ORIGINAL ARTICLE

ISSN (Print): 2517-9675
ISSN (Online): 2518-2625

GENETIC EVALUATION OF SUNFLOWER POPULATIONS (*HELIANTHUS ANNUUS* L.) FOR ACHENE YIELD AND RELATED TRAITS

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Keywords:
Achene yield, genetic variation, population, range, regression

ABSTRACT

Background Sunflower is an important oil seed crop. The existence of genetic variability within cultivated sunflower is pre-requisite for its improvement.

Methodology The present study was planned to assess the genetic variation in six sunflower populations by manipulating nine yield contributed plant parameters. The experimental material comprised of six cultivated sunflower populations named as population 1, population 2, population 3, population 4, population 5 and population 6. Phenotypically 50 healthy plants from each population were selected as parents and data were recorded for plant height, head diameter, 100-achene weight and achene yield plant^{-1}.

Results The statistical means comparison indicated that there were significant differences among six sunflower populations for achene yield and other yield related traits. A wide range of variation for different plant traits was observed in population 1 and population 6 which indicated that achene yield improvement in these two sunflower populations could be possible through simple selection. Significant difference for plant height was found in population 3 while, population 6 exhibited maximum variation for head to soil surface distance among all sunflower populations. The means comparison for head diameter and 100-achene weight among all populations revealed that maximum variation was present in population 6 which differed significantly from population 2 and population 3. Achene yield plant^{-1} also showed a wide range of variation from 3.7 to 71.3 g with an average of 21.64 g among sunflower populations. The magnitude of variation coefficients revealed that all sunflower populations had exploitable genetic variability for all agronomic characters under investigation. Regression coefficients exhibited that plant height (R^2 = 0.7221), stem diameter (R^2 = 0.9109) and head diameter (R^2 = 0.7322) had significant and positive impact on achene yield plant^{-1}.

Conclusion Based on the results, it was suggested that achene yield plant^{-1} of a sunflower population could be improved by selecting tall plants having thick stem and large heads with more achenes.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the 4th largest oilseed crop in the world (FAO 2019). Sunflower oil is also called as health promoting oil. Its seed contain 20-28% protein contents, 25-48% oil contents, 60% poly unsaturated fatty acid, 72% linoleic acid and 16.2% oleic acid (Hatam and Abbasi 2018). Edible oil is a major component of human diet, but Pakistan is constantly deficient in oil seed production and larger portion of the country's edible oil necessities are met through import (Kang et al. 2013; Satyabrata

Cite As: Akhtar N, S Shukat, A Aziz, M Asif, U Saleem, T Mahmood, R Kausar, S Nawaz (2019) Genetic evaluation of sunflower populations (*Helianthus annuus* L.) for achene yield and related traits. *J. Environ. Agric., 4*(2): 407-414.

et al. 2016). One of the insuperable challenges, Pakistan confronted with its attaining self-sufficiency in edible oils which constitutes the largest food import commodity. This critical vegetable oil situation is not only due to increase in population but also due to increase in total consumption. Currently, Pakistan meets only 27% of its total requirement from all its resources while the remaining 73% is made available through import (GOP 2019). Thus, Pakistan has to import large quantities of edible oil per annum to meet the consumption requirements. During 2018-19 (July-March), 2.421 million tons edible oil valued Rs. 192.203 billion (US$ 1.455 billion) was imported to fulfill country demand. During this period, local production of edible oil was recorded at 0.500 million tons (PODB 2019).

The cultivation of sunflower as an oilseed crop was introduced in Pakistan during early 1960's (PODB 2009). Sunflower is one of the principal oil-bearing crops with over 40-48% oil in its achene, and has potential to further increase oil content up to 60% through breeding (Iqbal et al. 2009; Sarwar et al. 2013: Razzaq 2017). Several selection methodologies are being employed to improve sunflower achene yield. Besides, sunflower breeders are also looking for new breeding systems and analysis techniques to improve the efficiency of the selection process (Syed et al. 2004). The choice of a breeding system in random mating sunflower population depends on the mean performance of the plant population, magnitude and type of different components of genetic variation present in the population as well as their reliable estimates (Akhtar et al. 2012). The present study was conducted to evaluate six sunflower open pollinated populations to observe the magnitude of variation and to identify the traits consistently related to improve achene yield.

MATERIALS AND METHODS

The research work was conducted at the experimental area of College of Agriculture, University of Sargodha, Sargodha, Pakistan. The experimental material comprised of six cultivated sunflower (*Helianthus annuus* L.) populations named as population 1, population 2, population 3, population 4, population 5 and population 6. Phenotypically healthy 50 plants from each population were selected as parents and data were recorded for plant height, head diameter, 100-achene weight and achene yield plant^{-1} (Table 1). The achenes of selected plants were harvested separately. Next year head to row progenies were sown by using randomized complete block design (RCBD) in triplicate with the help of a hand drill from the selected plants of each population by maintaining plant to plant and row to row distances 23 cm and 76 cm, respectively. Data were recorded from 10 random selected plants from each row in each population for plant height, number of leaves plant^{-1}, internodal length, stem diameter, head to soil surface distance, head diameter, 100-achene weight, bird damage and achene yield plant^{-1}. The recorded data were analyzed to estimate mean, range, variance, co-efficient of variation and regression analysis, respectively (Steel et al. 1997). Analysis of variance (ANOVA) was used for determining significance among treatments and mean values between treatments were compared by least significant difference (LSD) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Parent populations

Plant height is an important plant trait to improve achene yield in open pollinated sunflower populations (Table 1). Statistical comparison among plant height means revealed that population 1 and population 2 were significantly different from the remaining populations. Therefore, simple selection based on plant height was important to improve achene yield in these two populations (Machikowa and Saetang 2008; Darvishzadeh et al. 2011). Mean comparison for head diameter among parent populations showed that population 4 had maximum head diameter (19.78 cm) while, population 3 had minimum head diameter (17.82 cm). Statistical comparison showed that population 4 was significantly different from the remaining sunflower populations (Table 1). Selection of larger head diameter with filled achenes must be preferred to improve seed yield in sunflower (Kaya et al. 2009; Darvishzadeh et al. 2011; Safavi et al. 2011). Based on 100-achene weight, parent population 3 had maximum 100-ahene weight with an average of 7.30 g while, population 6 had minimum achene weight (Table 1). The least significant differences among means at 5% level of probability exhibited that population 3 having minimum head diameter was significantly different for 100-achene weight from all the remaining studied sunflower populations. This indicated that more 100-achene weight with compact head diameter must be preferred to increase seed yield in sunflower. Therefore, selection in population 3 based on higher achene weight was desirable to improve the achene yield in this population (Khokhar et al. 2006; Kholghi et al. 2011; Akhtar et al. 2012). The means comparison for achene yield plant^{-1} revealed that population 2 had maximum achene yield plant^{-1} (73.36 g) and was significantly different ($p = 0.05$) from population 1, population 3 and

population 5 (Table 1). This indicated that genetic variation was present for achene yield plant^{-1} among six sunflower populations and could be used for further investigation (Arshad et al. 2007; Kholghi et al. 2011; White 2016).

Offspring populations

Plant height revealed sufficient variation ranging from 64 to 179 cm with an average of 122.66 cm among six sunflower populations (Table 2 and Figure 1). This variation suggested that there was an ample scope of achene yield improvement by using plant height as selection tool through simple selection. The statistical comparison of means and coefficients of variation indicated that population 3 was significantly different from other sunflower populations for plant height. This revealed that variation was present for achene yield plant^{-1} in sunflower populations 3 and improvement of achene yield was possible through simple selection. The results were in agreement with the findings of Khan et al. (2007), Kaya et al. (2009), Darvishzadeh et al. (2011), Akhtar et al. (2012) who reported that plant height was observed to be the one of the main yield improving component which had direct effect on achene yield in sunflower. On the basis of plant height response to achene yield in sunflower populations, it was concluded that good plant height could be desirable for achene yield improvement. Number of leaves plant^{-1} also showed sufficient variation ranging from 14 to 36 leaves plant^{-1} (Table 2). Mean values comparison exhibited significant difference of population 6 with the remaining sunflower populations. Plants with numerous leaves were usually late in maturity. Hence for early maturity, less number of leaves plant^{-1} was desirable without reducing achene yield (Darvishzadeh et al. 2011). The coefficients of variation suggested that improvement in achene yield of sunflower populations by using this trait was possible through selection.

The existence of internodal length ranging from 2 to 11 cm with an average of 5.34 cm exhibited a good source of variation among six sunflower populations (Table 2). The coefficient of variation (12.74%) and variance for internodal length were high for population 6. In sunflower, the stem length was determined by number and length of internodes and dwarf plant height was only due to shorter internodes (Miller and Gulya 1989). The mean values comparison indicated that population 3 was differed significantly from remaining populations due to its shorter internodal length. The results revealed that shorter internodal length reduced plant height as well as achene yield plant^{-1}. However, selection of plants with low internodal length might be useful for the development of early maturing variety. These results were supported by the findings of Ahmad et al. (2012) who reported ample variation for internodal length, and had a significant impact on achene yield improvement in sunflower.

Stem diameter variation among the sunflower populations ranged from 2 to 11 cm with an average of 5.35 cm (Table 3 and Figure 2). The statistical comparison of means and coefficients of variation for stem girth revealed that population 1 was significantly differed from population 2 and population 3. A positive association between internodal number and stem diameter was also observed. Moreover, stem diameter had direct effect on achene yield by providing resistance to lodging (Iqbal et al. 2009). However, narrow range of variability for stem diameter was also observed in sunflower by Sujatha (2002). Head to soil surface distance showed a lot of variation among six sunflower populations ranging from 15 to 139 cm with an overall average of 69.21 cm (Table 3). Head to soil surface distance could be helpful in estimating stem curvature. The greater value of stem curvature (nearness of head from soil surface) could be preferred because achenes were not exposed and protected from birds. However, this trait was assumed to cause stem weakness (Akhtar et al. 2012). Sufficient variation for this trait suggested that improvement should be done through selection among populations. The statistical comparison among means showed that maximum head to soil surface distance was obtained in population 6 which differed significantly from other studied populations.

The results exhibited sufficient variation for head diameter ranging from 6 to 25 cm with an average of 13.48 cm among sunflower populations (Table 3 and Figure 3). The mean values comparison revealed that maximum average head diameter (14.98) was attained by population 6 and it differed significantly with population 2 and population 3. Wide range of variation for head diameter in sunflower and its significant relationship with achene yield were also reported by Kaya et al. (2009), Darvishzadeh et al. (2011), Akhtar et al. (2012), Kang et al. (2013). The present range of variation indicated that improvement in this trait could be achieved through simple selection.

Achene weight in sunflower is also an important yield component which ultimately results in an increase in achene yield. Remarkable variation for 100-achene weight was observed in sunflower populations which ranged from 1.55 to 11.9 g with an average of 3.76 g among sunflower populations (Table 4). These variations suggested that there was a scope of improvement in this character through

Table 1 Mean performance of six sunflower parent populations

Sunflower populations	Plant height (cm)	Head diameter (cm)	100-achene weight (g)	Achene yield plant^{-1} (g)
Population 1	138.9 c*	18.18 bc	6.88 ab	73.36 c
Population 2	141.7 abc	19.40 ab	6.77 b	86.62 a
Population 3	142.0 abc	17.82 c	7.30 a	77.97 c
Population 4	144.8 a	19.78 a	7.25 a	86.49 ab
Population 5	140.1 bc	18.04 c	6.86 ab	78.08 bc
Population 6	142.6 ab	18.72 abc	6.55 b	78.35 abc

*The mean values shearing common letter in a column do not differ significantly from each other at 0.05 probability level

Table 2 Comparison of plant height, number of leaves plant^{-1} and internodal length of six offspring plant populations

Plant traits	Population 1	Population 2	Population 3	Population 4	Population 5	Population 6	Average
Plant height (cm)							
Mean	127.59 a	122.39 a	111.31 b	123.43 a	125.03 a	126.18 a	122.66
Range	83-162	77-155	64-149	74-153	89-179	81-160	
Variance	63.89	57.38	142.62	129.73	80.79	95.22	
CV (%)	6.16	6.08	10.55	9.08	7.07	7.61	
Number of leaves plant^{-1}							
Mean	26.00 a	26.01 a	24.37 ab	24.86 a	25.09 a	22.81 b	24.86
Range	17-32	18-35	17-33	14-36	18-31	16-32	
Variance	3.68	2.41	5.98	4.69	3.89	2.50	
CV (%)	7.12	5.76	9.69	8.41	7.59	6.69	
Internodal length (cm)							
Mean	5.31 a	5.33 a	4.88 b	5.55 a	5.53 a	5.46 a	5.34
Range	3-7	2-10	3-7	3-9	4-11	3-10	
Variance	0.18	0.21	0.29	0.39	0.23	0.52	
CV (%)	7.70	8.29	10.64	10.84	8.36	12.74	

*The mean values sharing common letter in a column do not differ significantly from each other at 0.05 probability level

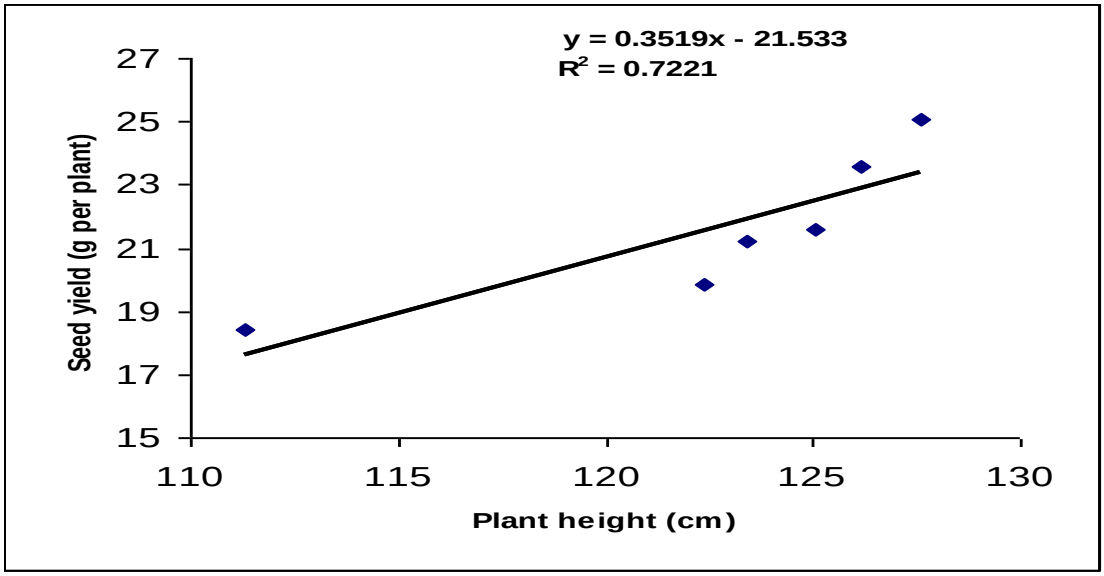

Figure 1 Relationship between plant height and achene yield plant^{-1} of sunflower

Table 3 Comparison of stem diameter, head to soil surface distance and head diameter of six offspring plant populations

Plant traits	Population 1	Population 2	Population 3	Population 4	Population 5	Population 6	Average
Stem diameter (cm)							
Mean	5.68 a	5.04 bc	4.95 c	5.31 abc	5.50 ac	5.59 a	5.35
Range	2-10	3-9	3-11	3-8	3-9	3-9	
Variance	0.20	0.35	0.33	0.50	0.38	0.42	
CV (%)	7.53	11.23	11.09	18.02	10.72	11.08	
Head to soil surface distance (cm)							
Mean	68.78 ab	65.37 bc	63.54 c	66.45 bc	64.06 bc	71.75 a	66.66
Range	26-124	27-137	124-123	16-119	24-122	15-139	
Variance	79.55	87.05	137.62	163.00	83.96	272.87	
CV (%)	12.49	13.75	17.78	18.51	13.78	22.18	
Head diameter (cm)							
Mean	13.77 ab	12.90 bc	12.72 c	13.51 abc	13.73 ab	14.25 a	13.48
Range	8-23	7-24	6-22	9-25	9-24	10-22	
Variance	0.99	0.82	1.45	1.96	1.12	1.04	
CV (%)	6.87	6.67	9.01	9.86	7.33	6.84	

*The mean values sharing common letter in a column do not differ significantly from each other at 0.05 probability level

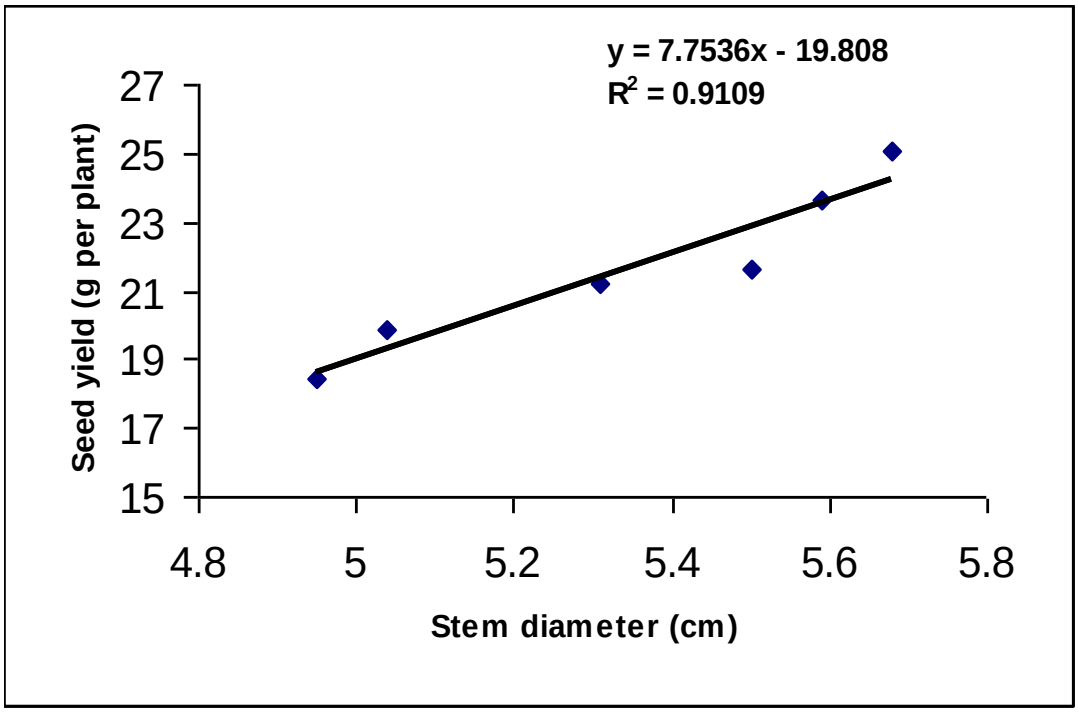

Figure 2: Relationship between stem diameter and achene yield plant^{-1} of sunflower

selection. The comparison of mean values and coefficients of variation indicated that maximum average 100-achene weight was attained by population 6 and it differed significantly from population 2 and population 3. These results were in accordance with Sarwar et al. (2013) who reported that 100-achene weight had a positive effect to improve yield in sunflower. Bird damage is a serious problem and a limiting factor in the production of sunflower. Certain plant characters of sunflower are found to limit the bird damage. But achene losses in case of sunflower were related to differences in head inclination, head shape, achene size and other agronomic traits. While, the results of present study

Table 4 Comparison of 100-achene weight, bird damage and achene yield plant^{-1} of six offspring plant populations

Plant traits	Population 1	Population 2	Population 3	Population 4	Population 5	Population 6	Average
100-achene weight (g)							
Mean	3.78 ab	3.55 b	3.52 b	3.76 ab	3.89 a	4.04 a	3.76
Range	1.55-7.31	2.0-8.03	1.89-8.94	1.69-7.36	2.13-7.49	2.04-11.9	
Variance	0.20	0.08	0.17	0.19	0.19	0.29	
CV (%)	11.26	7.58	11.14	11.04	10.66	12.70	
Bird damage (%)							
Mean	16.78 a	11.77 b	17.11 a	14.76 ab	12.12 b	10.84 b	13.90
Range	6-87	5-56	5-77	5-59	5-73	5-81	
Variance	60.60	21.51	55.21	55.55	65.33	78.79	
CV (%)	43.91	37.28	41.10	47.81	63.15	77.52	
Achene yield per plant (g)							
Mean	25.09 a	19.85 bc	18.43 c	21.22 abc	21.61 abc	23.61 ab	21.64
Range	6.5–71.3	4.9–44.6	4.6–59.0	3.7–69.1	4.5–61.8	8.3–55.4	
Variance	28.40	8.62	12.83	26.85	17.87	25.87	
CV (%)	20.43	14.23	18.69	23.35	18.82	20.07	

*The mean values sharing common letter in a column do not differ significantly from each other at 0.05 probability level

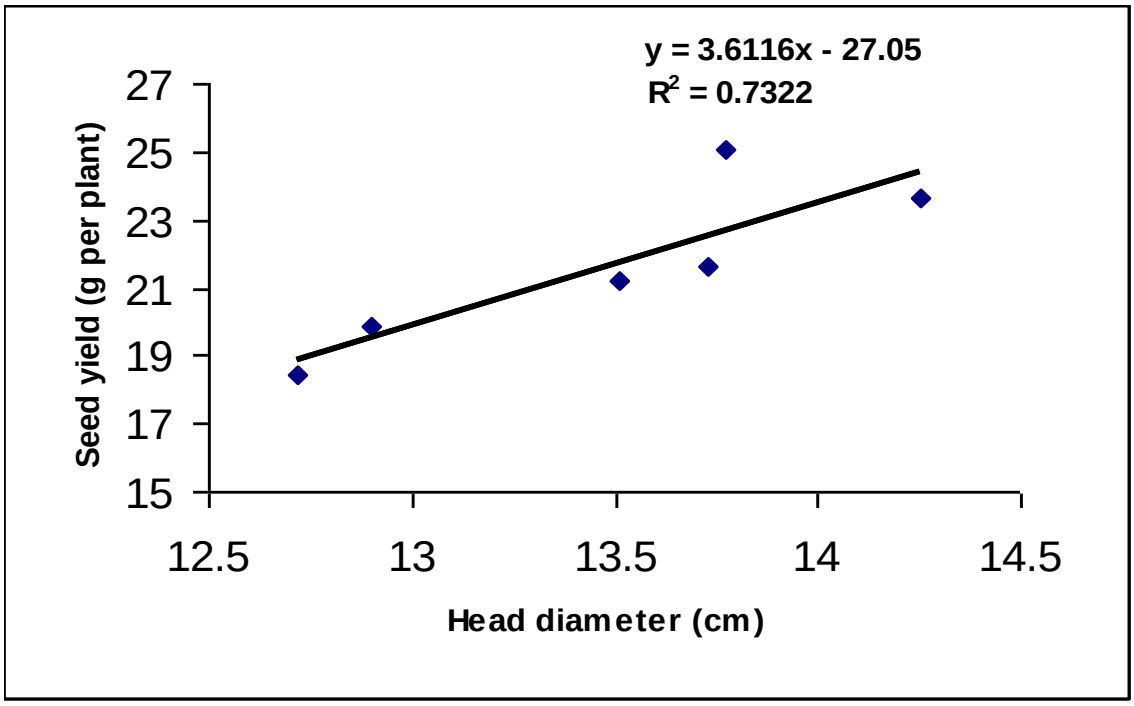

Figure 3 Relationship between head diameter and achene yield plant^{-1} of sunflower

indicated that there was a high range of variation for this trait ranging from 5 to 87% with an average of 13.90% among sunflower populations (Table 4). The mean values indicated that maximum average variation was found in population 3 which significantly differed from population 2, 5 and 6. The vast variation among sunflower populations showed that selection of drooping shaped heads during grain filling stage might be practiced to minimize bird damage (Hassan et al. 2007; Rauf et al. 2008; Darvishzadeh et al. 2011). Yield production is the outcome of combined effects of different morphological parameters showing the complexity of this trait. In the present study, a wide range of variation (3.7 to 71.3 g) for achene yield plant^{-1} was observed (Table 4). The mean values comparison indicated that population 1 had maximum average achene yield and significantly differed from

population 2 and 3. The coefficients of variation also revealed high variation which suggested that further achene yield plant^{-1} improvement could be done by selecting large head with filled achenes. Our results were in contrary with the findings of Zali and Samadi (1978) who found narrow range of variation for achene yield while a wide range of variation for achene yield in sunflower had also been observed by Arshad et al. (2007), Kholghi et al. (2011), Akhtar et al. (2012), Sarwar et al. (2013), White (2016).

The regression analysis of achene yield with other quantitative traits revealed that achene yield plant^{-1} had strong significant positive relationship with plant height (R^2 = 0.7221, Figure 1), stem diameter (R^2 = 0.9109, Figure 2) and head diameter (R^2 = 0.7322, Figure 3) while, non-significant positive relationship with intermodal length, head to soil surface distance and 100-achene weight (Data not shown). However, number of leaves plant^{-1} and bird damage had a negative association with achene yield plant^{-1} in this study.

CONCLUSIONS

Achene yield plant^{-1} is highly variable character in sunflower which in turn is dependent on a number of plants traits and other environmental factors. On the basis of present study results, it was concluded that plant parameters like good plant height, more stem diameter, longer intermodal length, larger diameter heads with heavier achenes and more 100-achene weight were the important plant traits in these populations and selection of plants on the basis of these plant parameters might be useful to improve the existing or to develop new sunflower populations to get high achene yield.

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