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Direct and Indirect Effects of Yield Related Traits on Seed Yield in Ethiopian Mustard (Brassica Carinata A. Braun) Genotypes at Holetta, Central Highland of Ethiopia

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Abstract

Understanding trait association is essential to increasing the effectiveness of crop plant improvement selection. In order to ascertain the direct and indirect effects of yield-related traits on Ethiopian mustard seed yield, as well as the extent of trait relationships, this study was carried out at the Holetta Agricultural Research Center's main station in 2020 and 2021. The study employed 23 advanced genotypes and two standard checks, Tesfa and Deresh. A 5x5 simple lattice design was used to set up the experiment. The [1] software was used to analyze the data on days to 50% flowering, days to maturity, plant height, yield per plot, number of primary branches, number of secondary branches, and number of pods per plant. Calculating the relative efficiency of randomized complete block design versus simple lattice design, 123% was found. Simple path coefficient and correlation coefficient analyses were conducted, and the significance and effects were evaluated in accordance with the standards set by various biometricians. The genotypes that were tested differed significantly, as demonstrated by the analysis of variance. All traits were positively and significantly correlated, both at the genotypic and phenotypic levels, with seed yield per plot, according to the correlation coefficient analysis. All traits had a positive and highest direct effect on seed yield, according to phenotypic and genotypic path coefficient analysis.

Introduction

Ethiopian mustard (Brassica carinata A Braun, BBCC, 2n=34), commonly referred to as Yehabesha Gomen, is a crop that originated in the highlands of Ethiopia and is cultivated both as an oilseed and a leafy vegetable [2]. Carinata has the ability to be grown as a spring or winter crop in double-cropped systems on the continents of Asia, Africa, North America, South America, Europe, and Australia. It is highly adaptive to a variety of growing regions, cropping systems, and management regimes. Carinata oil is classified as valuable industrial oil rather than valuable food oil due to its high concentration of erucic acid (about 36%). It stands out as one of the significant orphan leafy vegetable crops that has largely been overlooked in research initiatives focused on enhancing yield and nutritional value [3]. Nevertheless, Ethiopian mustard has been utilized as a leafy vegetable

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and oilseed for many years [4]. It offers numerous benefits, including its use as food, animal feed, medicinal applications, and as a potential alternative energy source.

Investigating the variety within orphan leafy vegetables, particularly Brassica species, is essential for uncovering their genetic potential for future breeding initiatives. To expedite global research efforts focused on the conservation and distribution of Brassica, it is imperative to secure genetic resources that will guarantee a sufficient supply of germplasm [5]. Furthermore, the preservation of crop germplasm plays a vital role in maintaining ecological balance, as nature inherently selects crops that demonstrate superior adaptability and yield in response to varying climatic conditions [6,7]. One of an outstanding vegetable and oilseed crop in the world is Ethiopian mustard. These days, however, the crop is more commonly used in developed nations for bio-industrial production than it is in developing nations, especially those in east Africa, where it is grown as a leafy vegetable for food.

The primary objective of Ethiopian mustard genetics and breeding research is to increase the plant's productivity and quality in terms of seed and oil yields, high and low erucic acid content, and low gluconisilate. Environmental factors have a significant influence on seed yield, which is a complex trait. Therefore, improving Ethiopian mustard through direct selection for seed yield is less effective. It is crucial to estimate the correlation between yield-related traits and seed yield. Therefore, the purpose of this study was to ascertain how yield-related traits in Ethiopian mustard affected seed yield both directly and indirectly.

Material and Methods

The study was conducted at Holetta Agricultural Research Center (on station) during the main cropping season of 2019-2020 in rain fed. Holetta Agricultural Research Center is located 29 km west of Addis Ababa at 09°04' N latitude and 38°29' E longitude, with an elevation of 2400 meters above sea level.

Description of the study area

Experimental materials used for study

The experimental materials were obtained from the National oilseed Coordinating Center, Holletta Agricultural Research Center. Twenty three Ethiopian mustard genotypes and two standard checks (Tesfa and Derash) were included in the study (Table 1). The field experiment was laid out using *a* simple lattice design (5x5). The *gross plot size for* the *treatment was set at* 5.*4 m^2* (*3 m x 1.8 m*). There were six rows on a 3 m by 60 m plot, with 30 cm separating rows and 60 cm separating plots. In accordance with national recommendations, all required agronomic practices were implemented.

Table 1: Materials used for correlation and path coefficient analysis at Holetta during 2020/2021.

No	Genotype	Source	Status	No	Genotype	Source	Status
1	PGRC/E-208512/12/1/1	HARC	PVT	**14**	208551/1	HARC	PVT
2	Yellow Dodola/5	HARC	PVT	**15**	21069/2/4/2	HARC	PVT
3	PGRC/E20080/5	HARC	PVT	**16**	21069/2/4/4	HARC	PVT
4	20130/1	HARC	PVT	**17**	20052/4/1/1	HARC	PVT
5	20080/3	HARC	PVT	**18**	Local Check/4	HARC	PVT
6	Local Check/1	HARC	PVT	**19**	21266/1/1/5	HARC	PVT
7	PGRC/E21001/4	HARC	PVT	**20**	208558/3/3/3	HARC	PVT
8	20080/4	HARC	PVT	**21**	PGRC/E -208513/2/3	HARC	PVT
9	21162/5	HARC	PVT	**22**	214620/1/3	HARC	PVT
10	Yellow Dodola/3	HARC	PVT	**23**	20068/6/6/4	HARC	PVT
11	PGRC/E 201303	HARC	PVT	**24**	Tesfa	HARC	PVT
12	208513/2/5	HARC	PVT	**25**	Derash	HARC	PVT
13	208507/1	HARC	PVT				

Whereas; HARC=Holetta Agricultural research and PVT=preliminary variety trial.

Data collection: data was collected for days to 50% flowering, days to maturity, plant height, number of primary branches, number of secondary branches, number of pods per plant and seed yield per plot on plant and plot basis.

Data Analysis: data collected were subjected to statistical analysis using SAS 9.3 (2014) [1] Software.

Phenotypic and Genotypic correlation analysis

Covarience analysis were estimated as described by [8] .To estimate the phenotypic and genotypic correlation coefficient, first covariance estimates between all pairs of the traits were be calculated using the formula:

Genotypic covariance $(\sigma g_{xy}) = \frac{MSPg - MSPe}{r}$

Phenotypic covariance $(\sigma p_{xy}) = \sigma g_{xy} + \frac{\sigma e_{xy}}{r}$

Where, MSPe =mean sum of cross product for error, MSPg= mean sum of cross products for genotypes and r=number of replications.

Phenotypic and genotypic correlation coefficients were calculated for each pair of character using the formulae suggested by [9,10].

$$\text{Genotypic correlation coefficient(rg)} = \frac{\text{Cov, xy(genotypic)}}{\sqrt{\text{var(X)} * \text{var(Y)(genotypic)}}}$$

$$\text{Phenotypic correlation cofficient} = \frac{\text{Cov x, y(phenotypic)}}{\sqrt{\text{var(X)} * \text{var(Y)(phenotypic)}}}$$

The values of genotypic correlation exceeding unity was considered as unit only (of some sign) to test the significance of correlation coefficients, the estimated values were compared with the table values of correlation coefficients at 5% level of significance at (n-2) degrees of freedom, where 'n' is the number of genotypes to be used in the experiment.

Path Coefficient Analysis

The use of simple correlation analysis could not fully explain the association among yield and yield related traits the direct and indirect effects at genotypic level for genotypes were estimated by taking seed yield as dependent variable, using path co-efficient analysis suggested by [11] and [12]. The direct and indirect effects in the different path orders were estimated [12] and classified as negligible (0.00-0.09), low (0.1-0.19), moderate (0.2-0.29) and high (0.3-0.99) [13].

Rij = Pij+ Σrikpkj

Where: - rij = Mutual association between the independent trait (i) and dependent trait (j) as measured by the correlation coefficient.

Pij = Component of direct effects of the independent trait (i) on the dependent variable (j) as measured by the path coefficient and, Σrikpkj = Summation of components of indirect effect of a given independent trait (i) on the given dependent trait (j) via all other independent traits (k).

Residual effect estimated by the following formula

$\sqrt{1 - R^2}$; Where: - $R^2 = \Sigma pijrij$ Where, $R^2$is the residual factor, Pij is the direct effect of yield by i^{th} trait, and rij is the Correlation of yield with the i^{th} trait.

Results and discussion

Mean performance of tested genotypes

Seed yield ranged from 328.235g/plot for genotype 208507/1 to756.905g/plot for genotype PGRC/E -208513/2/3. Number of primary branch varied from 7 to 11. The highest primary number of pods per plant observed for genotype PGRC/E -208513/2/3 while the lowest was shown by genotype 21162/5. Genotype PGRC/E-208512/12/1/1 is the tallest with the average mean height of 177.660cm while the shortest genotype was Yellow Dodola/5 with mean height of 153.847. Genotype PGRC/E -208513/2/3 is earliest in maturity than the rest with average days to maturity of 151days and it also out yielded both standard checks Tesfa and Derash. Days to flowering ranged from 152 to 156.

Table 2: Mean performance of 25 Ethiopian mustard genotypes tested at Holetta during 2020-2021.

Genotype	DF	DM	PH	YPP	PB	SB	PPP
PGRC/E-208512/12/1/1	87	154	177.660	464.360	9	9	114
Yellow Dodola/3	84	155	157.502	402.764	10	11	115
PGRC/E 201303	86	155	166.494	491.981	8	9	122
208513/2/5	87	154	170.492	414.782	8	9	125
208507/1	86	155	157.805	328.235	6	11	128
208551/1	88	156	157.147	615.671	8	11	102
21069/2/4/2	82	154	154.805	600.785	8	15	110
21069/2/4/4	82	154	156.258	538.410	8	11	136
20052/4/1/1	79	153	159.911	622.500	8	10	121
Local Check/4	82	154	157.625	643.254	10	11	88
21266/1/1/5	86	152	170.911	379.850	9	12	136
Yellow Dodola/5	82	152	153.847	362.107	10	12	161
208558/3/3/3	84	153	162.069	408.264	10	14	123
PGRC/E -208513/2/3	82	151	161.876	756.905	11	12	113
214620/1/3	82	152	166.745	549.048	9	10	87
20068/6/6/4	82	152	167.245	466.098	10	16	141
Tesfa	79	152	168.031	679.644	9	8	76
Derash	87	156	167.878	501.004	9	10	180
PGRC/E20080/5	87	156	162.716	567.900	9	11	111
20130/1	84	153	157.002	403.246	9	13	146
20080/3	83	152	169.349	355.456	9	9	96
Local Check/1	82	155	167.192	549.960	8	11	155
PGRC/E21001/4	85	155	173.190	573.911	8	10	140
20080/4	87	155	165.558	403.904	8	10	87
21162/5	85	156	172.190	525.661	7	9	105
Grand Mean	**84**	**154**	**164.060**	**504.228**	**9**	**11**	**121**
LSD(0.05)	**8**	**4**	**6.658**	**342.89**	**2**	**6**	**12**
CV	**6.287**	**1.513**	**5.189**	**29.835**	**11.535**	**40.414**	**29.026**

Whereas; DF: days to 50% flowering; DM: days to maturity; PH: Plant height; YPP: yield per plot; PB: number of primary branch; SB: number of secondary branch and PPP: number of pods per plant.

Correlation coefficient analysis

The phenotypic and genotypic correlation coefficient between seven quantitative traits considered in this study was presented in Table 3 and Table 4 respectively. Seed yield showed positive and significant correlation with days to 50% flowering (0.460**), days to maturity (0.480**), plant height (0.540**), primary branch (0.83**), secondary branch (0.510**) and number of productive pods per plant (0.890**) at phenotypic level. Positive and significant phenotypic correlation was also found between days to maturity and plant height (0.655**) and number of productive pods per plant and secondary branch (0.328*). Negative and significant phenotypic correlation was observed between days to maturity and number of primary branch (-0.393*), days to maturity and number of secondary branch (-0.350*) and plant height and number of secondary branch (-0.453**).

Negative non significant phenotypic correlation was found between days to flowering and days to maturity, days to flowering and plant height, days to flowering and number of secondary branch, days to flowering and number of pods per plant, days to maturity and number of pods per plant, days to maturity and number of primary branch, days to maturity and number of secondary branch, plant height and number of primary branch, plant height and number of secondary branch and plant height and number of pods per plant (Table 3). Non significant positive phenotypic correlation was observed between days to flowering and number of primary branch, number of primary branch and number of secondary branch and number of pods per plant and number of primary branch (Table 3).

Seed yield showed positive and significant genotypic correlation with number of primary branch (0.700**), plant height (0.520**), number of pods per plant (0.470**), days to maturity (0.45**), days to flowering (0.420**) and number of secondary branch (0.390*). Positive and significant genotypic correlation was observed between days to flowering and number of primary branch (0.389*) and days to maturity and plant height (0.694**). Negative and significant genotypic correlation was found between days to flowering and days to maturity (-0.270*), days to maturity and number of primary branch (-0.379*), days to maturity and number of secondary branch (-0.29*), plant height and number of secondary branch (-0.491**) and plant height and number of pods per plant (-0.308*). Negative and non significant genotypic correlation was observed between days to flowering and plant height, days to flowering and number of pods per plant, days to maturity and number of pods per plant, plant height and number of primary branch and number of primary branch and number of pods per plant (Table 4). Positive non significant genotypic correlation was found between days to flowering and number of secondary branch and number of primary branch and number of secondary branch.

Table 3: Phenotypic correlation of 25 Ethiopian mustard genotypes tested at Holetta during 2020-2021.

Variable	DF	DM	PH	YPP	PB	SB	PPP
DF	1	-0.077ns	-0.091ns	0.460**	0.138ns	-0.155ns	-0.093ns
DM	-0.077ns	1	0.655**	0.480**	-0.393*	-0.350*	-0.067ns
PH	-0.091ns	0.655	1	0.540**	-0.169ns	-0.453**	-0.204ns
YPP	0.460**	0.480**	0.540**	1	0.830**	0.510**	0.890**
PB	0.138ns	-0.393*	-0.169ns	0.830**	1	0.183ns	0.098ns
SB	-0.155ns	-0.350*	-0.453**	0.510**	0.183ns	1	0.328*
PPP	-0.093ns	-0.067ns	-0.204ns	0.890**	0.098ns	0.328*	1

Whereas; DF: days to 50% flowering; DM: days to maturity; PH: Plant height; YPP: yield per plot; PB: number of primary branch; SB: number of secondary branch and PPP: number of pods per plant.

Table 4: Genotypic correlation of 25 Ethiopian mustard genotypes tested at Holetta during 2019/2020.

Variable	DF	DM	PH	YPP	PB	SB	PPP
DF	1	-0.270*	-0.120ns	0.420**	0.389*	0.038ns	-0.136ns
DM	-0.270*	1	0.694**	0.450**	-0.379*	-0.291*	-0.133ns
PH	-0.120ns	0.694**	1	0.520**	-0.016ns	-0.491**	-0.308*
YPP	0.420**	0.450**	0.520**	1	0.700**	0.390*	0.470**
PB	0.389*	-0.379*	-0.016ns	0.700**	1	0.010ns	-0.069ns
SB	0.038ns	-0.291*	-0.491**	0.390*	0.010ns	1	0.329*
PPP	-0.136ns	-0.133ns	-0.308*	0.470**	-0.069ns	0.329*	1

Whereas; DF: days to 50% flowering; DM: days to maturity; PH: Plant height; YPP: yield per plot; PB: number of primary branch; SB: number of secondary branch and PPP: number of pods per plant.

Path coefficient analysis

The phenotypic and genotypic direct and indirect effects of yield related components on seed yield were presented in Table 5 and Table 6 respectively. Number of primary branch (0.922) exerted the highest phenotypic direct effect on seed yield followed by plant height (0.838), number of pods per plant (0.818), number of secondary branch (0.792), days to maturity (0.677) and days to 50% flowering (0.659) (Table 5). The phenotypic correlation of these traits with seed yield was also positive and significant. This implies giving attention to those traits in selection for seed yield improvement is important. The positive phenotypic indirect effect through number of primary branch is exerted by number of secondary branch, days to flowering and number of pods per plant while the negative indirect effect via this trait was recorded for plant height and days to maturity (Table 5). The highest positive phenotypic indirect effect on seed yield via plant height was exerted by days to maturity. Days to flowering, days to maturity and plant height showed negative indirect effect on seed yield through number of pods per plant whereas number of primary branch and number of secondary branch exerted positive indirect effect on seed yield via number of pods per plant at phenotypic level (Table 5). Number of primary branch exerted the highest genotypic direct effect on seed yield (0.881), followed by days to maturity (0.784), number of secondary branch (0.655), number of pods per plant (0.651), plant height (0.563) and days to flowering (0.421) (Table6). The genotypic correlation of these traits with seed yield were also significant and positive indicating considering of those traits in the enhancement of genetic potential for seed yield is critical. Days to flowering showed the highest genotypic indirect effect on seed yield through number of primary branch followed by number of secondary branch while days to maturity, plant height and pods per plant exerted negative indirect effect on seed yield via number of primary branch (Table 6).

Table 5: Genotypic correlation of 25 Ethiopian mustard genotypes tested at Holetta during 2019/2020.

Variable	DF	DM	PH	PB	SB	PPP	Pr
DF	**0.659**	-0.05222	-0.07588	0.127588	-0.12236	-0.07623	**0.46****
DM	-0.05084	**0.677**	0.548877	-0.36272	-0.27748	-0.05491	**0.48****
PH	-0.05969	0.443584	**0.838**	-0.15582	-0.35858	-0.16728	**0.540****
PB	0.091206	-0.26636	-0.14159	**0.922**	0.144643	0.080089	**0.830****
SB	-0.10186	-0.23729	-0.37943	0.168442	**0.792**	0.268404	**0.510****
PPP	-0.06141	-0.04545	-0.17129	0.090255	0.259738	**0.818**	**0.890****

Whereas; DF: days to 50% flowering; DM: days to maturity; PH: Plant height; YPP: yield per plot; PB: number of primary branch; SB: number of secondary branch and PPP: number of pods per plant.

Table 6: Genotypic path of 25 Ethiopian mustard genotypes tested at Holetta during 2020-2021

Variable	DF	DM	PH	PB	SB	PPP	gr
DF	**0.421**	-0.212	-0.068	0.342	0.025	-0.089	**0.420***
DM	-0.114	**0.784**	0.391	-0.334	-0.190	-0.087	**0.450***
PH	-0.051	0.544	**0.563**	-0.014	-0.322	-0.200	**0.520****
PB	0.164	0.353	-0.009	**0.881**	0.007	-0.045	**0.700****
SB	0.016	-0.228	-0.277	0.009	**0.655**	0.214	**0.390***
PPP	-0.057	-0.104	-0.174	-0.061	0.216	**0.651**	**0.470***

Whereas; DF: days to 50% flowering; DM: days to maturity; PH: Plant height; YPP: yield per plot; PB: number of primary branch; SB: number of secondary branch and PPP: number of pods per plant.

Conclusion

The results obtained from this study showed that Seed yield recorded positive and significant genotypic correlation and phenotypic correlation with number of primary branch, plant height, number of pods per plant, days to maturity, days to flowering and number of secondary branch. Path coefficient analysis showed that all traits exhibited high direct effect on seed yield. Therefore, it is suggested that those traits which exhibited maximum direct effects on grain yield should be considered in selection programme for enhancing yield potential in Ethiopian mustard.

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Conflict of interest: The authors declares that no conflict of interest.

References

1. SAS Institute. SAS/STAT guide for personal computers, version 9.3 edition. SAS Institute Inc. Cary, NC. 2014.

2. Getinet A, Rakow G, Raney JP, Downey RK. Development of zero erucic acid Ethiopian mustard through an interspecific cross with zero erucic acid oriental mustard. Canad J Plant Sci. 1994; 74: 4. https:// doi. org/ 10. 4141/ cjps94- 141.

3. Rahiel H, Abdulwahab SS, Lei Z, Xu C, Jianli L, et al. Ethiopian mustard (Brassica carinata A. Braun) as an alternative energy source and sustainable crop: a review. Sustainability. 2020; 12: 7492. https:// doi. org/ 10. 3390/ su121 87492.

4. Misteru TWY, Yared SB. Genetic variability of Ethiopian mustard (Brassica carinata A. Brun) accessions based on some morphological characters. Int J Plant Breed Genet. 2013; 7: 169-175. https:// doi. org/ 10. 3923/ ijpbg. 2013. 169. 175.

5. Subramanian P, Kim S. Brassica biodiversity conservation: prevailing constraints and future avenues for sustainable distribution of plant genetic resources. 2023; 1-13. https:// doi. org/ 10. 3389/ fpls. 2023. 12201 34.

6. Jarvis A, Upadhyaya H, Gowda CLL, Aggarwal PK, Fujisaka S, et al. Climate change and its effect on conservation and use of plant genetic resources for food and agriculture and associated biodiversity for food security. FAO Thematic Background Study Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). 2010. https:// hdl. handle. net/ 10568/ 33384.

7. Raza A, Razzaq A, Mehmood SS, Zou X, Zhang X, et al. Impact of climate change on crops adaptation and strategies to tackle its outcome: a review. Plants. 2019; 8(2): 234.https:// doi. org/ 10. 3390/ plant s8020 034.

8. Singh RK, Chowdhary BD. Biometrical methods in quantitative genetics analysis. Kalayani Publishers, New Delhi. 1977; 88.

9. Singh RK, Chaudhary BD. Biometrical Methods in Quantitative Genetic Analysis. Kalayani Publishers, New Delhi, Ludhiana, India. 1987; 318.

10. Singh RK, Chaudhary BD. Biometrical Methods in Quantitative Analysis. New Delhi, India: Kalayani Publishers. 1985.

11. Wright S. Correlation and causation. J. Agric. Res. 1921; 1(20): 557-585.

12. Dewey D R, Lu KH. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal. 1959; 51: 515-518.

13. Lenka D, Misra B. Path-coefficient analysis of yield in rice varieties. Indian Journal of Agricultureal Science. 1973; 43: 376-379. https://www.scirp.org/(S (351jmbntvnsjt1aadkposzje))/reference/ ReferencesPapers.aspx? ReferenceID=2427494.