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Research Article
Direct and Indirect Contribution of Yield Related Components on Seed Yield in Sunflower Genotypes

[1]Mohammed Abu, [2]Sentayehu Alamerew and [1]Mistru Tesfaye

[1]Ethiopian Institute of Agricultural Research, Holetta Research Centre, P.O. Box 2003, Addis Ababa, Ethiopia
[2]College of Agriculture and Veterinary Medicine, Jimma University, Ethiopia

Abstract
Background and Objective: Correlation and path coefficient analysis were studied in 24 sunflower genotypes along with one released variety (Oissa) to estimate the association and contribution of yield-related traits towards seed yield. The study was conducted at Holetta and Adadi, central highlands of Ethiopia during 2017/18 using a simple lattice design. **Materials and Methods:** The study of correlation coefficient revealed that seed yield per hectare exhibits positive and significant genotypic correlation with the number of seeds per plant, yield per plant, head diameter and seed filling percentage. Positive and significant phenotypic correlation with seed yield per hectare was also observed for petiole length, yield per plant, number of seeds per plant, head diameter, plant height, seed filling percentage and hundred seed weight. **Results:** Phenotypic path coefficient analysis showed that oil yield per hectare, hundred seed weight and seed filling percentage had the highest positive direct effect on seed yield per hectare were as negative phenotypic direct effects were observed for plant height, petiole length, the number of seeds per plant and head diameter. Genotypic path coefficient analysis showed that oil yield, seed filling percentage, seed yield per plant and number of seeds per plant had a positive direct effect on seed yield per hectare. **Conclusion:** Hence, the study revealed that selection based on oil yield, seed filling percentage, seed yield per plant and number of seeds per plant as a base will be more effective in improving seed yield per hectare.

Key words: Path analysis, phenotypic and genotypic correlation coefficient, sunflower, plant breeding, genetic potential, agrichemicals, germplasm

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Corresponding Author: Mohammed Abu, Ethiopian Institute of Agricultural Research, Holetta Research Centre, P.O. Box 2003, Addis Ababa, Ethiopia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) 2n = 30 is one of the most important oil crops in the world. The origin of the crop is thought to be North America from where it was introduced to Europe and then to Africa[1]. It was probably domesticated by the western Native American tribes around1000 BC and then carried eastward and southward of North America. It is a cross-pollinated crop that has been used as edible oil, used in certain paints, varnishes, plastics, in the production of agrochemicals, surfactants, adhesives, plastics, fabric softeners, lubricants, coatings and as a sillage crop[2]. The sunflower use as an oil crop started in the 1960s, however, intensive research work on the crop was started in the 1980s with the production of hybrid seeds[3]. Sunflower which is primarily cultivated for edible oil has several industrial applications such as a basic component for polymer synthesis, biofuel, emulsifier or lubricants[4]. It is also used as a meal for livestock[5] and has esthetic and ornamental values[6]. As the rising world human population increases the demand for food and causes hunger, starvation and disease outbreak there is a need to improve crops genetic potential through plant breeding for maximum food production[7].

Plant breeding is essentially the selection of plants among germplasm. The development of genetic material is considered to be an essential part of enhancing the genetic potential of cultivated crops[8]. Yield enhancement in crop genetic resources are currently of great interest to ensure food security. Seed yield is a polygenic trait involving several genes contributing to it and their interaction with the environment[9]. It is influenced by several characters called yield contributing traits. These traits are associated among themselves and with seed yield either positively or negatively[8].

Therefore it is important to measure the association between seed yield and yield component traits and determine the component characters, on which selection procedure can be based for direct and indirect selection for genetic improvement of seed yield[10]. Path coefficient analysis is used to separate correlation coefficients into direct and indirect effects and correlation coefficient analysis is important in the evaluation of different traits and the study of their interrelationships[8]. In Ethiopia, there is a lack of sufficient released varieties for the large scale production of the crop. To solve the problem of the shortage of released variety there is a need to study the nature and association of traits that primarily influence the seed yield of the crop.

The present study has been undertaken to estimate the direct and indirect contribution of yield-related components about seed yield to sort out the best selection criteria to improve seed yield per hector.

MATERIALS AND METHODS

Study area: The study was conducted at Holetta Agricultural Research Centre (9°00′ N latitude and longitude 38°30′ E) and the Adadi Subcenter (08°31′ N latitude and longitude 38°13′ E) from June, 2017-January, 2018. The altitude of Holetta Agricultural Research Centre is 2400 m.a.s.l with min annual rainfall of 1144 mm whereas, Adadi Subsite is 2383 m.a.s.l. with 1105 mm of min annual rainfall.

Sample collection: Twenty four sunflower genotypes along with one standard check (Oissa) were sown following a simple lattice design. Plant to plant distance was maintained at 25 cm and row to row distance of 75 cm was adopted. Two seeds were dribbled per hill to facilitate the best emergency and thinning was adopted after the emergency at 2 leaf stages to maintain optimum plant population.

Phenotypic and genotypic correlation: Phenotypic and genotypic correlation coefficients were done following different biometricians. Direct and indirect effects of yield-related traits on seed yield were also computed following[10].

RESULTS AND DISCUSSION

Correlation of seed yield with other yield-related traits: The correlation of seed yield with yield-related traits is presented in (Table 1 and 2). Seed yield per hectare had a positive and significant genotypic correlation with the number of seeds per plant (0.513), yield per plant (0.651), head diameter (0.612), seed filling percentage (0.664) and oil yield per hectare (0.897) (Table 2). Based on this finding, the high yielding sunflower genotype is the genotype with a big head to hold more number of and heavy seeds. This indicated that the correlation of these traits with seed yield could be fruitfully utilized to enhance the yield potential of sunflowers. This result was supported by the findings of Tahir *et al.*[11] which reported the positive significant correlation of seed filling percentage, head diameter and hundred seed weight with seed yield.

Positive and significant phenotypic correlation of seed yield per hectare with, petiole length (0.223), yield per plant (0.293), number of seed per plant (0.311), head diameter (0.371), plant height (0.250), seed filling percentage (0.562), oil yield per hectare (0.873) and hundred seed weight (0.240) was also observed (Table 1). This implies considering these traits in selection is important to improve seed yield per hectare. Abbas *et al.*[12]. reported the significant correlation of seed yield with head diameter, plant height, hundred seed weight and oil content. The genotypic and phenotypic

Table 1: Phenotypic correlation among fifteen quantitative traits in 25 sunflower genotypes

Variables	RFN	LN	PL	YPP	NSPP	OC	HD	SD	PH	DF	DM	SFP	HSWT	OYPH	YPH
RFN		0.410**	0.398**	0.480**	0.581**	0.342*	0.151^{ns}	-0.155^{ns}	0.401**	-0.193^{ns}	0.532**	-0.060^{ns}	0.041^{ns}	0.258^{ns}	0.150^{ns}
LN			0.451**	0.570**	0.432**	0.201*	0.092^{ns}	-0.091^{ns}	0.491**	-0.345*	0.691**	0.136^{ns}	0.350*	0.108^{ns}	0.064^{ns}
PL				0.561**	0.571**	0.290*	0.201*	0.032^{ns}	0.543**	-0.112^{ns}	0.550**	0.194^{ns}	0.195^{ns}	0.306*	0.223*
YPP					0.810**	0.330*	0.426**	-0.011^{ns}	0.501**	-0.461**	0.732**	0.350*	0.520**	0.456**	0.293*
NSPP						0.514**	0.432**	0.050^{ns}	0.520**	-0.240*	0.661**	0.142^{ns}	0.091^{ns}	0.463**	0.311*
OC							0.028^{ns}	-0.087^{ns}	0.442**	0.001^{ns}	0.430**	-0.123^{ns}	-0.223*	0.451**	0.071^{ns}
HD								0.112^{ns}	0.182^{ns}	0.075^{ns}	0.097^{ns}	0.199*	0.281*	0.246*	0.371*
SD									-0.002^{ns}	0.311*	-0.094^{ns}	0.152^{ns}	0.035^{ns}	0.013^{ns}	0.085^{ns}
PH										0.021^{ns}	0.601**	0.080^{ns}	0.062^{ns}	0.376*	0.250*
DF											-0.481**	-0.099^{ns}	-0.390**	0.112^{ns}	-0.101^{ns}
DM												0.098^{ns}	0.270*	0.281*	0.121^{ns}
SFP													0.530**	0.441**	0.562**
HSWT														0.094^{ns}	0.240*
OYPH															0.873**
YPH															

^{**,*,ns}Significant at 0.01, 0.05 and non-significant at 0.05, respectively, RFN: Number of ray floret, LN: Number of leaves per plant, PL: Petiole length, YPP: Seed yield per plant, 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: Genotypic Correlation among fifteen quantitative characters in 25 sunflower genotypes

Variables	RFN	LN	PL	YPP	NSPP	OC	HD	SD	PH	DF	DM	SF	HSWT	OYPH	YPH
RFN		0.015^{ns}	0.240^{ns}	0.151^{ns}	0.550*	0.250^{ns}	0.132^{ns}	-0.198^{ns}	0.261^{ns}	0.260^{ns}	0.143^{ns}	-0.361^{ns}	-0.430*	0.215^{ns}	0.131^{ns}
LN			0.171^{ns}	0.065^{ns}	-0.121^{ns}	-0.011^{ns}	-0.161^{ns}	0.070^{ns}	0.312^{ns}	0.161^{ns}	0.260^{ns}	0.027^{ns}	0.181^{ns}	-0.124^{ns}	-0.120^{ns}
PL				0.391^{ns}	0.431*	0.290^{ns}	0.190^{ns}	0.371^{ns}	0.580*	0.470*	0.530*	0.092^{ns}	-0.096^{ns}	0.261^{ns}	0.171^{ns}
YPP					0.560*	-0.013^{ns}	0.711**	0.070^{ns}	0.195^{ns}	0.079^{ns}	0.182^{ns}	0.570*	0.350^{ns}	0.514*	0.651*
NSPP						0.510*	0.530*	0.225^{ns}	0.460*	0.450*	0.391*	-0.065*	-0.570*	0.481*	0.513*
OC							-0.038^{ns}	0.051^{ns}	0.416*	0.490*	0.362^{ns}	-0.340^{ns}	-0.620*	0.433*	0.006^{ns}
HD								0.330^{ns}	0.134^{ns}	0.260^{ns}	0.173^{ns}	0.321^{ns}	0.071^{ns}	0.28^{ns}	0.612*
SD									0.510*	0.631*	0.551*	0.310^{ns}	0.042^{ns}	0.123^{ns}	0.131^{ns}
PH										0.680*	0.610*	-0.041^{ns}	-0.331^{ns}	0.35^{ns}	0.232^{ns}
DF											0.760**	0.110^{ns}	0.440*	0.163^{ns}	0.022^{ns}
DM												-0.005^{ns}	-0.265^{ns}	0.238^{ns}	0.131^{ns}
SFP													0.570*	0.451*	0.664*
HSWT														0.098	0.194^{ns}
OYPH															0.897**
YPH															

^{**,*,ns}Significant at the alpha level of 0.01, 0.05 and non-significant at the alpha level of 0.05, respectively, RFN: Number of ray floret, LN: number of leaves per plant, PL: Petiole length, YPP: Seed yield per plant, 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: Phenotypic path coefficient analysis of the direct (diagonal) and indirect (off-diagonal) effects of other traits on seed yield per hectare in sunflower genotypes

Variables	PL	HD	NSPP	YPP	PH	SFP	HSWT	OYPH	Pr
PL	-0.012	-0.091	-0.01	0.02	-0.006	0.028	0.029	0.265	0.223*
HD	-0.007	-0.162	-0.014	0.039	-0.005	0.05	0.077	0.393	0.371*
NSPP	-0.007	-0.132	-0.017	0.04	-0.006	0.021	0.013	0.399	0.311*
YPP	-0.003	-0.069	-0.0074	0.092	-0.002	0.028	0.042	0.212	0.293*
PH	-0.0065	-0.083	-0.009	0.017	-0.011	0.012	0.01	0.325	0.2545*
SFP	-0.002	-0.057	-0.0024	0.018	-0.001	0.142	0.078	0.386	0.562**
HSWT	-0.002	-0.085	-0.002	0.026	-0.0007	0.076	0.147	0.081	0.2403*
OYPH	-0.004	-0.074	-0.008	0.023	-0.004	0.064	0.014	0.862	0.873**

Residual, R = 0.42, **,*Significant at the alpha level of 0.01, 0.05, respectively, PL: Petiole length, HD: Head diameter, NSPP: Number of seed per plant, YPP: Seed yield per plant, PH: Plant height, SFP: Seed filling percentage, HSWT: Hundred seed weight and OYPH: Oil yield per hectare

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 Hladni *et al*.[13].

Phenotypic path coefficient analysis: Phenotypic path coefficient analysis showed that oil yield per hectare (0.862) had the highest positive direct effect on seed yield per hectare followed by hundred seed weight (0.147) and seed filling percentage (0.142) (Table 3). The indirect effects of other characters through these traits were also positive. These traits also showed a positive and significant phenotypic correlation with seed yield per hectare. Therefore, considering these traits as selection criteria will be an opportunity for the

Table 4: Genotypic path coefficient analysis the direct (diagonal) and indirect (off-diagonal) effects of other traits on seed yield per hectare in sunflower genotypes

Variables	HD	NSPP	YPP	SFP	OYPH	rg
HD	-0.561	0.118	0.417	0.281	0.357	0.612*
NSPP	-0.315	0.211	0.312	-0.032	0.337	0.513*
YPP	-0.4	0.113	0.585	0.158	0.195	0.651*
SFP	-0.32	-0.014	0.188	0.492	0.318	0.664*
OYPH	-0.289	0.103	0.165	0.225	0.692	0.897**

R = 0.142, **,*Significant at an alpha level of 0.01, 0.05, respectively, YPP: Yield per plant, NSPP: Total number of seed per plant, HD: Head diameter, SFP: Seed filling percentage and OY: Oil yield

improvement of seed yield per hectare. From the result of this study giving attention to heavy seeds in phenotypic selection for yield, improvement is important.

Dagustu[14] reported a positive direct effect of hundred seed weight and seed filling percentage on seed yield. According to Singh[15], if the correlation coefficient is positive but the direct effect is negative or negligible, the indirect effects might be the causal factor of correlation. Negative direct effects on seed yield per hectare were observed for the height of plant (-0.011), petiole length (-0.012), a total number of seeds per plant (-0.017) and head diameter (-0.162). Similarly, indirect effects of other characters through, these traits were also negative.

The negative phenotypic direct effect of plant height, petiole length and the total number of seeds per plant and head diameter on seed yield per hectare indicate direct selection of these traits may be ineffective in the improvement of seed yield per hectare. The positive correlation observed between these traits and seed yield at the phenotypic level is explainable by the positive indirect effect they produce through, seed filling percentage, seed yield per plant and one hundred seed weight. Plant height and numbers of seeds per plant were significantly and positively associated with seed yield[16].

Genotypic path coefficient analysis: In this study, path coefficient analysis showed that oil yield per hectare (0.692) exerted the highest genotypic direct effect on seed yield per hectare. The indirect effect of head diameter, the number of seed per plant and seed filling percentage through it were also high. The direct effect of seed yield per plant (0.585) on seed yield per hectare was also high and followed by seed filling percentage (0.492) and a total number of seeds per plant (0.211). The indirect effect of other traits through seed filling percentage was less. This suggests that the high correlation it showed with seed yield per hectare is explainable largely by its direct influence on seed yield per hectare (Table 4).

Seed filling percentage, oil yield, seed yield per plant and number of seeds per plant showed positive and significant genotypic correlation with seed yield per hectare. The positive direct effect of these traits implies that direct selection of these traits can be effective in the improvement of seed yield per hectare of sunflower. The indirect effects of other characters through these traits were also positive except the indirect effect of seed filling percentage through the total number of seeds per plant and the indirect effect of the total number of seeds per plant through seed filling percentage which were negative.

The genotypic direct effect of head diameter (-0561) on seed yield per hectare was negative. The indirect effects of other characters through head diameter on seed yield per hectare were also negative. This indicates, taking this trait as selection criteria in the improvement of seed yield per hectare may not be effective. An increase in head size may increase the husk percentage and the incidence of empty seeds This result is following the findings of patil[17], who stated a negative direct effect of head diameter on seed yield of sunflower. This result is confirmatory with the finding of Illah[18], who reported positive genotypic direct effect number of seed per plant, seed filling percentage and plant height of the same crop.

Generally, if the correlation between dependent and independent characters 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 oil yield per hectare, seed filling percentage, seed yields per plant and number of seeds per head in a positive direction for improvement of seed yield per hectare in breeding for the yield improvement program. The residual effect indicates how much the causal factors account for the variability of independent character[15]. The residual factor of genotypic path coefficient analysis was 0.142. This indicated that the yield-related characters found in this study explain 85.8% of the variability in the yield. The remaining is due to other traits not considered in this study.

CONCLUSION

Positive and significant phenotypic and genotypic correlation with seed yield per hectare was observed for head diameter, seed filling percentage and seed yield per plant implying that considering big heads and heavy seeds as the basis of selection criteria will help to improve seed yield per hectare. Phenotypic path coefficient analysis showed the highest direct effect of oil yield hundred seed weight and seed filling percentage. Genotypic path coefficient analysis revealed that the highest direct effect of head diameter, number of seeds per plant and seed filling percentage. This implies that giving attention to a head with more number of seeds, well-filled and heavy seeds per head will help improve seed yield per hectare.

SIGNIFICANCE STATEMENT

This study discovered that number of seeds per plant and hundred seed weight are important traits to be considered to improve seed yield per hectare. The result obtained from this study will provide useful information for researchers who wants to improve the crop. Thus considering positively and significantly yield-related traits will help to improve seed yield indirectly.

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