*Pak. J. Biotechnol. Vol. 21(1), 172-177, **2024*** http://doi.org/10.34016/pjbt.2024.21.01.893

Research Article

OPEN ACCESS

Available on http://www.pjbt.org
Pakistan Journal of Biotechnology
(PJBT)
(P-ISSN: 1812-1837 and E-ISSN: 2312-7791)

CORRELATION AND REGRESSION ANALYSIS IN DIFFERENT GENOTYPES OF SUNFLOWER (*HELIANTHUS ANNUS* L.)

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Article Received 14-10-2023, Article Revised 02-01-2024, Article Accepted 03-01-2024.

ABSTRACT

In 2017, a study at Oilseed research station in Tandojam was conducted to analyze growth and yield across eight sunflower genotypes: Corolla, Melbour, Vulgare, Turkish, Samson-30, Sputnik, HO-1, and Parson. Using a randomized complete block design with triple repetitions, noteworthy variations were discovered in days to blooming and maturity, plant stature, flower head diameter, seed count per head, seed yield, and 100-seed weight, emphasizing the distinct performance of each genotype. Advanced genotypes like Sputnik and HO-1 required more days to flower, with Parson and Sputnik showing the latest maturity. Turkish plants were notably taller, while Parson had the shortest stature. Parson and HO-1 stood out with larger flower head diameters and higher 100-seed weights, and Parson also led in seed yield, suggesting their high breeding value. However, positive correlations among various growth and yield parameters underscore the potential of these genotypes in breeding programs aimed at improving sunflower yields. This concise analysis highlights the diversity and breeding prospects within sunflower genotypes, offering valuable insights for future genetic improvement efforts.

Keywords: Sunflower, seed yield, plant stature, flower head diameter, days to blooming, days to maturity

INTRODUCTION

Sunflower (*Helianthus annuus* L.), ranking as the fourth major source of edible oil globally following soybean, groundnut, and mustard, recorded production of 43.8 million metric tons in the 2016/17 season, particularly in European and South Asian countries (Chambo *et al.,* 2017). Native to southwestern America and Mexico, sunflower thrives in soils rich in organic matter, with optimal drainage and water-holding capacities. It can adapt to various soil types, from sandy to heavy clay. Sunflower's high cross-pollination rate, facilitated by pollinating insects, contributes significantly to seed yield, with a 43% expansion in seed yield per head observed with cross-pollination (Chambo *et al.,* 2011).

Introduced in Pakistan during the 1960s, sunflower cultivation aimed to bridge the gap between edible oil production and consumption. Sunflower is grown over an area of 87449 hectares across all provinces, with seeds containing 44% high-quality oil, low in cholesterol, and rich in vitamins A, B, E, and K (Arshad *et al.,* 2019). Its significance extends beyond cooking oil to biodiesel production, drawing attention from farmers, growers, and oil companies. Research in plant breeding and genetics is crucial for enhancing crop production through the evaluation of genotypes, focusing on traits influential to the production process (Mijic *et al.*, 2009).

Correlation analysis plays a pivotal role in plant breeding by highlighting dependencies between variables, aiding in simultaneous character improvement (Nadaf, 2013). Studies show positive correlations between traits like plant stature, flower head diameter, and seed yield, guiding the selection of high-yielding genotypes (Baloch *et al.,* 2016). Understanding the relationship between seed yield and related traits is vital for breeding programs, analyzed through regression and correlation analyses to identify significant relationships (Evci *et al.,* 2012). Variations in quantitative traits like head breadth, plant stature, total leaves per plant, seeds per head, and 1000-seed weight are influenced by environmental and genetic factors. For breeders, deciphering these variations is crucial (Fattahi *et al.,* 2017).

Sunflower breeding focuses on understanding the relationships between traits and environmental interactions to enhance selection efficiency. Test weight, as a seed quality trait, directly impacts seed yield, emphasizing its importance in selecting high-yielding germplasm lines (Rani *et al.,* 2017). Fahmideh *et al.* (2015) evaluated five cultivars of sunflower to determine relationship of genotypes contribution yield characters through Correlation and regression analysis. Likewise, plant height, number of seed per head, days to flowering, and head diameter showed significant correlation and other characteristics had non-significant effects on seed yield traits. Hybrid vigor improvement relies on genetic diversity among parents, with correlation analysis shedding light on the interplay of yield-contributing traits (Punitha *et al.*, 2010). This research aims to evaluate new sunflower genotypes to understand their mutual trait associations, building on the foundation of previous studies.

MATERIALS AND METHODS

This research work primarily focused on correlation and regression analysis in distinct lines of sunflower. The trial was conducted in the year 2017 by randomized complete block design with three repetitions at the Oilseeds research section in Tandojam. Eight genotypes, namely Corolla, Melobour, Vulgare, Turkish, Samson-30, Sputnik, HO-1, and Parson were studied. The observation was recorded on seven traits viz; days to 75% blooming, days to 90% maturity, plant stature, flower head diameter, seed count head^{-1}, 100-seed weight, and seed yield plant^{-1}. The seed was sown by drilling, maintaining a plant row spacing of seventy five centimeters. Thinning was performed after fifteen days of planting to ensure the standard plant-to-plant distance. For data collection, five plants were randomly selected from each replication. Analysis of variance was employed after data collection using the method proposed by Gomez and Gomez (1984). Phenotypic correlation and regression analysis were obtained through SPSS v.19 computer software.

RESULTS

The trial was conducted to calculate correlation and regression analysis of different traits of sunflower (*Helianthus annus* L.) at the Oilseed research station, Tandojam. This study included eight different sunflower varieties, namely Corolla, Melbour, Vulgare, Turkish, Samson-30, Sputnik, Ho-1, and Parson, to compare the mean performance.

The mean squares regarding sunflower including characters of various genotypes (Table 1) demonstrated that the genotypes, differences are highly significant (P<0.01) for days to 75% blooming, days to 90% maturity, plant stature, flower head diameter, seed count head^{-1}, 100-seed weight, and seed yield plant^{-1}. These similarities or differences in yield-related traits within sunflower genotypes are said to exist due to the genetic composition of ancestors.

Table 1. Mean squares after analysis of variance for different metric characters of sunflower genotypes

Characters	Replication (D.F - 2)	Genotype (D.F - 7)	Error (D.F - 21)
Days to 75% blooming	0.13	28.76**	2.16
Days to 90% maturity	0.73	48.85**	2.59
Plant stature	23.03	1865.66**	13.11
Flower head diameter	0.05	7.51**	0.76
Seed count head^{-1}	931.8	11072.9**	1699.9
100-seed weight	0.00	0.72**	0.01
Seed yield plant-^{1}	1.36	103.47**	3.74

*** = Significant at P<0.01 probability*

Mean performance: The data with concerning the mean performance of studied characters are reported in Table 2. The data reflected within sunflower genotypes that the 'Sputnik (71.65 days) and HO-1 (71.52 days) comparatively took more days to bloom followed by Vulgare (70.50 days) and Melbour (69.31 days); while the minimum days to blooming were taken by variety Corolla (64.75 days). Relatively delayed maturity (96.75 and 95.62 days) was recorded equally in advance genotypes 'Parson and Sputnik, followed by advance lines Vulgare (93.07 days) and HO-1 (92.67 days) and early maturity was noted in Corolla (86.00 days). Significantly taller plants within genotypes were noted in Turkish (167.50 cm) than the genotypes Vulgare (163.00 cm) and Corolla (159.70 cm). The lowest plant stature (100.15 cm) was recorded in the Parson genotype. Advance sunflower genotypes 'Parson and HO-1' produced relatively bigger flower head diameter of 14.62 and 14.55 cm followed by genotypes Melbour (13.67 cm) and Vulgare (12.60 cm); while the minimum flower head diameter (12.30 cm) was recorded in Turkish genotype. However, maximum seed count (933.30 head^{-1}) was obtained for genotype 'HO-1' followed by Parson (915.70 head^{-1}), Melbour (846.01 head^{-1}) and Turkish (830.45 head^{-1}); whereas minimum seed count (788.25 head^{-1}) was recorded in Vulgare genotype. Moreover, maximum 100-seed weight (4.02 g) was noticed for genotype 'Parson' compared to HO-1 (3.75 g) and Samson-30 (3.31 g), respectively. Whereas minimum 100-seed weight (2.66 g) was recorded for genotype 'Spuntik'. Similarly, relatively more seed yield plant^{-1} (36.33 g) were found in variety 'Parson' followed by genotypes HO-1 (32.10 g) and Melbour (26.10 g); though the minimum seed yield plant^{-1} (20.94 g) was recorded in Sputnik genotype

Table 2. Mean performance of sunflower genotypes for various quantitative traits.

Genotypes	Days to 75% blooming	Days to 90% maturity	Plant stature (cm)	Flower head diameter (cm)	Seed count head^{-1}	100-seed weight	Seed yield plant^{-1}
Corolla	64.75	86.00	159.70	12.10	829.85	3.00	24.29
Melbour	69.31	89.17	155.85	13.67	846.01	3.14	26.10
Vulgare	70.50	93.07	163.00	12.90	788.25	3.10	22.58
Turkish	67.90	90.12	167.50	12.30	830.45	3.29	26.04
Samson-30	65.25	91.00	148.20	12.60	800.50	3.31	25.16
Sputnik	71.65	95.62	139.98	10.50	814.35	2.66	20.94
HO-1	71.52	92.67	158.85	14.55	933.30	3.75	32.10
Parson	67.22	96.75	100.15	14.62	915.70	4.02	36.33
Average	68.51	91.80	149.15	12.90	844.80	3.28	26.69
L.S.D (5%)	2.16	2.36	5.32	1.28	60.62	0.16	2.84

Correlation and regression analysis: The data about correlation and regression are presented in Table 3. The results are as under:

Days to 75% blooming *v/s* days to 90% maturity: The interrelationship was found positively significant (r = 0.40*) between days to 75% blooming and days to 90% maturity, thus expressing direct relationship between days to 75% blooming and days to 90% maturity. Furthermore, the regression coefficient revealed that a unit enhance in days to 75% blooming will result in an increase of 0.31 days in days to 90% maturity.

Days to 75% blooming *v/s* plant stature: The interrelation within days to 75% blooming and plant stature was found to be negative and non-significant (r = -0.62*), resulting a unit increase in days to 75% blooming, decrease of 0.012 cm of plant stature.

Days to 75% blooming *v/s* flower head diameter: The non-significant and negative correlation (r = -0.27) was found among days to 75% blooming and flower head diameter. The regression coefficient (b) revealed that a unit enhanced in days to 75% blooming has no effect on flower head diameter.

Days to 75% blooming *v/s* seed count head^{-1}: The highly significant and positive correlation (r = 0.68**) was found between days to 75% blooming and seed count head^{-1}. Thus regression coefficient (b) indicates neutral effect of days to 75% blooming on seed count head^{-1}.

Days to 75% blooming *v/s* 100-seed weight: The positive and highly significant interrelation (r = 0.61**) was found among days to 75% blooming and 100-seed weight.

Days to 75% blooming *v/s* seed yield plant^{-1}: The highly significant and positive correlation (r = 0.89**) was found between days to 75% blooming and seed yield plant^{-1}. The regression coefficient indicated that a unit enhancement or decrease will produce no effect on seed yield plant^{-1}.

Days to 90% maturity *v/s* plant stature: Negative and non-significant correlation (r = -0.62ns) was found among days to 90% maturity and plant stature thus showing reciprocal association between days to 90% maturity and plant stature. Moreover, the regression coefficient showed that a unit enhancement in days to 75% maturity will result in decrease of -0.107 cm in plant stature.

Days to 90% maturity *v/s* flower head diameter: Positive and highly significant correlation (r = 0.08**) was found among days to 90% maturity and flower head diameter. Therefore, regression coefficient demonstrated no any effect of days to 90% maturity on flower head diameter.

Days to 90% maturity *v/s* seed count head^{-1}: The highly significant and positive correlation (r = 0.25**) was found within days to 90% maturity and seed count head^{-1}.

Days to 90% maturity *v/s* 100-seed weight: The significant and positive correlation (r = 0.31*) was found among days to 90% maturity and 100-seed weight. The regression coefficient revealed unremarkable effect of days to 90% maturity on 100-seed weight.

Days to 90% maturity *v/s* seed yield plant$^{-1:}$ The significant and positive correlation (r = 0.33*) was found within days to 90% maturity and seed yield plant^{-1}. Thus if total days to 90% maturity enhances it will ultimately enlarge seed yield plant^{-1}. Moreover, the regression coefficient showed that a unit enhance in days to 90% maturity will result in rise of 0.237 in seed yield plant^{-1}.

Plant stature *v/s* flower head diameter: The non-significant but positive correlation (r = -0.27*) was found between plant stature and flower head diameter. Thus, that expresses no relation of decreasing or increasing character value.

Plant stature *v/s* seed count head^{-1}: The non-significant and negative correlation (r = -0.37) was found between plant stature and seed count head^{-1}, which means if plant stature increases simultaneously seed count head^{-1} will decrease. On the other hand, the regression coefficient value denotes that unit enhancement in plant stature will result in decrease of -0.125 in seed count head^{-1}.

Plant stature *v/s* 100-seed weight: The non-significant and positive correlation (r = -0.45ns) was found between plant stature and 100-seed weight expressing that increasing plant stature will decrease 100-seed weight. The regression coefficient (b) revealed that a unit enhance in plant stature will result in decrease of -22.80 in 100-seed weight.

Plant stature *v/s* seed yield plant^{-1}

The non-significant negative correlation (r = -0.56ns) was observed among plant stature and seed yield plant^{-1}. The negative and significant association indicates that increase in plant stature will decrease seed yield plant^{-1}. The regression coefficient revealed that a unit enhance in plant stature will result in decrease of -2.28 in seed yield plant^{-1}.

Flower head diameter *v/s* seed count head^{-1}: The highly significant and positive correlation (r = 0.68**) was found among the flower head diameter and seed count head^{-1} showing that flower head diameter increment will result in increase of seed count head^{-1}. The regression coefficient revealed that a unit enhance in flower head diameter will result in an increase of 0.016 in seed count head^{-1}.

Flower head diameter *v/s* 100-seed weight: The highly significant and positive correlation (r = 0.76**) was found amid flower head diameter and 100-seed weight expressing the direct association of flower head diameter and 100-seed weight. Moreover, the regression coefficient revealed that a unit enhance in flower head diameter will result in an increase of 2.72 in 100-seed weight.

Flower head diameter *v/s* seed yield plant^{-1}: The highly significant and positive correlation (r = 0.73**) was observed amid flower head diameter and seed yield plant^{-1}. The regression coefficient revealed that a unit enhance in flower head diameter will result in an increase of 0.214 in seed yield plant^{-1}.

Seed count head^{-1} *v/s* 100-seed weight: The highly significant and positive correlation (r = 0.61**) was found between seed count head^{-1} and 100-seed weight. The regression coefficient showed that a unit enhance in seed count head^{-1} will result in an increase of 90.31 in 100-seed weight.

Seed count head^{-1} *v/s* seed yield plant^{-1}: The highly significant and positive association (r = 0.80**) was found amid seed count head^{-1} and seed yield plant^{-1}. The regression coefficient revealed that a unit enhance in seed count head^{-1} will result in an increase of 9.59 in seed yield plant^{-1}.

100-seed weight *v/s* seed yield plant^{-1}: The positive and highly significant interrelation (r = 0.89**) was found amid 100-seed weight and seed yield plant^{-1}. The regression coefficient revealed that a unit enhance in 100-seed weight will result in an increase of 0.072 in seed yield plant^{-1}.

Table 3. Correlation (r) and regression (b) of sunflower genotypes for various quantitative traits

Traits	Correlation coefficient (r)	Coefficient determination $(r)^2$	Regression coefficient (b)
Days to 75% blooming *v/s* days to 90% maturity	0.40*	0.16	0.31
Days to 75% blooming *v/s* plant stature	-0.62ns	-0.38	-0.012
Days to 75% blooming *v/s* flower head diameter	0.27**	0.07	0.021
Days to 75% blooming *v/s* seed count head^{-1}	0.68**	0.46	0.005
Days to 75% blooming *v/s* 100-seed weight	0.61**	0.37	0.72
Days to 75% blooming *v/s* seed yield plant^{-1}	0.89**	0.79	0.055
Days to 90% maturity *v/s* plant stature	-0.62ns	-0.38	-0.107
Days to 90% maturity *v/s* flower head diameter	0.08**	0.006	0.209
Days to 90% maturity *v/s* seed count head^{-1}	0.25**	0.06	0.014
Days to 90% maturity *v/s* 100-seed weight	0.31*	0.09	2.74
Days to 90% maturity *v/s* seed yield plant^{-1}	0.33*	0.10	0.237
Plant stature *v/s* flower head diameter	-0.27*	-0.07	3.781
Plant stature *v/s* seed count head^{-1}	-0.37ns	-0.13	-0.125
Plant stature *v/s* 100-seed weight	-0.45ns	-0.20	-22.80
Plant stature *v/s* seed yield plant^{-1}	-0.56ns	-0.31	-2.28
Flower head diameter *v/s* seed count head^{-1}	0.68**	0.46	0.016
Flower head diameter *v/s* 100-seed weight	0.76**	0.57	2.72
Flower head diameter *v/s* seed yield plant^{-1}	0.73**	0.53	0.214
Seed count head^{-1} *v/s* 100-seed weight	0.61**	0.37	90.31
Seed count head^{-1} *v/s* seed yield plant^{-1}	0.80**	0.64	9.59
100-seed weight *v/s* seed yield plant^{-1}	0.89**	0.79	0.072

DISCUSSION

Character association analysis is a pivotal tool for sunflower breeders, allowing them to discern the relationships between various agronomic traits (Goksoy *et al.*, 2007). This study's findings highlight the diversity and significant variations at P<0.01 among sunflower genotypes in key growth and yield parameters, including days to 75% and 90% maturity, plant stature, flower head diameter, seed count per head, seed yield per plant, and 100-seed weight. Advanced genotypes like Sputnik and HO-1 required longer periods to reach flowering, while Corolla exhibited the earliest flowering. Similarly, maturity was delayed in genotypes Parson and Sputnik, with Corolla maturing earliest. The tallest plants were observed in the Turkish genotype, and the shortest in Parson.

In terms of flower head diameter and seed production, Parson and HO-1 stood out, with Parson also showed the highest 100-seed weight. Conversely, Sputnik had the lowest 100-seed weight, indicating a variance in seed size and weight among the genotypes. Seed yield per plant was highest in Parson, further emphasizing the genetic potential of specific genotypes for breeding programs focused on yield improvement. These variations in growth and yield traits underscore the genetic diversity among the parental materials of these genotypes. Supporting studies by Ahmed *et al.* (2017) and Saed-Saed-Moucheshi *et al.* (2013) affirm that seed count per head and seed yield per plant are critical factors in selecting high-yielding sunflower cultivars. The significant genotype-specific performance variations revealed in this study highlight the importance of genetic composition in determining the agronomic potential of sunflower genotypes, offering valuable insights for future breeding efforts aimed at yield enhancement.

Correlation studies play a crucial role in elucidating the relationships between quantitative traits in sunflower genotypes. The correlation coefficient (r) analysis in this research revealed positive and significant correlations among several pairs of traits, such as days to 75% blooming and days to 90% maturity, days to 75% maturity and seed yield per plant, plant stature and 100-seed weight, flower head diameter and seed count per head, flower head diameter and 100-seed weight, flower head diameter and seed yield per plant, seed count per head and 100-seed weight, seed count per head and seed yield per plant, and 100-seed weight and seed yield per plant. These findings align with the work of several researchers, including Baloch *et al.* (2016), Habibullah *et al.* (2007) and Fahmideh *et al.* (2015) who conducted correlation and regression analyses on various sunflower genotypes to investigate the influence of morphological traits such as seed count per head, 100-seed weight, and seed yield per head on overall yield.

These studies highlight the significance of traits like plant stature, seed count per head, days to blooming, and flower head diameter in determining yield outcomes, while other traits may have a non-significant impact on yield. This is consistent with the findings of Fattahi *et al.* (2017), who explored the genetic basis of sunflower traits and reported non-significant correlation results for similar morphological characteristics. The consensus among these studies underscores the importance of specific agronomic traits in enhancing sunflower yield, guiding breeders in the selection of genotypes with optimal performance traits for breeding programs aimed at yield improvement.

Regression analysis was employed to discern the impact of various independent variables on seed yield per plant (the dependent variable) in sunflower genotypes. The analysis provided insightful coefficients (b) indicating how changes in one variable affect another. Specifically, an increase of one unit in days to 75% blooming was associated with a 0.31-day increase in days to 90% maturity, a decrease of 0.107 cm in plant stature, and an increase of 0.237 g in seed yield per plant. Conversely, a unit increase in plant stature predicted a decrease of 0.125 in the seed count per head, a significant reduction of 22.80 in the 100-seed weight, and a decrease of 2.28 g in seed yield per plant.

Furthermore, the analysis highlighted that an increase in flower head diameter would result in a modest increase of 0.016 in seed count per head. Interestingly, an increase in seed count per head was highly beneficial, leading to a 90.31 increase in 100-seed weight and a 9.59 g increase in seed yield per plant. Likewise, an increase in the 100-seed weight was associated with a 0.072 g increase in seed yield per plant.

The results of this study were in concordance with Manjula (1997), who explored the association between various traits in sunflower, and with the research conducted by Baloch *et al.* (2016), further validating the results. In conclusion, enhancing seed yield in sunflower genotypes can be effectively achieved by selecting for a higher seed count per head and minimizing the days to full flowering. Additionally, for optimizing oil yield, criteria such as the seed count per head, 1000 seed weight, and plant stature emerge as pivotal indirect selection parameters. Emphasizing these traits, alongside reduced days to full blooming, presents a promising strategy for genetic improvement programs targeting sunflower oil and seed yield enhancement

CONCLUSIONS

The research reveals significant variations in sunflower genotypes, with HO-1 and Parson standing out for their superior performance in flower head diameter, seed yields per head, and overall seed yield per plant. Conversely, the Corolla genotype, while maturing early, exhibited less impressive results. The study concludes that Parson and HO-1 hold promise for breeding programs focused on enhancing sunflower yields, providing valuable genetic resources for high-yielding cultivar development.

REFERENCES:

Ahmad, I., Mohammad, F., Taj, S., Munsif, F., & Akber, S. (2017). Performance of F1 hybrids in sunflower (*Helianthus annuus* L) under the enviromental conditions of peshawar valley. *Int. J. Agri and Env. Res.*, **3***(1): 112-115*.

Arshad, M., Jan, S., Awan, S., Azam, S., Khalid, S., & Khan, M. A. (2019). Investigation of genetics divergence in newly developed local sunflower (*Helianthus annuus* L.) hybrids. *Pakistan Journal of Agricultural Research*, **32**(1), 33-40.

Chambó, E. D., Escocard de Oliveira, N. T., Garcia, R. C., Ruvolo-Takasusuki, M. C. C., & de Toledo, V. D. A. A. (2017). Phenotypic correlation and path analysis in sunflower genotypes and pollination influence on estimates. *Open Biological Sciences Journal*, **3**(1).

Chambó, E. D., Garcia, R. C., Oliveira, N. T. E. D., & Duarte-Júnior, J. B. (2011). Honey bee visitation to sunflower: effects on pollination and plant genotype. *Scientia Agricola*, **68**, 647-651.

Evci, G., Pekcan, V., IbrahimYilmaz, M., & Kaya, Y. (2012). Determination of the Relationships between Oil Content and Important Yield Traits in Sunflower. *Proceedings of 18th ISC, Mar del Plata, Argentina*, **1**, 185.

Fahmideh, L., Sargazi, A., & Golparvar, A. R. (2015). Correlation, regression and path analysis of seed and oil yield in sunflower (Helianthus annus L.) genotypes. *Trends in life sci*.

Fattahi, S. H., Abdollahpour, S., Ghassemzadeh, H., Behfar, H., & Mohammadi, S. A. (2017). Regression model of sunflower seed separation and the investigation of its germination in corona field. *Agricultural Engineering International: CIGR Journal*, **19**(2).

Göksoy, A., & Turan, Z. (2007). Correlations and path analysis of yield components in synthetic varieties of sunflower (Helianthus annuus L.). *Acta Agronomica Hungarica*, **55**(3), 339-345.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Habibullah Habib, H. H., Mehdi, S. S., Anjum, M. A., & Rashid Ahmad, R. A. (2007). Genetic association and path analysis for oil yield in sunflower (*Helianthus annus* L.).

Manjula, K. (1997). *Genetic Variability, Diversity and Path Co-efficient Analysis in Non-oil Seed Sunflower (Helianthus Annuus L.) Genotypes* (Doctoral dissertation, University of Agricultural Sciences).

Mijić, A., Liović, I., Zdunić, Z., Marić, S., Marjanović-Jeromela, A., & Jankulovska, M. (2009). Quantitative analysis of oil yield and its components in sunflower elianthus annuus L.). *Romanian Agricultural Research*, **26**, 41-46.

Munaiza Baloch, M. B., Kaleri, M. H., Baloch, A. W., Baloch, T. A., Naila Gandahi, N. G., Qamaruddin Jogi, Q. J., & Hakro, J. A. (2016). Phenotypic correlation and heritability analysis in sunflower (Helianthus annuus L.) germplasm.

Nadaf, H. L. (2013). Correlation for yield and yield related trait in mutant and segregating genotypes in sunflower (Helianthus annus L.). *Molecular Plant Breeding*, **4**(32).

Punitha, B., Vindhiyavarman, P., & Manivannan, N. (2010). Genetic divergence study in sunflower (Helianthus annuus L.). *Electronic Journal of Plant Breeding*, **1**(4), 426-430.

Rani, M., Sheoran, O. P., Sheoran, R. K., Jambholkar, S., & CHANDER, S. (2017). Studies on Genetic Variability and Interrelationship of Seed Yield and Quality. *Annals of Biology*, **33**(1), 82-85.

Saed-Moucheshi, A., Fasihfar, E., Hasheminasab, H., Rahmani, A., & Ahmadi, A. (2013). A review on applied multivariate statistical techniques in agriculture and plant science. *International Journal of Agronomy and Plant Production*, **4**(1), 127-141.