Received: 20 Aug 2023 | Revised: 08 Sep 2023 | Accepted: 22 Sep 2023

Electronic Journal of Plant Breeding

Research Article

Exploring the genetic variability and association for yield and its integrant traits in sunflower (*Helianthus annuus* L.)

M. Vivek[1] , R. Sasikala[2*], K. Thangaraj[1], S. Harish[2] and M. Sudha[3]

[1]Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai-625 104, Tamil Nadu, India.
[2]Department of Oilseeds, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore- 641 003, Tamil Nadu, India.
[3]Department of Plant Biotechnology, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore- 641 003, Tamil Nadu, India.
***E-Mail:** sasikalacpbg@gmail.com.

Abstract
Sunflower production can be increased by exploring genetic variability present in the population. The nature of relationship between yield and its associated traits should be clearly understood to achieve parallel improvement of yield by indirect selection of beneficial traits. In the present study, 50 sunflower accessions along with five checks were evaluated for nine biometrical traits *viz.* days to 50% flowering, days to maturity, plant height, head diameter, hundred seed weight, volume weight, hull content, oil content and single plant yield to assess the variability and character association. The analysis of variance revealed the presence of significant variation among the genotypes for all the traits under consideration. Phenotypic coefficient of variation and genotypic coefficient of variation values were high for hundred seed weight and single plant yield. High heritability along with high genetic advance was observed for the traits *viz.* days to 50% flowering, plant height, head diameter, volume weight, oil content, hundred seed weight and single plant yield. Correlation studies revealed the presence of a positive and significant correlation between single plant yield and the traits head diameter and hundred seed weight. Similarly, oil content exhibited a positive and significant correlation with head diameter and volume weight. Path analysis also indicated the presence of high and moderate positive direct effect of head diameter and hundred seed weight on single plant yield. Based on the above, head diameter and hundred seed weight could be used as selection indices for yield improvement in sunflower.

Keywords: Genotypes, Sunflower, Variability, Correlation, Path analysis.

INTRODUCTION

Sunflower (*Helianthus annuus. L*) is an important oilseed crop grown in both subtropical and temperate regions worldwide. The genus name "*Helianthus*" is a combination of Greek words "Helios" (sun) and "Anthos" (flower) indicating the heliotropic (the plant facing towards the direction of sun) nature of the crop and the species name "*annuus*" meaning annual crop. It is the third major oilseed crop in the world (Pilorgé, 2020). In India, it is cultivated in an area of 0.271 M ha with an annual production of about 0.250 M tonnes (INDIASTAT, 2022). Globally, India accounts for 13–15% of the world's oilseed area, 4% of the world's production of edible oils, 14% of the world's imports of vegetable oils, and 10–12% of the world's consumption of edible oil (Narayan, 2016). Even though, it is one of the nations that produce sunflower seeds, India continues to import a substantial volume of sunflower oil from foreign countries because of the demand and supply gap (Sampath *et al.*, 2023). National Mission on Oilseed and Oil palm (NMOOP) trusts that if India improves its production in oilseeds it can achieve self-sufficiency and economic independence in vegetable oils (Narayan, 2016).

Sunflower, being a highly cross-pollinated crop possess high variability within it. Germplasm are naturally an important source of genetic variation and acts as an important part of gene pool of a crop. Germplasm conservation and proper usage is necessary as they act as a crucial source of genes for yield improvement, biotic and abiotic stress resistance. In India, currently about 3273 sunflower germplasm is conserved in gene bank of Indian Institute of Oilseeds Research, Hyderabad. Genetic variability is an important criterion for a crop improvement program. The study of variability can assist the breeder in understanding the extent of variation existing within each characters present in the given breeding material and assessing its suitability for utilization in breeding program. Yield is a complex trait that depends on contribution of different biometrical traits. The genetic correlations by bringing out the inter-relationship between different component traits can be applied in conventional plant breeding to identify the useful traits associated with yield (Kumar and Hazarika., 2020). Genetic improvement of any complex trait can be attained by applying a strong selection on the traits which are highly associated with it (Simmonds, 1979). Information on this inter-relationship between the biometrical traits and their direct and indirect effects on yield helps a breeder in the decision of selection for desirable characters to improve the yield. Considering these points, the experiment was laid out to assess the genetic variability and correlation for nine yield contributing traits in sunflower.

MATERIALS AND METHODS

The present study was conducted at Department of Oilseeds, TNAU, Coimbatore (11.0231° N latitude and 76.9288° E longitude) during *rabi* 2022-23. Fifty sunflower genotypes including five checks (COSF 6B, CSFI 99, IR 6, CMS 852 B and LTRR 341) were raised in randomized complete block design with three replications. Each genotype was raised in a 4 m row, with a row to row spacing of 60 cm and plant to plant spacing of 30 cm. All the recommended agronomic practices were followed throughout the cropping period (Crop production guide, 2020). Observations were recorded on nine quantitative traits namely, days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), volume weight (g/100 ml), hundred seed weight (g), hull content (%), single plant yield (g) and oil content (%). The traits *viz*., plant height (cm), head diameter (cm) and single plant yield (g) were recorded on five randomly selected plants in each replication, while other traits were recorded on plot basis. Oil content (%) was estimated using Soxhlet's method (Soxhlet, 1879). The statistical parameters *viz.* analysis of variance (ANOVA), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) (Burton and Devane, 1952), heritability (Lush *et al*., 1940)**,** genetic advance (Johnson *et al*., 1955), correlation (Pearson, 1896) and path analysis (Dewey and Lu., 1959) were computed using TNAUSTAT statistical programme. The classification for PCV and GCV was adopted from Sivasubramanian and Menon (1973) while for heritability and genetic advance from Johnson *et al.* (1955).

RESULTS AND DISCUSSION

The analysis of variance revealed the presence of significant differences between the genotypes for all the traits under study (**Table 1**). This indicated that each of the genotypes has characteristic features different from the other.

Mean performance: The assessment of the mean performance of the 50 genotypes revealed a greater range of variability for all the considered biometrical traits (**Table 2**). The genotypes evaluated showed earliness to 50 % flowering at 50 days (GMU 713) which extended up to a maximum of 74 days (PB 881). For days to maturity the range was between 82 (GMU 428) to 107 days (PB 881 and PB 1196).With respect to plant height, the genotype GMU 428 was the shortest with 94.25 cm while the tallest genotype was PB 1196 with 191.91 cm.

Table 1. Analysis of variance for nine yield attributing traits in sunflower genotypes.

Characters	Genotypes
Degrees of freedom	49
	Mean sum of squares
Days to 50% flowering (days)	122.35**
Days to maturity(days)	125.75**
Plant height (cm)	1288.91**
Head diameter (cm)	11.91**
Hundred seed weight (g)	3.52**
Volume weight (g/100ml)	64.06**
Hull content (%)	57.60**
Oil content (%)	88.13**
Single plant yield (g)	242.14**

* - Significance at 5% level; ** - Significance at 1% level.

Table 2. Mean performance of sunflower genotypes for nine biometrical traits.

	Mean	Range		SE	CV (%)
		Min	Max		
Days to 50% flowering (days)	60	50	74	0.97	2.77
Days to maturity (days)	92	82	107	1.37	2.58
Plant height (cm)	133.38	94.25	191.91	1.76	2.28
Head diameter (cm)	11.16	8.03	17.82	0.53	8.22
Hundred seed weight (g)	3.30	1.60	6.48	0.20	10.61
Volume weight (g/100ml)	31.83	22.87	42.84	0.80	4.36
Hull content (%)	35.21	24.72	45.71	1.83	9.01
Oil content (%)	32.79	21.83	43.47	0.89	4.69
Single plant yield (g)	17.16	3.91	47.52	1.91	19.26

Min- Minimum; Max- Maximum; SE- Standard error; CV- Co-efficient of variation.

The head size among the genotypes varied widely with a minimum diameter of 8.03 cm in genotype NGM 21 to a maximum of 17.82 cm in genotype 302 B. The range for hundred seed weight revealed the presence of genotypes with very small seed size having a minimum hundred seed weight of 1.60 g (PB 917) and extending up to a maximum of 6.48 g (GMU 520). The quantity of seed that can be packed in a volume of 100 ml ranged from 22.87 g (GMU 461) to 42.84 g (IR 6). The proportion of hull that occupied the total kernel varied from 24.72% in CSFI 99 to 45.71% in NGM 21. The genotypes exhibited double-fold variation for oil content ranging from 21.83% (GMU 461) to 43.47% (PB 1012). The genotypes varied widely for single plant yield with NGM 21 recording the least yield of 3.91 g to a maximum of 47.52 g in 302 B. These indicated the presence of desirable variation among genotypes for sunflower crop improvement.

To have a better insight into that portion of variability that could be inherited by selection the total variability needs to be partitioned into genetic and environmental, and subjected to co-efficient of variation, heritability and genetic advance analysis.

Phenotypic and Genotypic coefficient of variation: Phenotypic coefficient of variation (PCV) implies the sum of all the observable variation for the trait, while the genotypic coefficient of variation (GCV) implies the variability under genetic control. Since PCV is an aggregate of genotypic and environmental variance, the PCV is greater than GCV for all the traits (**Table 3**). The narrow difference between PCV and GCV indicates the presence of a high degree of genetic variation and small environmental variation. The values of both PCV and GCV were high (>20%) for characters such as hundred seed weight and single plant yield. These findings were similar to Rani *et al.* (2017), Divya *et al.* (2019) and Reavanth *et al.* (2021). These results suggest the presence of high genetic variability for these traits thereby supporting the effectiveness of selection for these traits. For days to 50% flowering, plant height, head diameter, volume weight, hull content and oil content the PCV and GCV were moderate (10-20%) while low (<10%) for days to maturity. These results were in agreement with the findings of Reddy and Nadaf (2014), Neelima *et al.* (2016), Supriya *et al.* (2016) and Shyam *et al.* (2021) for days to 50% flowering, plant height, head diameter, volume weight and

Table 3. Variability estimates of 50 sunflower genotypes for nine quantitative traits

	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
Days to 50% flowering	10.81	10.45	93.43	20.80
Days to maturity	7.35	6.89	87.67	13.28
Plant height	15.65	15.48	97.88	31.56
Head diameter	19.07	17.20	81.40	31.97
Hundred seed weight	33.96	32.26	90.23	63.12
Volume weight	14.95	14.30	91.50	28.18
Hull content	14.46	11.30	61.20	18.20
Oil content	16.97	16.31	92.36	32.29
Single plant yield	54.66	51.16	87.59	98.63

PCV- Phenotypic coefficient of variation; GCV - Genotypic coefficient of variation; h^2 - Heritability; GAM- Genetic advance as per cent of mean.

oil content. For days to maturity the results stayed parallel with the findings of Supriya *et al.* (2016), Rani *et al.* (2017) and Divya *et al.* (2019), Neelima *et al.* (2016) and Reavanth *et al.* (2021).

Heritability and Genetic advance: Heritability is an estimate that denotes the heritable variation present in the genotypes controlled by genetic factors. The assessment of heritability in broad sense revealed high heritability for all the traits, days to 50% flowering (93.43%), days to maturity (87.67%), plant height (97.88%), head diameter (81.40%), hundred seed weight (90.23%), volume weight (91.50%), hull content (61.20%), oil content (92.36%) and single plant yield (87.59%) (Table 3). These outcomes were in accordance with Sujatha and Nandini, (2002), Vidhyavathi *et al.* (2005), Ramesh *et al.* (2013) and Shyam *et al.* (2021). High heritability indicates that portion of variation that is heritable, hence selection based on these traits will be effective for crop improvement.

Genetic advance is the amount of genetic gain attained by selection of the character. The high estimates (> 20%) of GAM was observed for days to 50% flowering, plant height, head diameter, hundred seed weight, volume weight, oil content, and single plant yield (**Table 3**). For days to maturity (13.28 %) and hull content (18.20), the estimate of GAM was moderate (10-20%).

High heritability associated with high genetic advance implies the presence of additive gene action and these traits can be easily improved by applying selection in early generations to maximize the genetic gain. (Shyam *et al.,* 2021). In the present study, days to 50% flowering, plant height, head diameter, hundred seed weight, volume weight, oil content and single plant yield exhibited such association. The findings were similar to the results reported by Dudhe *et al.* (2020) and Baraiya and Patel, (2018) for days to 50% flowering and days to maturity; Reddy and Nadaf (2014), Reavanth *et al.* (2021) and Kamalnathu *et al.* (2022) for head diameter and hundred seed weight.

Correlation: Yield being an intricate trait, its outcome always results from the compounding effect of inter-related traits. Hence, correlation study is necessary to understand the association of other characters on yield. In the present study, head diameter (0.744) and hundred seed weight (0.747) had significant positive correlation with single plant yield (**Table 4**) indicating the parallel improvement of yield while selection for head diameter and hundred seed weight. These results were found to be in agreement with Zia *et al.* (2013), Sowmya *et al.* (2010), Aanandhan *et al.* (2010), Baloch *et al.* (2016) and Rigon *et al.* (2014) for the correlation of head diameter and hundred seed weight with single plant yield. Further, the traits head diameter and hundred seed weight were significantly inter-correlated (0.648) with each other providing opportunities for simultaneous improvement of head diameter with hundred seed weight and *vice versa*. Days to 50% flowering (-0.406) and days to maturity (-0.388) had high significant negative correlation with single plant yield. Similar associations were reported by Binod *et al.* (2008) and Pandya and Narwade, (2015) for days to 50% flowering with single plant yield. Significant positive correlation was found between days to 50% flowering and days to maturity (0.986), days to 50% flowering and plant height (0.490) and days to maturity and plant height (0.503). Reavanth *et al.* (2021) also reported similar association between days to 50% flowering with days to maturity, volume weight and oil content. Significant negative correlation were found between days to 50% flowering (-0.535) and days to maturity (-0.527) with hundred seed weight. These reports were similar to the results of Ramzan *et al.* (2015) for days to 50% flowering with hundred seed weight and Dudhe *et al.* (2020) for days to maturity with hundred seed weight.

In sunflower, oil is the primary significant product and hence understanding their association with other traits helps in improving oil yield. In this study, the oil content exhibited positive correlation with all traits while the association was significant only with head diameter and volume weight. This provides the opportunity for

Table 4. Correlation coefficients for yield and its contributing traits of the evaluated 50 sunflower genotypes

	DFF	DM	PH	HD	HSW	VW	HC	OC
DM	0.986**							
PH	0.490**	0.503**						
HD	-0.102	-0.086	0.234					
HSW	-0.535**	-0.527**	-0.116	0.648**				
VW	0.073	0.066	0.258	0.273	0.142			
HC	0.167	0.169	0.197	-0.268	-0.226	0.037		
OC	0.261	0.267	0.170	0.301*	0.037	0.493**	-0.061	
SPY	-0.406**	-0.388**	0.050	0.744**	0.747**	0.181	-0.197	0.016

* - Significance at 5% level; ** - Significance at 1% level.
DFF-Days to 50% flowering; DM- Days to maturity; PH- Plant height; HD- Head diameter; HSW- Hundred seed weight; VW- Volume weight; HC- Hull content; OC- Oil content; SPY- Single plant yield.

Table 5. Direct (Bold values) and indirect effects of quantitative traits on single plant yield in sunflower

	DFF	DM	PH	HD	HSW	VW	HC	OC	Correlations Coefficients of SPY
DFF	**-0.359**	0.178	0.021	-0.057	-0.159	0.005	0.005	-0.041	-0.406**
DM	-0.354	**0.181**	0.021	-0.048	-0.156	0.004	0.005	-0.042	-0.388**
PH	-0.176	0.091	**0.042**	0.131	-0.035	0.017	0.006	-0.026	0.050
HD	0.037	-0.016	0.01	**0.558**	0.192	0.018	-0.008	-0.047	0.744**
HSW	0.192	-0.095	-0.005	0.362	**0.297**	0.009	-0.007	-0.006	0.747**
VW	-0.026	0.012	0.011	0.152	0.042	**0.066**	0.001	-0.077	0.181
HC	-0.06	0.031	0.008	-0.15	-0.067	0.002	**0.029**	0.01	-0.197
OC	-0.094	0.048	0.007	0.168	0.011	0.032	-0.002	**-0.156**	0.016

Residual value: 0.282

* - Significance at 5% level; ** - Significance at 1% level.

DFF-Days to 50% flowering; DM- Days to maturity; PH- Plant height; HD- Head diameter; HSW- Hundred seed weight; VW- Volume weight; HC- Hull content; OC- Oil content; SPY- Single plant yield.

simultaneous improvement of oil content with these two traits and *vice versa*. The non-significant positive correlation with single plant yield (0.016) in the present study indicates the possibility for oil content improvement without yield penalty. The study by Reavanth *et al.* (2021) also observed a similar correlation between volume weight and oil content.

Path coefficient analysis: Path coefficient analysis was done to comprehend the direct and indirect effects of each trait on single plant yield. In the current study, path coefficient analysis revealed that head diameter had high positive direct effect (0.558) on single plant yield followed by hundred seed weight (0.297) with moderate positive effect (**Table 5**). In the case of days to maturity though it has the positive direct effect (0.181) on single plant yield, it has a negative correlation with single plant yield. It can be explained by the negative indirect effect exerted by days to maturity on single plant yield through days to 50% flowering (-0.354) and hundred seed weight (-0.156). High direct negative effects on single plant yield were exerted by days to 50% flowering (-0.359) and oil content (-0.156) exerted low direct negative effects. Highest positive indirect effect on single plant yield was imposed by hundred seed weight through head diameter (0.362). while head diameter *via* hundred seed weight (0.192) followed by hundred seed weight *via* days to 50% flowering (0.192) followed by days to 50% flowering *via* days to maturity (0.178) followed by oil content *via* head diameter (0.168) and volume weight *via* head diameter (0.152). From these results we can deduce that head diameter and hundred seed weight can be reliably used for selection taking into consideration that it has moderate to high positive direct and indirect effects on single plant yield. These estimates were found to be in agreement with Pandya *et al.* (2015), Rani *et al.* (2016), Reavanth *et al*. (2021) and Arshad *et al.* (2010) for direct effects of head diameter and hundred seed weight.

To conclude, the study revealed the presence of wide variability for all the characters under study and identified head diameter and hundred seed weight as the most desirable traits for improving yield through selection. Similarly for oil content improvement, selection can be favored towards head diameter and volume weight. Further, the identified genotypes based on *per se* performance with desirable yield and its attributing trait can be utilized for trait specific improvement in sunflower. Adding to this, attempting crosses between genotypes holding traits of interest will be advantageous for the development of promising inbreds/hybrids and also for widening the gene pool.

REFERENCES

Anandhan, T., Manivannan, N., Vindhiyavarman, P. and Jeyakumar, P. 2010. Correlation for oil yield in sunflower (*Helianthus annuus* L.). *Electron. J. Plant Breed*., **1**(4): 869-871.

Arshad, M., Khan, M. A., Jadoon, S. A. and Mohmand, A. S. 2010. Factor analysis in sunflower (*Helianthus annuus* L.) to investigate desirable hybrids. *Pak. J. Bot*, **42**(6), 4393-4402.

Baloch, M., Kaleri, M.H., Baloch, A.W., Baloch, T.A., Gandahi, N., Jogi, Q., Bhutto, L.A. and Hakro, J. A. 2016. Phenotypic correlation and heritability analysis in sunflower (*Helianthus annuus* L.) germplasm. *Pure Appl. Biol*, **5**:641-646. [Cross Ref]

Baraiya, V. K. and Patel, P. J. 2018. Genetic variability, heritability and genetic advance for seed yield in sunflower (*Helianthus annuus* L.). *Indian J. Crop Sci*., **6**(5): 2141-2143.

Binodh, A. K.., Manivannan, N. and Varman, P. V. 2008. Character association and path analysis in sunflower. *Madras Agricultural Journal*, **92**:295-299.

Burton, G.W. and Devane, E.H. 1952. Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. *Agronomy Journal*, **45**: 478-481. [Cross Ref]

Crop Production Guide. 2020. Available at: https://tnau.ac.in/

Dewey, D. R. and Lu, K. 1959. A Correlation and Path Coefficient Analysis of Components of Crested Wheatgrass Seed Production. *Agron J*., **51**(9): 515-518. [Cross Ref]

Divya, S., Kalaimagal, T., Manonmani, S. and Rajendran, L. 2019. Genetic analysis of variability, heritability and genetic advance in F_3 populations of sunflower (*Helianthus annuus* L.). *Electron. J. Plant Breed*., **10**(2): 761-765. [Cross Ref]

Dudhe, M. Y., Mulpuri, S., Meena, H. P., Ajjanavara, R. R., Kodeboyina, V. S. and Adala, V. R. 2020. Genetic variability, diversity and identification of trait-specific accessions from the conserved sunflower germplasm for exploitation in the breeding programme. *Agric. Res*., **9**(1): 9-22. [Cross Ref]

Rigon, C. A., Rigon, G., Paulo, J. and Capuani, S. 2014. Correlation and path analysis as an indirect selection criterion for sunflower achene productivity. *Bioscience Journal*, 768-773.

INDIASTAT. 2022. Indiastat DataNet India Private Limited. Available at: https://www.indiastat.com/table/sunflower/season-wise-area-production-yield-sunflower-india-/17394

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybeans. *Agron J*., **47**(7): 314-318. [Cross Ref]

Kamalnathu, T., Manivannan, N., Sasikala, R. and Marimuthu, S. 2022. Selection indices for oil content and oil yield improvement in low and high oleic acid content populations in sunflower (*Helianthus annuus* L.). *Electron. J. Plant Breed*., **13**(2):, 584-589. [Cross Ref]

Kumar, P. and Hazarika, M. 2020. Application of Correlation Analysis in Conventional Plant Breeding and Genome Wide Association Mapping. *International Journal of Current Microbiology and Applied Sciences*, **9**(8): 3372–3375. [Cross Ref]

Lush, J. L. 1940. Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. *J. Anim. Sci*., **19**(1): 293-301.

Manivannan, N. 2014. TNAUSTAT- Statistical package. Available at: https://sites.google.com/site/ tnaustat

Narayan, P. 2016. Recent demand-supply and growth of oilseeds and edible oil in India: an analytical approach. *International Journal of Advanced Engineering Research and Science*, **4**(1): 32-46. [Cross Ref]

Neelima, S., Kumar, K. A., Venkataramanamma, K. and Padmalatha, Y. 2016. Genetic variability and genetic diversity in sunflower. *Electron. J. Plant Breed*., **7**(3): 703-707. [Cross Ref]

Pandya, M. M. and Narwade, P. P. A. 2015. A study on correlation and path analysis for seed yield and yield components in sunflower [*Helianthus annuus* (L.)]. *Electron. J. Plant Breed.,* **6**(2): 540-545.

Pearson, K. 1896. IV. Contributions to the mathematical theory of evolution. III. Regression, heredity, and panmixia. *Proc. R. Soc. Lond*., **59**: 69-71. [Cross Ref]

Pilorgé, E. 2020. Sunflower in the global vegetable oil system: situation, specificities and perspectives. *OCL*, *27*, 34. [Cross Ref]

Ramesh, M., Arunakumari, J., Prashanth, Y., Ranganatha, A. R. G. and Dudhe, M. Y. 2013. Population improvement for seed yield and oil content by using working germplasm in sunflower (*Helianthus annuus* L.). *SABRAO J. of Breeding & Genetics*, **45**(2): 252-259.

Ramzan, I., Sadaqat, H. A., Shah, M. and Ali, Q. 2015. Correlation and path coefficient analyses of yield components in S_3 progenies of *Helianthus annuus*. *Life Science Journal*, **12**(4): 109-112.

Rani, R., Sheoran, R. K. and Sharma, B. 2017. Studies on variability, heritability and genetic advance for quantitative traits in sunflower (*Helianthus annuus* L.) genotypes. *Research in Environment and Life Sciences*, **10**(6): 491-493.

Reavanth, T., Manivannan, N., Sasikala, R. and Rajendran, L. 2022. Genetic variability and association analysis for yield and its component traits in sunflower (*Helianthus annuus* L.). *Madras Agricultural Journal*, **109**:10-12. [Cross Ref]

Reddy, V.R.P. and Nadaf, H.L. 2014. Genetic variability and diversity studies in sunflower (*Helianthus annuus* L.). *Ann. Biol*., **30**(2): 299-302.

Sampath., Madhu, Rakesh, B. and Manoj, S. 2023. Why Does India Import Sunflower Oil from Other Countries? *Just agriculture newsletter*, **3**(9)

Shyam Sundar, L., Nihar Ranjan, C., Sandip, D. and Achal, K. 2021. Genetic variability, character association and divergence studies in sunflower (*Helianthus annuus* L.) for improvement in oil yield. Journal name

Simmonds. N.W. 1979. Principles of crop improvement, Longman, New York.

Sivasubramanyam, M.S. and Menon, M. P. 1973. Path analysis of yield components in rice. *Madras Agric. Jl.* **60**(9/12): 1217-1221.

Sowmya, H. C., Shadakshari, Y. G., Pranesh, K. J., Srivastava, A. and Nandini, B. 2010. Character association and path analysis in sunflower (*Helianthus annuus* L.). *Electron. J. Plant Breed*. **1**(4): 828-831.

Soxhlet, F. 1879. Die gewichtsanalytische Bestimmungdes Milchfettes, *Polytechnisches J. Dingler's*), **232**, 46.

Sujatha, H. L. and Nandini, R. 2002. Genetic variability study in sunflower inbreds. *Helia*, **25**(37): 93-100. [Cross Ref]

Supriya, S. M., Kulkarni, V. V., Lokesha, R. and Govindappa, M. R. 2016. Genetic variability studies for yield and yield components in sunflower (*Helianthus annuus* L.). *Electron. J. Plant Breed*., **7**(3): 737-741. [Cross Ref]

Vidhyavathi, R., Mahalakshmi, P., Manivannan, N. and Murulidharan, V. 2005. Correlation and path analysis in sunflower (*Helianthus annuus* L.). *Agricultural Science Digest*, **25**(1): 6-10.

Zia, Z., Sadaqat, H.A., Tahir, M.N. and B. Sadia. 2013. Correlation and path coefficient analysis of various traits in Sunflower (*Helianthus annuus* L.). *J. Glob. Innov. Agric. Soc. Sci*., **1**(1): 5-8.