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Correlation and path analysis studies among yield and yield related traits in Ethiopian Mustard (*Brassica Carinata*A.Brun) accessions

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Abstract: **This investigation were undertake in order to evaluate the association of characters and path coefficient analysis on seed yield and yield contributing traits in Ethiopian mustard planted at Kulumsa Agricultural Research Center during the 2017/18 main cropping season.. The correlation analysis showed seed yield per plot was highly significant and positively correlated with oil yield, biomass per plot, harvest index, plant height and thousand seed weight. In contrast, seed yield per plot was negatively correlated with number of pod per plant (rph= -0.294,rg= 0.473)both at genotypic and phenotypic level. Character association analysis among oil yield at phenotypic and genotypic level highly significant (p<0.001) and positively correlated with seed yield per plot, thousand seed weight, harvest index, seed per pod, seed yield per plant and oil content. The path analysis indicated the higher magnitude positive direct effect at phenotypic and geneotypic level on seed yield per plot was exerted by biomass per plot, harvest index and thousand seed weight. This showed those traits can be used as an indirect selection criteria to improve Ethiopian mustrard since the traits have strong positive correlation with seed yield per plot.**

Keywords: **selection index, association among traits.**

1. INTRODUCTION

The genera Brassica belongs to family Cruciferae comprises of economically important species.*Brassica carinata* (A. Braun) is an amphi-diploid species that originated from interspecific hybridization between *Brassica nigra* and *Brassica oleracea* in the highlands of Ethiopia.The crop has many desirable agronomic traits but with oil quality constraints like high erucic acid and glucosinolate contents. In Ethiopia, the crop is traditionally used for many purposes, such as greasing traditional bread-baking clay pans, curing certain ailments and preparing beverages (Alemayehu, 2001).Ethiopian mustard is also very beneficial in farming systems, as a potential rotational crop for cereals and pulses. The industrial value of Brassica carinata oil is indeed immense in leather tanning, the manufacture of varnishes, paints, lubricants, soap and lamps (Doweny, 1971; Bhan, 1979). Recent investigations have witnessed that after transesterification, the oil exhibits physical and chemical properties suitable for bio-diesel (Cardone et al., 2002).The breeding program of Ethiopian mustard work with the objective of improving grain yield, oil content of the seeds, resistance to disease and pests.

To improve Ethiopian mustard, it requires studying the association and path analysis of the yield component traits and identifies the possible indirect selection criteria since determining the oil content in Ethiopian mustard is an expensive task and require good laboratory facility. Grain yield is the result of a number of complex morphological and physiological processes that interact with each other and with the environment at different growing stages (Semahegn, 2011). The improvement of landraces for grain yield is not only dependent on the nature and extent of genetic variability, heritability and genetic advance in the base population but also on the association of yield and yield-related traits with desirable biochemical composition (Said, 2012; Temesgen et al., 2013a; Sabaghnia et al., 2015). Genetic evaluation of large number of Ethiopian mustard genotypes related to yield and seed quality related traits such as oil contents is paramount importance. Measurement of simple correlation coefficient helps to identify the relative contribution of component characters towards yield (Panse, 1957). But the simple correlation coefficients are not always effective in determining the real relationships among traits. So that the path coefficients analysis will have a great contribution since it show direct and the indirect influence of independent variable upon dependent variable. Besides it help to identify which trait can be used as indirect selection criteria during selection especially for those trait high economic importance but difficult to determine it in routine basis. In path analysis it is important to specifies the cause and effect relationship among the dependent and independent variables; therefore, path coefficient analysis would provide a more meaningful interpretation of such association (Dewey and Lu, 1959; Mondal et al., 2011; Malek et al.,2014). Therefore, the present study was undertaken to determine the degree and nature of associations among seed yield and seed quality related characters and develop a selection criteria to improve the Ethiopian mustard.

2. MATERIALS AND METHODS

2.1 Description of the study area

The field experiment was conducted in Kulumsa Agricultural Research center which is located 167 km south east of Addis Ababa at altitude of 2200 meters above sea level. It receives an average rainfall of 576.1mm.

2.2 Experimental Materials and Procedures

One hundred seventy of Ethiopian Mustard genotypes including the three standard checks were used for this study. The genotypes were collected by Ethiopian Biodiversity Institute (EBI) from divers agro-ecological areas of Ethiopia in altitude range of 1050 – 2800 meter above sea level, representing the major mustard production areas in the country. The experiment was laid out in 16 x11 alpha lattice designs using 2m x 0.9m plots with two replications. Each genotype was planted in a plot consisting of three rows of 2 m long with spacing of 30 cm between rows. A seed rate of 0.9 g per plot based on the seed rate of 5 kg/ha was used for each genotype. Fertilizers were applied at the rate of 46/69 kg/ha N/P2O5and all necessary cultural practices were undertaken as recommended for the crop.

2.3 Data Collection

The following data were collected from the experiment both per plot and per plant basis. From plot we recorded days to flowering, days to maturity, biomass per plot, thousand seed weight, seed yield per plot, oil content, oil yield per plot and harvest index. Those data collected from five randomly taken plants of each genotypes characters namely number of primary branch, number of secondary branch, number of seed per pod, plant height, biomass per plant and seed yield per plant.

2.4 Statistical Analysis

Analysis was computed using the following model=$Yil(j) = \mu + gi + rj + (b|r)l(j) + eil(j)$

Where, Yij = the response of trait Y in the i^{th} genotype and the j^{th} replication

μ = the grand mean of trait Y

rj = the effect of the j^{th} replication

gi = the effect of the i^{th} genotype

(b|r)l(j) = block within replicate effect

εil(j)= experimental error effect

The correlation coefficients were calculated to determine the degree of association of characters with yield and among themselves. Estimation of genotypic and phenotypic correlation coefficients was done based on the procedure of Dabholkar (1992).

Genotypic correlation coefficient (rg) = $COVg\ (xy)/\ \sigma g\ (x)\ *\ \sigma g\ (y)$

Phenotypic correlation coefficient (rph) = $COVph\ (xy)/\ \sigma ph\ (x)\ *\ \sigma ph\ (y)$

Where, COVg (xy) and COVph (xy) are the genotypic and phenotypic covariance of two variables (X and Y), respectively, while σg (x) and σg (y) are the genotypic standard deviations for variables X and Y, respectively, and. σph (x) and σph (y) are the phenotypic standard deviations of variables X and Y, respectively.

The calculated phenotypic correlation value was tested for its significance using t-test:*t = rph/SE (rph),*Where, rph = Phenotypic correlation; SE (rph) = Standard error of phenotypic correlation obtained using the following formula (Sharma, 1998).

SE (rph) = √ (1-r2ph)/ (n-2)

Where, n is the number of genotypes tested, rph is phenotypic correlation coefficient.

The coefficients of correlations at genotypic levels were tested for their significance by the formula described by Robertson (1959) as indicated below:

t = rgxy/SErgxy

The calculated "t" value was compared with the tabulated "t" value at (n-2) degree of freedom at 5% level of significance. Where n is the number of genotypes.

SErgxy = √ (1-r2gxy) 2/2h2x.h2y .Where, h2x = Heritability of trait xh2y = Heritability of trait y

Path analysis was used for exhibiting the direct and indirect effects on seed yield according to the method suggested by Dewey and Lu (1959) and with biotool package of R (da Silva, 2017).

rij = Pij + Σrikpkj .Where, rij = mutual association between the independent character (i) and dependent character (j) as measured by the genotypic (Phenotypic) correlation coefficients. Pij = direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic (phenotypic) path coefficients, and Σrikpkj = Summation of components of indirect

effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).The residual effect (p2R) was estimated using the formula;

$\sqrt{1-R^2}$ *Where,* $R^2 = \Sigma pijrijp^2 R = \sqrt{1-\Sigma \text{pijrij}}$

The phenotypic and genotypic variances, phenotypic and genotypic correlation and its path analysis was performed using different packages of R software accordingly.

3. RESULTS AND DISCUSSION

3.1. Correlations of Seed Yield and Yield Related Traits

Genotypic and phenotypic correlations among the characters are shown in Table 1. Seed yield per plot had positive and very high significant ($P < 0.001$) genotypic correlations with oil yield per plot (rg =0.991), biomass per plot (rg =0.896), plant height (rg=0.583), number of seed per pod (rg = 0.567), harvest index per plot (rg = 0.916), and 1000 seed weight (rg =0.425). This result is in agreement with Yared (2011), Aytac and Kinaci (2009), Enggvist and Becker (1993) andJeromala*et al.*, (2007), Shabana*et.al*., (1990); Thompson (1983), who report positive correlation of seed yield per plot with number of seeds per pod and thousand seed weight, whichindicates that considering number of seeds per pod and thousand seed weight as selection criteria will be an effective way to increase both seed and oil yield.

Significant phenotypic correlation ($p<0.001$) was observed among the genotypes for seed yield per plot with oil yield per plot (rph =0.966), biomass per plot (rph=0.837), harvest index per plot (rph=0.731), plant height (rph= 0.475) and 1000 seed weight (rph=0.333). On the other hand, seed yield per plot was negatively correlated with number of pod per plant (rph= -0.294,rg= 0.473)both at genotypic and phenotypic level (Table 1). Generally, seed yield per plot was positively correlated with oil yield per plot, biomass per plot,harvest index per plot, plant height, days to flowering,days to maturity and 1000 seed weight at both genotypic and phenotypic levels. Similar results were reported by Nigussie (1990) with regard to the correlations between seed yield per plotand plant height. Delesa(2006) also reported seed yield per plot had highly significant and positive correlation with oil yield, biomass per plot, harvest index and plant height at genotypic and phenotypic level. The significant positive correlation of the traits described above with oil yield and quality will be an interest of the breeders since it facilitates the indirect selection of the oil yield via these traits. The negative correlation among number of pod per plant with grain yield indicated the importance of balancing of this trait during selection since as the number pods per plant increased the seed weight decreased due to computation for sink.

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3.2. Correlation among yield contributing traits

The correlation estimate among the yield contributing traits showed that thenumber of primary branch per plant ($p<0.001$) has highly significant correlation with days to flowering (rph=0.421and rg =0.615), days to maturity (rph= 0.387 and rg =0.559), secondary branch per plant (rph= 0.383 and rg = 0.109),seed per pod(rph= 0.290 and rg = 0.367) as the same time primary branch have significant and positive correlation with plant height(rph= 0.160). The phenotypic correlations of primary branch per plant with oil yield were positively correlated but oil yield had negatively correlated with primary branch per plant at genotypic level.

Thousand seed weight strong significantly and positively correlated with plant height, biomass per plot, seed yield per plot, harvest index, primary branch per plant, seed per pod, oil content and oil yield both phenotypically and genotypically. This result indicated the increment of these traits would contribute for the increase in the 1000 seed weight. The plant height had strong and positive correlation with both biomass per plot and plant, seed yield per plot (rg=0.583 and rph=0.475), thousand seed weight (rg=0.619 and rph=0.568), seed per pod (rg=0.604 and rph=0.509),oil content (rg=0.552 and rph=0.464) and oil yield per plot (rg = 0.649 and rph=0.504). This implies, plant height also had a significant role in producing more seed yield since as a plant height increase the plant will have more primary branches with more number of numbers of pods.

In the present analysis, relationship between biomass per plot was strongly and positively correlated with plant height (rg = 0.749 and rph = 0.557), seed yield per plot (rg=0.896 and rph=0.837), thousand seed weight (rg=0.474 and rph=0.351), oil content (rph=0.244) and oil yield per plot (rg = 0.889 and rph = 0.819). In contrast the biomass yield was negative correlated with secondary branch per plant and number of pod per plant. .Correlations of biomass per plant also had positive and strong associations with days to maturity, plant height, number of seeds per pod, seed yield per plant and oil content both phenotypically and genotypically.

When we see the genotypic and phenotypic correlations of Oil yield per plot has positive and highly significant ($p<0.001$) positively correlation with seed yield per plot (rg = 0.991 and rph =0.966),1000 seed weight(rg=0.447 and rph=0.335), harvest index (rg = 0.891 and rph =0.691), number of seed per pod (rg = 0.378 and rph = 0.561), seed yield per plant(rg=0.528 andrph=0.397) and oil content (rg = 0.396 and rph = 0.329).

Generally, the study of interrelations between character can be exploited by the breeders to improve the genotypes with a combination of traits and also important in defining the indirect selection criteria for the traits difficult to measure such as oil yield and quality. The study of the interrelations among traits reveals how the improvement of one character can causealterations in others (Vencovsky and Barriga, 1992) so that the breeder can make a decision with care.

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among 15 characters in 170 Ethiopian mustard genotypes studied at Kulumsa, 2017.

	DF	DM	Hei	BM.P	SY.P	TSW	HI	PB.PL	SB.PL	SD.PD	BM.PL	SY.PL	Oil.con	Oyld
DF		0.944***	0.494***	0.179*	0.061***	0.715	0.009***	0.421***	-0.274***	0.699	0.650	0.251	0.537***	0.074
DM	0.969***		0.513***	0.183*	0.102***	0.752	0.077***	0.387**	-0.242***	0.721***	0.679***	0.308	0.538***	0.118
Hei	0.541***	0.552***		0.557***	0.475***	0.568***	0.237**	0.160*	-0.276***	0.509***	0.453***	0.371	0.464***	0.504***
BM.P	0.209**	0.217**	0.749***		0.837***	0.351***	0.296*	0.031***	-0.164***	0.361	0.074	0.273	0.244**	0.819***
SY.P	0.045***	0.094***	0.583***	0.896***		0.333***	0.731***	0.033***	-0.084***	0.410	0.049	0.431	0.215**	0.966***
TSW	0.724	0.771	0.619***	0.474***	0.425***		0.267***	0.264***	-0.411***	0.672***	0.480	0.311	0.577***	0.335***
HI	0.009	0.082	0.277	0.633***	0.916***	0.345***		0.070***	-0.007***	0.411	0.070	0.476	0.200**	0.691***
PB.PL	0.615***	0.559***	0.194**	-0.098***	-0.058***	0.394***	0.135		0.383***	0.290***	0.555	0.438	0.178*	0.022
SB.PL	-0.414***	-0.372***	-0.510***	-0.518***	-0.314***	-0.578***	-0.045***	0.109***		-0.151*	0.310***	0.465***	-0.340***	-0.102
SD.PD	0.782***	0.816***	0.604***	0.510***	0.567***	0.753***	0.584***	0.367***	-0.292***		0.577***	0.554***	0.469***	0.378***
BM.PL	0.776***	0.806***	0.512***	-0.006***	-0.020***	0.577***	0.117***	0.552***	0.076	0.716***		0.708***	0.316**	0.037
SY.PL	0.326***	0.397***	0.431***	0.312	0.565	0.401***	0.768	0.331	0.249	0.707***	0.684***		0.143	0.397***
Oil.con	0.602***	0.629***	0.552***	0.335	0.313	0.647***	0.320	0.303	-0.555	0.623***	0.404***	0.192*		0.329***
Oyld	0.059	0.118	0.649***	0.889***	0.991***	0.447***	0.891***	-0.062	-0.386***	0.561***	-0.047	0.528***	0.396***	

*, **, *** Indicate significance at 0.05, 0.01and 0.001 probability levels, respectively.

DF = Days to flowering, DM = Days to maturity, Hei = Plant height, PB/PL = Number of primary branches per plant, SB/PL = Number of secondary , SD/PD = Number of seeds per pod, BM/PL = Biomass per plant, BM/P = Biomass per plot, SY/PL = Seed yield per plant, SY/P = Seed yield per plot, HI/P = Harvest index per plot, TSW = Thousand seed weight, OC = Oil content and OY/P = Oil yield per plot.

3.3 Path Coefficient analysis

Seed yield is the final product of components of several characters, since the simple correlation coefficients did not give clear information about the interrelationship between the causal and resultant variables; the correlation coefficient estimates were partitioned into direct and indirect effects to establish the intensity of effects ofindependent variables on dependent one. Hence, path analysis provides effective means through disentangling direct and indirect causes of association among the variables. Therefore, in this study the genotypic and phenotypic correlations were further analyzed by path coefficient analysis technique to partition the correlation coefficients in to direct and indirect effects.

In this study, seed yield and oil yield were considered as dependent variables (the resultant traits or complex outcomes) and the rest as causal variables. Thus, the direct and indirect effects of selected characters on seed yield per plot at both phenotypic andgenotypic levels are presented in Table 2 and 3, respectively.

3.3.1 Estimates of direct and indirect effects of several traits on seed yield per plot at phenotypic level

The phenotypic path analysis (Table 2) showed that the positive direct effect on seed yield per plot was exerted by the independent variables - oil yield (0.491) followed by the strong effects of biomass per plot (0.378), harvest index (0.299), and thousand seed weight. These traits exhibited positive and highly significant (P<0.001) phenotypic and genotypic correlation with seed yield per plot (Table 2). Consequently, these characters can be considered for indirect selection criteria to improve the seed yield in the breeding program. The path analysis model employed in this study is efficient to explain the seed yield per plot since the coefficient of determination was about 0.98.On the other hand, there was relatively considerable positive phenotypic indirect effects on seed yield per plot by plant height (0.143), number of secondary branches per plant (0.128), seeds per pod (0.120) and oil content (0.224) through oil yield. Similarly, number of primary branches also showed relatively weak positive indirect effect on seed yield per plot through thousand seed yield. Related results were reported by Nigussie (1990) for plant height and primary branches, but opposite results were reported for number of pods by Singh *et al.* (1979) and Nigussie (1990). Both authors found plant height and number of pods asthe most important components contributing to seed yield.

Table 2. Estimates of direct (bold-diagonal) and indirect effects (off-diagonal) of 9 traits on seed yield per plot, at phenotypic levels in Ethiopian Mustard accessions tested at Kulumsa during the main cropping season of year 2017.

Var	Hei	BM.P	TSW	HI	PB.PL	SB.PL	SD.PD	Oil.con	Oyld	r_{ph}
Hei	**0.048**	0.144	0.059	0.046	-0.004	0.016	0.008	0.034	0.143	0.475***
BM.P	0.027	**0.378**	0.063	0.058	-0.017	0.015	0.005	0.044	0.231	0.837***
TSW	0.027	0.152	**0.106**	0.087	-0.244	0.008	0.010	0.035	0.167	0.333***
HI	0.011	0.076	0.047	**0.299**	-0.019	0.015	0.006	0.042	0.204	0.731***
PB.PL	0.008	0.008	0.022	0.014	**-0.025**	0.016	0.004	0.008	0.018	0.033***
SB.PL	0.006	0.089	0.020	0.072	-0.508	**0.042**	0.006	0.028	0.128	-0.084***
SD.PD	0.025	0.093	0.068	0.080	-0.007	0.016	**0.015**	0.033	0.120	0.410
Oil.con	0.022	0.155	0.050	0.113	-0.003	0.016	0.006	**0.073**	0.224	0.215**
Oyld	0.024	0.211	0.063	0.141	-0.002	0.019	0.006	0.058	**0.491**	0.966***

R-Squared =0.98, Residual = 0.13

Hei= Plant height in centimeter, BM.P= Biomass yield, TSW= Thousand seed weight ,HI= Harvesting index , PB.PL =number of primary branch per plant ,SB.PL= Number of secondary branches per plant, SD.PD=Number of seeds per pod, Oil.con= oil content in percentage, Oyld =Oil yield , Var.= variables, r_{ph}= phenotypic correlation coefficient.

3.3.2 Estimates of direct and indirect effects of several traits on seed yield per plot at genotypic level

When we see genotypic path analysis the maximum positive direct effect (0.529) was contributed by harvest index followed by plant height (0.332), biomass per plot (0.177), seed yield per plant (0.139), oil content (0.136) and thousand seed weight (0.110). All these characters showed highly significant (P<0.001) and positive genetic association with seed yield per plot (Table 3). This indicates that traits can be used for indirect selection criteria to improve seed yield per plot, favorable direct effects of those traits on seed yield indicate that, with other variables kept constant, improvement of these characters will increase seed yield. The residual factor of 0.11 in the present study indicated that most of yield related traits were included and perfectly explained the total variation on seed yield per plot.

Table 3. Estimates of direct (bold-diagonal) and indirect effects (off-diagonal) of 9traits on seed yield per plot, at genotypic levels in Ethiopian Mustard accessions tested at Kulumsa during the main cropping season of year 2017.

Var	DF	DM	Hei	BM.P	TSW	HI	PB.PL	SY.PL	Oil.con	r_g
DF	**-0.029**	0.007	0.027	0.017	0.078	0.002	-0.203	0.090	0.043	0.045***
DM	-0.028	**0.007**	0.028	0.018	0.084	0.013	-0.189	0.096	0.055	0.094***
Hei	-0.015	0.004	**0.332**	0.060	0.085	0.041	-0.059	0.013	0.003	0.583***
BM.P	-0.006	0.001	0.038	**0.177**	0.084	0.095	0.008	0.037	0.343	0.896***
TSW	-0.021	0.005	0.040	0.062	**0.110**	0.092	0.303	0.065	-0.35	0.425***
HI	0.000	0.001	0.014	0.052	0.068	**0.529**	-0.03	0.123	0.142	0.916***
PB.PL	-0.018	0.004	0.010	-0.008	0.051	0.025	**-0.082**	0.107	0.189	-0.058***
SY.PL	-0.015	0.004	0.035	0.049	0.088	0.116	-0.052	**0.139**	0.229	0.565
Oil.con	-0.005	0.002	0.032	0.067	0.085	0.134	-0.677	0.147	**0.136**	0.313

R-Squared= 0.98, Residual =0.11

DF = Days to 50% flowering, DM= Days to maturity, Hei= Plant height in centimeter, BM.P= Biomass yield perplant,TSW= Thousand seed weight,HI= Harvesting index ,PB.PL =number of primary branch per plant SY.PL=Seed yield per plant, Oil.con= oil content in percentage, Var.= variables, r_g= genotypic correlation coefficient.

3.3.3 Estimates of direct and indirect effects of several traits on Oil yield per plot at phenotypic level

When we see the phenotypic path analysis days to flowering (0.454), seed yield per plot (0.428), secondary branches per plant (0.279), oil content (0.177) and thousand seed weight (0.146) showed positive phenotypic direct effect on oil yield. These traits were accompanied by positive and significant correlation coefficient with oil yield except secondary branch per plant and number of pod per plant (Table 4). The residual factor of 0.22 in the present study indicated that most of yield related traits were included.

Table 4. Estimates of direct (bold-diagonal) and indirect effects (off-diagonal) of nine traits on oil yield, at phenotypic levels in Ethiopian Mustard accessions tested at Kulumsa during the main cropping season of year 2017.

Var	DF	DM	Hei	SY.P	TSW	SB.PL	SD.PD	BM.PL	Oil.con	r_{ph}
DF	**0.454**	-0.181	-0.055	0.013	0.067	0.039	-0.542	0.294	-0.001	0.074
DM	0.429	**0.088**	-0.057	0.021	0.070	0.044	-0.768	0.307	-0.001	0.118
Hei	0.225	-0.098	**0.051**	0.074	0.067	0.038	0.029	0.205	-0.002	0.504***
SY.P	0.040	-0.027	-0.056	**0.428**	0.073	0.124	0.497	0.033	-0.004	0.966***
TSW	0.254	-0.111	-0.062	0.089	**0.146**	0.052	-0.086	0.151	-0.002	0.335***
SB.PL	0.063	-0.030	-0.015	0.065	0.022	**0.279**	-0.398	0.138	-0.206	-0.102

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SD.PD	0.317	-0.138	-0.056	0.065	0.077	0.109	**-0.292**	0.261	-0.002	0.378***
BM.PL	0.295	-0.130	-0.050	0.011	0.040	0.085	-0.168	**-0.13**	0.071	0.037
Oil.con	0.071	-0.037	-0.052	0.106	0.057	0.109	-0.084	0.072	**0.177**	0.329***

R –Squared = 0.95, Residual effect = 0.22

DF=days to flowering, DM= days to maturity, Hei=Plant height, SY.P= Seed yield per plot, TSW= Thousand seed weight, SB.PL=number of secondary branch per plant, SD.PD=number of seed per pod, BM.PL=Biomass per plant, Oil.con=oil content, r_{ph}= phenotypic correlation coefficient, Var=variables

3.3.4.Estimates of direct and indirect effects of several traits on Oil yield per plot at genotypic level

From the results the traits with higher positive genotypic direct effect on oil yield were number of secondary branch per plant (0.921) followed by thousand seed weight (0.732), seed yield per plot (0.551), days to flowering (0. 236), oil content (0.136), plant height (0.117), pod per plant (0.105) and harvest index (0.100). Similarly these traits have positive strong correlation with oil yield that showed these traits can be used as indirect selection criteria to improve oil yield. Seed per pod, pod per plant, oil content, plant height, days to maturity, biomass per plot, seed yield per plot, days to flowering, harvest index, biomass per plant and secondary branch per plant showed maximum positive genotypic indirect effect on oil yield *via* thousand seed weight.

On the other hand, negative genotypic direct effect was exerted on oil yield by biomass per plot and number of seed per pod, Table 5.

Table 5. Estimates of direct (bold-diagonal) and indirect effects (off-diagonal) of nine traits on oil yield, at genotypic levels in Ethiopian Mustard accessions tested at Kulumsa during the main cropping season of year 2017.

Var	DF	Hei	BM.P	SY.P	TSW	HI	SB.PL	SD.PD	Oil.con	r_g
DF	**0.236**	0.063	-0.096	-0.054	0.791	0.001	0.172	-1.036	-0.092	0.059
Hei	0.127	**0.117**	-0.34	-0.044	0.86	0.027	0.162	-0.046	-0.3	0.649***
BM.P	0.05	0.086	**-0.459**	-0.198	0.844	0.064	0.366	0.455	-0.401	0.889***
SY.P	0.021	0.062	-0.422	**0.551**	0.832	0.089	0.531	-0.303	-0.472	0.991***
TSW	0.169	-0.489	-0.35	-0.162	**0.732**	0.062	0.197	0.547	-0.376	0.447***
HI	0.003	0.032	0.463	-0.193	0.689	**0.1**	0.582	-0.45	-0.436	0.891***
SB.PL	0.044	0.021	-0.183	-0.124	0.236	0.063	**0.921**	-0.428	-1.032	-0.386***
SD.PD	0.185	0.07	-0.236	-0.119	0.989	0.059	0.515	**-0.764**	-0.254	0.561***
Oil.con	0.045	0.072	-0.38	-0.21	0.861	0.09	0.652	-0.39	**0.136**	0.396***

R –Squared =0.98, Residual effect =0.13

DF=days to flowering, DM= days to maturity, Hei=Plant height , BM.P= Biomass yield per plot , SY.P= Seed yield per plot ,TSW= Thousand seed weight, HI= Harvesting index, SB.PL=number of secondary branch per plant, PD.PL= Number of pod per plant, SD.PD=number of seed per pod, BM.PL=Biomass per plant, Oil.con=oil content, r_g= genotypic correlation coefficient, Var= variables

Generally, path coefficient analysis at both genotypic and phenotypic levels for different characters influencing oil yield of the Ethiopian mustard seed revealed that the trait seed yield per plot and thousand seed weight had the maximum direct positive effect. For this reason, the seed yield per plot and thousand seed weight were the most prominent traits to increase oil yield. Erena (2003) also reported the importance of 1000-seed weight as an indirect selection criterion for improving oil content in linseed.

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