Topic: Study of Correlation and Path Coefficient Analysis of Oil, Protein and Yield Related Traits in Sunflower (*Helianthus annuus* L.)

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Abstract: Sunflower became a major oilseed crop in Pakistan. Pakistan is facing a shortage of edible oil. Need to improve the oil and seed yield of sunflower. Correlation study is necessary to find out the relationship between two traits. Path analysis tells about the direct and indirect effect of different traits on yield and on yield related traits. This helps to further improve our genetic material to obtain high yield. Present study is aimed to find out the relationship of different yield related traits with oil and protein contents and to know how different traits including oil and protein contents directly or indirectly effects the yield. The results of present study explained that different traits can be used for direct and indirect selection of high yielding sunflower lines. It can be concluded that presence of adequate genetic variability in any research material makes it valuable for future breeding programs aimed at improvement of sunflower yield. This review will help to the researchers that the study of what type of traits have in their interest to improve considerably the yield of sunflower.

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Introduction:

Sunflower is an important oilseed crop which is grown to meet the demand of vegetable oil and protein all over the world. Important features of sunflower are, short growing period, high yield potential, wide range of growing seasons, less water requirement and wide range of adaptability to soil and moisture conditions which makes it more popular among the farmers (Darvishzadeh *et al*., 2011). But its production in Pakistan is very low as compared to other countries. Domestic production of edible oil is valued 0.462 million tons. Vegetable oil from all sources was 2.667 million tons. Pakistan is facing a shortage of edible oil due to non-availability of improved cultivars and high yielding hybrids. Two most important economic traits in sunflower are seed yield and oil content. Breeders focus their entire attention in developing sunflower genotypes with higher oil yield. Genetic variability is necessary for the success of breeding programs. Sunflower has both polygenic and monogenic traits but most of the traits are polygenic in nature such as yield related traits which are quantitative in nature. Achene yield is a most complex character and is a polygenic trait involving a number of genes contributing in it and their interaction with environment. It is more desirable that the structure of yield is probed through breeding techniques. It is important to measure the mutual relationship between various plant attributes and to determine the component characters, on which selection procedure can be based for direct and indirect genetic improvement of crop yield. Success of plant breeders depends on the magnitude of variation present in it.

Correlation measures all positive and negative effects of traits on achene yield. Simple correlation analysis cannot give details about relationship of yield and yield related traits so that path coefficient analysis is used. It is a tool that split the correlation coefficient into its direct and indirect effects. Breeders always use well organized methods to overcome large number of breeding lines. Variability among all genotypes must be determined at both genotypic and phenotypic levels to obtain desirable characters for future breeding programs. Estimation among characters is done to determine the impact of various traits on seed yield. To determine the association or interrelationship among traits correlation analysis is used while path analysis helps us to understand the relationship of yield and yield related traits.

Review Of Literature

Ghanavati *et al*. (1981) led an analysis to create sunflower populations, reasonable for thesemi arid areas of Iran. Crosses were made between Chernianka 66 which have less yield, less oil contents, short stem, and early development as the female parent and VNIMK 8931 which was high yielder, long stem, high oil contents and late development as the male

guardians. Determination, collectively with sib-crossing and selfing brought about six populaces with significant returns, short stem, high oil contents, and early development. Connection coefficient of oil yield and its parts, i.e. achene yield and oil substance, were highly significant and huge individually. Head distance across had very critical connections with achene yield and oil yield. Early development was related with less oil content and shorter stems.

Ahmad *et al*. (1991) concentrated the relationship of 20 genotypes of sunflower for various attributes identified with seed yield and their effects on seed yield. He explored that most of the qualities exhibited diverse relationship in the spring and pre-winter season. The connection between plant stature and 100 achene weight, oil contents and number of achenes per capitulum, plant tallness and capitulum width stayed predictable in both spells and over the seasons. Through various relapse examinations he distinguished six characters identified with seed yield on which mean coefficient investigation was finished. Mean examination spoke to that yield contributing attributes like 100 achene weight, head width and number of achenes per head had nearly littler direct consequences for seed yield. Days to physiological development oil contents and plant stature had moderately more grounded direct consequences for seed yield. Days to physiological development, plant tallness and head measurement had significant indirect impacts. Head measurement, number of achenes per head and 1000-achene weight were perceived as choice criterion for yield change.

Sadras and Villalobos (1993) determined that number of leaves at floral initiation was correlated with final number of leaves in sunflower. Four inbred lines and eight hybrids were observed for these investigations. The investigation was helpful for future breeding progress in sunflower.

Alza*et al*. (1997) developed 36 sunflower hybrids by factorial cross of six male-sterile and six restorer lines. Guardians and their hybrids were evaluated in eight situations. Six situations comprised of two neighboring trials in the test zone, the first under water system and the second under dry land environment, amid 1987, 1988 and 1992. Alternate situations where one before time planting experiment in dry land environment, carried out during 1987, and a winter examination planted in January amid 1988. Approximate of female variance (σ_f) were noteworthy for seeds per capitulum, achene weight, capitulum sterile center, days to sprouting and oil contents. Female × male collaborations (σ^2_{fm}) were significant for all traits aside from gather list and record of defenselessness to dry spell. heritability's, calculated with information from analyses combined across environments, were 0.65 for achene yield, 0.80 for achenes per capitulum, 0.84 for achene weight, 0.81 for capitulum diameter, 0.60 for sterile capitulum center, 0.72 for oil contents, 0.61 for collect record, 0.72 for biomass, 0.94 for considerable length of time to sprout and 0.42 for dry season vulnerability file. Heritability approximation for individual situations showed more variety for yield than for different attributes. It is reasoned that a proficient rearing procedure for sunflower under direct dry season focused on circumstances is the concurrent choice for achene yield per plant in both rainfed and dry situations jointly with choice for shade temp. and stem breadth.

Assad *et al*. (1999) conducted a research to study association between seed and agronomic characters and their direct as well as indirect effects on seed yield per plant under normal and drought conditions. Two field trials were carried out in 1996 at the Experimental area of College of Agriculture, Shiraz University at Badjgah. Fourteen sunflower genotypes consisting of eight hybrids and six open pollinated varieties were developed in two randomized complete block designs with four replications. Two experiments differed in respect to irrigation regime. The cause and effect relationships of 12 different characters were assessed. Most of the characters including oil content and achene yield showed great genotypic and phenotypic differences. Genotypic and phenotypic correlations revealed that seed yield had significant and positive correlations with days to physiological maturity, days to flowering, plant height, head diameter, 1000 achene weight and oil contents under normal and limited irrigation. Achene yield had significant correlations with oil content and kernel percentage under normal irrigation regime, whereas these interrelationships were largely reduced under stress conditions and were non significant. The highest direct effect was exhibited by filled achenes per head and 1000-seed weight in normal and limited irrigation conditions. However, cause and effect relations of other traits with seed yield changed due to irrigation conditions. Direct effect of oil content was fairly lower than its interrelationship with achene yield. There was lowest direct effect found for plant tallness.

Ashok *et al*. (2000) evaluated 40 sunflower hybrids and found the interrelationship of different traits as well as their effects on yield. Percentage of oil content, 100 achene weight and harvest index showed positive direct effects on yield but they were negatively correlated with yield. The difference between genotypic and phenotypic values was minor showing no effects of environment on correlation values of characters or their relation with yield. Dagustu (2002) determined simple correlations among seed yield and yield related traits in 35 genotypes of sunflower. The research included five yield indices.

Traits like 1000-seed weight, plant height, number of leaves per plant, number of seeds per head and head diameter showed positive and significant correlation with seed yield per plant. Path coefficient analysis was used to estimate the direct and indirect effects of various yield related traits on achene yield per plant. Results showed that 1000 seed weight and number of seeds per head had significant direct effects on seed yield per plant. So, these traits were considered important to increase yield of sunflower.

Tahir *et al*. (2002) directed a review for relationship and means coefficient investigation of morphological attributes of four open pollinated populations of sunflower, each containing 13 lines were incorporated into this review. The most elevated relationship of achene yield was seen with number of filled achenes per plant, trailed by rate of filled achenes and capitulum distance across. Greatest direct impact on achene yield was applied by number of filled achenes per head. Head measurement additionally considerably affected achene yield. It was presumed that number of filled achenes per plant, head breadth and 1000 seed weight were critical traits to enhance achene yield.

Rao *et al*. (2003) examined genetic variation, character association and path coefficients in 82 sunflower genotypes for 11 yield related characters. Analysis of variance presented that there were significant differences among all studied characters. Among all studied parameters plant height, test weight, number of filled seeds per head and seed yield per plant showed highest phenotypic and genotypic coefficients of variance. All characters showed high values of heritability indicating additive types of gene actions. Correlation studies showed that seed yield had significant and positive association with plant height, head diameter, test weight, number of leaves per plant, number of filled seeds per head and stem girth. Oil content revealed non significant and negative association with seed yield. Head diameter, number of filled seeds per head and test weight had maximum direct effect on seed yield. It was concluded that sunflower yield could be increased by increasing the head diameter, test weight and number of filled achenes per head.

Subrahmanyam *et al*. (2003) studied genetic variability in 85 sunflower lines including 80 inbred lines and five check varieties for eleven characters. All the genotypes were significantly different for all studied characters. Among all the studied characters, seed yield per plant, number of filled seeds per head kernel to hull ratio and test weight showed highest genetic variability. I was indicated that the lines GP-347, GP-1341, GP-507, GP-831, GP-913, ARM-244, ARM-248, B-300, B-853 and HAR-5 could result in development of superior lines of sunflower in future breeding programs. Cosge *et al*. (2004) notices correlation among different physio-morphological characters in different hybrids, lines and varieties of sunflower. The correlation analysis revealed that seed yield had significant and positive association with plant height, head diameter and stalk yield per plant. Syed *et al*. (2004) determined variability in sunflower for seven morphological characters including plant height, head diameter, days to maturity, days to flowering, days to maturity, seed yield per plant and days to anthesis. They observed positive and significant association between seed yield per plant and head diameter. Days to maturity and days to anthesis also had significant direct effect on seed yield per plant. It was observed that phenotypic correlations were less as compared to genotypic correlations for all studied characters. Plant height showed positive and significant association with seed yield per plant.

Ergen and Salgam (2005) analyzed interrelationship among yield and yield related traits of six confectionery varieties of sunflower. They observed plant height, head diameter seed yield, seed length, 1000-seed weight, oil content, protein content and hull ratio for all varieties of sunflower under study. Among all the varieties TTAE-2 showed highest seed yield and lowest hull ratio. Correlation analysis revealed that seed length and seed yield was significantly and positively associated. However, hull ration and seed yield was negatively and non-significantly correlated. Plant height was positively correlated with protein content but negatively correlated with 100 seed weight and hull ratio. Path analysis revealed that plant height and seed length had highest positive direct effect on protein ratio and seed yield in confectionery sunflower. Hassan *et al.* (2005) studied five hybrids of sunflower to study the seasonal effect on yield of sunflower. It was observed that head diameter of sunflower was more in case of spring crop as compared to fall crop while 1000 seed weight was more in fall crop as compared to spring crop. On the other hand, the overall yield of sunflower was more in spring crop than fall crop. It was concluded that it would be better to sow spring crop while fall crop could be used as supplementary crop to increase yield of oilseed crops.

Vidyavathi *et al*. (2005) evaluated 29 hybrids of sunflower to check the association of different yield and its contribution traits. The results revealed that there was positive association among head diameter and other characters while path analysis revealed that positive correlation among head diameter was higher as compared to plant height. They found that that these characters were helpful in breeding of non-oil type sunflower varieties.

Farhatullah *et al.* (2006) noticed interrelationship among yield related traits in nine hybrids of sunflower.

They observe that seed yield had significant and positive association with plant height, head diameter and oil content. There was significant and positive association between oil yield and number of seeds per head. Grain yield was directly and significantly affected by plant height, plant population, 1000 seed weight, number of seeds per head, days to maturity and oil content. Seed yield was negatively and indirectly affected by number of leaves per plant and days to flowering. Head size, number of seeds per head and 1000 seed weight had positive and significant effect on seed yield per plant. These characters can be considered for further progress in sunflower breeding programs.

Gouri *et al.* (2006) evaluated that various yield related components were significantly and positively associated with seed yield in sunflower. Maximum association was observed between number of seeds per head and seed yield. Plant height, seed filling percent, 100 seed weight, stem diameter and head diameter had significant and positive correlation with seed yield. Path analysis exhibited that maximum direct effects of seed yield was exerted by 100 seed weight and number of seeds per plant. Therefore, these traits could be considered as major contributing traits to enhance seed yield in sunflower.

Habib *et al.* (2006) conducted research on 104 genotypes of sunflower to approximate correlation, direct and indirect effects of many morphological traits including head diameter, seed yield, number of seeds per head, 100 achene weight, and stem girth. There were significant differences for all quantitative traits among all genotypes. Seed yield was positively and significantly associated with 100 achene weight, number of seeds per head, stem girth and head diameter. Head diameter was significantly and positively associated with all other characters except stem girth. Numbers of seeds per plant were significantly and positively associated with all characters. Path analysis showed that number of seeds per head, 100 seed weight and stem girth had positive and direct effect on seed yield per plant.

Khokhar *et al.* (2006) studied 10 genotypes of sunflower to observe association among various yield related traits. There was positive and significant association of 100 achene weight with head diameter, number of whorls per head and stem diameter. Achene yield was highly positively and significantly affected by stem diameter. Head size had positive and indirect effect on seed yield through stem diameter. These traits con be considered as selection parameters to increase yield of sunflower.

Mijic *et al.* (2006) studied 24 sunflower hybrids to investigate correlation of oil yield with head diameter, plant height, 1000 seed weight, seed yield, oil yield and oil content. The highest significant and positive association was observed between grain yield and oil yield. There was weak correlation between 1000 seed weight and plant height. 1000 seed weight and grain yield was significantly and positively associated with each other but non significantly and negatively association was observed among oil content and 1000 grain weight. Seed yield was non significantly and negatively associated with oil content. It was observed that grain yield and oil content exert strongest direct effect on oil yield.

Sridhar *et al.* (2006) evaluated variability parameters among yield related components in 44 sunflower genotypes. 100 seed weight, seed yield per plant, number of filled seeds per head and harvest index had highest phenotypic coefficients of variation. There was close phenotypic and genotypic coefficients of variation correspondence shown by days to flowering, days to maturity and plant height. While plant yield, number of filled seeds per head, number of unfilled seeds per head and harvest index were most affected by environmental factors. Traits like harvest index, 100 seed weight, seed yield per plant and number of filled seeds per head acquire high genetic advance. It was suggested that these traits can be considered as selection parameters for genetic advancement of sunflower.

Uttam *et al.* (2006) evaluated 66 genotypes of sunflower to check yield related components and seed quality parameters. Days to flowering, days to maturity exhibited close relationship. Among all studied traits plant height, head diameter, 100 seed weight, number of seeds per head, seed viability and emergence percentage was significantly and positively correlated with seed yield per plant. The study indicated that indirect selection of characters like head diameter, days to flowering and seeds per head can improve oil content and seed yield in sunflower.

Arshad *et al.* (2007) studied variability in 20 hybrids of sunflower. The hybrids were assessed through correlation and path analysis for yield and its related parameters. The studies showed that there were significant variations among all hybrids. There was non significant and negative association between days to seed yield and days to maturity but days to maturity was positively and significantly associated with head diameter. Seed yield was non significantly and positively associated with 100 seed weight but significantly and positively associated with oil content. Oil content was highly negatively and non significantly associated with days to flower initiation. There were positive direct effects of head diameter, days to flower initiation on grain yield and plant height. Plant height exhibited maximum positive direct effect on the grain yield per plant. It was suggested that exploit selection of these traits for better yield in sunflower breeding.

Goksoy *et al*. (2007) led a review to discover the relationships between achene yield and yield related attributes and the immediate and backhanded impacts of these qualities on achene yield in sunflower. Four engineered assortments (Syn 1s), their parental blends (SynOs) and two standard assortments (open pollinated: Vniimk 8931, and business cross breed: Sunbred-281) were assessed in reproduced field trials under Turkish conditions in 1995, 1996 and 1997. Agronomic attributes, for example, plant stature, capitulum breadth, seeds per capitulum, 1000 achene weight and achene yield were watched for connections and way coefficient examination. The outcomes demonstrated that the seed yield gave critical positive relationships with plant stature, capitulum distance across, number of seeds per capitulum and 1000 achene weight. The most astounding positive connection was seen between achene yield and number of achenes per capitulum. Way investigation demonstrated that the quantity of achenes per capitulum gave the best direct impact (+0.7269) on achene yield, trailed by 1000 achene weight (+0.3215) and capitulum distance across (+0.1689). The rate of direct impacts on achene yield was 80.8%, 50.6% and 24.0% for number of achenes per capitulum, 1000 seed weight and capitulum breadth, individually.

Habib *et al.* (2007) evaluated 104 genotypes of sunflower to observe correlation among various yield related characters under charcoal rot stress conditions. There was positive and significant association of achene yield with 100 seed weight, number of seeds per head, stem width and head diameter. It was suggested that characters like 100 seed weight and number of seeds per head can be used as selection parameters to progress yield of sunflower under charcoal rot stress condition.

Kaya *et al.* (2007) studied 13 sunflower hybrids to find the interrelationship among yield related components. Plant height, 100 seed weight and oil contents were significantly and positively associated with seed yield. Days to flowering and seed yield had non significant and negative association. Early maturing hybrids had more yield as compared to late maturing. 100 seed weight, plant height and head diameter showed highest direct effect on seed yield.

Khan *et al.* (2007) performed research on eight genotypes of sunflower to estimate correlation and genetic variability among various yield related traits. There were significant differences among plant height, days to maturity, head diameter, seed yield and oil yield, oil content and number of seeds per head. Minimum days to maturity and flowering were taken by PARSUN-1. Tallest plant was found in 65A-24 and shortest plant was found in Tarnab-1 line. Maximum number of seeds per head was shown by 65A-24 while highest 1000 seed weight was shown by Tarnab-1. SMH-9704 and PARSUN-1 exhibited maximum yield. PCV was higher than GCV for all observed parameters. Seed yield was significantly and positively associated with plant height, oil yield, oil content, number of seeds per head and seed weight.

Kothai *et al.* (2007) analyzed the correlation among yield and related traits in 23 genotypes of sunflower. Seed yield per plant, head diameter, 100 seed weight and volume weight were positively and significantly correlated with the oil yield per plant. Path analysis showed that there were highest direct effects of seed yield and oil content on oil yield. Head diameter and volume weight exerted low indirect effect on seed yield. Head diameter showed high indirect effects on seed yield through 100 seed weight. Oil content and volume weight and exhibited low indirect effects on seed yield per plant. It was suggested that 100 seed weight, volume weight, head diameter and seed yield are vital indices for improvement of oil yield in sunflower.

Samo *et al.* (2007) assessed the yield performance of different sunflower varieties. Linear correlation coefficient and path analysis was used to determine the interrelationship and direct and indirect effect of different yield related characters. It was observed that all the varieties were significantly different for most of the studied characters. Days to flowering revealed significant and positive association with plant height, head diameter, days to maturity and seed index while non-significant and positive association with the number of seeds per head. Head diameter was positively and significantly associated with number of seeds per head while negative and significant association with seed index. Seed yield was significantly and positively associated with days to flowering and days to maturity. Head diameter, days to maturity, plant height, and number of seeds per head was significantly and positively associated with the seed yield. Therefore there traits can be considered as desirable yield attributes in sunflower.

Amorim *et al.* (2008) observe correlation among 13 different agronomic characters in 14 lines of sunflower. They used the path coefficient analysis to determine the direct and indirect effect of these parameters on seed yield per plant. Seed yield was positively correlated with 1000 seed weight and head diameter. Weight of 1000 grains, percentage of filled grains and head diameter was positively associated with seed yield. So, these traits can be considered as selection criteria for improving sunflower yield. Ashish *et al.* (2008) studied that path coefficient analysis provide us with the tool for estimation of breakdown of genotypic correlation into its direct and indirect effects. Different breeders detected various types of association among various characteristics of

sunflower that contributed towards increase in yield of sunflower.

Binodh *et al.* (2008) used 24 genotypes of sunflower to evaluate the performance of yield and its related traits through correlation and path coefficient analysis. Seed yield was significantly positively associated with oil yield while there was non-significant and negative association with days to 50% flowering. Oil yield and volume weight showed positive and significant relationship. Head diameter and plant height showed positive and significant association with oil yield per plant but oil yield had significant negative association with days to 50% flowering. Path analysis revealed that oil yield had positive and direct effects on seed yield. Volume weight had highest direct negative effect on seed yield. The studies revealed that these characters can be considered reliable for selection to improve seed yield in genotypes of sunflower.

Machikowa and Saetang (2008) conducted research experiment on 12 lines of sunflower to investigate association among eight agronomic characters through correlation and path analysis. Oil content and days to flowering showed highly non-significant and negative association. Seed yield was significantly and positive associated with plant height, 100 seed weight, percent seed set and head diameter. Numbers of seed per plant were significantly and positively associated with oil content. The maximum direct effect on seed yield was exhibited by head diameter. Most of these characters had indirect effect on seed yield. Hence, the results of correlation and path coefficient analysis depicted that plant height and head diameter could be used as selection criteria for improving efficiency of sunflower genotypes.

Said and Azam (2008) assessed interrelationship among yield and its related traits in sunflower hybrids. Their research revealed that the seed yield was positively and significantly associated with head diameter, plant height and oil content. Number of seeds per plant was positively and significantly associated with yield at both phenotypic and genotypic levels. While number of plants showed significant positive correlation at genotypic level. Kaya *et al.* (2008) observed 2932 hybrids of sunflower by conducting 118 trials. They reported that plant height, head diameter and 1000 seed weight had significant positive correlation with grain yield. 1000 seed weight have direct effect on achene yield in both rainy and dry conditions.

Behradfar *et al.* (2009) investigated nine genotypes of sunflower that consist of eight hybrids in their studies to check the inter-character association for oil yield and seed yield. They studied nine characters i.e. plant height, head diameter, numbers of leave per plant, 1000 seed weight, numbers of filled seeds per head, numbers of unfilled seed, kernel percentage, days to physiological maturity, days to 50 percent flowering, seed tiled, oil yield and oil percentage. They found that three traits like head diameter, 1000 seed weight and percent filled seeds could be used as selection criteria to increase sunflower yield substantially.

Boain and Kongsami (2009) evaluated growth characteristics, yield and yield related characteristics of some oil type cultivars of sunflower. Environment×varieties interaction on seed yield and growth attributes all the measured traits. On the other hand these characters were negatively associated with oil content.

Kaya *et al.* (2009) performed correlation and path coefficient analysis among yield and its related characters in sunflower. Yield showed significant positive association with plant height, head diameter and 1000 seed weight. They found that earliness of hybrids was non significantly and positively correlated with yield. They suggested that to get satisfied yield in sunflower, look for lines that are taller in height, larger head diameter, higher seed volume, early in maturity and low husk content.

Khan *et al.* (2009) studied 8 sunflower parents and 16 F_1 hybrids to estimate relationship among various morphological characters of sunflower. Days to maturity showed positive significant association with 100 percent flowering, internodal length, days to maturity and stem width. Plant height was positively significantly associated with days to first flowering, days to 100 percent flowering, internodal length, and numbers of leave. They recommended that to evolve sunflower hybrids with early maturity, maximum number of leaves and stem width must be focused.

Iqbal *et al.* (2009) evaluated the ten lines of sunflower to determine the genetic behavior of different agronomic traits. All genotypes were significantly diverse for all observed characters. Number of leaves and whorls per plant showed maximum genotypic and phenotypic coefficient of variation. Oil content showed maximum broad sense heritability. Plant height was significantly and positively associated with leaf area and achene yield. There was positive and significant relationship among head diameter, number of whorls per head and stem diameter. Oil content and whorls per head were positively significantly associated. Leaf area, number of leaves, stem width and grain yield showed positive direct effect on oil content. Stem diameter showed highest indirect positive effect on oil contents. It was suggested that these characters could be used for efficient selection of different sunflower lines for oil content.

Ilahi *et al*. (2009) conducted an experiment with twelve sunflower genotypes to determine correlation

among achene yield and its component traits. The results showed that the plant height had positive and significant association with the no. of leaves per plant, internodal length, head diameter and achene weight per head. Number of leaves per plant correlated significantly and positively with internodal length, stem diameter at the base, 100-achene weight and achene weight per head. Internodal length had significant and positive association with achene weight per head. Head diameter also correlated significantly and positively with 100-achene weight.

Mijic *et al.* (2009) used 7 single crossed hybrids and 7 three way crossed hybrids to study interrelationship between oil yield and its components. It was estimated that H-2001A had maximum weight, short height, better yield and highest oil contents. H93-FA showed the maximum plant height, 100 seed weight and achene yield but with lowest value of oil contents.

Ozturk and Ada (2009) studied 15 cultivars of sunflower to observe yield and various yield related components as well as direct and indirect effect of these components on seed and oil yield. Oil content and oil yield was positively and significantly associated. 100 seed weight, oil content and oil yield had direct effect in yield improvement. Oil yield was negatively affected by head diameter.

Radic *et al*. (2009) investigated interdependence of sunflower quality parameters. They focused on different characters that affect the oil content of sunflower seed. The results showed that there were negative as well as positive correlations among quality parameters like genotypes, environment and steps taken during the crop production.

Schwertner *et al.* (2009) performed experiment for quantification of direct and indirect effects to obtain the genotypes with more yield through direct selection. Number of seeds and head diameter would be improved because these two characters had direct positive effect on seed yield. These characters were also used in indirect selection for improvement of grain yield of sunflower.

Yesilova *et al.* (2009) performed experiment on 9 sunflower genotypes to assess association among 12 quantitative traits. Among all the characters that were studied head diameter, 1000 seed weight and number of filled achenes per head were significantly and positively associated with grain yield. The grain yield was significantly and positively related with oil yield. These traits were considered valuable to increase grain production in sunflower.

Anandhan *et al*. (2010) performed an experiment with 55 hybrids of sunflower to determine the correlation for oil yield. They reported positive and significant association of plant height with head diameter and volume weight per 100ml. 100 seed weight was significantly and positively correlated with seed yield. Oil yield and volume weight per 100 ml were also significantly and positively associated with seed yield per plant.

Arshad *et al.* (2010) reported 37 hybrids of sunflower to study correlation and path coefficient analysis among eight agronomical characters. All the hybrids were significantly different for yield related traits. Plant height was significantly and positively associated with days to maturity and days to initiation of flowering. Head diameter was significantly and negatively associated with 100-seed weight. Non significant and negative correlations were found between seed yield and oil content. There was positive direct effect of plant height, head diameter and days to maturity on seed yield. The research suggested that LG 56-35 and LG 54-15 hybrids were most appropriate for cultivation.

Bonciu *et al.* (2010) studied character association among seed yield and yield related characters and the effect these traits on seed yield and 21 hybrids of sunflower. The correlation was divided into direct and indirect effects by using path coefficient analysis. Positive and significant association was observed among number of leaves per plant, 1000 seed weight, head diameter, oil content, number of seeds per head and seed yield. Capitulum diameter was positively and significantly related with number of seeds but non significantly and positively associated with oil content. To get cultivars with high oil content it is very important to carry out indirect selection for these characters in sunflower.

Deengra *et al.* (2010) studied the significant correlation of plant height, head diameter, plant dry matter, harvest index and filled seed per head with seed yield but days to flowering, days to maturity and capitulum size were negatively correlated with oil yield. Number of filled seeds was positively associated with head size and plant height. Results showed that there was direct effect of 100 seed weight and filled seeds per head on seed yield. Indirect effects were also observed for these characters. Days to flowering and days to maturity had direct effect on seed yield. In addition, negative direct effects and negative association was also observed between achene yield and oil content.

Kalukhe *et al.* (2010) reported 26 germplasms of sunflower for 13 yield related traits to study interrelationship among them. Plant height, number of filled grains per head, volume weight, head diameter, hull content, days to maturity and oil content were positively correlated with seed yield at both genotypic and phenotypic levels. Among all the studied traits 100 seed weight had highest direct effects on seed yield followed by plant height, number of filled seeds, volume weight, days to maturity, head diameter and

hull content. The study suggested that most of the traits indirectly affect seed yield through 100 seed weight. So, keeping in view the above studies selection for these characters will be rewarding in sunflower.

Kumar *et al.* (2010) studied correlation and path analysis for different agro-morphological characters in sunflower. They found that seed yield was positively and significantly associated with plant height, head diameter, harvest index and number of filled seeds. Oil percent was negatively and significantly associated with days to flowering, days to maturity and head diameter. Seed yield was non significantly and negatively associated with oil percentage. Seed yield was significantly and positively associated with number of filled seeds and 100 seed weight.

Sowmya *et al.* (2010) completed the test amid Summer 2009 at ZARS, GKVK, Bangalore. The base material included 38 sterility maintainer lines ('B' lines) and 38 fruitfulness restorer lines ('R' lines). He contemplated relationship and way coefficient investigation in sunflower traits including days to half blooming, days to development, plant stature, head width, 100 achene weight and oil content characteristics were emphatically and essentially connected with seed yield per plant. Among these characters head breadth recorded most extreme direct impact on achene yield per head though all different attributes demonstrated low direct impact, plant stature recorded greatest circuitous impact on seed achene per plant through head distance across. The aftereffects of the review uncovered that the character head distance across could be given accentuation for confinement of attractive genotypes, with high hereditary potential for achne yield.

Tyagi *et al.* (2010) estimated interrelationship and genetic variability among yield related characters in 22 sunflower genotypes. All genotypes revealed significant variations for all the observed traits. There were higher values of all studied characters for genotypic correlation as compared to phenotypic correlation. All characters showed insignificant positive correlation with yield except percent filled seeds and days to 50 % flowering. Though characters like plant height, head weight, head diameter and number of seeds per head were positively and significantly associated. Path analysis showed that head diameter had positive and direct effects on achene yield.

Yasin and Singh (2010) studied 24 lines of sunflower for correlation and path analysis among eight yield related characters. The yield was positively and significantly associated with head diameter, 1000 seed weight and number of seeds per head. Yield per plant was highly associated with head diameter, 1000 seed weight and number of seeds per head. Therefore, they suggested that the characters like head diameter, 1000 seed weight and number of seeds per head can be regarded as selection parameters for improving yield of sunflower.

Alias *et al.* (2011) concluded that agronomic characters had large involvement in increased production of sunflower. Two hybrids of sunflower were assessed in randomized complete block design under split plot with diverse nutritional levels. Both hybrids demonstrated similar results for number of achenes per capitulum and head diameter. Results revealed that seed yield is increased by improving agronomic characters. Maximum yield was achieved when sunflower hybrid S278 was cultivated on an area of 60×20 cm. It was resulted in greatest stalk and achene yield per plant.

Darvishzadeh *et al.* (2011) reported that plant height, number of leaves per plant, head diameter, chlorophyll contents and seed yield had significant and positive association with achene yield. Path analysis showed that number of seeds per plant and head diameter had direct effects on yield in both stress and stress free conditions but chlorophyll contents had direct positive association on seed yield in water stress condition.

Hladni *et al.* (2011) evaluated from their research that it is essential to test the association of yield related components for their appropriate use in breeding program. Analysis of variance was carried out to check differences in GCA and SCA. A positive association of seed yield was observed with mass of hundred seeds and number of seeds per head. Results showed inter-specific hybridization for production of new sunflower hybrids with greater yield. Kholgi *et al.* (2011) studied the direct and indirect effect of yield components on achene yield of sunflower. Thirty six genotypes of sunflower were characterized by days to 50% flowering, number of seeds per head, number of leaves, head diameter, stem diameter, leaf area (length*width), 100-seed weight and seed yield. There were positive association of plant height, number of seeds per head, head diameter and stem diameter seed yield. Path analysis revealed that achene yield was directly affected by plant height, 100 seed weight and head diameter. It was concluded that the selection would be more effective by improving the above characters.

Nasreen *et al.* (2011) conducted field experiment on six genetically different inbred lines. Before crossing, these inbred lines were evaluated for some parameters such as harvest index, leaf area, head diameter, yield per hectare, protein and oil contents, moisture factor and fatty acid composition. There were high genetic diversity for yield contributing traits and moderate heritability existed among all sunflower hybrids.

Nisar *et al.* (2011) evaluated that sunflower had the stunning potential for bridging the gap of edible oil requirement of Pakistan. They worked to assess 100 seed weight, mineral composition and estimation of moisture content. They noticed that mineral composition, moisture content and 100 seed weight were high in open pollinated population as compared to hybrids.

Patil (2011) conducted experiment on two genotypes of sunflower which were improved through recurrent selection without pollens and with pollens to find out correlation and path analysis. Correlation analysis showed that there was significant negative correlation among head diameter, seed yield and percent disease index at both stages. There were positive correlation of seed yield with plant height, volume weight and head diameter. The path analysis showed that the percent disease index had direct positive effect on plant height, volume weight and head diameter on seed yield.

Safavi *et al.* (2011) determined genetic variability among physiological characters in 36 lines of sunflower. There was significant variation among genotypes for head diameter, number of leaves and 1000 kernel weight. Correlation analysis showed that head diameter was significantly and positively correlated with 1000 kernel weight. There were high heritability estimates for head diameter, leaf number, 1000 kernel weight and seed yield.

Safavi (2011a) reported correlation and genetic parameters in 36 genotypes of sunflower under irrigated conditions. The studies revealed that the genotypes were significantly different for two characters i.e. seed yield and days to maturity. The characters like head diameter, seed yield and 1000 seed weight showed high genotypic and phenotypic coefficients of variation. High genetic gain was observed for seed yield, head diameter and 1000 seed weight. Number of leaves was significantly and positively associated with head diameter, days to maturity and 1000 seed weight. These traits showed high genetic advance along with high heritability estimates. They recommended that these characters like days to maturity, seed yield and 1000 seed weight could be used as selection parameters for development of genetically efficient genotypes of sunflower.

Safavi *et al.* (2011 b) reported genetic variability, heritability and interrelationship among seven physiological traits in 36 lines of sunflower. Genotypes showed significant variations among all recorded parameters. Characters like head diameter, seed yield, 1000 seed weight and leaf number showed highest phenotypic and genotypic coefficient of variation. Significant positive relationship was observed between head diameter and 1000 seed weight. High heritability and genetic advance was observed for characters like head diameter, days to maturity and seed yield.

Tyagi (2011) studied the interrelationship, direct and indirect effects of yield and yield contributing factors at phenotypic level. This study showed that days to 50% flowering, % filled seeds and oil content had non-significant association with seed yield and the other characters showed positive association with yield. In this study correlation was also observed with number of seeds per head, head diameter and head weight. Path coefficient analysis indicated that there was positive direct effect of stem diameter and head weight on achene yield. While for all other characters indirect effects were also observed.

Chigeza *et al.* (2012) examine two data sets of their studies to locate the correlation among different characters of sunflower. One set consist of side by side estimation of previous and present sets of widespread cultivars. Other sets were to observe the yield trends of commercial farmer field's cultivars. They expected the relative genetic gain in yield for both sets and they found that 1.5% and 1.9% per year gain in yield for side by side set and commercial cultivars respectively. On the other hand absolute genetic gain was 18-32 kg ha-1/year with mean of 24 kg ha-1/year for side by side set and under commercial production it was 12 kg ha-1/year. The results showed positive contribution of new cultivars in achene yield but there was low relative gain found in oil content.

Hassan *et al.* (2012) studied genetic variation in forty sunflower hybrids among various plant characters like head diameter, plant height, internodal length and stem diameter. Maximum heritability was related with protein contents, oil contents, plant height and achene weight while high heritability and moderate genetic advance was exhibited by achene weight. G-46 genotype was more lodging resistant while bemisal-205 show minimum stem diameter which were not resistant to lodging. Maximum and minimum plant height was exhibited by G-34 and FH-243 respectively.

Haghi *et al.* (2012) studied the correlation and path analysis in soybean at different nitrogen starter and plant density levels. Correlation analysis revealed that there were significant and positive association among harvest index, achene yield and achene diameter. Oil and protein percent was negatively and significantly correlated. Plant height was negatively and significantly correlated with oil content. Path coefficient analysis showed that pod per plant had positive and direct effect on seed yield. Results revealed that there were highly positive and direct effects of no. of pods per plant, achene diameter and 100-achene weight.

Jackovic *et al.* (2012) studied the forty hybrids of sunflower to find out correlation and genetic diversity

between yield and other morphological traits. These traits were considered to have great agronomic importance for the improvement of achene yield. Cluster analysis was used to find out the genetic diversity. It was concluded from the above study that there was positive correlation between head diameter and plant height but negative association exist between days to flowering and achene weight at both phenotypic and genotypic levels. The objective of this study was to develop lines with early flowering, large head diameter and stem resistance to lodging.

Martin *et al.* (2012) conducted path coefficient analysis on six sunflower cultivars and used spatial distribution of 40 and 60 cm between rows. They examine various traits that influence the 100 seed weight and seed yield. Regression analysis was also carried out to get the 100 seed weight and seed yield. They reveal in their results that spatial distribution had no effects on seed yield. On the other hand characters like number of plants and stem diameter at 15 days had direct effect on grain yield. Seed yield was indirectly affected by stem diameter and plant stature both at 15 days. Plant stature at 90 days had negative effect on 100 seed weight.

Sharankumar *et al.* (2012) conducted experiment to observe the correlation of yield with seedling, growth, seed weight and yield attributes in sunflower hybrids. Among all observed characters kernel to hull ratio, 100 seed weight, plant height, seed density, root length, shoot length, head diameter, number of leaves, seed filling percentage and seed weight per head revealed significant and positive correlation with achene yield. The main characters that contributed positively and significantly towards seed yield included capitulum diameter, 100-achene weight, achene density, kernel to hull ratio, no. of seeds per capitulum and achene filling percentage. Number of leaves and plant height were proved as valuable phenotypic indices for best genotypic identification of sunflower.

Arshad *et al.* (2013) concluded that number of days to flower initiation and flower completion had positive and significant genotypic and phenotypic association with plant height in sunflower. Head diameter and oil content had significant and positive association with plant height. The study revealed that by improving seed weight and head diameter, seed yield could be increased.

Deengra *et al.* (2013) studied that seed yield was positively and significantly associated with plant height, capitulum size, 100 seed weight, number of filled achenes per capitulum, plant dry matter and harvest index. Oil percentage was significantly and negatively associated with plant height, head size, days to maturity and days to flowering. Days to flowering and days to maturity were significantly and positively associated. Number of filled seeds per plant was positively and significantly correlated with plant height, dry matter and head size. There were high direct effects of 100-acheneweight and number of filled achenes per head on seed yield. Number of filled seeds per plant also had indirect effects of these traits. There were very low direct effects of days to flowering and days to maturity on achene yield but their indirect effects were also noticed via number of filled achenes per plant. The oil percentage was significantly and negatively correlated with seed yield.

Radic *et al.* (2013) conducted an experiment on ten female parental lines of sunflower to estimate correlations, genetic parameters and path analysis. Correlations among oil and protein content, 1000 seed weight and seed germination were examined. Seed yield was significantly and positively associated with 1000-achene weight. Achene yield had negative significant association with seed germination while there was positive and non significant association between achene yield and oil content. Path coefficient analysis showed that 1000-achene weight had highest positive effect on achene yield but seed germination had highest negative effects on seed yield.

Sujatha and Nadaf (2013) used 146 genotypes of sunflower to conduct their experiment. The results revealed that days to flowering had positive and significant relationship with plant height and days to maturity while capitulum diameter, test weight and achene yield per plant had positive and significant correlations with days to flowering. Plant height correlated positively and significantly with days to maturity while negatively with capitulum diameter. Capitulum diameter had positive and significant association with test weight and achene yield per plant while achene yield per plant also correlated positively with test weight.

Zia *et al.* (2013) conducted an experiment to check the correlation among various yield related traits like head diameter, percent filled achene, 100 achene weight, achene yield per plant, plant height, harvest index, oleic acid, linoleic acid, oil content, stearic acid and palmitic acid. There were significant and positive correlation of capitulum diameter, 100-seed weight and harvest index with yield per plant. Path coefficient analysis revealed that there were high direct effects of 100 achene weight, capitulum diameter and harvest index. Achene yield per plant were highly contributed by harvest index, head diameter, percent filled achene and head diameter.

Memon *et al.* (2014) performed an experiment with eighteen F_1 hybrids of sunflower to find correlation among different traits related to seed yield and oil contents. They reported significant and positive correlation of days to germination with leaves per plant, head diameter, seeds/plant, 100 achene

weight and oil contents. No. of leaves per plant correlated positively with capiulum diameter, no. seeds per plant and oil content. Hundred achene weights had significant and positive association with achene yield per plant and oil contents. Seed yield per plant were also significantly and positively associated with oil content.

Rigon *et al.* (2014) studied path correlation and coefficients in eight sunflower hybrids. The experiment was conducted in two different locations and correlations were same in both environments. 1000 seed weight and head diameter were significantly correlated with sunflower yield. Numbers of achene per head were significantly associated with productivity but was indirectly affected by primary components and it was an undesirable character for selection.

Amin *et al*. (2016) conducted an experiment to determine correlation among many important traits of sunflower. The results revealed that plant height had positive and significant relation with leaf area, stem diameter, head diameter, 100-achene weight and achene yield per plant. Days to maturity correlated significantly and negatively with number of achenes per head. Leaf area had significant and positive association with stem diameter, capitulum diameter, 100-achene weight and yield of seeds per plant. Harvest index and weight of 100 seeds also correlated significantly and positively with yield of seeds per plant.

Baloch *et al.* (2016) conducted an experiment on 18 genotypes of sunflower to evaluate heritability and phenotypic correlation. Significant differences were observed for all studied traits. The results showed that traits like head diameter, plant height, seed per plant and seed index were significantly and positively associated with seed yield per plant. High broad sense heritability was observed for all studied traits excluding head diameter that showed moderate heritability. Results depicted that genotypes with high value of these characters may be preferred in selection for enhancement of sunflower yield.

Conclusion:

We are facing many complications regarding the quality edible oil and oil yield this time. Sunflower has the potential to fulfil the world oil requirements in all the aspects because it has a large variability present in it. The present study was made to tell the importance of correlation and path analysis that how different characters affect the yield and by the use of which ultimately we can get improve grain and oil yield and our problem of quality oil can be overcome.

References:

1. Ahmad O, Rana MA, Siddiqui SU. Sunflower seed yield as influenced by some agronomic and seed characters. Euphytica. 1991 Jul 1;56(2):137-42.
2. Bukhsh MA, Kaleem S, Ishaque M, Iqbal J, Randhawa MA, Rasheed M, Khan HA. Morphological features in sunflower as influenced by varying nutritional area. Pakistan Journal of Nutrition. 2011.
3. Alza JO, Fernandez-Martinez JM. Genetic analysis of yield and related traits in sunflower (Helianthus annuus L.) in dryland and irrigated environments. Euphytica. 1997 May 1;95(2):243-51.
4. Perito Amorim E, Ramos NP, Gonçalves Ungaro MR, Kiihl TA. Correlation and path analysis in sunflower. Bragantia. 2008;67(2):307-316.
5. Anandhan T, Manivannan N, Vindhiyavarman P, Jeyakumar P. Correlation for oil yield in sunflower (Helianthus annuus L.). Electronic Journal of Plant Breeding. 2010 Jul;1(4):869-71.
6. Arshad M, Khan MA, Jadoon SA, Mohmand AS. Factor analysis in sunflower (Helianthus annuus L.) to investigate desirable hybrids. Pak. J. Bot. 2010 Dec 1;42(6):4393-402.
7. Arshad M, Ilyas MK, Khan MA. Genetic divergence and path coefficient analysis for seed yield traits in sunflower (Helianthus annuus L.) hybrids. Pak. J. Bot. 2007 Dec 1;39(6):2009-15.
8. Razi H, Assad MT. Comparison of selection criteria in normal and limited irrigation in sunflower. Euphytica. 1999 Jan 1;105(2):83-90.
9. Baloch, M., M.H. Kaleri, A.W. Baloch, T.A. Baloch, N. Gandahi, Q. Jogi and J.A. Hakro. 2016. Phenotypic correlation and heritability analysis in sunflower (*Helianthusannuus* L.) germplasm. Pure and Appl. Biol. 5(3): 641.
10. Behradfar A, Gorttapeh AH, Zardashty MR, Talat F. Evaluation correlated traits for seed and oil yield in sunflower (Helianthus annuus L.) through path analysis in under condition relay cropping. Res. J. Biol. Sci. 2009;4(1):82-5.
11. Binodh AK, Manivannan N, Varman PV. Character association and path analysis in sunflower. Madras Agric. J. 2008;95(7-12):425-8.
12. Boain N, Kongsamai B. Yield potential of the open-pollinated oil-type sunflower varieties. Witthayasan Kamphaengsaen. 2009.
13. Bonciu E, Iancu P, Soare M. The yield relationships in sunflower (Helianthus annuus). Journal of Horticulture, Forestry and Biotechnology. 2010;14(2):123-8.
14. Chigeza G, Mashingaidze K, Shanahan P. Seed yield and associated trait improvements in

sunflower cultivars over four decades of breeding in South Africa. Field Crops Research. 2012 Mar 29;130:46-56.
15. Coşge B, Bayraktar N. Correlations between some yield and yield components in sunflower (Helianthus annuus L.) hybrid, line and varieties. Journal of agricultural science. 2004;10(1):111-5.
16. Dagustu N. Correlations and path coefficient analysis of seed yield components in sunflower (Helianthus annuus L.). Turkish J. Field Crops. 2002;7(1):15-9.
17. Darvishzadeh R, Maleki HH, Sarrafi A. Path Analysis of the Relationships between Yield and Some Related Traits in Diallel Population of Sunflower ('Helianthus annuus' L.) under Well-Watered and Water-Stressed Conditions. Australian Journal of Crop Science. 2011 Jun;5(6):674.
18. Deengra SK, Navneet K, Vinit K, Dhaka RP. Correlation and path coefficient analysis in sunflower (Helianthus annuus L.). Progressive Agriculture. 2010;10(2):318-22.
19. Deengra SK, Kumar N, Kumar V, Dhaka RP. Correlation and path coefficient analysis in sunflower (Helianthus annuus L.). Progressive Agriculture. 2013;13(2):197-202.
20. Amin ESA., Abdullah AA, Ezeldeen AB and Mohamed YM. Heritability, genetic advance and correlation of some traits in six sunflower generations (*Helianthus annuus* L.). International Journal of Research in Agriculture Research 2016; 2: 1-13.
21. Ergen Y, Saglam C. Yield and yield characters of differrent confectionery sunflower varieties in conditions of Tekirdag. Journal of Tekirdag Agricultural Faculty. 2005.
22. Farhatullah F, Khalil IH. Path analysis of the coefficients of sunflower (Helianthus annuus L.) hybrids. International journal of agriculture and biology. 2006;8(5):621-5.
23. Ghanavati NA, Nahavandi E, Ghaderi A. Breeding sunflower for semi-arid regions. The Journal of Agricultural Science. 1981 Apr;96(2):447-50.
24. Göksoy A, Turan Z. Correlations and path analysis of yield components in synthetic varieties of sunflower (Helianthus annuus L.). Acta Agronomica Hungarica. 2007 Sep 1;55(3):339-45.
25. Shankar VG, Ganesh M, Ranganatha AR, Bhave MH. A study on correlation and path analysis of seed yield and yield components in sunflower (Helianthus annuus L.). Agricultural Science Digest. 2006;26(2):87-90.
26. Habib H, Mehdi SS, Rashkf A, Aniurrr MA. Genetic association and path analysis for seed yield in sunflower (Helianthus annuus L.). Pak. J. Agri. Sci. Vol. 2006;43:3-4.
27. Habib H, Mehdi SS, Anjum MA, Mohyuddin ME, Zafar M. Correlation and path analysis for seed yield in sunflower (Helianthus annuus L.) under charcoal rot (Macrophomina phaseolina) stress conditions. International Journal of Agriculture and Biology (Pakistan). 2007.
28. Haghi Y, Boroomandan P, Moradin M, Hassankhali M, Farhadi P, Farsaei F, Dabiri S. Correlation and path analysis for yield, oil and protein content of Soybean (Glycine max L.) genotypes under different levels of nitrogen starter and plant density. Biharean Biologist. 2012 Jun 1;6(1):32-7.
29. Akhtar Cheema M, Qadir G, Azim CM. Influence of seasonal variations on yield and yield components of sunflower. HELIA. 2005 Dec 1;28(43):145-52.
30. Hassan, SMF., Iqbal MS, Rabbani G., Din NU and Shabbir G. Genetic variability, heritability and genetic advance for yield and yield components in sunflower (*Helianthus annuus* L.). Electronic Journal of Plant Breeding 2012; 3: 707-710.
31. Hladni N, Škorić D, Kraljević-Balalić M, Jocić S, Dušanić N. Line x tester analysis for yield components in sunflower and their correlations with seed yield (Helianthus annuus L.). Genetika. 2011;43(2):297-306.
32. Ilahi F, Muhammad HN, Hafeez SA. Correlation and path coefficient analysis for achene yield and yield components in sunflower. Pak. J. Agri. Sci. 2009;46(1):20-4.
33. Mudassar I, Ali MA, Amjad A, Zulkiffal M, Zeeshan M, Sadaqat HA. Genetic behavior and impact of various quantitative traits on oil contents in sunflower under waters stress conditions at productive phase. Plant Omics. 2009;2(2):70-7.
34. Jocković M, Marinković R, Marjanović-Jeromela A, Radić V, Čanak P, Hladni N. Association between seed yield and some morphological characteristics in sunflower. Ratarstvo i povrtarstvo. 2012;49(1):53-7.
35. Kalukhe VK, Moon MK, Magar NM, Patil SS. Character association and path analysis for seed yield in sunflower (Helianthus annuus L.). International Journal of Plant Sciences (Muzaffarnagar). 2010;5(2):594-8.
36. Kaya Y, Evci G, Durak S, Pekcan V, Gücer T. Determining the relationships between yield and yield attributes in sunflower. Turkish Journal of Agriculture and Forestry. 2007 Oct 26;31(4):237-44.

37. Kaya Y, Evci G, Durak S, Pekcan V, Gucer T. Yield components affecting seed yield and their relationships in sunflower (Helianthus annuus L.). Pak. J. Bot. 2009 Oct 1;41(5):2261-9.
38. Kaya Y, Evci G, Pekcan V, Gucer T, Durak S, Yilmaz MI. The path analysis of yield traits in sunflower (Helianthus annuus L). Agronomijas Vestis. 2008(11):72-7.
39. Khan H, Muhammad S, Shah R, Iqbal N. Genetic analysis of yield and some yield components in sunflower. SARHAD JOURNAL OF AGRICULTURE. 2007;23(4):985.
40. Khan SA, Ahmad H, Khan A, Saeed M, Khan SM, Ahmad B. Correlation studies among morpho-physiological characters in eight sunflower parents and their sixteen F1 hybrids. Recent Research in Science and Technology. 2009 Nov 20;1(4).
41. Khokhar MI, Sadaqat HA, Tahir MN. Association and effect of yield related traits on achene yield in sunflower. Int. J. Agric. Biol. 2006;8(4):450-1.
42. Kholghi M, Bernousi I, Darvishzadeh R, Pirzad A. Correlation and path-cofficient analysis of seed yield and yield related trait in Iranian confectionery sunflower populations. African Journal of Biotechnology. 2011;10(61):13058-63.
43. Kothai KS, Manivannan N, Vindhiyavarman P. Correlation and path analysis in sunflower (Helianthus annuus L.). Madras Agricultural Journal. 2007;94(1/6):120-4.
44. Kumar, DS, Naveel K, Vinit K and RPS Dhaka. Correlation and path coefficient analysis in sunflower. Progressive Agriculture 2010; 10(2): 316-322.
45. Machikowa T, Saetang C. Correlation and path coefficient analysis on seed yield in sunflower. Suranaree J. Sci. Technol. 2008;15(3):243-8.
46. Martin TN, Pavinato PS, Lorentz LH, Zielinski RP, Refatti R. Spatial distribution of sunflower cultivars and the relationship between growth features. Revista Ciência Agronômica. 2012 Jun;43(2):338-45.
47. Memon S, Baloch MJ, Baloch GM, Keerio MI. Heritability and correlation studies for phenological, seed yield and oil traits in sunflower (Helianthus annuus L). Pak J Agri Agril Engg Vet Sci. 2014;30(2):159-71.
48. Mijić A, Liović I, Zdunić Z, Marić S, Marjanović Jeromela A, Jankulovska M. Quantitative analysis of oil yield and its components in sunflower (Helianthus annuus L.). Romanian Agricultural Research. 2009 Jan 1;26:41-6.
49. Mijić A, Krizmanić M, Guberac V, Marić S. Path coefficient analysis of several components oil yield in sunflower (Helianthus annuus L.). Poljoprivreda. 2006 Jun 20;12(1):11-5.
50. Nasreen S, Fatima Z, Ishaque M, Mohmand AS, Khan M, Khan RA, Chaudhary MF. Heritability analysis for seed yield and yield related components in sunflower (Helianthus annuus L.) based on genetic difference. Pak. J. Bot. 2011 Apr 1;43(2):1295-306.
51. Nisar M, Hussain S, Nausheen A, Siddique F. Chemical composition of open pollinated and hybrid population of sunflower (helianthus annuus l.). Pakistan Journal of Botany. 2011;43(1):157-63.
52. Ozturk O and Ada R. Correlation and Path Coefficient Analysis of Yield and Quality Components of Some Sunflower (Helianthus annuus L.) Cultivars. Asian Journal of Chemistry. 2009 Feb 10;21(2):1400.
53. Patil LC. Research Note Correlation and path analysis in sunflower populations. Electronic Journal of Plant Breeding. 2011 Sep;2(3):442-7.
54. Radić V, Mrđa J, Terzić S, Dedić B, Dimitrijević A, Balalić I, Miladinović D. Correlations and path analyses of yield and other sunflower seed characters. Genetika. 2013;45(2):459-66.
55. Radic, V., Vujakovic M, Marjanovic-Jeromela A, Mrda J, Miklic V Dusanic N, and Balalic I. Interdependence of sunflower seed quality parameters. Helia 2009; 32(50): 157-164.
56. Rao NV, Mohan YC, Reddy SS. Variability and character association in the elite lines of sunflower (Helianthus annuus L.). Research on crops. 2003;4(1):104-9.
57. Rigon G, Alberto C, Rigon G, Paulo J, Capuani S. Correlation and path analysis as an indirect selection criterion for sunflower achene productivity. Bioscience Journal. 2014 Oct 1:768-73.
58. Sadras VO, Villalobos FJ. Floral initiation, leaf initiation and leaf appearance in sunflower. Field Crops Research. 1993 Jun 30;33(4):449-57.
59. Safavi, SM. Correlation between traits and estimation of genetic parameters in sunflower under irrigation conditions. American Journal of Scientific Research 2011; 28: 13-17.
60. Safavi SM, Safavi AS, Safavi SA. Heritability and genetic gain of some morphological traits in sunflower (Helianthus annua L.) under water stress conditions. American Journal of Scientific Research. 2011;19:27-31.
61. Safavi AS, Safavi SM, Safavi SA. Genetic variability of some morphological traits in sunflower (Helianthus annus L.). American Journal of Scientific Research 2011;17:19-24.
62. Said A, Azam F. Correlation studies for yield and yield components in sunflower hybrids

(Helianthus annuus L.). Pakistan Journal of Scientific Research 2008; 60(2): 16-19.
63. Samo, RP. Direct and indirect influence of yield components on yield in sunflower. Plant Genetic Breed 2007; 18(2): 17-20.
64. Schwertner DV, Wagner JF, Mattioni TC, Fontaniva C, Bandeira TP, Viera R, de Olivera JM, da Silva AJ, Maixner AR, da Silva JA. Path analysis to direct components of yield and physiological parameters in sunflower.. Turkish Journal of Agronomy 2009; 324-30.
65. Sharankumar MA, Mreire AA and Micalles KW. 2012. Correlation studies between seed, seedling, growth and yield in sunflower. Agric. Science Digest 2012; 24(7): 200-224.
66. Sowmya HC, Shadakshari YG, Pranesh KJ, Srivastava A, Nandini B. Character association and path analysis in sunflower (Helianthus annuus L.). Electronic Journal of Plant Breeding. 2010 Jul;1(4):828-31.
67. Sridhar V, Shankar VG, Dangi KS. Variability parameters for yield and its components in sunflower (Helianthus annuus L.). Agricultural Science Digest. 2006;26(4):288-90.
68. Subrahmanyam SV, Kumar SS, Ranganatha AR. Genetic divergence for seed parameters in sunflower. Helia. 2003 Jul 1;26(38):73-80.
69. Sujatha K and Nadaf HL. Correlation for Yield and Yield Related Trait in Mutant and Segregating Genotypes in Sunflower (Helianthus annus L.). Molecular Plant Breeding. 2013 Aug 24;4(32).
70. Syed WH, Syed SM, Hasnain S. Variability for agronomic traits in sunflower random mating populations: Correlations estimated gains from selection and correlated responses to selection. Helia 2004; Dec 1;27(41):85-98.
71. Tahir MH, Sadaqat HA, Bashir SA. Correlation and path coefficient analysis of morphological traits in sunflower (Helianthus annuus L.) populations. Int. J. Agri. Biol. 2002;4(3):341-3.
72. Tyagi SD. An analysis of the association factors influencing seed yield and oil percentage in sunflower (Heliatnthus annuus L.). Progressive Agriculture. 2011;11(1):149-55.
73. Tyagi SD, Tyagi JP. Correlation and Path Coefficient Analysis of the Components of Yield in Sunflower Cultivars (Helianthus annuus L.). Indian Journal of Plant Genetic Resources. 2010;23(3):321-3.
74. Uttam KK, Sheoran RK, Punia RC, Rakesh K. Correlation studies of seed yield and seed quality traits in sunflower (Helianthus annuus L.). National Journal of Plant Improvement. 2006;8(1):47-9.
75. Vidhyavathi R, Mahalakshmi P, Manivannan N, Murulidharan V. Correlation and path analysis in sunflower (Helianthus annuus L.). Agricultural Science Digest. 2005;25(1):6-10.
76. Singh S. Correlation and path coefficient analyses in sunflower. Journal of Plant Breeding and Crop Science. 2010 May 31;2(5):129-33.
77. Yesilova A, Gorttapeh AH, Zardashty MR, Talat F. Evaluation correlated traits for seed and oil yield in sunflower (Heliathus annuus L.) through path analysis in under condition relay cropping. Research Journal of Biological Sciences. 2009;4(1):82-5.
78. Zia-Ullah Z, Sadaqat HA, Tahir MH, Sadia B. Path coefficient analysis of various traits in sunflower (Helianthus annuus L.). J Glob Innov Agric Soc Sci. 2013;1:5-8.

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