Journal of Plant Sciences
2014; 2(2): 89-96
Published online April 20, 2014 (http://www.sciencepublishinggroup.com/j/jps)
doi: 10.11648/j.jps.20140202.12

Correlation and path coefficient analysis among yield component traits of Ethiopian mustard (*Brassica carinata* a. brun) at Adet, northwestern, Ethiopia

Tesfaye Walle Mekonnen[1, *], Adugna Wakjira[2], Tsige Genet[3]

[1]Department of Horticulture, Wolkite University, Wolkite, Ethiopia
[2]Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
[3]Department of Plant Science, College of Agriculture and Environmental Science, Bahir Dar University, Bahir Dar, Ethiopia

Email address:
tesfaye.walle@gmail.com (T. W. Mekonnen)

To cite this article:
Tesfaye Walle Mekonnen, Adugna Wakjira, Tsige Genet. Correlation and Path Coefficient Analysis among Yield Component Traits of Ethiopian Mustard (*Brassica Carinata* a. Brun) at Adet, Northwestern, Ethiopia. *Journal of Plant Sciences.* Vol. 2, No. 2, 2014, pp. 89-96. doi: 10.11648/j.jps.20140202.12

Abstract: The knowledge of Ethiopian mustard improvement for a targeted character can be achieved by indirect selection via other characters that are more heritable and easy to select. This selection strategy requires understanding the interrelationship of the characters among themselves and with the target character. The degree of association between two characters is measured by the correlation coefficient. Correlation is, therefore, helpful in determining the component characters of a complex trait, like yield. The present study was undertaken to determine nature of association of agronomic traits of thirty six Ethiopian mustard (*Brassica carinata*) genotypes which were evaluated Adet Agricultural Research Center, Ethiopia. The experiment was laid out in simple lattice design with two replications. The correlation and path coefficient analysis were conducted for 15 and five traits respectively at phenotypic and genotypic levels. Seed yield per plot was positively correlated with oil yield, biomass, plant height, days to maturity, grain-filling period, and secondary branches per plant and 1000seed weight at both genotypic and phenotypic levels. However, it was negatively correlated with days to flowering, number of pod per plant, number of seeds per pod and pod length at phenotypic level and, with primary branches per plant and harvest index at genotypic level, and oil content negatively correlated with at both levels. Phenotypic and genotypic path coefficient analysis of harvest index had exerted positive direct effect on seed yield. Grain filling period and harvest index had exerted positive direct effect on oil content at genotypic level. Day to maturity, grain filling period, secondary branches per plant, harvest index and seed yield seed yield per plot had exerted negative effect on oil content at phenotypic level.

Keywords: Correlation, Direct Effect, Ethiopian Mustard, Indirect Effect, Path Coefficient

1. Introduction

Ethiopian mustard *(Brassica carinata* A. Braun), gomenzer, is an oilseed crop that is well adapted to the highlands of Ethiopia. It is one of the six economically important species, *Brassica carinata*, commonly known as Ethiopian mustard, arose as a natural cross between *B. nigra* and *B. oleracea* in north-eastern Africa, in all probability in the Ethiopian plateau, where wild forms of *B. nigra* co-exist with cultivated forms of *B. oleracea* since ancient times (Tsunoda 1980).

In Ethiopia, it is cultivated as an oilseed crop science ancient time and third in its production next to noug (Guizotia abyssinca Casa) and Linseed (Linum ustatismum L). Ethiopian mustard oil, which is very often adulterated with oils from Niger seed (*Guizotia abyssinica*) or linseed (*Linum ustatissimum*), is the main commercial product (Nigussie, 2001).

Research on rapeseed (*Brassica napus L.and B.rapa L.*) and gomenzer started in early 1970's at the Institute of Agricultural Research, Addis Ababa (Getinet *et al*., 1996). In 1976 the B.carinata cultivars S-67,S-71 and S-115 and Hawassa area population were recommended for production by the Institute, and also yellow Dodolla and Holeta-1 recently released, specially holetta-1 released 2005.

The oil present in the embryo represent about 38-45% of the seed dry weight. The meal that is remaining after oil extraction is protein rich (30-45%) to be used either as high protein feed supplement provided that glucosinolate level is reduced or as organic fertilizer (Nigussie, 1990). The industrial value of its oil is indeed immense in: leather tanning, the manufacture of varnishes, diesel fuel, soap and lamps (Doweny, 1971; Bhan, 1979).

Therefore, Ethiopian mustard can be an alternate choice by improving the oil and protein contents of an already adapted high yield giving oilseed varieties (Nigussie, 2001). Furthermore, adding Ethiopian mustard to everyday meal as a vegetable is advantageous. This is because; it has special nutritional components like vitamins, minerals, trace elements, dietary fiber and protein. It also gives zest and flavor of diets (Zemede, 1992; Tsige *et al*., 2005b).

Selection based on the performance of grain yield, a polygenetically controlled complex character, is usually not very efficient (Singh and Singh 1973; Sastri, 1974). The identification and manipulation of characters contributing to grain yield is important as this increases breeding efficiency. Thus, giving emphasis to easily measurable characters with high heritability and having useful relationship with grain yield are of paramount importance to practice indirect selection for high yield (Falconer and Mackay, 1996).

Seed yield is the result of many characters, which are interdependent. Breeders always look for genetic variation among traits to select desirable types. Some of these characters are highly associated among themselves and with seed yield. The analysis of the relationship among these characters and their association with seed yield is essential to establish selection criteria (Singh *et al*., 1990).

Path coefficient analysis is basically a standardized partial regression coefficient and as such it measures the direct influence of one variable upon the other and permits the separation of correlation coefficients into the measures of direct and indirect effects (Singh and Narayanan, 1993).

In agriculture, plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield have used path analysis. One component is being the path coefficient or standardized partial regression coefficient that measures the direct effect of a predicator variable upon its response variable and the second component being the indirect effect(s) of a predictor variables (Kumar and Chauhan, 1979).

When more characters are involved in correlation study, it becomes difficult to ascertain the characters that really contribute to yield. Path coefficient analysis provides more effective means of separating direct and indirect factors; permitting a critical examination of the specific forces acting to produce a given correlation and measuring the relative importance of the causal factors. The path coefficient analysis under such situations helps to determine the direct contribution of these characters and their indirect contributions via other characters.

2. Material and Methods

2.1. Description of the Experimental Site

The field experiment was conducted in Adet Agricultural Research Center which is located at 37°29 ´E and 11°16 ´N in the Amhara National Regional State, Ethiopia. Adet is found 45km from Bahir Dar along the main road that runs from Bahir Dar to Addis Ababa through Mota. It is located at 2240 meter above sea level and receives an average annual rain fall of 1230 mm

2.2. Experimental Materials and Procedures

Thirty six genotypes of Ethiopian mustard including the standard check (Holetta-1and Yellow Dodolla) were used in the study. The genotypes were collected by Institute of Biodiversity and Conservation (IBC) from different geographical region of the country. The genotypes by origin are described in Table 1.

Table 1. *List of genotypes considered in the study and their origin.*

Code	Acc.No.	Area of collection	Altitude(m)	Code	Acc.No.	Area of collection	Altitude(m)	Code	Acc.No.	Area of collection	Altitude(m)
1	PGRC/E 20052	Shewa/AdisAlem	2540	13	PGRC/E208558	*	*	25	PGRC/E 21001	Shewa/Jibat	2350
2	" 20059	Shewa/Chaliya	1630	14	"208559	*	*	26	"21057	Gojjam	*
3	"20068	Shewa/Ambo	2010	15	"208560	*	*	27	"21069	Bale	2450
4	"20080	*	*	16	"208565	*		28	"21162	Bedele	1920
5	"20163	East Tigray	2300	17	"208570	*	*	29	"21163	Wellega/Jima Arjo	1820
6	"20168	Gondar	2400	18	"208571	*	*	30	"21266	Wollo/Borena	2570
7	"20169	*	*	19	"208572	*	*	31	"21278	Welo/Desezuriya	*
8	"208507	*	*	20	"208576	*	*	32	"21369	Jimma	1720
9	"208524	*	*	21	"208584	*	*	33	"213168	Kefa	*

Code	Acc.No.	Area of collection	Altitude(m)	Code	Acc.No.	Area of collection	Altitude(m)	Code	Acc.No.	Area of collection	Altitude(m)
10	"208528	*	*	22	"208585	Shewa/Boset	1600	34	YD	Released in 1986	
11	"208545	*	*	23	"208594	Hararghe	1750	35	Holetta-1	Released in 2005	
12	"208551	*	*	24	"208961	E. Wellega	2700	36	LC	®	2240

*donated by foundation for agricultural plant breedingS.V.P.P.O.Box117 Wageningen, The Netherlands. -: Information not available. Code: Genotype by code. Acc. No: Genotype accession number.

The experiment was carried out using 6x6 simple lattice designs with two replications. Each genotype was planted in a plot size of 9 m^2 (6 rows, 5 m row length x 1.8m width). The distances between plots, rows and replications were 0.6 m, 0.3 m and 2 m, respectively. The rates of fertilizer application was 40.3 kg/ha and 150 kg/ha Urea and DAP respectively. Fertilizer were applied in one times at sowing, the seed rate was 10 kg/ha. Seed and fertilizer were drilled uniformly by hand. Other cultural practices were followed as recommended for the area (Nigussie, 2001).

2.3. Data Collection

The following data were collected from the experiment both per plot and per plant basis.

The following data was recorded from the central four rows.

1. Days to flowering (DF): It was recorded as number of days from planting to a stage when 50% of the plants in a plot produced flower.
2. Days to maturity (DM): The number of days from the date of sowing to a stage when 90% of plants have reached their physiological maturity.
3. Biomass (BM/P): The total above ground biological yield in grams obtained from each plot at harvest.
4. Harvest index (HI/P): The fraction of dry seed in the above ground biological yield on a plot basis.
5. Thousand Seed weight (TSW): The weight in grams of 500 seeds sampled from each plot and multiplied by two.
6. Seed yield (SY/P): Seed yield per plot was measured in grams after moisture of the seed is adjusted to 7%.
7. Oil content (OC): The proportion of oil in the seed to the total oven dried seed weight as measured by Nuclear Magnetic Resonance Spectrometer (NMRS).
8. Oil yield (OY/P): The amount of oil in grams obtained by multiplying seed yield per plot by corresponding oil percentage.

The data for the following characters were recorded from ten randomly taken plants each experimental plot and the average were considered per plant basis.

1. Primary branches per plant (PB/PL): The average number of primary branches/plant.
2. Secondary branches per plant (SB/PL): The average number of secondary branches formed on primary branches/plant.
3. Number of pods per plant (PD/PL): The average number of pods counted from the same sample plants.
4. Silique (Pod) Length (SL): The main Silique from the ten sampled plants were measured in cm and averaged to represent the pod length.
5. Number of seeds per pod (SD/PD): The average number of seeds per pod obtained from two randomly sampled pods of each of the 10 randomly taken plants.
6. Plant height (PH): The height of plants in each plot measured in centimeters from the ground surface to the top of the main stem at maturity.

2.4. Statistical Analysis

Correlation coefficient, the degree of association between two characters, is measured *via* the correlation coefficient. Correlation is, therefore helpful in determining the component characters of a complex trait, like yield. Such studies are useful in revealing the magnitude and direction of these relationships between the different characters and grain yield as well as among the characters themselves (Falconer and Mackay, 1996). Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Miller *et al.*, (1958).

$rp_{xy} = \frac{Covp_{xy}}{\sqrt{Vp_x Vp_y}}$, Where: r_{pxy} = phenotypic correlation coefficient between character x and y, Cov_{pxy} = Phenotypic covariance between character x and y, Vp_x = Phenotypic variance for character x and Vp_y = Phenotypic variance for character y.

$rg_{xy} = \frac{Covg_{xy}}{\sqrt{Vg_x Vg_y}}$, Where: r_{gxy} = Genotypic correlation coefficient between character x and y, Cov_{gxy} = Genotypic covariance between character x and y, Vg_x= Genotypic variance for character x and Vg_y = Genotypic variance for character y.

The coefficients of correlations at phenotypic level were tested for their significance by comparing the value of correlation coefficient with tabulated r-value at g^{-2} degree of freedom. However, the coefficients of correlations at genotypic level were tested for their significance using the formula described by Robertson (1959) as indicated below:

Genotypic correlation coefficient was tested with the following formula suggested by Robertson (1959). $t = \frac{(rg_{xy})}{SEg_{xy}}$,the calculated 't' value was compared with the tabulated 't' value at g-2 degree of freedom at 5% level of significance, where, g = number of genotypes

$SEg_{xy} = \sqrt{\frac{(1-r^2 g_{xy})}{2h_x.h_y}}$,Where: SEg_{xy} = standard error of genotypic correlation coefficient between character x and y, h_x = Heritability value of character x, Hy = Heritability value of character y, r = Correlation coefficient and g_{xy} = value of character x and y

The calculated absolute t value was tested against the tabulated t-value at g-2 degree of freedom for both phenotypic and genotypic correlations. Environmental correlation coefficients was tested at [(g-1) (r-1)-1)] degree of freedom, where g is the number of genotypes.

Path coefficient analysis was conducted as suggested by Wright (1921) and worked out by Dewey and Lu (1959) using the phenotypic as well as genotypic correlation coefficients to determine the direct and indirect effects of yield components on seed yield based on the following relationship.

$R_{ij} = P_ij + \sum_{rik} P_{kj}$, Where: Rij = Mutual association between the independent character (i) and dependent character, grain yield (j) as measured by the correlation coefficients. P_{ij} = Components of direct effects of the independent character (i) as measured by the path coefficients and $\sum$ Rik p_{kj} = summation of components of indirect effect of a given independent character (i) on a given dependent character (j) via all other independent characters (k). The contribution of the remaining unknown factor was measured as the residual factor (P_R), which is calculated as:

$P_R = \sqrt{(1-\sum r_{ij} p_{ij})}$, where: i=any trait in the model, Y=dependant variable (grain yield) and r=correlation coefficient between any trait i and the dependant variable. Residual (R), is the square root of non determination; the magnitude of P_R indicates how best the causal factors account for the variability of the dependent factor (Singh and Chaudhary, 1999).

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 2. In the present study, seed yield per plot had positive and significant ($p<0.05$) genotypic associations with biomass per plot (r_g = 0.021), and grain filling period (r_g = 0.025). It also had highly significant ($p<0.01$) with the harvest index per plot (r_g =-0.577).

At phenotypic level, seed yield per plot were observed to have positive and highly significant ($p<0.01$) correlations with harvest index. Though low, 1000-seed weight and biomass per plant had positive associations with seed yield per plot, at phenotypic level. On the other hand, seed yield per plot was negatively correlated with number of seeds per pod (r_g = -0.102), days to flowering (r_g = -0.117), number of pods per plant (r_g = -0.057) and pod length (r_g = -0.113). But the other characters; plant height, primary branches per plant, secondary branches per plant, and days to maturity, biomass per plot and 1000-seed weight had positive phenotypic correlations with seed yield per plot. It also had significant ($p<0.05$) and negative phenotypic correlations with grain filling period (r_{ph} = -0.215).

Oil content showed only positive and significant ($p<0.05$) relative with biomass (r_g = 0.045) whereas, it revealed negative correlation with seed yield (r_g = -0.265), and day maturity (r_g = -0.231).

Biomass was positive and significant ($p<0.05$ association with day to maturity (r_g = 0.229) and length of pod (r_g = 0.09), while it was negatively and highly significantly correlated with harvest index (r_g = -0.577) and positively and highly significantly correlated with seed yield (r_g = 0.021). Harvest index revealed negative and significant correlation with length of (r_g = -0.128), while length had positive significant (r_g = 0.28) with number of pod/plant.

Secondary branches per plant had negative significant (r_g = 0.05) with number of seed per and primary branches per plant, whereas number of pod per plant showed positive highly significant correlation with day to maturity (r_g = 0.275). Grain filling period had revealed positive highly association with day to maturity (r_g = 0.663), while it had negative correlation with day to flowering (r_g = - 0.745).

At phenotypic level, seed yield had positively significant (r_{ph} = 0.215) with grain filling period, while it had negative correlation with harvest index (r_{ph} = 0.551).it also oil yield (r_{ph} = 0.926) had strongly correlation with seed yield. Day to maturity and number of pod per plant were negatively and significant ($p<0.05$) correlations with oil content.

Biomass had negative significant ($p<0.01$) with harvest index, whereas, day to maturity and secondary branches/plant correlations with biomass. Harvest index revealed positively and highly significant correlation with secondary branches per plant (r_{ph} = 0.317). Grain filling period had revealed strong positively highly significant association with day to maturity (r_{ph} = 0.656), while it had strong negative highly significant correlation with day to flowering (r_{ph} = -0.737)

Generally, seed yield per plot was positively correlated with oil yield per plot, biomass per plot, plant height, days to maturity, grain-filling period, and secondary branches per plant and 1000-seed weight at both genotypic and phenotypic levels. However, it was negatively correlated with days to flowering, number of pod per plant, number of seeds per pod and pod length at phenotypic level and, with primary branches per plant and harvest index at genotypic level, and oil content negatively correlated with at both level. Hence, making simultaneous increase for these characters with seed yield per plot is difficult. The present result was in line with that reported by Nigussie (1990) with regard to the correlations between seed yield per plot and plant height and primary branches per plant.

3.2. Correlation among Yield Related Traits

Many interesting associations were observed among yield related traits (Table 7). Harvest index per plot was

positively correlated with plant height (r_g = 0.079 and r_{ph} = 0.062), grain filling period (r_g = 0.079 and r_{ph} = 0.04), primary branches per plant (r_g = 0.074 and r_{ph} = 0.031), secondary branches per plant (r_g = 0.23 and r_{ph} = 0.317), oil yield per plot (r_g = 0.459) and r_{ph} = 0.465). However, its phenotypic and genotypic correlation with days to flowering (r_g = -0.167 and r_{ph} = -0.139), days to maturity (r_g = -0.069 and r_{ph} = -0.097), number of pods per plant (rg = -0.154 and r_{ph} = -0.2), pod length (r_g = -0.128 and r_{ph} = -0.147), number of seeds per pod(r_g = -0.109 and r_{ph} = -0.149) and 1000-seed weight, (r_g = -0.029 and r_{ph} = -0.005) was negative and non-significant except pod length at phenotypic level. This implies increasing these characters will lead to decrease in harvest index.

Biomass per plot was positively correlated with days to flowering (rg = 0.171 and r_{ph} = 0.181),days to maturity (r_g = 0.229 and r_{ph} = 0.225), plant height, (r_g = 0.008 and r_{ph} = 0.0084), grain filling period (r_g = 0.025 and r_{ph} = 0.015), primary branches per plant(r_g = 0.185 and r_{ph} = 0.179), number of seeds per pod (rg = 0.043 and r_{ph} = 0.035), number of pods per plant (r_g = 0.147 and r_{ph} = 0.141),pod length (r_g = 0.09 and r_{ph} = 0.087) and 1000-seed weight, (r_g = 0.015 and r_{ph} = 0.025). It also at phenotypic and genotypic correlation with days to maturity (r_g = 0.229 and r_{ph} = 0.225) was also positive and significant ($p<0.05$).

Primary branches per plant was positively correlated with grain filling period (r_g = 0.011 and r_{ph} = 0.008), plant height (r_g = 0.149 and r_{ph} = 0.114), number of seeds per pod (r_g = 0.158 and r_{ph} = 0.127), biomass per plot (r_g =0.185 and r_{ph} = 0.179), 1000-seed weight (r_g = 0.137 and r_{ph} = 0.166) and seed yield per plant (r_g = 0.185 and r_{ph} = 0.054). On the other hand, primary branches had negative correlation with days to maturity (r_g = -0.002 and r_{ph} = -0.029) secondary branches per plant (r_g = -0.234 and r_{ph} = -0.181), pod length (r_g = -0.106 and r_{ph} = -0.125) and oil yield per plot (r_g = -0.136and r_{ph} = -0.144). Similarly, secondary branches per plant had phenotypic and genotypic correlation with day of maturity, grain filling period, plant height, number seed per pod, primary branch per plant, pod length and oil yield per plot. Nevertheless, most of the character depicted significant and negative association with secondary branches per plant at genotypic level.

The genotypic and phenotypic correlations between days to flowering and days to maturity were though low in magnitude, positive (r_g = 0.006 and r_{ph} = 0.026), genotypes of late flowering were also early in maturity. Days to flowering and maturity had also negative correlation with harvest index. Plant height, number of pod per plant, number of seed per pod, pod length and biomass had positively correlation with days to flowering and maturity.

Plant height had positive correlation with oil content (r_g = 0.017 and r_{ph} = 0.047). This implies, tall plants tend to produce more oil. The number of seed per plant, secondary branches per plant, pod length, 1000-seed weight and oil yield per plot negatively correlations of genotypic and phenotypic at both levels.

Among the characters considered in the present study, only plant height was positively correlated with number of pod per plant (r_g = 0.077 and r_{ph} = 0.108), biomass (r_g = 0.008 and r_{ph} = 0.0084) and oil content (r_g = 0.017 and r_{ph} = 0.047) at both levels. The correlation between 1000-seed weight and oil content was also positive, though significant ($p<0.05$) and non-significant at genotypic and phenotypic level respectively. The genotypic and phenotypic correlation between oil content and oil yield per plot was negative, but highly significant ($p<0.01$).

Oil yield per plot was positively correlated with days to maturity (r_g = 0.05 and r_{ph} = 0.047), grain filling period (r_g = 0.198 and r_{ph} =0.198), secondary branches per plant r_g = 0.116 and r_{ph} =0.13), harvest index per plot (r_g = 0.459 and r_{ph} = 0.465) and seed yield per plot (r_g = 0.763 and r_{ph} = 0.926).However, oil yield per plot was negatively correlated with characters such as days to flowering (r_g = -0.22 and r_{ph} = -0.219), Plant height(r_g = -0.031 and r_{ph} = -0.036), number of pod per plant(r_g -0.126 and r_{ph} = -0.087), biomass (r_g = -0.077 and r_{ph} = -0.078), 1000-seed weight (r_g = -0.013 and r_{ph} = -0.01) primary branches per plant (r_g = -0.136 and r_{ph} = -0.144) and number of seeds per pod (r_g = -0.091 and r_{ph} = -0.097) oil content (r_g = -0.352 and r_{ph} = -0.351).

Table 2. *Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among 15 characters in 36 Ethiopian.*

	DF	MD	GFP	PH	PBP	SBP	LP	NPP
DF		-0.023	-0.705**	-0.094	0.274*	-0.09	0.074	-0.135
MD	-0.11		0.722*	0.063	-0.193	0.134	-0.26*	0.396
GFP	-0.755**	0.733**		0.103	-0.324	0.161	-0.245	0.386
PH	-0.074	0.115	0.12		-0.018**	0.212*	-0.171	-0.034
PBP	0.28**	-0.208*	-0.326**	-0.018		--0.018	-0.024	-0.014
SBP	-0.098	0.133	-0.326	0.217	-0.04*		-0.273*	0.098
LP	0.105	-0.224*	-0.23*	-0.19	-0.024	-0.272*		-0.175
NPP	-0.197	0.333**	0.366**	-0.006	-0.014	0.093	-0.145	
NSP	0.162	-0.075	-0.171	0.059	-0.004	-0.148	0.231*	-0.293**
BM	0.316**	0.02	-0.208*	-0.026	0.163	-0.115	0.066	-0.196
HI	-0.431*	0.02	0.319**	-0.11	-0.201*	0.126	-0.083	0.163
TSW	0.116	-0.081	-0.141	0.105	0.029	-0.134	0.228*	0.163
SYh	0.007	-0.003	0.005	-0.133	0.066	-0.092	0.086	0.105
SY	-0.086	0.028	0.081	-0.242*	-0.016	-0.094	0.113	0.046
OC	-0.086	0.028	0.002	0.121	-0.033	-0.02	0.289**	-0.278**
OY	-0.004	-0.017	0	-0.1	0.075	-0.091	0.148	0.038

Table 2. *continue.*

	NSP	BM	HI	TSW	SYh	SY	OC	OY
DF	0.157	0.301**	-0.447**	0.076	0.041	-0.138	-0.09	0.029
MD	-0.074**	0.002	-0.039	-0.144	0.064	-0.089	-0.079	0.049
GFP	-0.171**	-0.212*	0.292**	0.292	0.029	0.037	-0.002	0.022
PH	0.06	-0.021	-0.092	0.123	-0.149	-0.198*	0.123	-0.116
PBP	-0.004	0.163	-0.198*	0.029	0.065	-0.014	-0.032	0.074
SBP	-0.148	-0.116	0.12	-0.137	-0.086	-0.099	-0.021	-0.084
LP	0.23*	0.071	-0.061	0.248*	0.06	0.149	0.29**	0.121
NPP	-0.286**	-0.2*	0.118	-0.062	0.144	-0.033	-0.276**	0.079
NSP		0.319**	-0.234*	0.051	0.071	0.002	0.137	0.118
BM	0.318**		-0.67**	0.211*	0.298	0.298**	-0.025	0.133
HI	-0.238*	-0.685**		0.267*	0.209*	0.401**	-0.169	0.152
TSW	0.05	0.207*	-0.302**		0.00	0.059	0.248*	0.055
SYh	0.074	0.14	0.241*	0.032		0.392**	0.073	0.975**
SY	0.00	0.299**	0.378**	0.005	0.47**		-0.284**	0.319**
OC	0.137	-0.027	-0.175	0.247*	0.079	-0.306**		0.276**
OY	0.121	0.142	0.181	0.089	974**	0.39**	0.285**	

*, ** = significant at 0.05 and 0.01 probability level

DF = Days to flowering, DM = Days to maturity, GFP =Grain filling period, PH = Plant height, PBP = Number of primary branches per plant, SBP = Number of secondary branches per plant, LP= Length of pod, NPP = Number of pods per plant, NSP =Number of seeds per pod, BM = Biomass SY(gm) = Seed yield per plot, SYh = Seed yield per hectare, HI = Harvest index per plot, TSW =Thousand seed weight, OC = Oil content and OY = Oil yield per plot.

3.3. Path Coefficient Analysis for Seed Yield per Plot

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 of independent variables on dependent one. Path coefficient analysis provides important benefits in Ethiopian mustard breeding studies in the future. Selection criteria will contribute to selection based on direct and indirect effects. Path coefficient analyses also have been used to evaluate selection criteria in several crops. This technique is useful in determining the direct influence of one variable on another and separates the correlation coefficient into its components of direct and indirect effects (Rodriguez *et al*., 2001).

Seed yield and oil content were considered as resultant (dependable) variable while the rest of the variables that were positively correlated with the causal (independent) variables. Indirect selection through yield components has been proved more effective (Adefris, 2005). This selection criterion takes into account the information on interrelationship among agronomic characters, their relationship with seed yield as well as their direct influence on grain yield.

3.4. Genotypic Path Analysis of Seed Yield with Other Characters

Harvest index followed by days to maturity and secondary branches per plant had exerted positive direct effect on seed yield. However, oil content had showed negative direct effect on seed yield. Singh and Singh (1997) and Sheikh *et al.* (1999) reported similar results in that days to maturity and secondary branches per plant had positive direct effect on seed yield toria (*Brassica campestris* L. var. Toria).

Table 3. *Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level for five characters on seed yield per plot in Ethiopian mustard genotypes.*

	DM	GFP	SBP	HI	OC	r_g
DM	0.167	0.0325	-0.0061	-0.036	0.0333	0.229
GFP	0.111	0.049	-0.007	0.0412	0.0246	0.025
SBP	-0.0159	-0.0055	0.064	0.182	-0.0602	-0.229
HI	-0.012	0.004	0.015	0.521	0.022	-0.577
OC	-0.0386	-0.0008	-0.0007	-0.01	-0.171	0.045

Residual = 0.36

DM = Days to maturity, GFP =Grain filling period, SBP = Number of secondary branches per plant, HI = Harvest index per plot, OC = Oil content and r_g = genotypic correlation with seed yield.

Harvest index followed by days to maturity and secondary branches per plant, which showed positive genotypic correlation with seed yield, had exerted considerable direct effect on seed yield (Table 3). Secondary branches per plant, grain-filling period contributed to seed yield mainly via their highest and positive indirect effect with harvest index. The residual (0.36) indicates that characters, which are included in the genotypic path analysis, explained 64% of the total variation in seed yield. Singh & Chaudhary (1999) reported that the residual value is small (for instance, nearly zero) the dependent character considered (seed yield) is fully explained by the variability in the independent characters.

3.5. Phenotypic Path Analysis of Seed Yield with Other Characters

Days to maturity, harvest index and secondary branches had exerted positive direct effect on seed yield at phenotypic level. However, grain filling period and oil content had negative direct effect on seed yield. Gangapur

(2008) reported similar results in that days to maturity, harvest index and secondary branches had direct effect on seed yield.

Table 4. *Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level for five characters on seed yield per plot in Ethiopian mustard genotypes.*

	DM	GFP	SBP	HI	OC	r_p
DM	0.308	-0.018	-0.007	-0.515	0.021	-0.216
GFP	0.202	-0.027	-0.006	0.021	0.014	-0.144
SBP	-0.019	0.001	0.11	0.168	0.017	-0.0172
HI	-0.299	-0.001	0.035	0.531	0.01	-0.097
OC	-0.067	0.004	-0.019	-0.052	-0.099	-0.262

Residual = 0.377

DM = Days to maturity, GFP =Grain filling period, SBP = Number of secondary branches per plant, HI = Harvest index, OC = Oil content and r_p= phenotypic correlation with seed yield.

Secondary branches had exerted positive direct effect on seed yield via harvest index at phenotypic level. This correlation was occurred due to their high and favorable indirect effects via harvest index (Table 4). The residual (0.377) indicates that characters, which are included in the genotypic path analysis, explained 62.3% of the total variation in seed yield. Singh & Chaudhary (1999) reported that the residual value is small (for instance, nearly zero) the dependent character considered (seed yield) is fully explained by the variability in the independent characters.

3.6. Genotypic Path Analysis of Oil Content with Other Characters

Grain filling period and harvest index had exerted positive direct effect on oil content at genotypic level. However, day to maturity, secondary branches/ and seed yield had negative direct effect on oil content. Abebe *et al*. (2006) reported similar results harvest index had direct effect on oil content. However, secondary branches/plant and seed yield plot had exerted negative direct effect on oil content (Table 5).

Table 5. *Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level for five characters on oil content in Ethiopian mustard genotypes.*

	DM	GFP	SBP	HI	SY	r_g
DM	-0.479	0.101	0.01	-0.001	-0.027	-0.231
GFP	-0.314	0.154	0.009	0.000	-0.031	-0.71
SBP	0.029	-0.008	-0.161	0.001	-0.028	-0.111
HI	0.067	0.006	-0.051	0.004	-0.078	-0.127
SY	-0.09	0.033	-0.032	0.002	-0.142	-0.263

Residual = 0.08

DM = Days to maturity, GFP =Grain filling period, SBP = Number of secondary branches per plant, HI = Harvest index per plot, OC = Oil content and r_g= genotypic correlation with oil content.

Day to maturity had exerted positive indirect effect on oil content via harvest index at genotypic level. The residual (0.08) indicates that characters, which are included in the genotypic path analysis, explained 92% of the total variation in oil content

3.7. Phenotypic Path Analysis of Oil Content with Other Characters

Day to maturity, grain filling period, secondary branches per plant, harvest index and seed yield seed yield/plot had exerted negative effect on oil content at phenotypic level. According to Abebe *et al* (2006), day to maturity and seed yield had exerted negative effect on oil content at phenotypic level.

Table 6. *Estimates of direct (bold diagonal) and indirect effect (off diagonal) at phenotypic level for five characters on oil content in Ethiopian mustard genotypes.*

	DM	GFP	SBP	HI	SY	r_p
DM	-0.0197	-0.004	0.009	0.0004	-0.039	-0.0216
GFP	-0.131	-0.006	0.0104	-0.0005	-0.045	-0.144
SBP	0.019	0.0001	-0.092	-0.0014	-0.037	-0.172
HI	0.0136	-0.0005	-0.0212	-0.006	-0.1127	-0.097
SY	-0.0374	-0.0013	-0.012	-0.0033	-0.206	-0.262

Residual = 0.112

DM = Days to maturity, GFP =Grain filling period, SBP = Number of secondary branches per plant, HI = Harvest index, OC = Oil content and r_p= phenotypic correlation with oil content.

The residual (0.112) indicates that characters, which are included in the genotypic path analysis, explained 88.8% of the total variation in oil content. In this study, day to maturity negatively direct effect with oil content, therefore, based on this result the earlier maturing genotypes had high oil content relatively than late maturing genotypes.

Acknowledgement

The author would like to acknowledge my elder brother Tsedalu Walle and beloved mother Mulu Geletie for their unreserved cooperation and encouragement during the entire study period and Adet Agricultural Research Center for financing the practical field expense of this study.

References

[1] Abebe Delesa, Adugna Wakjira and Ketema Belete, 2006. Genetic variability and Association among seed yield and Yield related traits in Ethiopian mustard (*Brassica carinata* A. Braun) at Kulumsa, Arsi .An M.Sc. Dissertation Presented to the School of Graduate Studies of Alemaya University. 90pp.

[2] Adefris Teklewold., 2005. Diversity study based on quality traits, RAPD Markers, and Investigations of Heterosis in Ethiopian Mustard. Doctoral Dissertation.George-Augest University of Gottingen, Germany. 160 pp.

[3] Bhan,S. ,1979. Effect of soil moisture and nitrogen on mustard under Gangetic alluvium of Uttarpradesh. Ind. J. Agron. 24: 180-186.

[4] Dewey, D.R. and K.H. LU., 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal. 51: 515-518.*

[5] Doweny, R. K., 1971. Agricultural and genetic potential of Cruciferous oilseed crops. Ame. Oil. Chem. Soc. J. 48: 728-732.

[6] Gangapur, D. R., 2008. Studies on Genetic Variability in the Indian mustard (*Brassica juncea* L. Czern and Coss) Germplasm and its Suitability to Northern Karnataka . Dharwad University of Agricultural Sciences (Indian), pp.50-54.

[7] Getinet Alemaw., G. Rakow and R. K. Doweny., 1996. Agronomic performance and seed quality of Ethiopian mustard in Saskatchewan. Can. J. Plant sci. 76: 387-392.

[8] Kumar, S. and B.P.S. Chauhan., 1979. Association analysis in the segregating populations of linseed. *Indian. J. Genet. 39: 506-510.*

[9] Falconer, D.S. and Mackay, F.C., 1996. *Introduction to quantitative genetics.* (4thEdition). Long man, New York,USA. Pp464.

[10] Miller, P.A., C. Williams, H.F. Robinson and R.E. Comstock., 1958. Estimates of genotypic and Environmental variances and co-variances in upland cotton and their implications in selection. *Agronomy Journal. 50:126 –131*.

[11] Nigussie Alemayehu, 1990. Yield and yield components of Ethiopian mustard and rapeseed as affected by some agronomic practices. An MSc. Dissertation Presented to the School of Graduate Studies of Alemaya University. 112p.

[12] Nigussie Alemayehu., 2001. Germplasm diversity and Genetics of Quality and Agronomic Traits in Ethiopian Mustard (Brassica carinata A. Braun). Ph. D. Dissertation, George-August University of Gottingen, Germany.

[13] Robertson ,A.,1959.The sampling variance of the genetic correlation coefficient. Biometrics 15:469-485.

[14] Sastri, A.B., 1974. Path analysis of yield components in Tobacco. *Indian. J. Genet. 34: 57-58.*

[15] Sheikh, F.A., A.G. Rather and S.A. Wani, 1999. Genetic variability and inter-relationship in toria (*Brassica campestris* L. var. Toria). Advances in Plant Sciences, 12(1): 139-143.

[16] Singh, K.B., Geletu, B. and Malhotra, R.S., 1990. Association of some characters with seed yield in check pea collections. Euphaytica. 49:83–88.

[17] Singh, R. K. and Chaudhary, B.D., 1999. *Biometrical methods in quantitative genetics analysis*. Kalyani publishers, New Delhi. Pp 73.

[18] Singh, P. and Narayanan, S.S., 1993. *Biometrical techniques in plant breeding*. Kayani Publishers, New Delhi.

[19] Singh, M. and G. Singh, 1997. Correlation and path analysis in Indian mustard (*Brassica juncea* L.) under mid hills of Sikkim. Journal of Hill Research (India)., 10(1): 10-12.

[20] Singh, T.P. and K.B. Singh, 1973. Association of grain yield and its components in segregating populations of green gram. *Indian J. Genet. 33:112-117.*

[21] Tsige Genet. Labuschagne, M.T. and Hugo, A., 2005b. Genetic relationships among Ethiopian Mustard genotypes on oil content and Fatty acid composition. *Afri. J. of Biotech. 4: 1256 - 1268.*

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

[23] Wright, S., 1921. Correlations and causations. *J. Agri. Res. 20:557-587.*

[24] Zemede Asfaw., 1992. Conservation and use of traditional vegetables in Ethiopia. http:www. Bioversity international