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Correlation and Path Coefficient Analysis of Sunflower Genotypes for Economically Important Agronomic Characters

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Abstract

Sunflower genotypes, 220, were evaluated for various traits under field conditions to estimate correlation coefficient and path analysis. The objectives of the study were to determine correlation and traits association among economically important agronomic traits of sunflower genotypes. The Analysis of variance showed highly significant ($p<0.01$) differences among the tested genotypes. Highly significant and positive phenotypic correlation was observed between seed yield per hectare and all studied traits except stand percentage, hundred seed weight and oil content. Highly Significant and positive genotypic correlation was observed between seed yield per hectare and all studied traits. Phenotypically, seed yield per hectare was positive and directly affected by days to flowering, leaf number per plant, stand percentage, seed yield per head and oil yield but negative effects were recorded by days to maturity, plant height, stem diameter, head diameter, petiole length, hundred seed weight, seed filling percentage and seed number per plant. Genotypic path coefficient analysis also showed that there was positive direct effect on seed yield per hectare by days to flowering, stem and head diameter, leaf number per plant, stand percentage, seed yield per head and oil yield. Improvement of sunflower genotypes having traits namely early to medium maturing, big-headed & tough stem, seed yield & number per head, medium plant height, hundred seed weight, oil content, seed filling percentage should be emphasized to obtain genotypes with high seed yield and oil content for the farming society and investors as well.

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Sunflower, phenotypic, Genotypic, Correlation, path analysis.

Introduction

Sunflower (*Helianthus annuus* L., 2n=34) is an important oilseed crop. It is an annual crop that stands out for its production of high-quality oil. Its oil is highly used in the human diet because of its high level of unsaturated fatty acids, lack of linolenic acid and bland flavor (Putman *et al.,* 1990). Sunflower can contribute a big share in improving local edible oil production due to its short interval for maturity, high oil contents, better fitting in the cropping pattern, tolerance to drought and its high yield potential. The seed of sunflower contains 40% oil though some high yielding varieties produce up to 50% oil content (Skoric and Marinkovic, 1986) with good adaptability under different agro-ecological conditions. High level of unsaturated fatty acids, light color, and high smoke point make sunflower oil more attractive (Reddy, 2006). It has the sturdy oxidative stability and alpha-tocopheroles as a source of vitamin E which is anti-inflammatory agent (Kaya *et al.,* 2009). The productivity, production and area coverage of sunflower in Ethiopia is about 1.2 metric tons per hectare, 9576.9

metric ton and 7967 ha, respectively which is lower than the world average, 2.09 metric tons (CSA, 2019). This low productivity problem is attached to certain yield constraints of biotic and abiotic stresses and sub optimal agronomic practices (Tesfaye *et al.*, 2000). To overcome this low yield potential, presence of basic information on genetic variability is important to plan breeding strategy and make effective selection for desirable traits directly or indirectly. Thus, during selection for yield more consideration has to be given to those attributes with low environmental variability. Yield being a complex character is collectively influenced by various component traits which are polygenically inherited. Correlations are used to help in selection, especially when there is a trait of interest that has low heritability or is difficult to measure. According to Santos & Vencovsky (1986), correlations are also useful for simultaneous selection efficiency. For an efficient selection, it is need to estimate the components of genetic and phenotypic variance, because through the relationship between the variances, it is possible to estimate the accuracy and heritability. Such estimates contribute to the effectiveness of the inferences of average genotypic from phenotypic (Resende & Duarte, 2007). Basically, correlation analysis demonstrates the association of economically important traits with seed yield. Path coefficient analysis facilitates the partitioning of correlation coefficients into its direct and indirect effects of economic traits on seed yield. So, the coefficients of variation expressed at phenotypic and genotypic levels are used to compare the variability observed among different characters. A wide range of variation has been reported for seed yield and seed number (Zain, 2015) and other important components of yield (Virupakshappa and Sindagi, 1988). Therefore, improvement for yield cannot be achieved through simple phenotypic selection because of its polygenic nature and low heritability estimates.

Understanding association of traits and variability among genotypes helps the breeders formulating effective selection procedure and identify traits which may help for indirect selection of grain and oil yield. Main challenge in sunflower breeding is getting uniform morphological characters in terms of height and head characters are the major once. This is mainly due to cross pollination and limited number of germplasms in the research system. So far, there are limited reports on studies done to assess the level of correlation and associations among economically important traits in sunflower in Ethiopia except few studies made involving limited number of genotypes. Realizing the importance of the sunflower for food security and the existing information gap; the present study was carried out with to describe Correlation and Path Coefficient Analysis of Sunflower Genotypes for Economically Important Agronomic Characters.

Materials and Methods

Study area Description

Field experiment was conducted at Holeta Agricultural Research Center, Oromia, Central Ethiopia in 2020/21 main cropping season. It is located at 9º 00’ N latitude and 38º30’ E longitude with an altitude of 2400 m.a.s.l. The mean annual rainfall was 1144 mm and temperature ranges from 6°C-22°C with rainy season from June to September. The dominant soil type is well drained Red Nitosols and characterized by soil pH 5.2-6.0 and 0.16% Nitrogen content with low organic carbon content 1.18% (Mekonen and Tilahun, 2019).

Experimental Design and Field Management

The experiment was arranged in 11x20 *Alpha lattice* design with two replications. Each genotype was planted in single rows having 0.25 m spacing between plants, 0.75m spacing between rows, and 1.5 m row length. Fertilizer was applied at the rate of 23/23 kg NP_2O_5 kg per hectare. Other agronomic and management practices was applied uniformly as per the recommendation for the area. Yield and yield related data were collected from all plants. Grain yields were adjusted to moisture content 7% using grain moisture analysis.

Data collection

The following data were collected both on plant bases and/or plot bases for quantitative traits by using descriptors of International Board for Plant Genetic Resources (IBPGR, 1985) for sunflower. Number of Leaves per plant (LNPP), Plant height [Ph, (cm)], Head Diameter [HD (cm)], Petiole length [PL (cm)], Days to 50% flowering [DF (days)], Days to maturity [DM(days)], Stem Diameter [SD (cm)], Seed filling percentage [SFP (%)] Seed filling percent =(number of filled seeds/total number of filled + unfilled seeds)x100, Hundred Seed weight [HSWT (g)], Seed yield per plant head [SYPPH (g)], Seed yield per hectare [SYPH (kg)], Oil yield [OYPH (kg/ha)], Oil yield in kg/ha was calculated by using the formula of Habib and Mehdi (2002). Oil yield kg/ha = [(seed yield (kg/ha) x oil content (%)]/100, Stand percentage [stand (%), seed number per plant head (SNPP).

Oil content [OC (%)]-the seed oil content was determined through non-destructive method by utilizing nuclear magnetic resonance (NMR) technique in the laboratory of oil seeds research at HARC. Sample of 25g of seeds were dried in an oven for 3hr at 78℃ and cooled for 30 minutes. Then oil contents of seeds were measured using nuclear magnetic resonance machine from 22 g working sample.

Data Analysis

To estimate phenotypic and genotypic correlation coefficients, covariance analysis between all pairs of characters were calculated by the following formula (Allard, 1960 & Falconer, 1989):

$$\sigma_{QXY} = \frac{MSP_g - MSP_e}{r}$$

$$\sigma_{pxy} = \sigma_{gxy} + \frac{\sigma_{exy}}{r}$$

Where, σ_{QXY} = genotypic covariance between traits x and y; σ_{pxy} = phenotypic covariance between traits x and y; MSP_g = Genotypic mean sum product of traits x and y; MSP_e = Environmental mean sum product of traits x and y; r = Number of replications

Estimation of Correlations and Path coefficient analysis

Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Singh and Chaudary (1999).

Phenotypic correlation coefficient:

$$rp_{xy} = \frac{\sigma_{pxy}}{\sqrt{\sigma^2{}_{px} \times \sigma^2{}_{py}}}$$

Genotypic correlation coefficient:

$$rg_{xy} = \frac{\sigma_{gxy}}{\sqrt{\sigma^2{}_{gx} \times \sigma^2{}_{gy}}}$$

Where, rp_{xy} = phenotypic correlation coefficient between character x and y

rg_{xy} = Genotypic correlation coefficients between character x and y

$\sigma^2{}_{px}$ = Phenotypic variance for character x

$\sigma^2{}_{py}$ = Genotypic variance for character y

The direct and indirect effects of the independent traits on grain yield were estimated by formula described by Dewey and Lu (1959) and analyzed by using statistical package developed by Wright (1921). Therefore, the formula could be written as:

$$r_{ij} = p_{ij} + \sum r_{ik} p_{kj}$$

Where, r_{ij}= Mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficient.; p_{ij+} = Component of direct effects of the independent character (i) and dependent (j) as measured by the path coefficient and,

$\sum r_{ik}\, p_{kj}$ = Summation of components of indirect effect of a given independent character (i) on the given dependent character (j) via all other independent character (k).

Results and Discussion

Correlation of Seed Yield with Economically Important Agronomic Characters

Correlation of seed yield per hectare and yield related characters are presented in Table 1. The understanding of association among different trait is essential to speculate selection criteria. Many fascinating associations were observed among yield related traits.

Nearly for most of the studied characters genotypic correlation coefficient values were greater than their corresponding phenotypic correlation coefficient values, depicting that inherent association of the studied characters.

Generally, both positive and negative phenotypic as well as genotypic correlations were observed between most of the characters studied. Seed yield per hectare showed highly significant and positive genotypic correlation with days to flowering (0.296), days to maturity (0.328), plant height (0.806), stem diameter (1.1), head diameter (0.297), Leaf number per plant (0.807), petiole length (0.888), seed filling percentage (0.250), seed number per plant (0.531) and yield per head (0.599). Stand percentage and hundred seed weight showed non-significant genotypic correlation with seed yield per hectare.

Highly Significant and negative genotypic and phenotypic correlation was observed between seed yield per hectare and oil content. Highly significant and positive phenotypic correlation of seed yield per hectare with days to flowering (0.291), days to maturity (0.324), plant height (0.510), stem diameter (0.452), head diameter (0.192), leaf number per plant (0.287), petiole Length (0.394), yield per head (0.594), Oil yield (0.915), seed filling percentage (0.104), seed number per plant (0.526).

Based on this finding, the high yielding sunflower genotype is the genotype with a big headed to hold a greater number of heavy filled seeds. This indicated that correlation of these traits with seed yield could be fruit fully utilized to enhance the yield potential of Sunflower.

This result is in accordance with Doddamani *et al.,* (1997) and Dasgustu (2002) who reported significant and positive correlation of hundred seed weight and plant height with seed yield and also agreement with Tahir *et al.,* (2002) who reported the positive significant correlation of seed filling percentage, head diameter and hundred seed weight with seed yield.

The genotypic and phenotypic significant positive association of seed yield with head diameter, oil content, hundred seed weight, number of seeds per head, days to maturity and plant height were reported by Prasad *et al.,* (2006). The negative phenotypic association of days to fifty percent flowering with seed yield was also reported by Arshad *et al.,* (2007).

Presence of positive association of seed yield with plant height, hundred seed weight and oil content were also reported by Kaya *et al.,* (2008). Nasim *et al.,* (2016). The authors reported the presence of significant association of seed yield with head diameter, plant height, hundred seed weight and oil content. Also, Abu (2019) reported similar results on seed yield per hectare and petiole length, yield per plant, number of seed per plant, head diameter, plant height, seed filling percentage and hundred seed weight.

Character Association Among Economically Important Agronomic Characters

Phenotypic Correlation

Phenotypic correlation coefficients among yield related traits are presented in (Table 1). Highly significant (P<0.01) and positive phenotypic correlation was observed among days to flowering, days to maturity, plant height, stem diameter, head diameter, seed filling percentage, hundred seed weight, Leaf number per plant, petiole length, stand percentage, seed number per plant, Oil yield per hectare and yield per head. Highly significant and negative phenotypic correlation was observed between oil content and days to 50% flowering, days to maturity, plant height, stem diameter.

Non-significant phenotypic correlation was observed between oil content and head diameter, leaf number per plant, petiole length, stand percentage, yield per head, seed filling percentage, hundred seed weight and seed number per plant. And also, between days to maturity and seed filling percentage, hundred seed weight and head diameter as well.

Head diameter and seed filling percentage, leaf number per plant and seed filling percentage, hundred seed weight, and stand percent and seed filling percentage showed non-significant phenotypic correlation among them. Days to 50% flowering showed negative phenotypic correlation with oil content.

Highly significant (P<0.01) and positive phenotypic correlation were observed between seed number per plant and days to 50% flowering, days to 80% maturity, plant height, stem diameter, head diameter, leaf number per plant and petiole length. Positive and highly significant phenotypic correlation were observed between leaf number per plant and days to 50% flowering, 80% maturity, plant height, stem diameter and head diameter. This shows that early maturing and flowering genotypes, tall height, big headed, and with large stem diameter genotypes had higher number of leaves as compared to late flowering and maturing genotypes.

Significant positive phenotypic association were also observed between head diameter and leaf number per plant, petiole length, yield per head, number of seed per plant, plant height, stem diameter. Negative and non-significant phenotypic association was observed between head diameter and oil content. Giriraj *et al.,* (1979) reported that plant height, head diameter and 100 seed weight had positive correlation with seed yield and among them at phenotypic and genotypic level. Ashok *et al.,* (2000) studied 40 sunflower hybrids and reported positive and significant genotypic and phenotypic correlation among seed yield per plant, days to maturity, plant height, diameter of stem and head diameter.

Positive associations between plant height and days to maturity were reported by various researchers (Mahmood and Mehdi, 2003). Syed *et al.,* (2004) reported positive phenotypic correlation between plant heights, days to maturity, oil content and head diameter.

According to Abu (2019) negative and significant phenotypic association was observed between leaf number and days to flowering and significant and positive phenotypic association was observed between head diameter, oil content, plant height, days to maturity and yield per plant.

Genotypic Correlation

Genotypic correlation coefficients among yield related traits are presented in Table 1. Seed number per plant showed positive and highly significant ($P<0.01$) genotypic association with days to flowering, days to maturity, plant height, stem diameter, head diameter, leaf number per plant, petiole length, yield per head, oil yield per hectare, seed filling percentage and hundred seed weight but negatively non-significant genotypic association was observed with oil content. positive and highly significant ($P<0.01$) genotypic correlation was observed between seed filling percentage with days to 80% maturity, yield per head, yield per hectare and oil yield per hectare and also positive and significant genotypic association with plant height and oil content as well. But negative and significant genotypic association were observed between seed filling percentage with stem diameter, head diameter and leaf number per plant.

Non-significant genotypic association were observed between seed filling percentage with days to 50% flowering and petiole length. Petiole length showed positive and highly significant genotypic correlation with days to 50% flowering, days to 80% maturity, plant height, stem diameter, head diameter, leaf number per plant, seed number per plant and hundred seed weight. Petiole length showed negative and non-significant genotypic association with oil content and also non-significant genotypic association with seed filling percentage.

Positive and highly significant ($P<0.01$) association were observed with head diameter and plant height, stem diameter, leaf number per plant, petiole length, yield per head, oil yield, hundred seed weight and seed number per plant. Negative and highly significant genotypic association were observed between head diameter and oil content. Head diameter had non-significant genotypic association with days to 50% flowering and 80% maturity and oil content. Stem diameter showed positive and highly significant genotypic association with days to 50% flowering and 80% maturity, plant height, head diameter, leaf number per plant, petiole length, yield per head, 100 seed weight, and seed number per plant but significant and negatively correlated with oil content, stand percentage and seed filling percentage. Positive and highly significant genotypic associations were observed between plant height and all yield related characters.

Oil content showed positive and highly significant genotypic association with all the traits except stand percentage and also negatively and non-significant genotypic association with seed number per plant. Oil yield showed negative and highly significant genotypic association with all the traits except seed filling percentage and hundred seed weight. This result disagrees with the findings of Tahir *et al.,* (2002) which reported negative correlation of one hundred seed weight with oil content. Oil content had also negative and non-significant genotypic correlation with head diameter and seed filling percentage. This result agrees with the findings of Habib *et al.,* (2007) who reported significant positive correlation between days to maturity, plant height and oil content on one side and oil yield on the other side whereas days to flower initiation was negatively correlated with oil yield. Dan *et al.,* (2012) reported positive and significant association of oil yield with seed yield per plant, plant height, head diameter, volume weight, 100-seed weight and oil content.

Leaf number had negative and non-significant genotypic association with number of seed per plant, oil content, head diameter and yield per hectare. Hussain *et al.,* (2012) reported positive significant genotypic association between plant height and stem diameter which is in agreement with the present study. This result agrees with the findings of Abu (2019) who reported positive and significant genotypic association of number of seed per plant with head diameter, stem diameter and plant height but disagree on yield per plant, days to flowering, oil content, days to maturity and seed filling percentage and hundred seed weight.

Path Coefficient Analysis

Knowledge of interaction among the characters is very essential in plant breeding to determine the extent and nature of relationship between yield, yield related and morphological characters. Path Coefficient analysis enables a plant breeder to separate direct and indirect effects attributable by partitioning the simple correlations coefficient. Thus, Correlation and Path coefficient analysis form a basis for selection and helps in understanding yield contributing characters affecting seed and oil yield of sunflower. Correlation is simply a measurement of mutual association without regards to causation, whereas path coefficient analysis indicates the causes and measures their importance. Because two characters may show correlation just because, they are correlated with a common third character. In such cases, it becomes necessary to use a method which takes into account the causal relationship between the variables, in addition to the degree of such relationship.

Path coefficient analysis therefore permits partitioning of the correlation coefficient into components of direct and indirect causes of association. The phenotypic and genotypic correlation coefficients were further partitioned as direct and indirect effects on yield by other characters. Yield is the output of different causal factors that contribute directly or indirectly. These independent factors exert specific forces to result in seed yield. So, Seed yield per hectare was considered as dependent character and other yield contributing characters as independent characters for path analysis. The path coefficient analysis was discussed as phenotypic and genotypic, direct and indirect effects of characters on seed yield per hectare are presented below.

Phenotypic Path Coefficient Analysis

At phenotypic level seed yield per head (0.857) exerted the highest and positive direct effect followed by days to 50% flowering (0.087), oil yield (0.063), stand percentage (0.048) and leaf number per plant on seed yield of sunflower (Table 2). The phenotypic indirect effects of other yield contributing characters through these characters were showed positive and negative contribution on seed yield.

Yield per head and leaf number per plant mostly contributed positive indirectly through other characters except through oil yield and stand percentage contributed positive indirect effect through all other characters on seed yield per hectare. These characters also showed positive and significant phenotypic correlation with seed yield per hectare except stand percentage. Therefore, considering these characters as selection criteria will be an opportunity in advance of seed yield per hectare in a sunflower breeding program. According to result of this study giving in-faces for good stand and single plant yield in phenotypic selection is important. This result disagrees with the findings of Chaudary and Anand (1985); Patil *et al.*, (1996) and Abu (2019) reported positive direct effect of hundred seed weight and seed filling percentage on seed yield.

According to Singh and Chaudhary (1999), if the correlation coefficient is positive but the direct effect is negative or negligible, the indirect effects might be the causal factor of correlation. This study agrees with the findings of Abu (2019) phenotypic path coefficient analysis showed that oil yield per hectare had the highest positive direct effect on seed yield per hectare. In other way; the highest negative direct effect was observed by days to maturity (-0.079) followed by plant height (-0.030), stem diameter (-0.004), head diameter (-0.016), petiole length (-0.016), seed filling percentage (-0.059), hundred seed weight (-0.030) and seed number per plant (-0.050) on seed yield per hectare. Likewise, indirect effects of other characters through these traits were also negative effect on seed yield per hectare (Table 2).

Negative phenotypic direct effect of days to maturity, plant height, stem diameter, head diameter, petiole length, seed number per plant, hundred seed weight and seed filling percentage on seed yield per hectare shows that direct selection based on these characters may be ineffective in improvement of seed yield. But highly significant and positive phenotypic correlation was observed between these characters and seed yield and this is explainable by positive indirect effect they produce through, seed filling percentage, seed yield per plant and one hundred seed weight. Negative direct effect of plant height on seed yield was reported by Gowda (1994) which agrees with our study. According to Abu (2019) Negative direct effect on seed yield per hectare were observed for plant height, petiole length, number of seed per plant and head diameter. Similarly, the author reported that the indirect effects of other characters through these characters were also negative with some exceptions of head diameter. Days to maturity, oil yield, seed yield per plant, head diameter and reproductive phase revealed positive association and had positive direct effect of seed yield was reported by Lagiso *et al.*, (2021) which is similar to our result except days to maturity.

Table.1 Genotypic Correlations (Below Diagonal) and Phenotypic correlation (Above Diagonal) Coefficient among sixteen quantitative characters in 220 Sunflower genotypes studied at HARC

Variables	DF (days)	DM (days)	PH (cm)	SD (cm)	HD (cm)	LNPP (No)	PL (cm)	Stand (%)	Yld/H (g)	Yld (kg/ha)	OC (%)	OY/ha (Kg)	SFP (%)	HSWT (g)	SNPP (No)
DF (days)		0.879**	0.482**	0.283**	0.010NS	0.184**	0.198**	0.096*	0.291**	0.174**	0.291**	-0.255**	0.173**	0.004NS	0.009NS
DM (days)	0.88**		0.547**	0.351**	0.041NS	0.232**	0.261**	0.136**	0.324**	0.213**	0.324**	-0.200**	0.218**	0.064NS	0.022NS
PH (cm)	0.77**	0.851**		0.643**	0.269**	0.533**	0.554**	0.349**	0.510**	0.394**	0.510**	-0.111*	0.440**	0.149**	0.124**
SD (cm)	0.717**	0.824**	0.905**		0.421**	0.450**	0.677**	0.270**	0.452**	0.399**	0.452**	-0.127**	0.384**	0.144**	0.206**
HD (cm)	0.00NS	0.053NS	0.423**	0.614**		0.278**	0.420**	0.107*	0.192**	0.203**	0.192**	0.012NS	0.171**	0.057NS	0.149**
LNPP(No)	0.58**	0.652**	0.729**	0.467**	0.684**		0.382**	0.322**	0.287**	0.221**	0.287**	0.048NS	0.250**	0.073NS	0.039NS
PL (cm)	0.46**	0.556**	0.675**	0.845**	0.797**	0.182**		0.244**	0.394**	0.351**	0.394**	0.002NS	0.388**	0.132**	0.183**
Stand (%)	0.234**	0.294**	0.143**	-0.35**	-0.297**	-0.402**	-0.284**		0.016NS	0.184**	0.016NS	0.041NS	0.034NS	0.089NS	0.106*
Yld/H (g)	0.296**	0.328**	0.806**	1.100**	0.297**	0.807**	0.888**	0.012NS		0.594**	1.000**	-0.134**	0.915**	0.104*	0.044NS
Yld/ha(kg)	0.175**	0.214**	0.631**	0.992**	0.309**	0.644**	0.803**	0.438**	0.599**		0.594**	0.086NS	0.527**	0.208**	0.252**
OC (%)	0.296**	0.328**	0.806**	1.100**	0.297**	0.807**	0.888**	0.012NS	1.000**	0.599**		-0.134**	0.915**	0.104*	0.044NS
OY/ha(Kg)	-0.258**	-0.20**	-0.18**	-0.33**	0.025NS	-0.12*	0.008NS	0.104*	0.136**	0.086**	0.136**		0.226**	0.05NS	0.067NS
SFP (%)	0.176**	0.220**	0.694**	0.927**	0.264**	0.716**	0.875**	0.038NS	0.915**	0.531**	0.915**	0.225**		0.100*	0.008NS
HSWT (g)	0.004NS	0.123**	0.095*	-0.095*	-0.176**	-0.298**	0.010NS	0.061NS	0.250**	0.493**	0.250**	0.102*	0.235**		0.106*
SNPP (No)	0.012NS	0.023NS	0.215**	0.460**	0.191**	0.068NS	0.414**	0.259**	0.046NS	0.262**	0.046NS	0.069NS	0.010NS	0.240**	

Whereas **, *, NS; are significant at 0.01, significant at 0.05 and non-significant at 0.05 respectively, LNPP=number of leaves per plant, PL=petiole length, Yld/H=Seed yield per plant head, Yld/ha=Seed yield per hectare, NSPP=number of seed per plant, OC=Oil content, HD=Head diameter, SD=Stem diameter, PH=Plant height, DF=Days to flowering, DM=Days to maturity, SFP= Seed filling percentage, OYPH=Oil yield per hectare and HSWT= Hundred seed weight

Table.2 Phenotypic path coefficient analysis: the direct (diagonal) and indirect (off-diagonal) effects of other characters on seed yield per hectare in 220 Sunflower genotypes

Variables	DF (days)	DM (days)	PH (cm)	SD (cm)	HD (cm)	LNPP (No)	PL (cm)	Stand (%)	Yld/H (g)	OY/ha (Kg)	SFP %	HSWT (g)	SNPP	P_r
DF (days)	**0.087**	-0.069	-0.014	-0.001	0.000	0.005	-0.003	0.005	0.149	-0.016	-0.010	0.000	0.000	***0.132***
DM (days)	0.076	**-0.079**	-0.016	-0.001	-0.001	0.007	-0.004	0.006	0.183	-0.013	-0.013	-0.002	-0.001	***0.143***
PH (cm)	0.042	-0.043	**-0.030**	-0.002	-0.004	0.016	-0.009	0.017	0.337	-0.007	-0.026	-0.005	-0.006	***0.280***
SD (cm)	0.025	-0.028	-0.019	**-0.004**	-0.007	0.013	-0.011	0.013	0.342	-0.008	-0.023	-0.004	-0.010	***0.280***
HD (cm)	-0.001	-0.003	-0.008	-0.002	**-0.016**	0.008	-0.007	0.005	0.174	-0.001	-0.010	-0.002	-0.007	***0.131***
LNPP(No)	0.016	-0.018	-0.016	-0.002	-0.004	**0.030**	-0.006	0.015	0.189	-0.003	-0.015	-0.002	-0.002	***0.182***
PL (cm)	0.017	-0.021	-0.017	-0.002	-0.007	0.011	**-0.016**	0.012	0.301	0.000	-0.023	-0.004	-0.009	***0.243***
Stand (%)	0.008	-0.011	-0.010	-0.001	-0.002	0.010	-0.004	**0.048**	0.157	0.003	-0.002	-0.003	-0.005	***0.188***
Yld/H (g)	0.015	-0.017	-0.012	-0.001	-0.003	0.007	-0.006	0.009	**0.857**	-0.005	-0.031	-0.006	-0.013	***0.793***
OY(Kg/ha)	-0.022	0.016	0.003	0.000	0.000	-0.001	0.000	0.002	-0.073	**0.063**	-0.013	-0.002	0.003	***-0.024***
SFP (%)	0.015	-0.017	-0.013	-0.001	-0.003	0.007	-0.006	0.002	0.451	0.014	**-0.059**	-0.003	0.000	***0.386***
HSWT (g)	0.000	-0.005	-0.004	-0.001	-0.001	0.002	-0.002	0.004	0.178	0.003	-0.006	**-0.030**	-0.005	***0.133***
SNPP (No)	0.001	-0.002	-0.004	-0.001	-0.002	0.001	-0.003	0.005	0.216	-0.004	-0.001	-0.003	**-0.050**	***0.154***

R=0.25982

Whereas **, *, NS; are significant at 0.01, significant at 0.05 and non-significant at 0.005 respectively. RFN=number of ray floret, LN=number of leaves per plant, petiole length, Yld/H=Seed yield per plant head, NSPP=number of seed per plant, OC=Oil content, HD=Head diameter, SD=Stem diameter, PH=Plant height, DF=Days to flowering, DM=Days to maturity, SFP= Seed filling percentage, OYPH=Oil yield per hectare and HSWT= Hundred seed weight

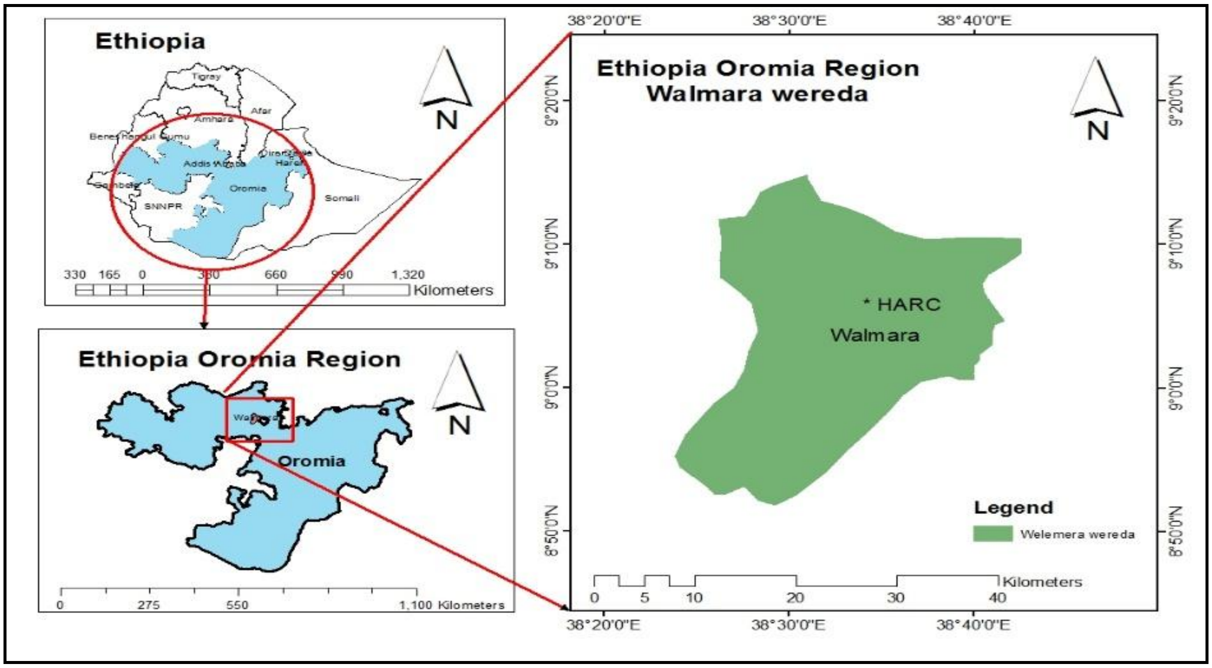
Table.3 Genotypic path coefficient Analysis: the direct (diagonal) and indirect (off-diagonal) effects of other characters on seed yield per hectare in 220 Sunflower genotypes

Variables	DF (days)	DM (days)	PH (cm)	SD (cm)	HD (cm)	LNPP (No)	PL (cm)	Stand (%)	Yld/H (g)	OY/ha (Kg)	SFP %	HSWT (g)	SNPP (No)	P_r
DF (days)	**0.104**	-0.007	-0.199	0.052	0.000	0.052	-0.051	0.028	0.146	-0.022	-0.009	0.000	0.000	***0.095***
DM (days)	0.092	**-0.008**	-0.217	0.059	0.001	0.059	-0.061	0.036	0.178	-0.017	-0.012	-0.009	0.000	***0.101***
PH (cm)	0.081	-0.007	**-0.255**	0.065	0.010	0.066	-0.075	0.017	0.525	-0.015	-0.037	-0.007	-0.004	***0.365***
SD (cm)	0.075	-0.007	-0.231	**0.072**	0.014	0.042	-0.093	-0.042	0.826	-0.027	-0.049	0.007	-0.010	***0.577***
HD (cm)	0.000	0.000	-0.108	0.044	**0.023**	0.062	-0.088	-0.036	0.258	-0.002	-0.014	0.012	-0.004	***0.147***
LNPP(No)	0.061	-0.005	-0.186	0.034	0.016	**0.090**	-0.020	-0.048	0.536	-0.010	-0.038	0.021	-0.001	***0.448***
PL (cm)	0.048	-0.004	-0.173	0.061	0.019	0.016	**-0.110**	-0.034	0.669	-0.001	-0.046	-0.001	-0.009	***0.434***
Stand (%)	0.024	-0.002	-0.037	-0.025	-0.007	-0.036	0.031	**0.121**	0.365	0.009	-0.002	0.004	-0.005	***0.440***
Yld/H (g)	0.018	-0.002	-0.161	0.072	0.007	0.058	-0.089	0.053	**0.833**	-0.007	-0.028	-0.034	-0.005	***0.715***
OY/ha (Kg)	-0.027	0.002	0.047	-0.024	-0.001	-0.011	0.001	0.013	-0.072	**0.083**	-0.012	-0.007	0.001	***-0.006***
SFP (%)	0.018	-0.002	-0.177	0.067	0.006	0.065	-0.097	0.005	0.442	0.019	**-0.053**	-0.016	0.000	***0.277***
HSWT (g)	0.000	-0.001	-0.024	-0.007	-0.004	-0.027	-0.001	-0.007	0.410	0.008	-0.012	**-0.069**	-0.005	***0.261***
SNPP (No)	0.001	0.000	-0.055	0.033	0.004	0.006	-0.046	0.031	0.218	-0.006	-0.001	-0.017	**-0.021**	***0.149***

R=0.23829

Whereas **, *, NS; are significant at 0.01, significant at 0.05 and non-significant at 0.005 respectively. RFN=number of ray floret, LN=number of leaves per plant, petiole length, Yld/H=Seed yield per plant head, NSPP=number of seed per plant, OC=Oil content, HD=Head diameter, SD=Stem diameter, PH=Plant height, DF=Days to flowering, DM=Days to maturity, SFP= Seed filling percentage, OYPH=Oil yield per hectare and HSWT= Hundred seed weight

Figure.1 Map of study area



Genotypic Path Coefficient Analysis

Genotypic path coefficient analysis showed that yield per head (0.833) exerted the highest genotypic positive direct effect on seed yield per hectare followed by stand percentage (0.121), days to 50% flowering (0.104), leaf number per plant (0.090), oil yield per hectare (0.083), stem diameter (0.072) and head diameter (0.023) (Table 3).

The indirect effect of other characters through seed number per plant, hundred seed weight and seed filling percentage were less and mostly negative. This implies that the high correlation it showed with seed yield per hectare is explainable largely by its direct influence on seed yield per hectare.

Highly significant and positive genotypic correlation were observed between seed yield per hectare and other yield contributing characters except stand percentage and hundred seed weight. Based on genotypic path coefficient analysis positive direct effect indicates that direct selection based on these traits can be effective in the improvement of seed yield per hectare of sunflower.

Genotypic, indirect effects of other characters through these traits were also mostly positive except the indirect effect of oil yield through days to flowering, hundred seed weight, oil yield and seed filling percentage through stem diameter and leaf number per plant were negative.

The genotypic direct effect of plant height (-0.255), days to 80% maturity (-0.008), petiole length (-0.110), seed filling percentage (-0.053), hundred seed weight (-0.069) and seed number per plant (-0.021) on seed yield per hectare was negative.

The indirect effects of other characters through these character on seed yield per hectare were also negative with some exceptions (Table 3). This strongly tell us, considering those characters as selection criteria in sunflower breeding program to improve seed yield per hectare may lead us in wrong direction and not be effective unless with separate breeding program for this special characters.

According to Abu (2019) Genotypic path coefficient analysis showed that oil yield per hectare exerted the highest genotypic direct effect on seed yield per hectare which is similar to our study and the direct effect of seed yield per plant on seed yield per hectare was also high which is confirmatory for this study.

The indirect effects of other characters through head diameter were also negative with some exception this study agree with this result. However, this study in disagreement with the result of Shivaram (1986); Skoric (1992); Illahi (2006); Lal *et al.*, (1997) and Abu (2019) who reported that head diameter as selection criteria may not be effective in improvement of seed yield per hectare.

Generally, if correlation between dependent and independent character is due to the direct effect of a character, it reflects a true relationship between them. Therefore, selection can be done to improve the dependent character. From the result of genotypic path coefficient analysis in this study selection pressure should be given on days to flowering, leaf number per plant, stem diameter, head diameter, oil yield, stand percentage and seed yields per plant in positive indication for improvement of seed yield per hectare in sunflower breeding for yield improvement program. The residual effect indicates how much the causal factors account for the variability of independent character (Singh and Chaudhary, 1999). The residual factor of genotypic and phenotypic path coefficient analysis was 0.2383 and 0.2598, respectively. This clearly shows that the yield related characters that indicated in this study inform 76.2% and 74.02% of the variability in the seed yield, respectively. The remaining percentage is due to other characters not considered in this study.

Conclusion and Recommendation

Limited number and low Productivity of sunflower varieties is becoming a serious issue to emerging oil factories in Ethiopia related to raw material availability especially sunflower seed. The demand of sunflower seed is increasing for the last five years and its mainly due to the above reasons. This all points out and forward the issue and need of sunflower oil to the national sunflower improvement program at the end. So, study of basic breeding research on variability and traits association among sunflower genotypes is a pilar and starting point to identify and select high yielding, tolerant or resistance to biotic and abiotic factors breeding plant materials to develop best sunflower varieties in general.

So, two hundred twenty sunflower genotypes including three released varieties and 108 accessions from EBI collected from different locations of Ethiopia and the remaining 109 were from Holeta mid and highland oilseed research program selected as single plant selections were evaluated in 2020 main growing season, at Holeta Agricultural Research Center using 11*20 *Alpha Lattice* design with two replications. The objectives of the study were to determine correlation and traits association among economically important agronomic traits of sunflower genotypes.

The Analysis of variance showed highly significant ($p<0.01$) differences among the tested genotypes. Highly significant and positive phenotypic correlation was observed between seed yield per hectare and all studied traits except stand percentage, hundred seed weight and oil content. Highly Significant and positive genotypic correlation was observed between seed yield per hectare and all studied traits.

Phenotypically, seed yield per hectare was positive and directly affected by days to flowering, leaf number per plant, stand percentage, seed yield per head and oil yield but negative effects were recorded by days to maturity, plant height, stem diameter, head diameter, petiole length, hundred seed weight, seed filling percentage and seed number per plant. Genotypic path coefficient analysis also showed that there was positive direct effect on seed yield per hectare by days to flowering, stem and head diameter, leaf number per plant, stand percentage, seed yield per head and oil yield.

Improvement of sunflower genotypes having traits namely early to medium maturing, big headed & tough stem, seed yield & number per head, medium plant height, hundred seed weight, oil content, seed filling percentage, head angle & shape and reaction to biotic and abiotic stress should be emphasized to obtain genotypes with high seed yield and oil content for the farming society and investors as well.

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