Study of trait association for the improvement of achene yield in sunflower: An overview

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Abstract: Sunflower is an important oilseed crop and one of the important sources of vegetable oil globally. Its fatty acid composition makes it a promising crop for use in industry as well for human consumption. Various approaches have been used to improve the key traits of sunflower. It has the highest potential to bridge a gap between oil production and consumption. By understanding yield and quality traits, it will be easy for breeders to develop selection criteria for the improvement of achene oil and yield. The performance of the breeding material depends upon how a yield component is correlated with yield and how it effects, directly or indirectly on yield. The expression of the particular genes may be changed under different agro-environmental conditions and similarly different genotypes may express differently in the same environment. The present review was written to focus the use of trait association studies to improve crop yield and quality of sunflower. Correlation and path coefficient analysis provide information about positive or negative association of traits. So, it is very helpful to improve achene, oil yield and modified fatty acid composition in sunflower.

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Introduction

Sunflower accounts major portion of oil production in the world. It is most important crop in the field of edible oil. The breeders of sunflower focus on its genotype to result more oil yield. As prime focus is oil yield, researcher's objective has become to produce effective crop. Several traits as; flower initiation, days to flower completion, days to maturity, flowering period, plant height and oil content etc. are prime concerns. Pakistan has been deficient in edible oil, most of the oil requirements are fed by imported oil (Arshad *et al.* 2013). During early sixties it was introduced in Pakistan, because of economic constraints its production and expansion was fluctuated. Literature has shown that there is a great potential of growing sunflower under different agro-economic zones. Sunflower can be successfully grown under harsh conditions of southern part of Pakistan and cool and mild north part of Pakistan. Hybrid seeds are provided by multinational seed companies in Pakistan because there are a few hybrids are available for cultivation. It is important to pay attention to head diameters for breeding sunflower. The analysis of genetic correlations measures the relationship among various plant characters which helps in determining yield components, which provides base for achieving genetic improvement in the yield while phenotypic correlation is association between two traits, describing genotypic and environmental effects (Naseer *et al*., 2015ab; Masood *et al*., 2015ab; Awan *et al*., 2015; Naseem *et al*., 2015ab; Saeed *et al*., 2014). Genetic parameters are essential to understand for crop yield improvement (Ali *et al*., 2013; Ali *et al*., 2014abcd; Ali and Ahsan 2015; Bhutta *et al*., 2015; Bibi *et al*., 2015; Rehman *et al.* 2013). There should be efficiency in selection procedure, depending upon nature as well as magnitude of component characteristics and achene yield. Its complex trait therefore, to have clear understanding of strength as well as type of association between yield and component traits. It is a prerequisite which formulate successful breeding program. Earlier, Fick *et al.* (1974), Green (1980) and Joksimovic *et al.* (1999) had used simple correlation while analyzing the relationship between oil yield and sunflower plant traits which did not depict clear picture of mutual relationship of plant traits but the path coefficient analysis is more precise method, partitions the direct as well as indirect effects of independent variables on the dependent variable. Such methods reflect more clear impact of independent variables on the dependent and have been extensively used by the sunflower researchers (Joksimovic *et al.,* 1999). Plant breeders and molecular plant breeders used various breeding programs to develop higher yielding crop plants to combat with increasing demands of food for human and feed for animals (Fawad *et al*., 2015; Ahmad *et al*., 2015ab; Javed *et al*., 2014 Khan *et al*., 2014; Raza *et al*., 2015ab; Riaz *et al*., 2015; Rmzan *et*

al., 2015; Waseem *et al*., 2014 and Zameer *et al*., 2015ab).

Correlation analysis

Genetic variability among morphological characters

Chervet and Vear (1990) reported significant variation among accessions for characters in sunflower morphological characters except number of days from sowing and emergence. Hussain *et al.* (1994) observed variability in five sunflower lines for days to maturity, plant height, 100 achene weight, head diameter and achene yield per plant ranging from 73-76 days, 3.72-5.88, 130.41-151.40cm, 24.60-42.24gm, respectively. Kshirsagar *et al*. (1995) studied the characters of 14 sunflower accessions in field trials. Achene yield, 100 achene weight and plant height showed greatest genetic variability. Sujalha *et al.* (2002) conducted an experiment on 51 inbred lines with three checks of sunflower and reported that there is significant variation in all 15 studied traits. Maximum variation was found in plant height and percentage of oil. They reported maximum magnitude of variation for plant height, achene yield, achene weight and head diameter. Illahi *et al.* (2009) experimented on 12 sunflower genotypes to check variability for plant height, number of leaves, head and stem diameter, head shape, inter-nodal length, achene weight and oil yield. Results showed that genotypes were significantly different from all attributed traits.

Positive association with achene yield

Ahmad *et al.* (1991) reported the interrelationship of maturity traits effects on achene yield of twenty accessions of sunflower. There was a positive association between 100 achene weight and plant height, number of achenes per head, head diameter and oil yield. Tariq *et al.* (1992) studied 14 hybrids of sunflower to assess genetic variability for morphological traits and some other characters. Except of 100 seed weight and days to maturity, all other characters showed positive relationship with yield. Habib *et al.* (2007) studied sunflower populations to determine the relationship between seed weight and seedling traits. Seed weight was significantly positive correlated with fresh shoot weight and fresh shoot length. Teklewold *et al.* (2000) studied 144 sunflower genotypes and determined the interrelationships of 12 physiological and morphological traits. Yield of seed per plant, height of plant, filled seeds percentage, diameter of head, stem diameter, weight of 100 seeds, harvest index and yield of oil per plant were significant and positively correlated. Ahmad (2001) compared sunflower hybrid PARC-92E that was produced at different locations in Pakistan for achene quality. 100 achenes weight ranged from 5.38-7.29g, germination potential from 97.5-100% and emergence index rate from 11.8-20.6. 100 seed weight showed positive correlation with all traits except oil percentage. Aslam and Ashfaq (2002) reported genetic variation for different traits in 14 cultivars of sunflower. They evaluated the days to 50% flowering and maturity. They showed differences of sunflower traits and suggested that seed yield could be enhanced by choosing the best traits. Achene yield showed great positive significant correlation with all those traits. Tahir *et al.* (2002) analyzed morphological data of 13 lines for the analyses of path coefficient and correlations. Highest positive correlation of seed yield with the number of filled seeds per plant followed by head diameter and seed filling percentage was found. It was also found that head diameter had large effect on seed yield. Number of filled seeds per plant, head diameter and 1000-seed weight played a significant role to increase seed yield.

Mahmood and Mehdi (2003) conducted an experiment on sunflower different traits. They also explained that seed and oil yield had positive correlation with morphological characters but oil content showed only with days to 50% flowering and maturity and 100 seed weight. Rao *et al.* (2003) conducted an experiment on 82 accessions of sunflower to measure the genetic variability and path coefficient analysis. It was observed that there was positive association of seed yield with filled seed, diameter of head, number of leaves per plant, plant height and stem girth.

Luczkiewicz *et al.* (2004) studied seven sunflower oil inbred lines for morphological traits. They reported genetic differences among those traits in genotypes. They checked the effect of studied characters on specific combining ability through regression line. Differences were significant for seed yield and number of seed per plant. Habib *et al.* (2006) reported positive correlations among stem diameter, head diameter, stem girth and length ratio, weight of 100 achenes and total achene yield per head. Arshad *et al.* (2007) reported that genotypic differences were significant for yield and yield components. Head diameter and days to maturity showed positive association. Seed yield and oil contents showed significantly positive genotypic association but their correlation with 100 seed weight was not significant. Days to flowering and height of plant significant positive association with seed yield. Kaya *et al.* (2007) conducted an experiment to check genetic variation in different sunflower genotypes. They found strong positive correlation of morphological traits with achene yield. Goksoy *et al*. (2009) studied achene yield and some other yield

components. Achene yield showed positive correlation with plant height, number of seeds per head, head diameter and 100 achenes weight. Khan *et al.* (2009) reported the association of different morpho-physiological characters at Agricultural Research Institute Tarnab, Peshawar of eight sunflower parents and their sixteen F1 hybrids. Positive correlation was observed among days to flowering, stem girth and intermodal length. It was reported that plant height showed positive correlation with number of leaves, stem girth, days to flowering and intermodal length. Rehman *et al*. (2012) conducted an experiment on 18 sunflower hybrids to measure genetic variability for nine agronomic traits like stem girth, plant height, days to flowering, days to maturity, diameter of head and achene yield. They reported that all studied traits had positive correlation with achene yield and weight except head diameter. There was positive correlation of plant height, head diameter and days to flower initiation with achene yield. They also reported that short heighted hybrids and early in maturity had more 100 achenes weight but lower in achene yield.

Negative association with achene yield

Tariq *et al.* (1992) studied 14 hybrids of sunflower to assess genetic variability for morphological traits and some other characters. 100 seed weight showed negative relationship with yield. Habib *et al.* (2007) studied sunflower populations to determine the relationship between seed weight and seedling traits. Results indicated that seed weight was significantly and negatively correlated with emergence. Medhat *et al*. (1993) reported all possible crosses of four sunflower varieties correlations of various plant characters along with bird damage. There was negative association with stem inclination, plant height and 100-achene weight. Doddamani *et al.* (1997) suggested that autogamy showed highly negative association with important yield contributing traits in sunflower studied accessions. Teklewold *et al.* (2000) studied 144 sunflower genotypes and determined the interrelationships of 12 physiological and morphological traits. There was a negative correlation between auto gamy percentage and yield of seeds per plant. By using breeding methods which were used in the development of new genotypes showed less impact in changing the extent and path of correlation. Arshad *et al.* (2007) reported that genotypic differences were significant for yield and yield components days to maturity showed negative correlation with seed yield. Days to flowering and height of plant showed negative correlation with oil contents. Kaya *et al.* (2007) conducted an experiment to check genetic variation in different sunflower genotypes. Oil and achene yield showed positive correlation to some extent and then negative. They showed two hybrids i.e. Sanbro and Tarsan 108 hybrids under unfavorable environment had significant results. Kaya also reported relationship between achene yield and agronomic characteristics in sunflower. Physiological maturity and flowering negatively correlated with achene yield. Achene yield and oil content showed negative correlation with each other.

Oil Yield

Genetic variability

Teklewold *et al*. (2000) studied genotypic and phenotypic coefficient of variation for seed and oil yield in sunflower accessions. Analysis of variance (ANOVA) revealed that studied accessions showed significant variation. Sujalha *et al.* (2002) conducted an experiment on 51 inbred lines with three checks of sunflower and reported that there is significant variation in all 15 studied traits. Maximum variation was found in percentage of oil and plant height.

Positive correlation

Mahmood and mehdi (2003) conducted an experiment on sunflower different traits. They also explained that seed and oil yield had positive correlation with morphological characters but oil content showed only with days to 50% flowering and maturity and 100 seed weight. Kaya *et al.* (2007) conducted an experiment to check genetic variation in different sunflower genotypes. Oil and achene yield showed positive correlation to some extent and then negative. They showed two hybrids i.e. Sanbro and Tarsan 108 hybrids under unfavorable environment had significant results.

Negative correlation

Hladni *et al.* (2010) reported highly significant negative association between diameter of stem, diameter of head and leaf area per plant with weight of 1,000 seeds as well as with seed oil content. Zheljazkov *et al.* (2011) analysed consequences of sowing date on achene yield, oil composition and oil contents in sunflower. Results showed variability in achene oil concentration from 25-47%. PR64H41 and DKF3510 had more than 85% of oleic acid concentration and PR63M80 and PR63M80 showed more than 65% concentration. Total saturated fatty acid i.e sum of stearic, lignoceric, behenic and palmitic acid showed range of 6.3-13%. Average oil production was ranged from 380-687 kg/hectare. They reported that late sowing in non-irrigated system might be decrease achene and oil production.

Genotypic and phenotypic correlation

Mahmood and mehdi (2003) conducted an experiment on sunflower different traits. They

estimated genotypic and phenotypic correlation for different characters. They evaluated two progenies i.e. S_1 and S_2. They reported that genotypic differences were greater than phenotypic variability. Iqbal *et al.* (2013) reported significant variability in total leaf area, plant height, total number of leaves, filled achenes, stem diameter, oil content and weight of 100 achenes. The highest genetic advance with the moderate broad sense heritability was recorded in achene yield and total area of leaf. They recommended that by using these traits as criteria of selection in sunflower germplasm could enhance oil content and achene yield.

Seedling and maturity traits

Positive correlation

Tahir and Mehdi (2001) recorded six maturity traits and ten seedling traits and analyzed statistically. Dry shoot and root weight showed positive correlation with seed yield per plant under water stress condition. Under normal irrigation, emergence rate index was significant and positive correlated with number of leaves per plant.

Negative correlation

Tahir and Mehdi (2001) recorded six maturity traits and ten seedling traits and analyzed statistically. Head diameter with fresh root and shoot weight showed significant and negative correlation under water stress.

Path coefficient analysis

Morphological characters and yield

Machikowa and Saetang (2008) studied correlation among morphological characters and others which were directly related to sunflower yield. Path analysis results revealed that sunflower seed yield could be increased by selection on the basis of head diameter and plant height.

Positive direct effects

Ahmad *et al*. (1991) reported the interrelationship of maturity traits effects on achene yield of twenty accessions of sunflower. Plant height and oil content had strong direct effect on achene yield due to physiological maturity. Patil *et al*. (1996) reported positive direct effect of 100 achene weight on achene yield in studied genotypes of sunflower. Doddamani *et al*. (1997) reported that there was positive effect of plant height with head diameter in different accessions of sunflower. Teklewold *et al*. (2000) studied physiological and morphological traits of 144 sunflower genotypes and reported that achene yield showed highly positive and direct impact on yield of oil per plant. These traits played a key role to give a direction to the other components that influences the seed and oil yields per plant. Chikkadevaiah *et al*. (2002) conducted an experiment on 51 inbred lines of sunflower. They performed path coefficient analysis for studied traits of sunflower. Achene yield showed positive direct effect for 100 seed weight and oil yield. Tahir *et al*. (2002) performed path coefficient analysis on 13 lines of sunflower. Morphological traits were evaluated. They showed number of filled achenes and diameter of head had direct positive effect on yield. They concluded that yield could be enhanced by improving morphological traits. Nehru and Manjunath (2003) reported that direct effects were the highest for total seeds per head in studied accessions of sunflower. Farratullah *et al*. (2006) conducted an experiment on morphological traits for nine sunflower hybrids. They performed path coefficient analysis for seed yield and its related morphological traits. There was direct positive effect of all traits on seed yield. Head diameter, 1000 seed weight and seeds per head had direct positive effect on seed yield. They suggested that by considering these traits it could be best for selection programs. Arshad *et al*. (2007) reported that genotypic differences were significant for yield and yield components. Results showed that height of plant, days to flowering and head diameter had positive direct effects. It was indicated that seed yield and head diameter had positive direct effect. Habib *et al*. (2007) conducted an experiment on sunflower lines, upon genotypic path analysis, it was cleared that days to flower completion, days to maturity and oil content had positive direct effect on oil yield.

Amorim *et al*. (2008) performed path analysis among achene yield and 13 agronomic characters in 14 sunflower genotypes. Percentage of achenes, head diameter and weight of 1000 achenes revealed positive direct effect on achene yield, which led them more suitable for indirect selection. Arshad *et al*. (2010) reported that plant height, days to maturity and head diameter showed positive direct effect in sunflower studied genotypes. Hladni *et al*. (2010) reported that weight of 1000 seeds showed highly significant positive direct impact on yield of seed. Total number of seeds depicted highly significant direct positive effect on yield of seed and oil contents. Seed yield and total leaf number per plant had a direct positive impact significantly. At phenotypic level, path coefficient analysis revealed positive direct effects of the weight of 1000 seeds, total number of seeds per head and total leaves per plant. Tyagi and Khan (2013) reported achene yield and its related traits in sunflower by using 22 different genotypes. They suggested that selection for head weight and diameter, plant height and number of achenes per head could be used to increase achene yield.

Negative direct effects

Doddamani *et al*. (1997) performed path analysis on days to 50% flowering that revealed negative direct effect in sunflower accessions. Arshad *et al*. (2007) reported that genotypic differences were significant for yield and yield components. Results showed that except of plant height, days to flowering and head diameter all other characters showed negative direct effect. Among all traits, days to flowering and height of plant showed the highest values. Habib *et al*. (2007) conducted an experiment on sunflower lines, upon genotypic path analysis, it was cleared that negative effect was found on days to flower initiation, flowering period and plant height on yield particularly on oil production. Hladni *et al*. (2010) reported that weight of 1000 seeds showed highly significant direct negative impact on oil content.

Positive indirect effects

Ahmad *et al*. (1991) reported the interrelationship of maturity traits effects on achene yield of twenty accessions of sunflower. Physiological maturity of agronomic traits like plant height and diameter of head had significant indirect effect on plant achene yield. Patil *et al*. (1996) reported that head size, 100 achene weight and number of whorls per head showed high positive indirect effect on achene yield in studied sunflower accessions. Nehru and Manjunath (2003) reported the highest indirect effect through seeds per head which had major direct contribution by itself after doing experiment on different genotypes of sunflower.

Conclusion

Sunflower has great importance as an oilseed crop. Different results obtained in various studies indicated that nature and the direction of the correlation and direct and indirect contribution vary with the genetic material used in these studies. Similarly, the extent and estimates of the genetic parameters associated with these characters and parameters were also variable when compared in different studies. This is a compelling evidence to perform the analyses of variance, genotypic and phenotypic correlations, path coefficient analysis, heritability and genetic advance in the new breeding material.

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