Genetic Variability, Heritability and Genetic Advance in Ethiopian Mustard (*Brassica carinata* A. Braun) for Leafy Vegetable Yield and Yield Related Traits

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Abstract: Ethiopia is center of origin for Ethiopian mustard (*Brsassica carinata*). The crop is one of the oldest oil crops and farmers in the highlands of the country grow as a leafy vegetable in their gardens. This study was conducted to assess the genetic variability, heritability and genetic advance components among Ethiopian mustard genotypes for leaf yield and yield related traits. A total of 36 Ethiopian mustard genotypes including five check varieties which developed for seed and oil yield were evaluated for 12 quantitative traits in 6 x 6 simple lattice design at Holeta in 2017/8. The results from analysis of variance revealed the presence of significant difference among genotypes for all quantitative traits. The PCV and GCV ranged from 9.01 to 54.57% and 6.61 to 47.99%, respectively. The lowest and highest values were calculated for ratio of leaf width to length and weight of harvested per plant for both GCV and PCV. The heritability and the GAM values ranged from 53.85 to 89.93% and from 10 and 90.11%, respectively. The lowest and highest values were calculated for ratio of leaf width to length and edible vegetable leaf yield for both heritability and GAM.

Keywords: Genetic Advance, Genotypic Variation, Heritability, Phenotypic Variation

1. Introduction

Ethiopian mustard (*Brassica carinata* A. Braun) is one of the species of the genus *Brassica* widely used as vegetable, condiment and production of vegetable oil. Several *Brassica* species are originated in the Mediterranean region. *Brassica carinata* evolved as a natural cross between *Brassica nigra* (BB) (n = 8) and *Brassica oleracea* (CC) (n = 9) and grown in the highlands of the Ethiopian plateau and adjoining portion of East Africa [24].

Ethiopian mustard, is one of the major traditional leafy vegetable in East Africa, particularly in Ethiopia, and is a well- established integral part of the local food system and diet [17]. It is cultivated as a multi-purpose crop in the Ethiopian highlands at altitudes between 1500 and 2600 meter above sea level. Its name in Amharic is *yabesha gomen*. The crop is still widely used for its young shoots and leaves and can be found in many home gardens and frequently grown at the edges of fields [10].

Proper management of crop variability/ diversity can produce permanent gain in the performance of plant and high heritability of the traits gives a better opportunity for breeders to select directly for the traits of interest [27]. In any crop improvement program, the first thing that the breeder looks into is the existence of genetic variability for the character of interest [18]. The efforts so far made are to select genotypes for seed and oil yield and not for leafy vegetable yield. As far as our knowledge, there is no Ethiopian mustard variety released for leafy vegetable yield in Ethiopia. In this regard, some African countries such as Tanzania (White Figiri, Purple Figiri, Lushoo, Mbeya Green), Zambia (Chibanga and NIRS-2), Zimbabwe (RRS- V) and USA (TAMU Tex Sel) developed varieties of Ethiopian mustard for leafy vegetable yield [10]. However, the country is center

of origin for the crop and immense diversity of the crop is expected that could be exploited to develop varieties of interest. The presence of variability among lines/ genotypes of Ethiopian mustard based on agro- morphology traits have been reported by many authors [11, 12, 26] and others.

Thus, the study on the genetic variability of Ethiopian mustard is important and rewarding in developing varieties to be used as leafy vegetable. Therefore; this research was initiated with objectives of assessing the genetic variability among Ethiopian mustard genotypes for leaf yield and yield and yield related traits.

2. Materials and Methods

2.1. Description of Experimental Site

The experiment was conducted at Holetta Agricultural Research Center during the main cropping season of 2017/2018 under rain fed condition. Holetta Agricultural research center is located at 9° 00'N, 38° 30'E at an altitude of 2400 m.a.s.l. It is characterized with mean annual rainfall of 1044mm, mean relative humidity of 60.6%, and mean maximum and minimum temperature of 22.1 and 6.2°C, respectively. The main rainy season is from June to September, which account for 70% of the rainfall while the remaining 30% is from February to April [4].

2.2. Experimental Materials

For this study, 36 genotypes of Ethiopian mustard collected from diverse agro ecological locations of Ethiopia were used. Among the tested genotype five check varieties were included which were released for seed production purpose but not for leaf purpose.

Table 1. *Description of Ethiopian mustard accessions used in the study.*

No	Accession code	Region	Collection Area Zone	Altitude (m.a.s.l)
1	Acc.21315	Oromiya	Mirab shewa	2410
2	Acc.21336	Oromiya	Mirab wellega	1480
3	Acc.21338	Oromiya	Mirab wellega	1680
4	Acc.21349	Oromiyaa	Illubabor	1750
5	Acc.21364	SNNP	Keficho shekicho	1780
6	Acc.21371	Oromiya	Jimma	2030
7	Acc.21374	Oromiya	Mirab shewa	1220
8	Acc.21377	SNNP	Gurage	2840
9	Acc.207915	Oromiya	Misrak wellega	2400
10	Acc.208355	SNNP	Gurage	2000
11	Acc.208404	Amhara	Misrak gojam	2650
12	Acc.208406	Amhara	Debub gondar	1850
13	Acc.208407	Amhara	Debub gondar	2650
14	Acc.208409	Amhara	Debub gondar	1850
15	Acc.208412	Amhara	Debub gondar	2530
16	Acc.208421	Amhara	Agew awi	1950
17	Acc.208593	Oromiya	Misrak hararge	2200
18	Acc.208598	Harari	Harar	1800
19	Acc.208601	Oromiya	Misrak hararge	1600
20	Acc.208602	Dire Dawa	Dire dawa	1700
21	Acc.208608	Oromiya	Misrak hararge	1840
22	Acc.208807	Oromiya	Arssi	1830
23	Acc.208969	Oromiya	Misrak wellega	2350
24	Acc.212665	Amhara	Misrak gojam	2540
25	Acc.212666	Amhara	Misrak gojam	2600
26	Acc.212668	Amhara	Bahir dar special	2210
27	Acc.212674	Amhara	Debub gondar	2650
28	Acc.212901	SNNP	Semen omo	1850
29	Acc.216845	Oromiya	Arssi	2340
30	Acc.219786	Tigray	Central	2130
31	Acc.237529	Tigray	Central	2110
32	S-67 Brown seed	Oromiya	HARC/Check	2400
33	S-67 Yellow seed	Oromiya	HARC/Check	2400
34	Holetta -1 Brown seed	Oromiya	HARC/Check	2400
35	Holetta-1 Yellow seed	Oromiya	HARC/Check	2400
36	Yellow Dodolla	Oromiya	HARC/Check	2400

HARC= Holeta Agriculture Research Center
SNNP = Southern Nation Nationalities and Peoples.

2.3. Experimental Design and Procedures

The experiment was conducted using 6×6 simple lattice design. Each genotype was planted I a plot size of 1.2 m by 3 m length in each block of replication. The spacing between plants and rows were 10 and 30 cm, respectively. The spacing between plots and blocks was 1 m while 2 m distance was maintained between replications.

The experimental field was calculated by a Tractor to a depth of 25-30 cm and after leveled rows was made by hand. Two seeds were placed in a row at the specified 10 cm plant spacing at the depth of 2 to 5 cm hole and latter thinning were conducted at two leaf stage and left one seedling. The seeds were sown at the beginning of main rainy season when the soil had enough moisture to support the emergence of the plants. The amount of P_2O_5 was applied at the rate of 69 kg ha-1 during the time of sowing while nitrogen was applied at the rate of 46 kg ha^{-1} in two equal split in which half of the recommended rate of N was applied at sowing and the other half at time of thinning (two leaf stage or one month after sown seeds). The source of N was urea while the source of P_2O_5 was DAP (diammonium phosphate) [12]. Weeding and other cultural practices were applied as per the recommendation for the crop.

2.4. Data Collection

Days to 50% maturity: it was registered as the number of days from the date of sowing to date on which 50% of plants reached for leafy vegetable harvesting in each plot.

Leaf petiole length (cm): it was measured from 10 randomly taken plants by measuring petiole length of the largest leaf where petiole intercepts the stem and leaf blade.

Petiole width (cm): it was registered from 10 randomly selected plants by measuring widest point of widest leaf, measured mid rib width where blade extends to the plant axis.

Leaf length (cm): samples taken from 10 random plants in each plot were measured for the largest leaf including petiole.

Leaf width (cm): the width of 10 random taken plants in each plot was measured for the widest portion/section of the largest leaf.

Ratio of leaf width/leaf length: calculated from previous measurements to get the ratio of leaf width to length.

Leaves/plant (No.): taken from 10 randomly taken plants number of intact leaves or leaf per plant.

Plant height (cm): the height of 10 random taken plants in each plot were measured from the ground level to the tip of uppermost part of the plants during harvesting using meter tape and the average of the plants height in each plot was considered for statistical analysis.

Plant diameter (cm): the diameter of the 10 random taken plants in each plot were measured to the broadest portion of the plants during harvesting using meter tape and the average was considered for statistical analysis.

Weight of harvested parts of plant (g/plant): the portion of plant parts harvested from the net plot weighed and divide by the number of harvested plants to register weight of harvested parts of plant.

Weight of edible parts of plant (g/plant): The plant parts harvested from net plot were sorted out as edible by removing leaves with odd colors, pierced by insect/diseases or mechanical injuries, the most end part of stems, in general parts of the plants not be marketed. The edible parts of plant was weighed and divided by the number of harvested plants to register weight of edible parts of plant.

Edible vegetable leaf yield (t ha^{-1}): it was calculated from the weight of edible parts of plants from net plot that was converted to yield per hectare.

2.5. Data Analysis

2.5.1. Analysis of Variance

The quantitative data were subjected to analysis variance (ANOVA). The ANOVA was computed with using Proc lattice and Proc GLM procedures of SAS statistical software (9.2) [16]. The traits that exhibited significant mean squares in general ANOVA were further subjected to genetic analyses. Phenotypic and genotypic variance and coefficient of variation, heritability, and genetic advance were computed using the using the excel Microsoft program.

2.5.2. Phenotypic and Genotypic Variability

The phenotypic and genotypic variability of each quantative trait were estimated as phenotypic and genotypic variances and coefficients of variation. The phenotypic and genotypic variations were computed using the formula suggested by Burton GW, Devane EH (1953) as follows [3].

$$\text{Genotypic variance } (\sigma 2g) = \frac{Mg - Me}{r}$$

Where, $\sigma^2 g$ = genotypic variance, Mg = mean square of genotype, Me = mean square of error and r = number of replications.

$$\text{Phenotypic Variance } (\sigma^2 p) = \sigma^2 g + \sigma^2 e$$

Where, $\sigma^2 g$ = genotypic variance, $\sigma^2 e$ = environmental variance and $\sigma^2 p$ = phenotypic variance.

$$PCV = \frac{\sqrt{p}}{x} \times 100$$

$$GCV = \frac{\sqrt{G}}{x} \times 100$$

Where; PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation and = population mean of the character being evaluated.

Heritability and genetic Advance

Broad sense of heritability values were estimated using the formula adopted by Falconer DS, Mackay TFC (1996) as follows [6].

$$H^2 = (\sigma^2 g / \sigma^2 p) \times 100$$

Where, H^2 = heritability in broad sense
$\sigma^2 p$ = phenotypic variance
$\sigma^2 g$ = genotypic variance

2.5.3. Expected Genetic Advance Under Selection (GA)

Genetic advance in absolute unit (GA) and percent of the

mean (GAM), assuming selection of superior 5%of the genotypes were estimated in accordance with the methods illustrated by [9] as:

$$GA = K * SDp * H^2$$

Where, GA = Genetic advance
SDp = phenotypic standard deviation on mean basis;
H^2 = Heritability in the broad sense.
k = the standardize selection differential at 5% selection intensity (K = 2.063).

2.5.4. Genetic Advance as Percent of Mean (GAM)

Genetic advance as percent of mean was estimated as follows

$$GAM = -X100$$

Where, GAM = Genetic advance as percent of mean
GA = Genetic advance

$\bar{x}$=Population mean of the character being evaluate

3. Results and Discussion

3.1. Analysis of Variance Agro-morphological Traits

The analysis of variance for 12 agro-morphological traits showed the presence of significant (P ≤0.01) differences among Ethiopian mustard genotypes. The coefficient of variation in percent was less than 20% for all traits except weight of leaf harvested per plant in gram indicated the degree of precision with which the treatments were compared was good (Table 2). Hence the ANOVA results of the present study for all agro morphological traits depicting the presence of significant variability among Ethiopian mustard genotypes collected from different parts of the country. Therefore the possibility of improving this crop is very high.

Table 2. Mean squares from analysis of variance for 12 agro-morphology traits of 36 Ethiopian mustard genotypes evaluated at Holeta during 2017/18 main season.

Trait	Rep (1)	Blocks/Rep (Adj)(10)	Genotype (Unadj.) (35)	Genotype (Adj.) (35)	Error		CV (%)
					RCBD (35)	Intra-block (25)	
Days to 50% maturity	48.35	15.95	112.71**	102.46**	10.03	7.67	4.3
Leaf petiole length (cm)	0.75	1.52	7.61**	6.52**	0.89	0.63	11.4
Leaf length (cm)	2.77	19.82	69.01**	49.21**	8.28	3.67	7.9
Leaf width (cm)	1.37	3.98	8.62**	5.89**	1.83	0.97	10.38
Petiole width (cm)	0.01711	0.014	0.071**	0.056**	0.01	0.0082	16.9
Ratio of leaf width/length (cm)	0.0031	0.0004	0.002**	0.002**	0.00053	0.00053	5.9
Leaf per plant (No)	4.17	1.47	2.92**	2.11**	0.86	0.61	8.5
Plant height (cm)	45.66	54.04	319.96**	234.05**	29.75	20.03	8.73
Plant Diameter	1.37	14.75	155.04**	139.07**	10.89	9.35	8.45
Weight of harvested per plant (g)	469.84	321.74	2205.09**	2098.9**	283.4	268.05	25.97
Weight of edible per plant (g)	209.59	79.21	1089.66**	1065.21**	73.95	71.84	16.52
Edible vegetable leaf yield (ton/ha-1)	0.69	7.75	105.72**	100.16**	6.01	5.31	15.4

** = significant at P≤0.01. Numbers in parenthesis represent degree of freedom for the respective source of variation. Rep = replication, CV (%) = coefficient of variation in percent.

3.2. Estimates of Variability Components

3.2.1. Phenotypic and Genotypic Coefficients of Variations

The estimated phenotypic (PCV) and genotypic (GCV) coefficient of variations for 12 quantitative traits of 36 Ethiopian mustard genotypes are presented in (Table 3). The phenotypic and genotypic coefficients of variation ranged from 9.01 to 54.57% and 6.61 to 47.99%, respectively. The lowest and highest values were calculated for ratio of leaf width to length (cm) and weight of harvested per plant (g) for both GCV and PCV. The estimated variability components observed in this study indicated that phenotypic was higher than genotypic but the difference between them was small (<5%) for most of traits. The low differences between phenotypic and genotypic coefficients of variation is an indication of the less influence of environmental factors in the expression of traits and the higher chance to improve the traits through selection breeding [20].

The ratio of leaf blade width to leaf length had also low (<10%) GCV and PCV (Table 3). This suggested that selection of genotypes for high mean values of these traits to

develop as varieties may not be appropriate breeding method.

The GCV and PCV values in the range between 10 and 20% and > 20% can be consider as moderate and high, respectively [21]. Accordingly, high values for both genetic parameters were computed for leaf petiole length, petiole width, plant height, plant diameter, weight of harvested parts of plant, weight of edible parts of plant, edible vegetable leaf yield. This suggested that most of the traits were less influenced by environmental factors and selection based on phenotypic expression of the genotypes could be applied as breeding method to improve the traits [1, 13, 15, 22]. In agreement with this study results, in a similar vegetable crop of Swiss chard [5] reported high PCV and GCV for leaf petiole length petiole width and [25] reported for petiole width, plant height, individual and total plant weight.

Moderate values for both PCV and GCV were calculated for day to maturity and leaf width. On the other hand moderate GCV coupled with highest PCV for leaf length and low GCV with medium PCV was recorded for leaf per plant. Moderate values for both PCV and GCV were calculated for day to maturity and leaf width. Similarly [23] reported moderate PCV

and GCV for leaf width in his study in vegetable amaranthus.

Table 3. Genetic variability components for 12 traits of 36 Ethiopian mustard genotypes evaluated at Holeta during the 2017/18 main season.

Trait	Range of mean	GCV (%)	PCV (%)	H² (%)	GA	GAM (%)	Diff. PCV & GCV
Days to 50% maturity	42 - 72	10.7	11.53	86.07	13.16	20.45	0.83
Leaf petiole length (cm)	3.08 - 10.4	24.55	27.05	82.38	3.21	45.9	2.5
Leaf length (cm)	12.8 - 35.35	19.78	21.31	86.12	9.12	37.8	1.53
Leaf width (cm)	5.4 - 13.98	16.58	19.58	71.72	2.74	28.92	3
Ratio of leaf width to length (cm)	0.35 - 0.48	6.61	9.01	53.85	0.04	10	2.4
Petiole width (cm)	0.22 - 0.97	28.08	33.64	69.7	0.26	48.3	5.56
Leaf per plant (No)	6.75 - 11.45	9.44	12.72	55.15	1.32	14.45	3.27
Plant height (cm)	20.44 - 71.05	20.2	22.01	84.23	19.56	38.18	1.81
Plant Diameter	17.65 - 55.9	22.26	23.81	87.4	15.51	42.87	1.55
Weight of harvested per plant (g)	22.93 - 194.69	47.99	54.57	77.35	54.82	86.95	6.58
Weight of edible per plant (g)	20.25 - 109.67	43.43	46.47	87.36	42.91	83.63	3.04
Edible vegetable leaf yield (ton/ha-1)	6.25 - 31.38	46.13	48.64	89.93	13.45	90.11	2.51

PCV = Phenotypic Coefficient of Variation, GCV = Genotypic Coefficient of Variations, H² = Heritability in broad sense, GA = Genetic Advance, GAM = Genetic Advance as Percent of Mean.

3.2.2. Estimates of Heritability and Genetic Advance

Estimates of heritability in broad sense (H²) and genetic advance as percent of mean (GAM) for 12 quantitative traits of Ethiopian mustard genotypes are presented in Table 3. The heritability values ranged from 53.85 to 89.93. The genetic advance as percent of mean estimated in the range between 10 and 90.11%. High values of heritability (>60%) were recorded for days to 50% maturity, leaf petiole length, leaf length, leaf width, petiole width, plant height, plant diameter, weight of harvested parts of plant, weight of edible parts of plant, edible vegetable leaf yield. Whereas moderate heritability (30-60%) was recorded for ratio of leaf length to width and leaf per plant. Similar results for different quantitative traits in vegetable amaranths were also reported by [23, 25].

Genetic advance as percent mean can be classified as low (<10%), moderate (10-20%) and high (>20%) (Johnson et al., 1955). In this study, the ratio of leaf width to leaf length and number of leaf per exhibits medium GAM (10-20%), whereas GAM was high (>20%) for all the remaining traits. Similarly, [8] reported high genetic advance as the percentage of the mean for leaf length, leaf width, leaf number, plant height and total marketable leaf yield in amaranths leaf genotypes. [25] Reported high values of genetic advance values for leaf number, leaf weight in gram, petiole length in Indian spinach genotypes.

The importance of considering both the genetic advance and heritability of traits was suggested than considering these genetic parameters separately to estimate how much progress can be through selection [9, 19]. In this study, high heritability was coupled with high GAM for all traits except for number of leaf per plant and ratio of leaf width in which medium heritability coupled with medium GAM. The results suggested selection of high performing genotypes is possible for the improvement of all the traits except few traits. The high heritability would be a close correspondence between the genotypic and phenotypic variation due to relatively small contribution of the environment to the phenotype

expression of the trait [20]. [14] Suggested that selection based on phenotypic performance of genotypes would be effective to improve the traits for which high genetic advance as percent of mean coupled with high heritability estimates. Similar results were also reported for leaf length, petiole width, total leaf weight, plant height in study of leafy Indian spinach [25] and for leaf length, leaf width and plant height in vegetable amaranths [2].

4. Conclusion

The research result revealed the presence of highly significant (P<0.01) differences among Ethiopian mustard genotypes for all quantitative traits. The results showed the higher chance of developing Ethiopian mustard varieties for high edible vegetable leaf yield through selection of all the estimated variability components (GCV, PCV, H² and GAM) were variability moderate to high for all traits except ratio of leaf width to length in which the values of these traits were categorized to low The differences between values of PCV and GCV were <5%, except for petiole width and weight of harvested part per plant. This showed that most of the traits were highly heritable and transmissible to next filial generation.

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