The African Journal of Plant Science and Biotechnology ©2012 Global Science Books

Genetic Associations of Seed Oil Quality Traits and Selection Criteria in Ethiopian Mustard (*Brassica carinata* A. Brun)

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ABSTRACT

Ethiopian mustard, as an oil seed crop, needs genetic improvement which integrates both quality and agronomic traits. In this study, the correlations of eight quality traits of the 36 genotypes were investigated using a 6 × 6 simple lattice design at Holetta Research Center, Ethiopia. Heritability and genetic advance (as percent of mean) of the studied traits ranged from 35.4-69.2 and 5-23.8%, respectively. A strong positive correlation (0.752) was observed between palmitic and erucic acid. Similarly, a strong but negative correlation (-0.866) was observed between oleic and erucic acid. In relation to agronomic traits, positive and significant correlation of stearic with number of primary branches (0.607), number of secondary branches (0.608) and number of pods (0.387) was observed. Palmitic showed negative correlation with seed yield/plot (-0.354), oil yield/plot (-0.393) and 1000-seed weight (-0.404). Oil content positively correlated with seed yield/plot (0.343) and oil yield/plot (0.446), while negative correlation was found with days to flowering (-0.373) and days to maturity (-0.394). Path analyses showed that oleic acid and oil content were found the most important components to be considered as selection criteria in the improvement of edibility of seed oil of Ethiopian mustard genotypes. This investigation also indicated that improvement in the oil content of the seeds of the genotypes would be possible through selecting early flowering genotypes.

Keywords: agronomic traits, association, Ethiopian mustard, genetic advance, heritability, quality traits, selection criteria

INTRODUCTION

Oilseeds are important agricultural resources in Ethiopia. Enhancing cultivation of oilseeds, in general, serve as a pillar for growth and development of the country through import substitution of edible oils and export of high value seed and oil (Wijnands *et al*. 2007). However, a high level of undesirable erucic acid in the seed oil (Becker *et al*. 1999; Alemayehu and Becker 2001) limits the production of Ethiopian mustard (*Brassica carinata*) for the food industry. There are breeding strategies such as intra-specific (Alemayehu and Becker 2001; Teklewold 2005) and inter-specific hybridization (Fernández-Escobar *et al*. 1988; Getinet *et al*. 1994) as well as induced mutation (Velasco *et al*. 1995) which have been successful in improvement of seed oil quality traits in terms of fatty acid composition. Genetic variation among genotypes of Ethiopian mustard has been studied by Belete *et al*. (2011).

By the same token, understanding of traits association using correlation coefficients is also helpful in selecting the breeding material for improving the intricate traits (Singh and Singh 1995; Ismail *et al*. 2001; Teklewold *et al*. 2001). However, to know the interrelationships of the traits, this correlation could be classified into causal and effect relationships using path analysis (Gravois and McNew 1993; Ray and Debi 1999; Teklewold *et al*. 2001; Kozak *et al*. 2007). This study was executed with the objectives of revealing the genetic association of quality traits, and determining the selection criteria for improvement of the seed oil of Ethiopian mustard genotypes.

MATERIALS AND METHODS

The material for the present investigation consisted of 33 genotypes and 3 standard checks. The experiment was carried out at Holetta research center using 6 × 6 simple lattice design in 2010 cropping season. Each genotype was grown in six rows of 3 m long with spacing of 30 cm between rows. Recommended management practices (Alemayehu and Abebe 1994) were followed for good establishment of the crop.

Eight seed oil quality traits which comprises of the seed oil content and the major fatty acid composition of the seed oil were analyzed using Nuclear Magnetic Resonance (NMR) for oil content and Near Infrared Reflectance Spectroscopy (NIRS) for fatty acids. 22 g of seed of each genotype was dried in an oven for 2 ½ h at 78°C and cooled for 30 min prior to oil content measurement. It was, then, measured following the procedure of Robbelen *et al*. (1989). Fatty acid composition of the seed oil was determined using the procedure of Thies (1971). 3 g of seed of each genotype was used to measure the fatty acids using Foss NIRS 5000 (Weltech Enterprises, Inc., Maryland, USA) in the 1108-2492 ranges with an 8 nm step. The spectrum of each sample was taken by scanning (Win Scan) version 1.5 international, L.L.C (Famatech. Corp., Viriginia, USA) as described in Belete *et al*. (2011). The agronomic traits considered in the study were days to flowering, days to maturity, number of primary branches/plant, number of secondary branches/plant, number of pods/plant, number of seeds/pod, plant height, number of seeds/plant, 1000-seed weight, seed yield/plot and oil yield/plot (Belete 2011).

Data analysis

Data were subjected to analysis of variance using the procedures outlined by Gomez and Gomez (1984). Phenotypic and genotypic variances and phenotypic and genotypic coefficients of variation were estimated following Burton and De vane (1953). Heritability in the broad sense of the traits studied was computed as per the suggestion of Allard (1960) and the expected genetic advance under selection assuming selection intensity of 5% (2.063) was calculated following Johnson *et al*. (1955). Genotypic correlation coefficients (Pearson's correlation) were computed using the genotypic values of the traits estimated (Belete *et al*. 2011) and Belete

Received: 17 August, 2011. Accepted: 27 November, 2011.

Original Research Paper

Table 1 Variance components, coefficient of variations, heritability in the broad sense, genetic advance and genetic advance as percent of mean of the seed oil quality traits of Ethiopian mustard genotypes.

	Variance components			CV		h^2 (%)	GA	GA as % of mean
	Phenotypic	Genotypic	Environmental	GCV (%)	PCV (%)			
Palmitic	0.14	0.09	0.05	8.8	9.3	64.3	0.49	14.6
Stearic	0.008	0.005	0.003	6.7	8.5	62.5	0.11	10.9
Oleic	2.8	1.3	1.5	17	25	46.4	1.6	23.8
Linoleic	1.3	0.9	0.4	5.3	6.3	69.2	1.62	9
Linolenic	3.9	1.9	2	11	15.8	48.7	1.98	15.8
Eicosenoic	6.5	2.3	4.2	14.3	23.9	35.4	1.86	17.5
Erucic	9.6	6.4	3.2	5.5	6.7	66.7	4.25	9.2
OC	3.5	2	1.5	3.2	4.3	57.1	2.2	5

CV: coefficient of variation, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, h^2: heritability, GA: genetic advance, OC: oil content

Table 2 Genotypic correlation coefficients among 8 quality traits in 36 Ethiopian mustard genotypes tested at Holetta, 2010/11.

	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Eicosenoic	Erucic	OC
Palmitic	1	-0.028	-0.531**	0.193	-0.099	0.391*	0.752**	-0.389*
Stearic		1	0.255	-0.562**	-0.712*	0.391**	-0.082	0
Oleic			1	-0.275	-0.045	0.154	-0.866**	0.138
Linoleic				1	0.530**	-0.374*	0.116	-0.007
Linolenic					1	-0.477**	-0.195	-0.068
Eicosenoic						1	0.193	-0.051
Erucic							1	-0.176
OC								1

OC: oil content, *: significant at $p \leq 0.05$, **: significant at $p \leq 0.01$

(2011). The path analyses were done following Dewey and Lu (1959) using the procedure PROC CALIS of the SAS software version 9.00 (SAS 2002).

RESULTS AND DISCUSSION

Heritability

The broad sense heritability and genetic advance of the traits are presented in **Table 1**. Heritability estimates were grouped into high (> 50%), moderate (20-50%) and low (< 20%) as described by Stansfield (1988). Accordingly, high heritability values were recorded for linoleic (69.2%), erucic (66.7), palmitic (64.3%), stearic (62.5%) and oil content (57.1%). This indicates that large proportion of the total variance was due to the high genotypic variance having less environmental influence. High heritability values of 71-82% and 71.5% for oil content were also reported by Teklewold (2005) in Ethiopian mustard and Aytac and Kinaci (2009) in rapeseed (*Brassica napus*), respectively. A moderate heritability value of 40% was also reported in the oil content of F3:4 lines of *B. napus* and *Brassica campestris* (Khan *et al*. 2008b). Moderate heritability was found for linolenic, oleic and eicosenoic.

The highest genetic advance as percent of mean was shown by oleic (23.8%) followed by linolenic (17.5%) and eicosenoic (15.8%). In this study, high genetic advance along with moderate heritability was observed for oleic, linolenic and eicosenoic which may be because of the presence of both additive and non-additive gene actions (Liang *et al*. 1972).

Genotypic correlation

Genotypic correlation coefficients among quality traits are presented in **Table 2**. Highly significant but negative genotypic correlation was shown between oleic and erucic acid (-0.866) which is in conformity with the result of other studies on rapeseed and mustard (*Brassica juncea*) (Islam *et al.* 2009), Indian mustard (*Brassica juncea*) (Patel *et al*. 2003), toria (*Brassica campestris*) (Sia *et al.* 2004) and Ethiopian mustard (Alemayehu 2001; Genet *et al.* 2005; Teklewold 2005). Highly significant positive correlation was found between palmitic and erucic acid (0.752), whereas a negative correlation was observed between palmitic and oleic acid (-0.531). Contrarily, a negative correlation (-0.789) between palmitic and erucic acids, and a positive correlation (0.577) between palmitic and oleic acids were reported by Islam *et al.* (2009) in rapeseed and mustard. These contradictions might have been occurred as a result of synchronized selection applied on the traits concerned. The result of positive correlation between palmitic and eicosenoic (0.391) is in agreement with Islam *et al.* (2009), who found a positive correlation (0.554) between these two traits.

Erucic acid showed a negative correlation with oil content (-0.176) though it was insignificant, which implies increasing oil content favors the oil for edible purpose interms of erucic and oleic acid content. A negative correlation was found between linoleic and oleic acid content (-0.275). Though insignificant, there was also a negative correlation between erucic and linolenic acid (-0.194) and between oleic and linolenic acid (-0.045), which is in agreement with the findings of Kumar and Tsunoda (1980) who found values of -0.766 and -0.029 for the respective pairs of traits in 159 species of the tribe *Brassiceae* and Teklewold (2005) who found a negative correlation (-0.54) between oleic and linolenic in 913 s_2 plants of Ethiopian mustard representing different geographic regions of Ethiopia.

Genotypic correlation coefficients between quality and agronomic traits are presented in **Table 3**. Correlation of oil content (-0.394) and linoleic (-0.192) with days to flowering was negative, the latter being insignificant. This agrees with the result of Lionneton *et al*. (2004) who reported that oil content was significantly but negatively correlated with days to flowering in mustard. A significant but negative correlation (-0.373) was also found between oil content and days to maturity.

As indicated in **Table 3**, the correlation of oil content with seed yield/plot (0.343) and oil yield/plot (0.446) was positive and significant. A significant but negative correlation of palmitic with seed yield/plot (-0.354), oil yield/per plot (-0.393) and 1000-seed weight (-0.404) was observed. Similarly, linolenic showed significant but negative correlation with number of secondary branches/plant (-0.492), seed yield/plot (-0.366) and oil yield/plot (-0.348). Oleic showed positive but insignificant correlation with number of secondary branches/plant (0.277), number of pods/plant (0.237) and 1000-seed weight (0.311). Positive correlation between the traits for oleic acid and number of pods/plant (0.73), and oleic acid and seed weight (0.40) were also reported by Khan *et al*. (2008a) in F3:4 lines of *B. napus* and *B. campestris*.

Though it was insignificant, oleic showed a positive correlation with seed yield/plot (0.110) and oil yield/plot

Table 3 Genotypic correlation coefficients between quality and agronomic traits in 36 Ethiopian mustard genotypes tested at Holetta, 2010/11.

	DF	DM	PH	NPB	NSB	NPP	LP	SPPD	SPP	SYPP	OYPP	TSW
Palmitic	0.002	0.082	-0.164	0.208	0.057	0.104	-0.11	-0.167	-0.271	-0.354*	-0.393*	-0.404*
Stearic	0.199	0.315	0.072	0.607**	0.608**	0.387*	0.229	-0.073	0.141	0.255	0.236	-0.08
Oleic	-0.109	-0.095	0.07	-0.046	0.277	0.237	0.012	-0.076	0.192	0.11	0.13	0.311
Linoleic	-0.192	-0.247	-0.079	-0.238	-0.495**	-0.412*	-0.141	-0.012	-0.274	-0.205	-0.196	-0.064
Linolenic	0.081	0.017	0.101	-0.221	-0.492**	-0.239	-0.091	-0.14	-0.267	-0.366*	-0.348*	0.11
Eicosenoic	-0.032	0.043	-0.159	-0.152	0.173	0.129	0.231	-0.104	-0.017	-0.123	-0.126	0.045
Erucic	-0.055	0.003	-0.216	0.092	-0.106	-0.03	-0.147	0.011	-0.13	-0.114	-0.139	-0.325
OC	-0.394*	-0.373*	-0.194	0.068	-0.104	-0.069	-0.258	0.264	0.303	0.343*	0.446**	0.235

*, ** significant at $p \leq 0.05$ and $p \leq 0.01$ significance level, respectively; DF: days to flowering, DM: days to maturity, PH: plant height, NPB: number of primary branches/plant, NSB: number of secondary branches/plant, NPP: number of pods/plant, LP: length of pod, SPPD: number of seeds/pod, SPP: number of seeds/plant, SYPP: seed yield/plot, OYPP: oil yield/plot, TSW: 1000-seed weight, OC: oil content

Table 4 Genotypic direct (**bold**) and indirect effect of quality traits on oil content.

	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Eicosenoic	Erucic	r_g
Palmitic	**-0.793**	0.022	0.421	-0.153	0.078	-0.317	-0.596	-0.389*
Stearic	0.001	**-0.052**	-0.013	0.029	0.037	-0.02	0.004	0
Oleic	-0.099	0.048	**0.187**	-0.051	-0.008	-0.029	-0.162	0.138
Linoleic	0.047	-0.138	-0.068	**0.246**	0.13	-0.092	0.029	-0.007
Linolenic	0.012	0.085	0.006	-0.063	**-0.119**	0.057	0.023	-0.068
Eicosenoic	0.075	0.075	0.029	-0.072	-0.091	**0.255**	0.037	-0.051
Erucic	0.368	-0.04	-0.424	0.057	-0.095	0.095	**0.489**	-0.176

r_g: genotypic correlation coefficient, *: Significant at $p \leq 0.05$

Table 5 Genotypic direct (**bold**) and indirect effects of quality traits on oil yield/plot.

		DF	DM	PH	NPB	NSB	NPP	LP	SPPD	SPP	SYPP	TSW	r_g
Palmitic	**-0.039**	0	0	-0.005	0.003	0	0.006	0	-0.016	0.022	-0.34	-0.024	-0.393*
Stearic	**-0.033**	0.003	0	0	0.008	-0.001	0.029	0	-0.006	-0.011	0.25	-0.003	0.236
Oleic	**0.039**	-0.002	0	0	-0.001	0	0.015	0	-0.006	-0.016	0.09	0.011	0.130
Linoleic	**0.018**	-0.003	0	0	-0.008	0	-0.026	0	-0.003	0.022	-0.194	-0.002	-0.196
Linolenic	**-0.018**	0.001	0	0.01	-0.003	0	-0.015	0	-0.011	0.03	-0.345	0.003	-0.348*
Eicosenoic	**0.005**	-0.001	0	-0.008	0.002	0	0.008	0	-0.015	0.001	-0.12	0.002	-0.126
Erucic	**0.045**	-0.001	0	-0.009	0.001	0	-0.018	0	0.001	0.011	-0.139	-0.03	-0.139
OC	**0.144**	-0.007	0	-0.001	0.001	0	-0.004	0	0.022	-0.025	0.308	0.008	0.446**

*, ** significant at $p \leq 0.05$ and $p \leq 0.01$ significance level, respectively; DF: days to flowering, DM: days to maturity, PH: plant height, NPB: number of primary branches/plant, NSB: number of secondary branches/plant, NPP: number of pods/plant, LP: length of pod, SPPD: number of seeds/pod, SPP: number of seeds/plant, SYPP: seed yield/plot, TSW: 1000-seed weight, OC: oil content

(0.130), whereas erucic acid correlated negatively with both seed yield/plot (-0.114) and oil yield/plot (-0.139). Negative correlation (-0.325), though insignificant, was observed between erucic acid and 1000-seed weight which almost agrees with the result of Khan *et al*. (2008a) who reported a correlation value of -0.5 for these traits. A positive correlation of oil content with 1000-seed weight is also supported by a positive correlation value of 0.48 in Alemayehu and Becker (2002) and 0.66 in Teklewold (2005) in Ethiopian mustard, but contrary to Khan *et al.* (2008a), who reported a negative correlation (-0.39) between the two traits. Stearic showed positive and significant correlation with number of primary branches/plant (0.607), number of secondary branches/plant (0.608) and number of pods/plant (0.387).

Path analyses

Oil content and oil yield/plot were considered as dependent traits in the path analyses (**Tables 4, 5**). Oleic (0.187), linoleic (0.246), eicosenoic (0.255) and erucic acid (0.489) had a positive direct effect on oil content, while their correlation with oil content was negative except the former which might have stem from their negative effect through other traits. On the other hand, palmitic (-0.793), stearic (-0.052) and linolenic acid (-0.119) showed negative direct effect which had also been expressed in their correlations with oil content except stearic. Stearic acid showed no correlation with oil content which may have stemmed from the canceling effect of its direct and indirect effects with other traits. The effect of palmitic acid through other quality traits such as stearic, linoleic, linolenic, eicosenoic and erucic acid was found positive. Similar findings of positive direct effects of oleic (0.970), linoleic (0.077), eicosenoic (0.820) and erucic (0.526) acid on oil content were also reported by Islam *et al*. (2009). The indirect negative effect of oleic acid through erucic acid (-0.843) and linolenic acid (-0.472) reported by these authors agrees with the present investigation, though its magnitude varies. Contrarily, these authors reported a positive direct effect of stearic (0.306) and linolenic (0.687) acid on oil content.

The path analysis for oil yield/plot showed that oleic (0.039), linoleic (0.018), eicosenoic (0.005), erucic (0.045) and oil content (0.144) had a positive direct effect on oil yield/plot, while stearic (-0.033), palmitic (-0.039) and linolenic acid (-0.018) revealed negative direct effect. Stearic acid had positive correlation with oil yield which might have been as a result of their effects via other traits which indicates that direct selection of this trait for improvement of oil yield will be ineffective. The positive (0.389) direct effect of oil content on oil yield/plot was also reported in sunflower (*Helianthus annuus*) by Teklewold *et al*. (2001).

The effect of oleic acid through 1000-seed weight was found positive, while the effect of erucic acid via 1000-seed weight was negative. Similarly, the effect of oil content through seed yield/plot and 1000-seed weight was positive, while it was negative via days to flowering which had also been expressed in their correlations. Generally, path analyses showed that oleic acid and oil content were the most important components in the improvement of the edibility of seed oil of Ethiopian mustard genotypes.

CONCLUSIONS

The present investigation shows that efforts of increasing palmitic and linolenic acids for improvement of the oil of Ethiopian mustard genotypes may be at the expense of oil content. Oleic acid and oil content should be considered as the most important selection criteria for improvement of edibility of Ethiopian mustard seed oil. Besides, improvement in oleic and erucic acids content of the seed oil could be favored through 1000-seed weight.

ACKNOWLEDGEMENTS

The study was sponsored by the Ethiopian Institute of Agricultural Research (EIAR) and Rural Capacity Building Project (RCBP). Mr. Dereje Fekadu and Mr. Gemechu Keneni are highly acknowledged with thanks for fatty acids analysis and advice on data analysis, respectively. We are also very grateful for Mr. Tadesse Debele for his excellent technical assistance.

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