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Correlation and path analysis for yield and related traits among confectionery sunflower in breeds

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Abstract
Fifty four confectionery inbred lines of sunflower along with three checks were evaluated during Spring 2019 and 2020 for 17 agro-morphological traits. Seed yield/ plant exhibited positive correlation with 100-seed weight during 2019 whereas, with days to flower initiation, plant height, stem girth, head diameter, head weight, biological yield and filled seeds/ head during 2020. Significant negative correlation was seen among seed yield per plant and seed length during 2019. According to pooled data, significant positive correlation was observed by seed yield per plant with days to flower initiation, days to maturity, plant height, head diameter, stem girth, head weight, biological yield and filled seeds per head whereas, negative significant correlation with seed width. The path coefficient analysis revealed maximum positive direct effect on seed yield/ plant exhibited by 100-seed weight followed by stem girth in 2019 whereas, during spring 2020 filled seeds/ head, seed volume weight were major contributors towards seed yield per plant. Based on path analysis of pooled data biological yield, filled seeds per head, harvest index and head weight can be used for indirect selection for seed yield per plant.

Keywords: Confectionery sunflower, correlation analysis, path analysis, physio-morphological traits

1. Introduction
Sunflower (*Helianthus annuus* L.) is an important oilseed crop owing to its adaptability under wide range of climates, photoperiod insensitivity and high quality of edible oil. This crop belonging to Asteraceae family, ranks third in production after soybean and rapeseed mustard. With market share of 9.2% sunflower oil comes at fourth position among vegetable oils after palm oil (36.5%), soybean oil (27.4%) and rapeseed mustard (12.5%) (Pilorge 2020) [17]. Out of the total production of sunflower, around 90% of production is used to extract sunflower oil, whereas the remaining 10% are used for non-oil purposes such as confectionery or table purpose. Sunflower is a non-traditional crop in India both for oilseed as well as confectionery purpose. Although there is huge production potential for the crop in India the acreage has drastically reduced since 2005 due to several contributing factors among which one key reason being less returns to farmers. Confectionery sunflower can enhance farmers income since the market price for "in shell" confectionery sunflower (suitable for human consumption as snack) is three times higher than the oilseed sunflower (Basavarajappa 2017) [4]. The non-oilseed sunflowers are different from oilseed sunflower with respect to seeds and quality characteristics (Fernandez-Cuesta *et al.* 2012) [9]. In general, market acceptance for large elongated seed with distinct stripped seed coat is there for these specialty sunflowers for table purpose. Moreover, high proportion of hull content, low oil content (< 30%) along with high seed yield is also important breeding objectives for confectionery sunflower. Seed yield is quite complex to carry out direct selection among germplasm owing to contribution of several characters towards seed yield and their interaction with environment. Evaluation of trait relationships between the yield component traits as well as other traits of interest like seed yield, seed length, oil content, hull content and other agronomic traits assists in indirect selection (Nadkarni *et al.* 2017) [15] for yield. Correlation studies allows us to understand the positive and negative association between different traits with seed yield while, path coefficient analysis divides such associations into direct and indirect effects contributing to target trait. Also variation present among germplasm contributed by individual traits can also be estimated thus suggesting which traits can be improved by selection among the population.

2. Material and Methods
The present study was carried out on 54 confectionery inbred lines along with three checks which were evaluated in an augmented design in the sunflower experimental area, Department

of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, during spring 2019 and spring 2020. Each sunflower inbred was raised in a plot area of 3.60 m^2 and the individual plot consists of two rows each having three meter length. The row to row and plant to plant spacing was 60 cm and 30 cm, respectively. The standard agronomic practices were followed as per the package of practices of the PAU Ludhiana to raise the crop.

The observations were recorded on traits such as days to flower initiation (DFI), days to 50% flowering (DFF), days to maturity (DM), plant height in cm (PH), head diameter in cm (HD), head weight in g (HW), stem girth in cm (SG), filled seeds/head (FSH), harvest index in % (HI), hull content in % (HC), biological yield in g (BY), seed yield/plant in g (SYP), seed volume weight in g (SVW), 100-seed weight (HSW), seed length in cm (SL), seed width in cm (SW) and oil content in % (OC). The collected data were subjected to the analysis of variance to estimate variability among inbreds for the traits under study. The adjusted means were used for estimation of correlation among all the traits and path coefficient analysis was also computed to estimate direct and indirect effect of each trait on seed yield. The statistical analysis for estimation of correlation coefficient was done using the formula as per Al-Jibouri *et al* (1958) [1].

$$r_{xy} = \frac{Cov_{xy}\,(P)}{\sqrt{V_x(P) \times V_y\,(P)}}$$

The path coefficient analysis was performed as per the formula given by Wright (1921) [23] using the WINDOW STAT software.

3. Results and Discussion

Correlation analysis revealed that days to 50% flowering was showed highly significant and positive correlation with days to flower initiation (r=0.795) and among the agronomic traits, the significant and positive correlation was found with respect to plant height, stem girth, head diameter, head weight, biological yield and filled seeds per head. Furthermore, oil content was showed positive significant correlation with seed width (r=0.385). However, the traits like seed length and seed width showed negative and significant correlation with 100-seed weight (r=-0481, -0.268). Seed yield per plant was showed significant positive correlation with 100-seed weight (r=0.571) whereas, negative and significant correlation was observed with biological yield (r=-0.263) and seed length (r=-0.316) but showed non-significant correlation with seed width (r=-0.066) during spring 2019 (Table 1). Significant correlation among seed parameters have also been reported by Sridhar *et al.* (2005) [19] and Machikowa *et al.* (2008) [13] for 100-seed weight and by Binodh *et al.* (2008) [6] for seed volume weight. On the other hand, Vidhyavathi *et al.* (2005) [22] reported non-significant correlation among seed yield and 100-seed weight, seed length, seed width and oil content. Among agronomic traits, Doddamani *et al.* (1997), Teklewold *et al.* (2000), Behradfar *et al.* (2009), Tyagi *et al.* (2010) and Kholghi *et al.* (2011) [8, 20, 5, 21, 12] reported significant positive correlation for head diameter, plant height, stem girth and number of filled seeds/head.

While during spring 2020, seed yield/plant had significant positive correlation with days to flower initiation (r=0.471), plant height (r=0.481), stem girth (r=0.592), head diameter (r=0.487), head weight (r=0.638), biological yield (r=0.403), filled seeds/ head (r=0.744) and non-significant correlation with seed length (r=-0.027), seed width (r=-0.235), 100-seed weight (r=0.125), hull content (r=-0.208), seed volume weight (r=0.186) and oil content (r=0.131). The agronomic traits like plant height, stem girth, head diameter, head weight, biological yield and filled seeds per head was showed significant positive correlation with days to flower initiation, days to maturity, plant height, stem girth, head diameter and head weight. The traits like seed length (r=-0.353) and seed width (r=-0.555) showed negative significant correlation with seed volume weight whereas, seed width also showed positive significant correlation with seed length (r=0.601). Among seed parameters, similar results were also found by Vidhyavathi *et al.* (2005) [22] for 100-seed weight, seed length, seed width and oil content while, contrast results were found by Sridhar *et al.* (2005) and Machikowa *et al.* (2008) [19, 13] for 100-seed weight and by Binodh *et al.* (2008) [6] for seed volume weight. Arshad *et al.* (2010), Yasin *et al.* (2010) and Neelima *et al.* (2012) [3, 24, 16] were also reported significant positive correlation among seed yield/ plant with head diameter, plant height, days to flower initiation and filled seeds/ head.

The correlation analysis of the combined two years of data revealed that Seed length and seed width had positive significant correlation with each other and showed negative significant correlation with seed volume weight. A significant positive correlation was observed by seed yield per plant with days to flower initiation, days to maturity, plant height, head diameter, stem girth, head weight, biological yield and filled seeds per head whereas, negative significant correlation with seed width. Similarly, Kholghi *et al.* (2011) [12] observed that seed yield had positive significant correlation with plant height, head diameter, stem girth and filled seeds per head. On the contrary, Chikkadevaiah *et al.* (2002) [7] observed that seed yield was showed positive significant correlation with seed volume weight and oil yield.

Path analysis revealed that maximum positive direct effect on seed yield per plant was exhibited by 100 seed weight (0.484), followed by stem girth (0.369) in 2019 (Table 2). Total variation explained by the traits studied was 87.29% with maximum proportion of variation towards seed yield was contributed by biological yield (24.5%) followed by 100 seed weight (23.4%) as given in Figure 1. Among all the studied traits in 2019, days to flower initiation (0.166) had showed greatest positive indirect effect on seed yield per plant *via* days to 50% flowering. Similarly, the traits like days to 50% flowering (0.062), days to maturity (0.089), plant height (0.124), head weight (0.140), biological yield (0.192), filled seeds per head (0.228), harvest index (0.137), hull content (0.087) and seed length (0.038) had showed greatest positive indirect effect through stem girth and the trait like seed width (0.055) and oil content (0.079) had showed positive indirect effect on seed yield per plant through biological yield. However, the trait like 100-seed weight (0.259) and seed volume weight (0.078) showed positive indirect effect through filled seeds/heads. The proportion of unexplained variation for seed yield was 0.433 suggesting that additional traits can be incorporated to the study. On the contrary, the traits like stem girth, head diameter, head weight, filled seeds per head and harvest index had showed greatest negative indirect effect on seed yield per plant through biological yield. Similarly, the traits such as days to flower initiation, days to 50% flowering, seed length, seed width and oil content

showed greatest negative indirect effect on seed yield per plant through 100-seed weight. Zia *et al.* (2013) [25] and Maria *et al.* (2018) [14] reported similar results for 100 seed weight which had greatest positive direct effect on seed yield. Similar results had also reported by Arshad *et al.* (2007) [2] for indirect effect of days to 50% flowering, plant height, head diameter and 100 seed weight on seed yield. Zia *et al.* (2013) [25] also reported that the traits such as harvest index and filled seeds/head had showed positive indirect effect on seed yield.

While in the year 2020, maximum positive direct effect on seed yield per plant was exhibited by filled seeds/head (0.547) followed by seed volume weight (0.420). Total variation explained by the traits studied was 80.98% with maximum proportion of variation towards seed yield was contributed by filled seeds/head (29.9%) followed by harvest index (17.6%) as given in Figure 2. The traits like days to flower initiation (0.236), plant height (0.228), stem girth (0.220), head diameter (0.173), head weight (0.265), biological yield (0.102), harvest index (0.229), 100-seed weight (0.072) and oil content (0.115) had showed maximum positive indirect effect on seed yield per plant through filled seeds per head. Furthermore, the traits like filled seeds per head (0.077) and days to maturity (0.092) showed greatest positive indirect effect on seed yield per plant through biological yield. Seed length (0.049) was showed greatest positive indirect effect through harvest index and seed width (0.094) showed greatest positive indirect effect through seed length. Seed volume weight (0.050) had showed positive indirect effect through seed width. The proportion of unexplained variation for seed yield was 0.129 suggesting that additional traits can be incorporated to the study. However, the traits such as days to maturity, plant height, biological yield, seed length and seed width had showed greatest negative indirect effect on seed yield per plant through seed volume weight. Similarly, the traits like stem girth, harvest index and oil content showed greatest negative indirect effect on seed yield per plant through seed length. The maximum positive direct effect of filled seeds/ head on seed yield were also revealed by Teklewold *et al.* (2000), Gouri *et al.* (2006), Kholghi *et al.* (2011) and Rao (2013) [20, 10, 12, 18]. Contrast results were obtained by Hladni *et al.* (2017) [11] for seed length and seed width.

According to two-year combined data, biological yield (0.396) had the maximum positive direct effect on seed yield per plant whereas, the seed width (-0.240) had maximum negative direct effect on seed yield per plant. Seed length was showed greatest positive indirect effect through seed volume weight whereas, seed width showed greatest positive indirect effect through biological yield on seed yield per plant. The traits like days to 50% flowering, seed volume weight and harvest index showed greatest positive indirect effect on seed yield per plant through seed width. Furthermore, the traits like head diameter, seed volume weight and seed width showed greatest negative indirect effect on seed yield per plant through seed length.

Table 1: Correlation coefficient analysis among seventeen traits

		DFI	DFF	DM	PH	SG	HD	HW	BY	FSH	HI	SVW	HSW	HC	SL	SW	OC
DFF	2019	0.79@															
	2020	0.20															
	Pooled	-0.17															
DM	2019	-0.10	-0.10														
	2020	0.25	0.22														
	Pooled	0.64@	-0.02														
PH	2019	0.06	0.23	0.07													
	2020	0.41@	0.00	0.31*													
	Pooled	0.38*	0.10	0.59@													
SG	2019	0.07	0.16	0.24	0.33@												
	2020	0.50@	0.11	-0.04	0.59@												
	Pooled	0.32*	-0.08	0.37*	0.38*												
HD	2019	-0.13	-.043	-.092	0.52@	0.41@											
	2020	0.23	-0.09	-0.03	0.36*	0.59@											
	Pooled	0.31*	-0.09	0.33*	0.53@	0.31*											
HW	2019	-0.09	-0.06	-0.31*	0.27*	0.37@	0.70@										
	2020	0.31*	-0.17	-0.07	0.56@	0.70@	0.58@										
	Pooled	0.36*	-0.12	0.36*	0.59@	0.75@	0.34*										
BY	2019	-0.03	0.04	-0.15	0.42@	0.52@	0.60@	0.71@									
	2020	0.14	-0.11	0.22	0.30*	0.09	0.25	0.18									
	Pooled	0.33*	-0.01	0.31*	0.54@	0.22	0.26	0.27									
FSH	2019	-0.03	0.11	-0.00	0.20	0.61@	0.43@	0.33*	0.40@								
	2020	0.43@	-0.10	-0.04	0.41@	0.40@	0.31*	0.48@	0.18								
	Pooled	0.51@	0.09	0.51@	0.58@	0.70@	0.37*	0.65@	0.27								
HI	2019	-0.04	-0.05	-0.03	0.60@	0.37@	0.54@	0.55@	0.66@	0.37@							
	2020	0.27	-0.00	0.10	0.12	0.08	0.05	0.00	0.00	0.41@							
	Pooled	-0.02	0.10	-0.02	-0.20	0.06	0.03	-0.10	-0.52@	0.10							
SVW	2019	0.03	-0.06	-0.05	0.11	-0.13	0.00	0.09	-0.05	-0.38@	0.14						
	2020	0.10	0.24	-0.27	-0.18	0.18	0.01	-0.02	-0.42@	0.03	0.20						
	Pooled	0.08	0.09	0.08	0.19	0.20	0.31*	0.07	-0.03	0.43@	0.08						
HSW	2019	-0.26*	-0.31*	0.08	-0.04	-0.02	-0.13	-0.20	-0.23	-0.12	0.09	0.04					
	2020	0.31*	0.12	0.02	0.20	0.26	-0.11	0.18	-0.18	0.13	0.18	0.13					
	Pooled	0.13	0.19	0.19	0.32*	0.36*	-0.06	0.19	0.02	0.21	-0.10	0.08					
HC	2019	-0.20	-0.14	0.36@	0.27*	0.23	0.27*	0.10	0.03	0.22	0.14	0.01	-0.22				
	2020	-0.00	0.10	0.13	-0.05	-0.36*	-0.28	-0.29*	0.04	0.02	0.07	-0.11	-0.09				
	Pooled	0.07	0.24	-0.04	-0.08	-0.34*	-0.13	-0.29	0.02	-0.21	-0.20	-0.01	0.18				

SL	2019	0.11	0.10	0.17	0.00	0.10	-0.03	-0.08	0.02	0.16	-0.10	-0.00	-0.48@	0.25			
	2020	-0.22	-0.27	0.03	0.00	-0.18	0.02	0.09	-0.02	0.00	-0.28	-0.35*	0.01	0.12			
	Pooled	0.04	-0.15	0.06	-0.07	-0.11	0.01	0.06	0.00	-0.09	-0.51@	-0.11	0.08	0.19			
SW	2019	-0.03	0.06	0.17	0.06	-0.07	0.05	-0.13	-0.11	-0.02	-0.15	0.02	-0.26*	0.22	0.13		
	2020	-0.14	-0.01	0.17	0.07	-0.15	0.05	-0.01	0.13	-0.15	-0.29	-0.55@	0.11	0.19	0.60@		
	Pooled	-0.06	-0.21	-0.10	-0.16	-0.11	0.05	-0.10	0.22	-0.31*	-0.49@	-0.34*	-0.06	0.19	0.47@		
OC	2019	0.09	0.07	-0.02	-0.13	-0.27*	0.10	-0.07	-0.15	0.16	-0.15	-0.24	-0.21	0.08	-0.00	0.38@	
	2020	0.15	-0.05	-0.02	0.17	0.21	0.34*	0.12	0.06	0.21	0.57@	-0.08	0.11	-0.14	-0.25	-0.07	
	Pooled	0.16	0.09	0.10	0.35*	0.29	0.28	0.13	0.13	0.31*	0.66@	0.04	-0.03	-0.17	-0.42@	-0.18	
SYP	2019	-0.05	-0.00	0.21	0.12	0.12	-0.05	-0.11	-0.26*	-0.14	0.08	0.25	0.57@	-0.02	-0.31*	-0.06	-0.12
	2020	0.47@	-0.14	0.00	0.48@	0.59@	0.48@	0.63@	0.40@	0.74@	0.22	0.18	0.12	-0.20	-0.02	-0.23	0.13
	Pooled	0.59@	0.01	0.59@	0.71@	0.64@	0.47@	0.69@	0.47@	0.81@	0.29	0.13	0.26	-0.13	0.01	-0.30*	0.26

*Significant at 5% level of significance, @ Significant at 1% level of significance

Table 2: Path coefficient analysis showing direct (diagonal and bold) and indirect (off- diagonal) effects of different traits on seed yield per plant in confectionery sunflower

		DFI	**DFF**	**DM**	**PH**	**SG**	**HD**	**HW**	**BY**	**FSH**	**HI**	**SVW**	**HSW**	**HC**	**SL**	**SW**	**OC**
DFI	2019	-0.081	0.166	-0.012	0.006	-0.027	0.007	-0.021	0.018	0.007	-0.007	0.005	-0.127	0.006	-0.007	0.000	0.012
	2020	0.069	-0.027	0.034	-0.011	0.078	-0.006	0.042	0.058	0.236	-0.048	0.044	0.007	0.000	-0.035	0.013	0.014
	Pooled	0.094	0.009	0.008	0.044	0.035	-0.026	0.095	0.129	0.170	-0.007	-0.005	0.008	0.002	0.007	0.014	0.010
DFF	2019	-0.065	0.208	-0.012	0.025	0.062	0.002	-0.013	-0.022	-0.022	-0.009	-0.011	-0.150	0.004	-0.006	0.000	0.009
	2020	0.014	-0.135	0.031	0.000	0.017	0.002	-0.023	-0.049	-0.059	0.0007	0.104	0.002	-0.008	-0.043	0.001	-0.005
	Pooled	-0.016	-0.056	0.000	0.011	-0.009	0.007	-0.032	-0.005	0.030	0.030	-0.005	0.012	0.005	-0.023	0.050	0.006
DM	2019	0.008	-0.021	0.123	0.000	0.089	0.005	-0.070	0.076	0.000	-0.005	-0.009	0.042	-0.011	-0.011	0.000	-0.003
	2020	0.017	-0.031	0.138	-0.008	-0.007	0.000	-0.010	0.092	-0.027	-0.019	-0.115	0.000	-0.010	0.005	-0.015	-0.001
	Pooled	0.061	0.001	0.013	0.069	0.040	-0.027	0.095	0.122	0.173	-0.006	-0.004	0.012	-0.001	0.008	0.025	0.006
PH	2019	-0.005	0.049	0.000	0.108	0.124	-0.028	0.061	-0.210	-0.041	0.093	0.019	-0.023	-0.008	0.000	0.000	-0.018
	2020	0.028	0.000	0.043	-0.026	0.092	-0.009	0.076	0.127	0.228	-0.022	-0.077	0.004	0.004	0.000	-0.006	0.016
	Pooled	0.036	-0.005	0.008	0.116	0.041	-0.044	0.155	0.213	0.195	-0.060	-0.011	0.021	-0.002	-0.010	0.039	0.022
SG	2019	0.006	0.035	0.029	0.036	0.369	-0.022	0.085	-0.259	-0.125	0.057	-0.024	-0.013	-0.007	-0.006	0.000	-0.038
	2020	0.034	-0.015	-0.006	-0.015	0.156	-0.015	0.094	0.038	0.220	-0.015	0.075	0.006	0.029	-0.028	0.013	0.020
	Pooled	0.030	0.005	0.005	0.044	0.110	-0.034	0.089	0.104	0.123	0.011	-0.018	-0.004	-0.003	0.002	-0.011	0.018
HD	2019	0.011	-0.009	-0.011	0.057	0.151	-0.054	0.158	-0.298	-0.087	0.084	0.000	-0.065	-0.008	0.002	0.000	0.014
	2020	0.017	0.013	-0.005	-0.009	0.093	-0.025	0.077	0.105	0.173	-0.010	0.004	-0.002	0.023	0.004	-0.005	0.033
	Pooled	0.029	0.005	0.004	0.062	0.046	-0.082	0.198	0.088	0.236	0.018	-0.011	0.023	-0.007	-0.016	0.027	0.018
HW	2019	0.007	-0.012	-0.038	0.029	0.140	-0.038	0.226	-0.352	-0.067	0.085	0.016	-0.100	-0.003	0.005	0.000	-0.010
	2020	0.021	0.023	-0.011	-0.015	0.110	-0.014	0.133	0.078	0.265	-0.001	-0.010	0.004	0.024	0.015	0.000	0.012
	Pooled	0.034	0.007	0.005	0.069	0.037	-0.062	0.263	0.107	0.218	-0.031	-0.004	0.012	-0.006	0.008	0.025	0.008
BY	2019	0.003	0.009	-0.019	0.046	0.192	-0.033	0.160	-0.495	-0.081	0.102	-0.008	-0.114	-0.001	-0.001	0.000	-0.022
	2020	0.009	0.016	0.030	-0.008	0.014	-0.006	0.025	0.416	0.102	-0.000	-0.178	-0.004	-0.003	-0.004	-0.012	0.005
	Pooled	0.031	0.001	0.004	0.062	0.029	-0.018	0.071	0.396	0.090	-0.159	0.002	0.001	0.000	0.000	-0.052	0.008
FSH	2019	0.003	0.023	0.000	0.021	0.228	-0.023	0.075	-0.199	-0.202	0.058	-0.068	-0.062	-0.006	-0.011	0.000	0.022
	2020	0.029	0.014	-0.006	-0.011	0.062	-0.007	0.064	0.077	0.547	-0.074	0.012	0.003	-0.002	0.000	0.013	0.020
	Pooled	0.048	-0.005	0.007	0.067	0.040	-0.058	0.170	0.106	0.337	0.031	-0.025	0.014	-0.004	-0.014	0.075	0.020
HI	2019	0.004	-0.012	-0.004	0.066	0.137	-0.030	0.126	-0.331	-0.076	0.153	0.026	0.048	-0.004	0.007	0.000	-0.022
	2020	0.018	0.000	0.014	-0.003	0.013	-0.001	0.0007	0.001	0.229	-0.177	0.087	0.004	-0.006	-0.043	0.026	0.055
	Pooled	-0.002	-0.006	0.000	-0.023	0.004	-0.005	-0.027	-0.207	0.034	0.304	-0.016	0.005	0.000	-0.017	0.081	0.002
SVW	2019	-0.002	-0.013	-0.006	0.012	-0.049	0.000	0.020	0.024	0.078	0.022	0.177	0.021	0.000	0.000	0.000	-0.033
	2020	0.007	-0.033	-0.038	0.004	0.028	0.000	-0.003	-0.176	0.016	-0.037	0.420	0.003	0.009	-0.055	0.050	-0.008
	Pooled	0.007	-0.005	0.001	0.023	0.034	-0.016	0.018	-0.013	0.146	0.083	-0.057	-0.006	-0.004	-0.076	0.117	0.042
HSW	2019	0.021	-0.064	0.010	-0.005	-0.010	0.007	-0.046	0.117	0.259	0.153	0.007	0.484	0.006	0.032	0.000	-0.030
	2020	0.022	-0.016	0.003	-0.005	0.041	0.002	0.024	-0.076	0.072	-0.033	0.056	-0.024	0.007	0.001	-0.009	0.011
	Pooled	0.012	-0.011	0.002	0.038	-0.007	-0.029	0.050	0.009	0.072	0.023	0.006	0.064	0.004	0.012	0.015	-0.002
HC	2019	0.016	-0.031	0.045	0.029	0.087	-0.015	0.023	-0.018	-0.045	0.021	0.003	-0.106	-0.030	-0.016	0.000	0.012
	2020	0.000	-0.014	0.018	0.001	-0.056	0.007	-0.039	0.017	0.015	-0.013	-0.047	-0.002	-0.081	0.019	-0.017	-0.014
	Pooled	0.007	-0.014	0.000	-0.009	-0.015	0.028	-0.076	0.009	-0.069	-0.002	0.011	0.011	0.021	0.029	-0.047	-0.011
SL	2019	-0.009	0.021	0.021	0.000	0.038	0.001	-0.019	-0.013	-0.033	-0.016	0.000	-0.232	-0.007	-0.066	0.000	0.000
	2020	-0.015	0.037	0.004	0.000	-0.028	0.000	0.013	-0.010	0.002	0.049	-0.148	0.000	-0.009	0.156	-0.054	-0.024
	Pooled	0.004	0.008	0.001	-0.008	0.002	0.009	0.015	-0.001	-0.031	-0.034	0.029	0.005	0.004	0.149	-0.113	-0.026
SW	2019	0.002	0.014	0.021	0.007	-0.028	-0.002	-0.031	0.055	0.005	-0.023	0.003	-0.129	-0.006	-0.009	0.002	0.053
	2020	-0.010	0.001	0.024	-0.001	-0.023	-0.001	-0.001	0.057	-0.083	0.051	-0.233	0.002	-0.015	0.094	-0.090	-0.006
	Pooled	-0.005	0.012	-0.001	-0.019	0.005	0.009	-0.027	0.086	-0.105	-0.103	0.028	-0.004	0.004	0.070	-0.240	-0.011
OC	2019	-0.007	0.014	-0.003	-0.014	-0.101	-0.005	-0.016	0.079	-0.032	-0.024	-0.043	-0.105	-0.002	0.000	0.001	0.139
	2020	0.010	0.007	-0.002	-0.004	0.032	-0.008	0.017	0.025	0.115	-0.103	-0.037	0.002	0.011	-0.039	0.006	0.096
	Pooled	0.015	-0.005	0.001	0.040	0.031	-0.024	0.034	0.050	0.105	0.011	-0.038	-0.002	-0.004	-0.062	0.043	0.063

Residual effect = 0.433, 0.129, 0.089

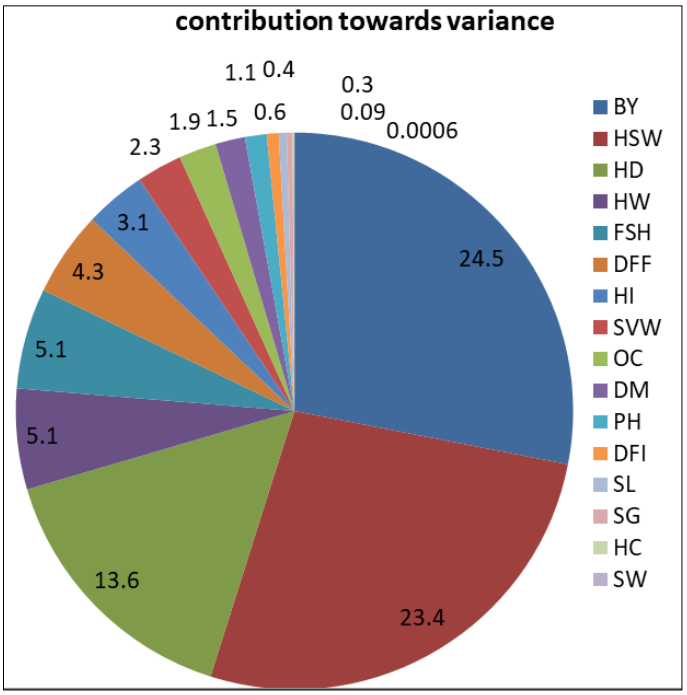

Fig 1: Contribution of different traits towards variance in 2019

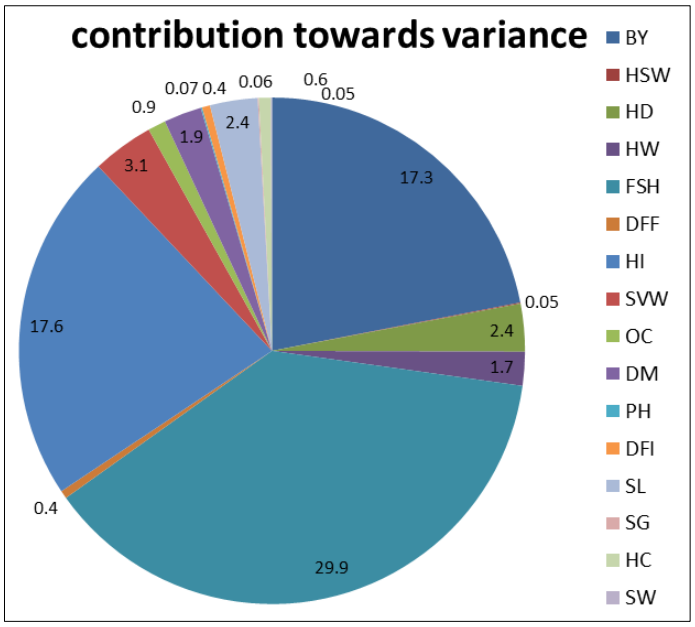

Fig 2: Contribution of different traits towards variance in 2020

4. **Conclusion**

Correlation analysis on the data observed during spring 2019 and 2020 revealed that positive association is present among seed yield/ plant with 100-seed weight and days to flower initiation, plant height, stem girth, head diameter, head weight, biological yield and filled seeds/ head. Seed yield also exhibited negative correlation with biological yield and seed length during spring 2019. According to combined data of both years, significant positive correlation was observed by seed yield per plant with days to flower initiation, days to maturity, plant height, head diameter, stem girth, head weight, biological yield and filled seeds per head. This means that while seed yield can be enhanced by improving for agronomic traits like plant height, head diameter, 100-seed weight and filled seeds per head, however with increase in seed length the seed yield/ plant is likely to be reduced. The Path analysis results during spring 2019 and 2020 revealed that 100-seed weight and filled seeds/ head had maximum positive direct effect on seed yield/plant. The maximum positive indirect effect on seed yield/ plant was exhibited by various traits in 2019 and 2020 through stem girth and filled seeds/ head. Hence indirect selection through stem girth and filled seeds/head will be effective for seed yield improvement. According to two year combined data, biological yield had the maximum positive direct effect on seed yield per plant. The maximum positive indirect effect on seed yield/ plant was exhibited by various traits through filled seeds/ head which indicates that indirect selection through filled seeds/ head will be effective for yield improvement.

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