the genotypic correlation coefficient had a larger magnitude than the phenotypic correlation coefficient. The presence of a strong genetic association between those characters is indicated by the more significant genotypic association between different pairs of characters than the phenotypic correlation; however, the significant interaction of environment reduces the phenotypic value [16, 22].

In addition leaf petiole thickness and leaf width show high significance correlation at genotypic level. These results indicated that any increase in leaf petiole thickness and leaf width could result in decrease in leaf yield. Which suggests caution is needed in selection programs that use these traits as selection criteria. Ethiopian kale's widest leaf decreases leaf yield because fewer leaves are produced per plant, as indicated by the negative phenotypic correlation coefficient of leaf width with leaf yield. Again Selection for high leaf width performance results in lower leaf yield performance. The present study is in consistent with the results on "Amaranthus foliage yield per plant which recorded positive and significant correlation with leaf weight per plant and number of leaves per plant, however they also reported with leaf width" [23, 24, 25].

Both at genotypic and phenotypic levels leaf petiole length, days to first leaf picking, number of leaves per plant, leaf dry matter content, leaf fresh weight, and days to second leaf picking showed positive and significant associations among them (Table 2). Days to second leaf picking had phenotypic and genotypic correlations with biomass that were both significant and positive, respectively. At the phenotypic level, days to second leaf picking, leaf length, leaf dry matter content, days to first leaf picking, and leaf petiole length showed highly significant and positive associations with leaf fresh weight. Days to first leaf picking had highly significant positive phenotypic correlation with days to second leaf picking. The number of leaves per plant had a highly significant and positive correlation with leaf fresh weight, leaf dry matter content, and leaf petiole length. A high number of leaves per plant is indicative of a high fresh leaf weight, a high dry leaf matter content, and a long petiole length in the plant.

All other component variables showed non-significant phenotypic correlation with plant height, with the exception of biomass, which demonstrates a highly significant and positive association. These results showed that biomass eventually increases with plant height but that no other traits do. There were negative and significant phenotypic association of number of leaf per plant with petiole thickness and width, leaf area and leaf length. Leaf fresh weight also showed negative associations with leaf width and leaf petiole thickness.

Table 2. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for studied quantitative characters

Characters	PHT	CW	NLPP	LW	DMC	LL	LW	PL	PTH	LA	FLP	SLP	BIM	LYD
PHT		-0.13	0.17	-0.12	-0.04	-0.21	0.13	-0.25	0.02	0.05	-0.08	0.01	0.26	-0.20
CW	0.08		-0.03	0.38**	0.21	0.58**	-0.23	0.48**	0.07	0.01	-0.06	-0.18	-0.10	0.09
NLPP	0.17	0.00		0.43**	0.62**	-0.54*	-0.78**	0.41**	-0.82**	-0.70**	0.09	-0.05	-0.38**	0.39**
LW	-0.07	0.35**	0.44**		0.85**	0.29**	-0.37**	0.55**	-0.23	-0.05	0.60**	0.42**	-0.03	0.72**
DMC	-0.01	0.22*	0.61**	0.85**		0.00	-0.50**	0.53**	-0.46**	-0.32**	0.49**	0.31**	-0.16	0.72**
LL	0.00	0.62**	-0.43*	0.28**	0.03		0.43**	0.17	0.65**	0.64**	0.20	0.16	0.27*	0.11
LW	0.19	-0.08	-0.72**	-0.33*	-0.45*	0.49**		-0.50**	0.88**	0.85**	0.02	0.22	0.66**	-0.29**
PL	-0.12	0.47**	0.38**	0.51**	0.49**	0.19*	-0.43*		-0.32**	-0.33**	0.10	-0.04	-0.26	0.27*
PTH	0.07	0.11	-0.77*	-0.21*	-0.42**	0.61**	0.87**	-0.25**		0.82**	-0.02	0.17	0.60**	-0.37**
LA	0.14	0.15	-0.62*	-0.01	-0.25**	0.63**	0.81**	-0.22*	0.76**		0.21	0.35**	0.57**	-0.07
FLP	-0.03	-0.04	0.09	0.54**	0.43**	0.18	0.06	0.05	0.00	0.22*		0.81**	0.22	0.65**
SLP	0.03	-0.13	-0.04	0.27**	0.20*	0.11	0.17	-0.03	0.16	0.20*	0.56**		0.30**	0.40**
BIM	0.25**	-0.07	-0.37*	-0.02	-0.15	0.23*	0.64**	-0.23*	0.57**	0.56**	0.21*	0.21*		-0.19
LYD	-0.17	0.07	0.38**	0.70**	0.70**	0.08	-0.27**	0.25**	-0.34**	-0.07	0.56**	0.24**	-0.19	

Where, PHT=plant height, CW=plant canopy width, NLPP= number of leaf per plant, LW=leaf fresh weight per plant, DMC= leaf dry matter content, LL= leaf length, LW=leaf width, PL=leaf petiole length, PTH=leaf petiole thickness, LA=leaf area, FLP= days to first leaf picking, SLP=days to second leaf picking, BIM=biomass, LYD=leaf yield per hectare

Table 3. Phenotypic path coefficient analysis indicating the direct (diagonal) and indirect (off diagonal) effect of the characters

Character	NLPP	LW	DMC	PL	FLP	SLP	r^p
NLPP	**0.03**	0.12	0.24	-0.05	0.03	0.003	0.38^{**}
LW	0.01	**0.28**	0.33	-0.06	0.16	-0.02	0.7^{**}
DMC	0.02	0.23	**0.39**	-0.06	0.13	-0.02	0.7^{**}
PL	0.01	0.14	0.19	**-0.12**	0.02	0.003	0.25^{**}
FLP	0.003	0.15	0.17	-0.01	**0.29**	-0.05	0.56^{**}
SLP	-0.001	0.08	0.08	0.004	0.16	**-0.08**	0.24^{**}
RE = 0.64							

*Where, NLPP= number of leaf per plant, LW=leaf fresh weight per plant, DMC= leaf dry matter content, PL=leaf petiole length, FLP= days to first leaf picking, SLP=days to second leaf picking, r^p= phenotypic correlation with leaf yield, RE=*Residual effect

Table 4. Genotypic Path coefficient analysis indicating the direct (diagonal) and indirect (off diagonal) effect of the characters

Character	NLPP	LW	DMC	FLP	SLP	r^g
NLPP	**0.04**	0.07	0.22	0.05	0.01	0.39^{**}
LW	0.02	**0.15**	0.30	0.35	-0.10	0.72^{**}
DMC	0.02	0.13	**0.35**	0.28	-0.08	0.72^{**}
FLP	0.003	0.09	0.17	**0.58**	-0.20	0.65^{**}
SLP	-0.002	0.06	0.11	0.47	**-0.25**	0.4^{**}
RE= 0.58						

Where, NLPP= number of leaf per plant, LW=leaf fresh weight per plant, DMC= Leaf dry matter content, FLP= days to first leaf picking, SLP=days to second leaf picking, r^g = genotypic correlation with leaf yield, RE=Residual effect

At genotypic level, leaf fresh weight, leaf dry matter content and leaf petiole length exhibited highly significant and positive correlation with number of leaves per plant. Leaf fresh weight showed highly significant and positive genotypic association with leaf petiole length, days to first leaf picking, days to second leaf picking, leaf length and leaf dry matter content. The genotypic association between days to first leaf picking and days to second leaf picking was highly significant and positive.

Number of leaves per plant demonstrate highly significant and negative genotypic association with biomass, leaf petiole thickness, , leaf area, leaf length and leaf width. Leaf width exhibited highly significant negative association with leaf fresh weight.

3.2 Path Coefficient Analysis

Results of phenotypic path coefficient analysis for yield and yield component showed that days to first leaf picking, leaf dry matter content, leaf fresh weight, and number of leaves per plant all had positive direct effects (Table 3). These result indicated that the improvement brought about by selection of one character would automatically lead to the improvement of its correlated characters and should be given top priority while selecting Ethiopian kale with the goal of increasing leaf yield, as it has a significant impact on leaf yield.

The highest positive indirect effects on leaf yield was recorded form days to first leaf harvest, , leaf fresh weight, days to second leaf harvest and leaf dry matter content. There was a positive indirect relationship between leaf yield and the number of leaves per plant. Thus, leaf dry matter content, leaf fresh weight and days to first leaf harvest are important traits to be considered when choosing the target trait. This implies that these traits should be taken into consideration during the selection process. The latest results indicate that enhancing the leaf yield of Ethiopian kale could be accomplished by directly selecting for component traits that positively contribute to leaf yield.

Days to first leaf picking had positive and significant genotypic coefficient and it showed the highest positive direct effect with leaf yield. The direct effect of leaf dry matter content followed by leaf fresh weight and number of leaves per plant was positive with significant correlation and so exerted positive direct effect (Table 4). Leaf dry matter content and leaf fresh weight revealed positive direct effect and had positive genetic correlation explaining the existence of real relation between the characters and yield indicating that, indirect selection of yield via this characteristic is effective. Even though the impact of the number of leaves per plant on yield is small but positive, it can be offset by the stronger positive indirect effects of leaf dry matter content, leaf fresh weight, days to first leaf picking, and days to second leaf picking. Therefore, focusing solely on the number of leaves on each plant as the primary direct yield component may not be beneficial for an improvement program. Thus, according to the current genotypic path coefficient analysis, traits which have positive direct effect on yield should be taken in to account when selecting a genotype would be more fruitful in the development of improved Ethiopian kale varieties. This finding is also in agreement with [26] in lettuce.

Leaf petiole length and days to second leaf picking exerted negative phenotypic direct effect on leaf yield ha-1. Under such circumstances, direct selection form these traits may be ineffective for leaf yield improvement, 'which is in agreement with the finding of [27] on Indian Spinach'.

Genotypic path coefficient analysis indicated that days to second leaf picking showed negative direct effects. This indicates that, genotypes that regenerate fast and composite for the harvested leaves will have more frequent harvests leading to high cumulative fresh leaf yield. Moreover, the short duration of the leaves on the plants between harvests helps avoid the chance of disease and insect pests landing and feeding on them increasing the marketable yield. Days to second leaf picking has also expressed negative indirect effect on days to first leaf picking, leaf dry matter content and leaf weight.

4. CONCLUSION

Leaf yield had a significant and positive phenotypic and genotypic correlation with all factors except for leaf width and leaf petiole thickness. By selecting traits that reveal a positive and significant correlation with leaf yield, there is a possibility of increasing the leaf yield of Ethiopian kale. Number of leaves per plant, leaf fresh weight, leaf dry matter content and days to first leaf picking were the most important yield components as they exerted positive direct effect on leaf yield as well as positive genetic association with each other explaining the existence of real correlation. This suggests that, simultaneous improvement in these traits might be possible. Generally, the traits showed that, there is a strong correlation between most of the studied desirable characters that can afford basic information for further breeding activities for crop improvement.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors' thank Ethiopian Institute of Agricultural Research for the financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Tsunoda S. Biosynthesis of seed oil and breeding for improved oil quality of rapeseed. in: brassica crops and wild allies: Biology and Breeding. 1980;253-283.
2. Rakow G. Species origin and economic importance of brassica. Biotechnology in Agriculture and Forestry. 2004; 54:3-7.
3. Mnzava N, Schippers R. *Brassica carinata* A Braun Record from Protabase. 2004.
4. Schippers R. African indigenous vegetables, an overview of the cultivated species. revised version in cd – ROM. Natural Resources International Limited; 2002.
5. Edwards S, Tadesse M, Demissew S, Hedberg I. Flora of Ethiopia and Eriterea. macnoliaceae to flacourtiaceae. 2000;121-125.
6. Courtny J, Massimo P. Morphological response to simulated wind in the genus Brassicaseae: allopolyploids and their parental species. Amer. J. Bot. 2005;92: 810-818.
7. Getinet A, Rakow G, Downey R. Agronomic performance and seed quality of Ethiopian mustard in saskatchewan. Can. Journal Plant Science. 1996; 76: 387-92.
8. Fereres E, Fernandez-Martinez J, Minguez I, Dominquez J. Productivity of *Brassica juncea* and *Brassica carinata* in relation to rapeseed proc. 6 int. Rapeseed Conf. 1983;293-298.
9. Malik R. Prospects for *Brassica carinata* as an oilseed crop in India. Exp. Agriculture. 1990; 26: 125-129.
10. Getinet A, Rakow G, Raney J, Downey R. The Inheritance of erucic acid content in Ethiopian mustard. Can Journal Plant Science. 1997; 77: 33-41.
11. Hiruy B, Riley K, Nigatu T, Getinet A. The Responses of three oilseeds *brassica* species to different planting dates and rate in highlands of Ethiopia. Ethiopian Journal Agriculture. Science, 1983:5:22-33.
12. Zelleke A, Mariam S. Role of research for horticultural development in Ethiopia. International Symposium on Horticultural Economics in Developing Countries. Alemaya, Ethiopia. 1991;189-196.
13. Tekelewold A, Alemayehu N. Agro-ecology, distribution and improved production technologies of the highland oil crops in Ethiopia. In: Abera D, Beyene S, editors. Research achievements and technology transfer attempts: Vignettes from Shewa; 1996.
14. Chen B, Haseen W, Simonsen V. Comparative and genetic studies of Isozymes in re-synthesized and cultivated *Brassica napus* L, *B. campestris,* L. and *B. algoblabra.* Bailey Threor. Appl. Genet. 1989:76.
15. Grafius J. Does over dominance exist for yield in corn. Agronomy Journal 1960; 52:361.
16. Falconer D, Mackay F. Introduction to Quantitative Genetics. 4th ed. Longman Group Limited: Malaysia; 1996.
17. Tollenaar M, Ahmaedzedah F, Lee E. Physiological basis of heterosis for grain yield in maize. Crop Science. 2004;44: 2086-2094.
18. Miller P, Williams J, Robinson H, Comstock R. Estimates of genotypic and environmental variances in upland cotton and their implications in selection. Agronomy Journal. 1957;50(3): 126-131.
19. Dewey D, Lu K. A Correlation and path coefficient analysis of components of

crested wheat grass seed production. Agronomy Journal. 1959; 51: 518.
20. Robertson G. The Sampling Variance of the Genetic Correlation Coefficients. Biometrics. 1959; 15: 494-496.
21. Kearsey M, Pooni H. The Genetic analysis of quantitative traits. Chapman and Hall, London, Weinhein, New York; 1996.
22. Singh R, Chaudhary B. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi. 1977.
23. Hasan M, Akther C, Raihan M. Genetic Variability, Correlation and Path Analysis in Stem Amaranth Genotypes. The Agriculturists. 2013; 11(1):1-7.
24. Abe S, Willem S, Patrick O. Genetic diversity of amaranthus species in South Africa, South African. Journal of Plant and Soil. 2015;32(1):39-46.
25. Tejaswini N, Reddy K, Saidaiah P, Ramesh T. Correlation and Path Coefficient Analysis in Vegetable Amaranth Genotypes. International Journal Current Microbiology Application Science. 2017;6(6):2977-2996.
26. Dolma T, Cupta A. Character association and path coefficient analysis in lettuce genotypes under kashmir conditions. Shalimar. 2011; 191-121.
27. Varalakshmi B. Genetic variability in Indian Spinach. Journal of Horticultural Science, 2016;5(1):21-24.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/110950