Original Research Article

Character Association and Path Coefficient Analysis studies in Ethiopian Kale (*Brassica Carinata* A.) Accessions

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ABSTRACT

Aims: The present study was to determineassociation of traits among leafy vegetable yield and yield related traits and to determine the direct and indirect effects of the traits.
Study design: The experiment were laid out in 7 × 7 simple lattice design.
Place and Duration of Study: Ethiopian kale accessions were evaluated at Debre zeit in 2017/18 main cropping season.
Methodology:A total of forty nine Ethiopian kale accessions, including one local check, were used for the study. The accessions were collected from diverse agro ecological area by Debre zeit Agricultural Research Center. Data were collected on fourteen traits on a plot basis, and from randomly taken five plants from the two central rows of each plots.
Results: The study results showed that Leaf yield had positive and significant correlation with number of leaves per plant, leaf fresh weight per plant, leaf dry matter content, days to first leaf picking and days to second leaf picking both at genotypic and phenotypic levels indicating that those traits as a selection criteria could be an effective way to improve yield. Path coefficient analysis revealed positive and direct effect of days to first leaf picking, leaf fresh weight per plant, leaf dry matter content and number of leaves per plant on yield,
Conclusion: The study,indicating that those traits should be considered important in Ethiopian kale yield improvement.

Key words: Correlation, leaf yield, Brassica, path coefficient, 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]. Those selected for their vegetables are often quite robust with thick stems and have large leaves and known to flower very late or none at all [5].

It is found exclusively in Ethiopia but, recently it has been cultivated in different parts (corners) of the world. Itproduces the greatest number of leaves and in 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 aggressive, 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 m.a.s.l. 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. MATERIAL AND METHODS

Forty nine Ethiopian kale accessions including one local check were grown in a simple lattice design at Debre zeit Agricultural Research Center (DZARC). The accessions were collected from Southern Nations,
Nationalities and Peoples' Region by Debre zeitAgricultural Research Center (Table 1.). The experiment was conducted throughout the main cropping season of 2017/2018 under rain fed conditions. Debre Zeit Agricultural Research Centre is located at 08^0 44'N latitude and $38^0$58'E longitude at an altitude of 1860 masl. The area has minimum and maximum daily temperature of 19.03 and 26.91^0C respectively and it receives average annual rainfall of 851mm. The soil type of the center is classified as black soil (Vertisol) and light soil (Alfisol).The materials were transplanted in a 7x7 simple lattice design and seven accessions were assigned into each incomplete block, using 2 m long x 2 m wide plot.

Spacing between rows and plants were 50 cm and 30 cm, respectively. All recommended management practices were followed during the crop season. 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, and leaf area were collected from five randomly taken plants of the two central rows of each plot whereas days to first leaf picking, days to second leaf picking and leaf yield per hectare were collected on plot basis. Phenotypic and genotypic correlations were estimated using the method described by [18]and Path coefficient analysis were computed using the formula suggested by [19].

Table 1. List of experimental materials used for the study

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

2.1 Correlation and Path Coefficient Analysis

2.1.1 Phenotypic and Genotypic Correlation Coefficient Analysis

Phenotypic and genotypic correlations were estimated using the method described [18].

$$rp_{xy} = \frac{\text{Covpxy}}{\sqrt{V_{PX}.V_{PY}}}$$

Where: rp_{xy}= phenotypic correlation coefficient between character x and y,
$Covp_{xy}$ = Phenotypic covariance between character x and y,
Vpx = Phenotypic variance for character x and
Vpy = Phenotypic variance for character y.

$$rg_{xy} = \frac{Covg_{xy}}{\sqrt{V_{gx}.V_{gy}}}$$

Where: rg_{xy} = Genotypic correlation coefficient between character x and y,
$Covg_{xy}$ = Genotypic covariance between character x and y,
V_{gx}= Genotypic variance for character x and
V_{gy} = Genotypic variance for character y.

Genotypic correlation coefficient was tested with the following formula suggested by [20].

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

2.1.2 Phenotypic and genotypic path coefficient analysis

Path coefficient analysis was computed using the formula suggested [19].

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

Where:
R_{ij} = Mutual association between the independent character (i) and dependent character, Leaf yield (j) as measured by the 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).

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

Where:

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

3. RESULTS AND DISCUSSION

3.1 Genotypic and Phenotypic Correlation of Grain Yield with Other Traits

A positive and significant phenotypic association was found between leaf yield per hectare and number of leaves per plant, leaf fresh weight, leaf dry matter content, leaf petiole length, days to first leaf picking and second leaf picking. Leaf fresh weight and leaf dry matter content displayed highly significant and positive correlation with leaf yield ha^{-1} (0.70) (Table 2.). It appears that phenotypic selection of phenotypically high values of these characters result in increasing yield potential. Similar results were reported by [21],on Amaranthus (*Amaranthus tricolor* L.) foliage yield per plant which recorded positive and significant correlation with leaf weight. According to [22],yield per plant had moderate and positive correlation with leaf width of Amaranthus.

Negative and highly significant phenotypic association were obtained for leaf petiole thickness (-0.34) and leaf width (-0.27) with leaf yield ha^{-1}. These results indicated that any increase in these traits could result in decrease in leaf yield ha^{-1}. Although thick leaf petiole is important to overcome mechanical damage, too much thickness leads to high accumulation of photosynthesis in the petiole and finally resulting in low leaf yield. Therefore, selection for thin to medium petiole thickness (7cm-12cm) in Ethiopian kale accessions could be effective in increasing leaf yield. Negative correlation coefficient of leaf width with leaf yield indicates that the widest leaf in Ethiopian kale reduces the leaf yield, due to decrease in number of leaves per plant (-0.72**).

Highly significant and positive genotypic association was found between leaf yield per hectare and leaf fresh weight per plant (0.72), leaf dry matter content (0.72), days to first leaf picking (0.65), days to second leaf picking (0.40), number of leaves per plant (0.39) and leaf petiole length (0.27^{*}), which indicates that considering those traits as selection criteria could be an effective way to increase yield. The positive genotypic correlation of yield with other component traits indicated that increase in one of the trait will result in increasing of the correlated trait. This result of such genotypic correlation could possibly from pleiotropic effect or linkage of gene governing inheritance of these traits. Therefore, priority should be given to these traits together to improve leaf yield. The present study is consistent with the results of [23], who reported on Amaranthus foliage yield per plant which recorded positive and significant correlation with leaf weight per plant and leaf width. Similarly, leaf yield per plant exhibited significant positive correlation with number of leaves per plant and leaf weight. Moreover, an experiment conducted on Swiss chard genotypes showed positive correlation of leaf weight, petiole length and petiole thickness with leaf yield [24].

Highly significant and negative genotypic correlation of yield was found with leaf petiole thickness (-0.37) and leaf width (-0.29). It indicated that an increase in one of the traits will result in a decrease in the negatively correlated trait. Therefore, determining the exact contribution of various components towards yield before selecting the genetic material could successfully help improvement of the crop through breeding.

Table 2. Estimation of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between yields, and yield component traits in 49 Ethiopian kale accessions evaluated in 2017/18 main cropping season at DZARC

Var	PH	PCW	NLP	LWT	DM	LL	LW	LPL	LPTH	LA	DFLP	DSLP	BM	LY
PH		-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
PCW	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
NLP	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**
LWT	-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**
DM	-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**
LPL	-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*
LPTH	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
DFLP	-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**
DSLP	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**
BM	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
LY	-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, * = significant at P<0.05;** = significant at P<0.01;PH=plant height, PCW=plant canopy width, NLP= number of leaf per plant, LWT=leaf fresh weight per plant, DM= leaf dry matter content, LL= leaf length, LW=leaf width, LPL=leaf petiole length, LPTH=leaf petiole thickness, LA=leaf area, DFLP= days to first leaf picking, DSLP=days to second leaf picking, BM=biomass, LY=leaf yield per hectare*

3.2 Estimate of correlation coefficients among other characters

At the phenotypic level, the number of leaves per plant had a highly significant and positive correlation with leaf dry matter content (0.61), leaf fresh weight (0.44), and leaf petiole length (0.38), indicating that as leaf number increases, that the increase in number of leaves per plant will also increase leaf fresh weight, leaf dry matter content and leaf petiole length proportionately. Except for biomass (0.25), which shows highly significant and positive association, all other component traits had non-significant phenotypic correlation with plant height (Table 2.). These findings demonstrated that as plant height increases, biomass ultimately increases but no other traits. Negative and significant phenotypic correlation with petiole thickness (-0.77) and width (-0.72), leaf area (-0.62*) and leaf length (-0.43*). At genotypic level, number of leaves per plant exhibited highly significant and positive correlation with leaf dry matter content (0.62), leaf fresh weight (0.44) and leaf petiole length (0.41), and highly significant and negative association with leaf petiole thickness (-0.82), leaf width (-0.78), leaf area (-0.70), leaf length (-0.54) and biomass (-0.38).

Leaf dry matter content (0.85), days to first leaf picking (0.54), leaf length (0.28), days to second leaf picking (0.27), and leaf petiole length (0.51) showed highly significant and positive phenotypic associations with leaf fresh weight, while leaf width (-0.33**) and leaf petiole thickness (-0.21*) showed negative associations. Leaf fresh weight showed highly significant and positive genotypic association with leaf dry matter content (0.85), days to first leaf picking (0.60), leaf petiole length (0.55), days to second leaf picking (0.42) and leaf length (0.29) but highly significant negative association with leaf width (-0.37**). Days to first leaf picking had highly significant positive phenotypic correlation with days to second leaf picking (0.56). The genotypic association between days to first leaf picking and days to second leaf picking (0.81) was highly significant and positive. Days to second leaf harvesting had phenotypic and genotypic correlations with biomass that were both significant and positive (0.21** and (0.3*), respectively.

3.3 Path Coefficient Analysis at Phenotypic Level

Results of phenotypic path coefficient analysis for yield and yield component showed that leaf dry matter content (0.39), days to first leaf plucking (0.29), leaf fresh weight (0.28), and number of leaves per plant (0.03) all had positive direct effects (Table 3.). Positive direct effects of these traits 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 prior attention in practicing selection aimed at the improvement of leaf yield of Ethiopian kale, because of major influence on leaf yield. In agreement with the present study [23], reported that leaf weight per plant had the highest positive direct effect on yield.

Leaf petiole length (-0.12) and days to second leaf picking (-0.08) exerted negative direct effect on leaf yield ha^{-1}. In such situations, direct selection for accessions that tallest leaf petiole length and took long time to second leaf harvest might be ineffective for leaf yield improvement in Ethiopian kale accessions. Similar finding was reported in Indian Spinach petiole length that exhibited negative direct effect on total plant vegetable yield [25].

Table 3. Phenotypic direct and indirect effects of six component characters on yield in Ethiopian kale accessions evaluated in 2017/18 main cropping season at DZARC

Character	Phenotypic direct effect	NLP	LWT	DM	LPL	DFLP	DSLP	r^{ph}

NLP	0.03		0.12	0.24	-0.05	0.03	0.003	0.38**
LWT	0.28	0.01		0.33	-0.06	0.16	-0.02	0.7**
DM	0.39	0.02	0.23		-0.06	0.13	-0.02	0.7**
LPL	-0.12	0.01	0.14	0.19		0.02	0.003	0.25**
DFLP	0.29	0.003	0.15	0.17	-0.01		-0.05	0.56**
DSLP	-0.08	-0.001	0.08	0.08	0.004	0.16		0.24**
Residual effect = 0.64								

Where, NLP= number of leaf per plant, LWT=leaf fresh weight per plant, DM= leaf dry matter content, LPL=leaf petiole length, DFLP= days to first leaf picking, DSLP=days to second leaf picking, r^{ph}= phenotypic correlation with grain yield

For leaf dry matter content (0.24), leaf fresh weight (0.12), days to first leaf harvest (0.03), and days to second leaf harvest (0.003), the indirect effect of the number of leaves per plant on leaf yield was in favor. While being negative (-0.05) for leaf petiole length. Therefore, along with number of leaves per plant, indirect selection for high leaf fresh weight, high leaf dry matter content, long time to first and second leaf harvest and also short leaf petiole length might be considered simultaneously, during in the process of selection for leaf yield improvement program in Ethiopian kale accessions. The current findings suggested that improvement of leaf yield of Ethiopian kale through selection could be achieved through direct selection for positively contributed component traits to leaf yield.

3.4 Path Coefficient Analysis at Genotypic Level

Days to first leaf picking had positive and significant genotypic coefficient (0.65**) and it showed the highest positive direct effect (0.58) 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. The least but positive and direct effect of number of leaves per plant (0.04) on yield could be compensated via the high and positive indirect effect of leaf dry matter content (0.22), leaf fresh weight (0.07), days to first leaf picking (0.05) and days to second leaf picking (0.01). Thus, considering number of leaves per plant alone as the most important direct yield component might be ineffective in improvement program. Therefore, from the present genotypic path coefficient analysis, traits like, number of leaves per plant, leaf fresh weight, leaf dry matter content and days to first leaf picking had positive direct effect on yield, which indicate that considering this trait during selection of genotype would be more rewarding to develop potential varieties of Ethiopian kale. Similarly, [26],reported maximum positive direct effect of number of leaf per plant (0.72) followed by average leaf weight (0.67) and days to first picking (0.44) on leaf yield per plant of lettuce.

Table 4. Genotypic direct and indirect effects of five component characters on yield in Ethiopian kale accessions evaluated in 2017/18 main cropping season at DZARC

Character	Genotypic direct effect	NLP	LWT	DM	DFLP	DSLP	r^g
NLP	0.04		0.07	0.22	0.05	0.01	0.39**
LWT	0.15	0.02		0.30	0.35	-0.10	0.72**

DM	0.35	0.02	0.13		0.28	-0.08	0.72**
DFLP	0.58	0.003	0.09	0.17		-0.20	0.65**
DSLP	-0.25	-0.002	0.06	0.11	0.47		0.4**
Residual effect = 0.58							

Where, NLP= number of leaf per plant, LWT=leaf fresh weight per plant, DM= Leaf dry matter content, DFLP= days to first leaf picking, DSLP=days to second leaf picking, r^g = genotypic correlation with leaf yield

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 negative direct effect and also expressed negative indirect effect on leaf yield through leaf weight (-0.10), leaf dry matter content (-0.08) and days to first leaf picking (-0.20).

4. CONCLUSION

The present study revealed that days to first leaf picking, leaf fresh weight per plant, leaf dry matter content and number of leaves per plant on yield had the highest contribution in determining leaf yield. Traits that showed positive direct effect as well as positive and significant correlation coefficient with yield were known to affect yield to the favorable direction. Maximum positive effect of days to first leaf picking and leaf dry matter content on leaf yield coupled with relatively strong and positive value of genotypic correlation suggested that direct selection for this trait would be effective for selecting for high yielding Ethiopian Kale. Likewise, correlation and path coefficient studies also showed that days to second leaf picking and leaf petiole length are also of much use to plant breeders for selection and breeding of genotypes with increased yield potential.

REFERENCES

1. Tsunoda S., 1980. Biosynthesis of seed oil and Breeding for improved oil quality of Rapeseed. In: Brassica crops and wild allies: Biology and Breeding. Tokyo, 253 - 283 pp.

2. Rakow G., 2004. Species origin and economic importance of *Brassica. Biotechnology in Agriculture and Forestry*. 54: 3-7.

3. Mnzava N. and Schippers R., 2004. Brassica carinata A Braun [Internet] Record from Protabase.

4. Schippers, R., 2002. African Indigenous vegetables, an overview of the cultivated Species 2002. Revised version in CD – ROM. Natural Resources International Limited, Aylesford, UK.

5. Edwards, S., Tadesse, M., Demissew, S. and Hedberg*, I. (2000). Flora of Ethiopia and Eriterea. macnoliaceae to flacourtiaceae. (2). National Herbarium, Addis Ababa, Ethiopia and Uppsala, Sweden, 121 - 125pp.*

6. Courtny J. and Massimo P., 2005. Morphological response to simulated wind in the genus Brassicaseae: allopolyploids and their parental species. *Amer. J. Bot.* 92: 810– 818.

7. Getinet, A., Rakow G. and Downey R., 1996. Agronomic performance and seed quality of Ethiopian mustard in saskatchewan. Can. Journal Plant Science 76: 387-92.

8. Fereres E., Fernandez-Martinez J., Minguez I. and Dominquez J., 1983. Productivity of *Brassica juncea*and *B. carinata*in relation to rapeseed Proc. 6 Int. Rapeseed Conf., pp. 293–298, GCIRC, Paris.

9. Malik R., 1990. *Prospects for Brassica carinata as an oilseed crop in India*. Exp.Agriculture 26: 125-129.

10.Getinet A., Rakow G., Raney J. and Downey R., 1997. The inheritance of erucic acid content in Ethiopian mustard. Can Journal Plant Science 77:33–41.

11. Hiruy B., Riley K., Nigatu T. and Getinet A., 1983. The responses of three oilseeds *Brassica* species to different planting dates and rate in highlands of Ethiopia. *Ethiopian Journal Agriculture. Science,* 5: 22-33.

12. Zelleke, A. and Mariam S., 1991. Role of research for horticultural development in Ethiopia. International Symposium on Horticultural Economics in Developing Countries. Alemaya, Ethiopia, 189 - 196 pp.

13. Tekelewold, A. and Alemayehu, N., 1996. Agro-ecology, distribution and improved production technologies of the highland oil crops in Ethiopia. In: Research achievements and technology transfer attempts: Vignettes from shewa: Abera, D. and Beyene, S. (eds) Proc. of the first technology generation, transfer and gap analysis workshop. 25-27 Dec. 1995, Nazret, Ethiopia, 38 - 48pp.

14. Chen, B., Haseen, W. and Simonsen, V., 1989.Comparative and genetic studies of Isozymes in re-synthesized and cultivated *Brassica napus* L.,*B. campestris,* L. and *B. algoblabra*Bailey. *Threor. Appl. Genet*. 76: 00 - 00.

15. Grafius, J., 1960. Does over dominance exist for yield in corn. Agronomy Journal 52: 361

16. Falconer D. and Mackay F., 1996. Introduction to Quantitative Genetics. 4th (eds). Longman Group Limited, Malaysia, 464p

17. Tollenaar M., Ahmaedzedah F. and Lee E., 2004. Physiological basis of heterosis for grain yield in maize. Crop Science. 44:2086–2094.

18. Miller, P., Williams J., Robinson H., and Comstock R., 1957. Estimates of Genotypic and Environmental Variances in Upland Cotton and their Implications in Selection. *Agronomy Journal* 50(3): 126-131.

19. Dewey, D. and Lu K., 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal, 51:518.

20. Robertson, G., 1959. The Sampling Variance of the Genetic Correlation Coefficients. *Biometrics* 15: 494-496.

21. Hasan, M., Akther, C. and Raihan, M., 2013. Genetic Variability, Correlation and Path Analysis in Stem Amaranth (*Amaranthus tricolor* L.) Genotypes. *The Agriculturists*, 11(1):1-7.

22. Abe, S., Willem S. and Patrick O., 2015. Genetic diversity of Amaranthus species in South Africa, *South African Journal of Plant and Soil*, 32(1): 39-46.

23. Tejaswini, N., Reddy, K., Saidaiah, P. and Ramesh, T., 2017. Correlation and Path Coefficient Analysis in Vegetable Amaranth (*Amaranthus tricolor* L.) Genotypes. *International Journal Current Microbiolology. Application Science*, *6*(6): 2977-2996.

24.Esiyok, D., Bozokalfa, K. and Kaygisiz-Aşçioğul, T., 2011. Variability, Heritability and Association Analysis in Plant Traits of Swiss chard (Beta vulgaris). *Genetika*, 43(2): 239-252.

25. Varalakshmi, B., 2016. Genetic variability in Indian Spinach (Basellaalba L.). *Journal of Horticultural Science*, 5(1): 21-24.

26. Dolma, T. and Cupta, A., 2011. Character Association and Path Coefficient Analysis in Lettuce (Lactuca Sativa L.) Genotypes under Kashmir Conditions. Sher-E-Kashmir University of Agricultural Sciences Technology, Shalimar 191-121, Srinagar.