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BREEDING OF ELITE LOCAL SUNFLOWER HYBRIDS WITH HIGH GENETIC YIELD POTENTIAL AND WIDE ADAPTABILITY

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Abstract

This research, which consisted of inbred lines development, making of cross combinations and preliminary agronomic evaluation of the hybrids, was carried out at National Agricultural Research Centre (NARC) over a period of eight years (2013-2020). Heterogeneous sunflower material available with Oilseeds Program (NARC) was used as base material for inbred lines development. The base material used were Shams-37 and NDMTC (OPVs) and RHA-439 and Hyolic-41R (heterogeneous multi-headed restorer lines). Initially, 100 single plants were selected in each of the above mentioned material based on their agro-morphological traits like desirable phenotype, yield superiority and disease resistance in the selection of B lines (maintainer lines) from OPVs while in case of restorer lines selection and development, phenotypes like desirable plant type, pyramid like branching pattern with flowering starting from the top going down to the bottom ensuring long time availability of pollen and disease resistance etc. were the basis of selection. The selfing process continued for six to seven generations after that the selection process was narrowed down retaining only the best single plant progenies with no segregation and highest level of stability. The best lines selected from OPVs were then put into the CMS background by backcrossing them to CMS sources. This process continued for six to seven generations and ultimately only six A & B lines were selected for use in making cross combinations because of their best uniformity with highest level of stability and other desirable morphological characters. Similarly, six restorer lines (R) were also selected from the progenies of the single plants originally selected from heterogeneous R lines after twelve generations of selfing based on their desirable morphologies and uniformity. These six A and six R lines were crossed in all possible ways during Spring-2018 and 24 crosses produced enough seed which were tested in a non-replicated trial for their yield potential assessment during Autumn 2018 using Hysun-33 as a standard check. All the hybrids out-yielded the standard check except four combinations where the seed yield remained non-significantly lower than the check. Ten hybrid combinations recorded > 20% yield increase over the check. Similarly, in the agronomic evaluation during Spring-2019 replicated trials, all ten elite local sunflower hybrids out-yielded the check hybrid (NKS-278) where seven crosses recorded > 20% genetic gain in terms of seed yield over the standard check. Again in Spring-2020, all the 18 locally developed elite sunflower hybrids out-performed the standard check (Hysun-33) in yield. Overall, 11 hybrids exhibited > 30% yield gain over the check hybrid.

Key words: Sunflower (*Helianthus annuus* L.), Local hybrids, Inbred lines, CMS source, Selfing, Homozygosity, Cross combinations, Agronomic traits, Yield performance.

Introduction

Pakistan has been facing chronic deficiency in edible oil production and around 85-90% of the local needs are met through import: which has been a big concern for researchers and policy makers. Despite being an agricultural country, local edible oil production is far lower than the total national annual consumption. Resultantly, the country spends huge amount of our meager foreign exchange reserves on its import every year. During 2020-21, US $ 3.419 billion were spent on the import of edible oil making it largest among the imported food items and second largest after petroleum products among all imported commodities (Eco. survey of Pak., 2020-21). Our local edible oil production is hardly enough to meet 10-15 % of our national requirements. In local production, major share comes from cotton (57 %) which is not actually an oilseed crop and is mainly grown for its yarn. The shares of sunflower and rapeseed-mustard in our total local edible oil production are 9% and 34 % respectively (Eco. survey of Pak., 2020-21).

Sunflower globally ranks 2nd in terms of the volume of breeding work done on it after maize (Sieler & Jan, 2014) and as regards its contribution to the total world vegetable edible oil production, it occupies 4th position after palm oil, soybean and canola (Rauf *et al*., 2017; Dimitrijevic and Horn, 2018; Grompone, 2011). It derives most of its economic value from its oil (Radanovic *et al*., 2018). In addition to use of its oil for direct human consumption, it has many industrial uses as well (Dimitrijevic *et al*., 2017). The widespread popularity of sunflower is based on its ability to grow in wide ranging ecologies and reasonable drought tolerance (Dimitrijevic and Horn, 2018) with low input requirements. In Pakistan, it is second most important oil crop after rapeseed-mustard in terms of its area and production (Agric. Statistics of Pak., 2017-18). Over 90 % of the area under sunflower in the country is in rice and cotton belts of lower Sindh and Southern Punjab respectively. It is also sporadically sown in KP and Baluchistan provinces but in small pieces of 1 to 2 acres but overall, sunflower acreage in these two provinces is negligible. Sunflower acreage in the country reached its maximum level of 3,97,306 hectares in 2007-08 with over 6,00,000 tons seed production. But then the area and production both recorded gradual decline and reached its lowest level of 82,600 hectares and 85,900 tons respectively during 2016-17 (Agric. statistics of Pakistan, 2017-18). Per unit area sunflower average yield in the country is also very low and is just a little over a ton/hectare representing only 25 % yield potential of the crop (Skoric *et al*., 2007). Our sunflower average seed yield is way lower than the yield farmers get in major sunflower growing countries (Jockovic *et al*., 2019).

The reasons for the decline in sunflower acreage in the country are high cost of imported hybrid seed, its non-availability on time, lack of awareness in the farming community about its latest production technology and lack of sunflower farm machinery specifically equipment used in planting, harvesting and threshing operations. There are some other socio-economic factors as well like lack of support price and credit facility from banks to sunflower growers, non-existence of enough oil extraction industry near sunflower production hubs and high cost of other inputs like fertilizers, insecticides etc. These factors add to the cost of production making sunflower less competitive as compared to well-established major crops and resultantly drive farmers away from sunflower cultivation in the country.

In sunflower production like any other crop, seed is the most important of all the inputs used, and all efforts and management practices are designed to make the most of its genetic potential. No matter how optimal level of other practices and inputs are used, they cannot enhance yield of a hybrid beyond its genetic potential. Now a days, 100% of seed used by sunflower growers is hybrid in nature because of its higher yield potential due to utilization of heterosis (Anyanga, 2007) and suitability for mechanized handling due to uniformity in height and maturity along with some other associated agronomic and economic advantages (Bohra *et al*., 2016) as against the pre-1970 era where only OPVs were used (Kaya *et al*, 2012; Vear, 2016). The trend from OPVs changed to hybrid seed because of the discovery of CMS source (Leclercq, 1969) and fertility restoring genes (Kinman, 1970) in addition to their attractiveness due to their higher seed and oil yield (Bohra *et al*., 2016) and easier mechanical harvesting (Bohra *et al*., 2016; Vear, 2016).

In Pakistan, nearly 100 % of the area under sunflower is planted to imported hybrid seed. On one hand, the country spends huge amount of money from its meager foreign exchange reserves and on the hand, it is so expensive adding to the cost of production plus its timely availability has been a big issue. So it is necessary to develop local sunflower hybrids with high genetic potential for seed and oil yields (Fick & Miller, 1997; Kaya, 2005) with good adaptation to our local climatic conditions (Muhammad *et al*., 2012). The objectives of the current research effort were to develop local sunflower hybrids with higher seed and oil yield potential, wide adaptability and reasonable resistance against major diseases so that its seed can be produced locally on large scale through public-private partnership for marketing in the country. It will not only bring farmers' cost of production down but its timely availability along with good adaptability to the local conditions will lead to higher per unit area seed yield. Higher yield will consequently lead to higher economic returns to the farmers which will help revive farmers' interest in the crop again in the country.

Material and Methods

This research was carried out at NARC, Islamabad during last 8 years. The purpose was to develop local sunflower inbred lines (A, B & R) with superior agronomic traits and good combining abilities. The starting or base material used for this study is given in the Table l. They were chosen from the available sunflower OPVs and R lines with the oilseeds program, NARC. Each line was actually a heterogeneous mass of plants where every plant was different from every other plant in the lines phenotypically and of course genetically as well. These lines were used as foundation material because of their heterogeneous nature.

Table. 1. Different heterogeneous sunflower lines used as base material for the development of different inbred lines.

S. No.	Names of the heterogeneous base material (OPVs & restorer lines, R)
1.	Shams-37
2.	NDMTC
3.	RHA-439
4.	Hyolic-41R

Initially, 100 single plant selections were made in all the four lines based on our selection criteria for B and R lines. In Pakistan, two crops of sunflower are grown (one each in spring and autumn) which helps in quickening the hybrid breeding process. The single plant selections in OPVs were bagged and selfed for six generations. The best single plant selection progenies (B lines) exhibiting highest level of uniformity and stability for plant type, plant height, head shape and curvature, disease and insect reactions were selected and repeatedly backcrossed with the CMS source (A line) for another six generations. On maturity, the seed of both the B and CMS lines was harvested and stored separately for use in the next planting season. Similarly, 100 plants selected out of two heterogeneous restorer lines (R) were bagged before anthesis for selfing for twelve generations focusing again on the selection of phenotypes according to our criteria. The heads in selected plants were always bagged before anthesis for avoiding contamination by unwanted stray pollens both in A/B and R lines. Some of the single plant selections, despite repeated selfing did not lead to any phenotypic uniformity and were discarded from the selection process and in this way the number of selections narrowed down with passage of time. For crossing B lines with CMS source, each selected single plant progeny from B line was planted in two rows on the sides with two rows of CMS source in the middle for ease of crossing. Heads of choice in the respective B lines were bagged along with few heads in the CMS source before flowering. After anthesis, selected maintainer line plants (B) were repeatedly crossed with CMS plants and this process continued for a week on alternate days for good seed set on the CMS plants. This process continued for upto six generations. The selection in single plant progenies from the R lines continued only retaining the progenies having the highest level of uniformity with no further segregation while making sure that the parameters of the initial selection criteria are not compromised.

Out of hundreds of single plant progenies initially selected, only six (A & B) lines and as many as R lines were selected based on their highest level of phenotypic uniformity and stability. These lines were then crossed in all possible combinations. CMS and B lines are basically isogenic lines except one difference that CMS is male sterile while maintainer line B has functional pollens with no fertility restoring genes. For making cross combinations, the respective CMS lines were planted in two rows in the middle with R lines on both the sides for ease of mating. Heads in both the lines were bagged before anthesis for maintaining genetic purity of the material. After anthesis, the plants bagged in the CMS lines were pollinated with the pollen from bagged plants in the R line. This process was repeated 3 to 4 times on alternate days for good seed set on the CMS lines.

Different newly developed combinations made during spring 2018 were tested during Autumn-2018 in non-replicated trials along with the standard check just to have an idea about their agronomic performance. Every entry was planted in a plot of four lines of 5 meter length with 0.75 m space between the lines. Data were mainly collected on the yield and other general phenotypic characters.

The best performing hybrids were again evaluated in Spring-2019 and Spring-2020 in randomized complete block design (RCBD) replicated three times. Each entry was planted on a plot of four rows of 5 m length with 0.75 m space in between. This time data, in addition to seed yield, were also recorded on maturity, plant height, head diameter, 100-GW and oil content (%). The procedure of data recording on these traits has already been given in our previous papers on sunflower. Oil content (%) of the oven-dried seed samples was determined using nuclear magnetic resonance (NMR). The data were subjected to ANOVA for partitioning the variance using software Statistix 8.1. Mean yield values were compared using LSD test at probability level of 5 % ($p \leq 0.05$).

Results and Discussions

Development of A/B and R lines: Base material used for selection were two OPVs namely Shams-37 and NDMTC and two heterogeneous R (fertility restorer) lines namely RHA-439 and Hyolic-41R (Table 1). These lines were selected out of the germplasm available with Oilseeds Program, NARC because of their heterogeneous nature showing a range of desirable morphologies. The breeding strategy was based on single plant selection and the criteria for selection in the base material was high seed yield, desirable plant height, head size, shape and compactness, head curvature, stem strength, good disease reaction in B lines. Skoric (2012) reported using good seed yield along with other desirable agronomic traits as general criteria for selection during inbred line development. While in R lines, selection criteria was based on desirable plant height, plant architecture ensuring pollen availability over a long period of time (Radanovic *et al*., 2018) and disease reaction etc. Initially, 100 single plant selections were made in each of four lines making total single plant selections of 400. These selected plants were bagged before anthesis and selfed at time of flowering for enhancing the homozygosity. The resulting seed was threshed, cleaned and stored separately for plantation in the next season. Two crops per year (one each in spring and autumn) were grown which helped shorten the breeding period. In the next season, the seed was sown in the head to progenies scheme. At the time of flowering, single plant selection was again done keeping in mind the selection criteria initially set. This time, out of each single plant progenies, more single plant selections were made. So with passage of time single plant selections increased by making more single plant selections in single plant progenies and at one stage they reached almost 1000 selections. This process of single plant selection and selfing continued for at least 6 generations. Along the way, selections with no visible improvement in stability and uniformity were discarded. Probably, they were genetically too much messy at the time of initial selection. While the selections showing visible improvement in stability and uniformity were retained. In the end, 6 best B (maintainer) lines with highest level of stability and uniformity in the traits under consideration were selected for putting them in the CMS background. These B lines were repeatedly back-crossed with CMS source for 6 generations to develop isogenic cytoplasmic male sterile (CMS) lines. Simultaneously, the single plant selections and selfing continued for almost 10-12 generations in the lines selected from heterogeneous two R lines. In the end, 6 R lines with no segregation and highest level of phenotypic uniformity were selected for use in making cross combinations. These 12 A/B and R inbred lines with highest level of uniformity are given in the (Table 2). Five A/B lines selections are from the original heterogeneous material NDMTC while one A/B line was obtained from the other OPV, Shams-37. Four and two fertility restoration lines (R) were respectively selected from original heterogeneous R lines, RHA-439 and Hyolic-41R.

Making of hybrid combinations using A & R lines: All the six CMS lines developed during this study were crossed with the six restorer lines during Spring-2018 at NARC in all possible combinations. Enough seed was obtained only in 24 out of 36 of the cross combinations while the remaining crosses did produce enough seed. The CMS and restorer lines used in the crossing scheme are given in the Table 2.

Preliminary agronomic evaluation of crosses during Autumn-2018: During Autumn-2008, 24 hybrids were evaluated for their yield performance in comparison with standard check, Hysun-33 (Table 3). Due to limited seed and preliminary testing, the hybrids were planted in non-replicated trials. The yield performance of all the successful hybrids is given in Table 3. The highest seed yield (3459 kg/ha) was recorded by cross combination SMH-1900L (A-S9-77(2) x RHA-71-SPS-3(S7)) followed by SMH-1900H (A-S9-85 x R-S9-18) and SMH-1900N (A-S9-23(5) x R-S9-65) with yields of 3328 and 3320 kg/ha respectively. The lowest seed yield of 2100 kg/ha was produced by SMH-1900V (A-S9-77(2) x R-S9-83(1). The highest yielding hybrid combination, SMH-199L recorded > 45% genetic gain over the standard check Hysun-33 (2383 kg/ha). Lowest level of genetic gain over the check hybrid was shown by the cross SMH-1900P (A-S9-85 x R-S9-24) which was 4.6 %. Overall, 10 hybrids recorded >20 % yield increase over Hysun-33. Only four out of 24 hybrid combinations recorded yield lower than Hysun-33. These hybrids are SMH-1900S, SMH-1900T, SMH-1900V and SMH-1900W with per hectare seed yields of 2289, 2315, 2100 and 2299 kg/ha respectively. They were out-yielded by the check hybrid (Hysun-33) although the differences were statistically non-significant except SMH-1900V. Hybrids with high seed yield were selected for further testing as high seed yield is one of the most important criteria in selection of hybrids (Vear, 2016).

Evaluation of hybrids in replicated trials during Spring-2019: Ten cross combinations, which exhibited more than 20 % yield increase over the check in the previous non-replicated trials of Autumn-2018, were selected for their further agronomic evaluation during Spring-2019 in replicated trials. The yield performance of all these hybrid combinations along with data on other agro-morphological traits is given the Table 4. All the studied traits recorded significant statistical differences among the hybrids. As regards yield performance, all the cross combinations out-yielded the check hybrid (NKS-278). Cross combination SMH-1900N recorded highest seed yield of 3739 kg/ha exhibiting > 50 % yield increase over NKS-278 (2451 kg/ha) used as check. Other cross combinations closely following SMH-1900N were SHM-1900M (3669 kg/ha), SMH-1900D (3293 kg/ha), PARSUN-3 (3264 kg/ha) and SMH-1900G (3214 kg/ha). The lowest level of seed yield increase over the standard check was recorded in cross combination SMH-1900K which was just over 2%. Overall, eight crosses recorded > 20 % gain in terms of seed yield over the standard check, NKS-278 (Table 4). As regards oil content (%), which is the main economic product of sunflower cultivation, all the newly developed local hybrids recorded higher expression for this character as compared to the standard check (35.02 %) except one hybrid (SMH-1900J) which had statistically non-significantly lower oil content (34.54 %). These results are similar to those reported by Makanda *et al*., (2012). Oil content (%) has high heritability and can be easily improved through selection (Vear, 2016) but some researchers have reported inverse relation between seed yield due to larger achene size and oil content (Heiser, 1951). In modern day hybrids, the oil content (%) ranges between 40 to 50 % (Jocic *et al*., 2015). Plant height was just around 200 cm which is considered the most suitable plant height for a good sunflower hybrid (Radanovic *et al*., 2018; Burke *et al*., 2005; Onemli & Gucer, 2010) making the crop less vulnerable to the lodging during heavy rains and wind storms. Maturity period (days to maturity) in hybrids did not vary much from the check and had a narrow range of 97 to 103.

Table 2. Different A, B & R inbred lines developed during 2013-18 using base heterogeneous material available with Oilseeds Res. Program, NARC, Islamabad.

S. No.	CMS (A) lines	Maintainer (B) lines	Fertility restorer (R) lines
1.	A-S11-23(5)	B-S11-23(5)	R-S12-65
2.	A-S11-85	B-S11-85	R-S12-24
3.	A-S11-77	B-S11-77	R-S12-83(1)
4.	A-S11-77(2)	B-S11-77(2)	R-S12-18
5.	A-S11-64(1)	B-S11-64(1)	RHA-71-SPS-3-(S11)
6.	Shams-37 (A)-SPS-3-(S11)	Shams-37 (B)-SPS-3-(S11)	RHA-71-SPS-11-(S11)

Table 3. Non-replicated yield data of the newly developed elite sunflower hybrids tested during Autumn-2018

S. No.	Hybrid name	Cross combination	Seed yield (kg/ha)
1.	SMH-1900N	A-S9-23(5) X R-S9-65	3320
2.	SMH-1900P	A-S9-85 X R-S9-24	2470
3.	SMH-1900Q	A-S9-23(5) X R-S9-24	2604
4.	SMH-1900R	A-S9-23(5) X R-S9-83(1)	2587
5.	SMH-1900S	A-S9-85 X R-S9-83(1)	2289
6.	SMH-1900A	A-S9-77 X R-S9-83(1)	2805
7.	SMH-1900B	A-S9-77 X R-S9-18	2831
8.	SMH-1900C	A-S9-77(2) X R-S9-65	2737
9.	SMH-1900T	A-S9-64(1) X R-S9-65	2315
10.	SMH-1900D	A-S9-85 X R-S9-65	3037
11.	SMH-1900E	A-S9-77 X RHA-71-SPS-3-(S7)	2861
12.	SMH-1900U	A-S9-77 (2) X R-S9-24	2650
13.	SMH-1900V	A-S9-77(2) X R-S9-83(1)	2100
14.	SMH-1900F	A-S9-77(2) X R-S9-18	2893
15.	SMH-1900G	A-S9-77 X R-S9-65	2871
16.	SMH-1900O	A-S9-77 X R-S9-24	2603
17.	SMH-1900W	A-S9-23(5) X R-S9-18	2299
18.	SMH-1900X	A-S9-64(1) X R-S9-24	2526
19.	SMH-1900H	A-S9-85 X R-S9-18	3328
20.	SMH-1900 I	A-S9-64(1) X RHA-71-SPS-3-(S7)	3192
21.	SMH-1900J	A-S9-23(5) X RHA-71-SPS-3-(S7)	3255
22.	SMH-1900K	A-S9-85 X RHA-71-SPS-3-(S7)	3090
23.	SMH-1900L	A-S9-77(2) X RHA-71-SPS-3-(S7)	3459
24.	SMH-1900M	SMH-0927 (shams-37 (A) SPS-3(S9) X RHA-71(SPS-11)(S9)	3013
25.	Hysun-33	ICI, Pakistan (used as check)	2383

Table 4. Morpho-agronomic performance of different locally developed elite sunflower hybrids tested during Spring-2019.

S. No.	Hybrid name	DFI	DFC	DM	Pht (cm)	HD (cm)	100-SW (gm)	OC (%)	SY (kg/ha)
1.	SMH-1900N	68	71	97	186	17.5	5.30	41.40	3735
2.	SMH-1900D	69	72	98	193	20.9	5.16	40.24	3293
3.	SMH-1900I	75	79	102	202	17.9	5.05	36.07	2787
4.	SMH-1900L	75	80	103	213	18.4	4.78	38.17	3058
5.	SMH-1900J	76	79	103	210	16.6	5.50	34.54	2948
6.	SMH-1900M	69	73	99	200	17.8	5.67	37.90	3669
7.	SMH-1900G	67	71	98	187	18.7	4.97	40.81	3214
8.	SMH-1900K	74	77	102	197	16.4	5.06	36.87	2502
9.	SMH-1900A	72	75	102	192	21.0	4.58	38.88	3005
10.	SMH-1900B	73	75	101	202	19.2	5.26	39.16	2872
11.	NKS-278	73	76	99	180	20.0	6.75	35.02	2451
12.	Parsun-3	68	74	100	191	18.7	4.66	39.71	3264
	CV%	4.83	4.57	2.67	6.15	12.25	15.81	7.62	18.31
	LSD	2.44	2.85	3.48	15.44	3.16	1.27	4.07	841.86
	Mean	71.7	75	100.47	195.96	18.59	5.22	38.23	3067

DFI: Days to flowering initiation; **DFC:** Days to flowering completion; **DM:** -Days to maturity; **Pht:** Plant height (cm); **HD:** Head diameter (cm); **100-SW:** 100 grain weight (grams); **OC (%):** Oil content percentage; **SY:** Seed yield (kg/ha)

Table 5. Average performance of different locally developed elite sunflower hybrids tested during Spring-2020.

S. No.	Hybrid name	DFI	DFC	DM	Pht (cm)	HD (cm)	100-GW (gm)	SY (kg/ha)
1.	SMH-1900K	94	100	131	227	19.5	5.46	3246
2.	SMH-1900B	90	95	131	220	22.2	5.91	2772
3.	SMH-1900M	88.5	95	131	223.5	17.5	6.20	3566
4.	SMH-1900L	92.5	99	131	229.5	19.9	5.64	3277
5.	SMH-1900I	93	98.5	131	224	19.2	5.66	3245
6.	SMH-1900E	92.5	99	130.5	222	18.7	5.61	2672
7.	SMH-1900H	91.5	94.5	131.5	209	20.9	5.55	2633
8.	SMH-1900C	86.5	92.5	131	180.5	20.3	6.13	2445
9.	SMH-1900X	87.5	93	131	206.5	18.8	6.85	3013
10.	SMH-1900P	89	94.5	131	203.5	18.2	6.51	3527
11.	SMH-1900N	85.5	94.5	131	189	21.1	5.89	2587
12.	SMH-1900Q	85	94	131.5	196.5	18.3	6.73	3500
13.	SMH-1900T	88	93.5	131	184.5	19.9	6.43	3222
14.	SMH-1900G	90	95.5	131	197	20.3	5.86	3011
15.	SMH-1900ZZ	90	95.5	131	208.5	19	6.22	3281
16.	SMH-1900A	89	95	131	210.5	17.9	6.23	3054
17.	Hysun-33	83.5	90.5	126	193	17.9	5.73	2225
	LSD	3.84	2.21	1.14	23.43	1.89	0.99	407.9
	CV%	2.06	1.11	0.41	5.42	4.65	7.86	6.54
	Mean	88.89	94.97	130.7	205.95	19.36	6.02	2970

DFI: Days to flowering initiation; **DFC:** Days to flowering completion; **DM:** Days to maturity; **Pht:** Plant height (cm); **HD:** Head diameter (cm); **100-SW:** 100 grain weight (grams); **OC (%):** Oil content percentage; **SY:** Seed yield (kg/ha)

Agronomic evaluation of hybrids in replicated trials during Spring-2020: All the better performing hybrids tested during Spring-2019 with two exceptions were once again planted during Spring-2020 along with some new combinations. In total, 17 hybrids including Hysun-33 used as standard check were evaluated during Spring-2020. The data on yield and other agronomic traits are given in Table 5. All the new crosses out-yielded the standard check (Hysun-33) which produced the lowest seed yield of 2225 kg/ha. Similar results were obtained by Mohamed (2010) studying sunflower hybrids under irrigated conditions of Sudan. The maximum seed yield of 3566 kg/ha was recorded by SMH-1900M exhibiting over 50 % yield increase as compared to the check. Yield superiority of the newly developed sunflower hybrids over the commercial hybrids already in the field is a must character for their approval and registration (Becker & Leon, 1988). Cross SMH-1900C recorded lowest seed yield of 2445 kg/ha among the newly developed hybrids showing only 10 % increase over the check. Overall, 11 hybrids exhibited > 30 % genetic gain over the check hybrid in terms of seed yield (Table 5). Check hybrid matured 4 to 5 days earlier than the rest of the hybrids. Plant height varied significantly among the hybrids. SMH-1900L proved to be the tallest hybrid (229.5 cm) while SMH-1900C had the shortest stature (180.5 cm). Height of the check hybrid was 193 cm. Mostly; the height was around 200 cm which is considered the best plant height for growing successful sunflower crop. The biggest head size was recorded in the hybrid SMH-1900B (22.2 cm) followed by SMH-1900N and SMH-1900H with heads size of 21.1 and 20.9 cm respectively. SMH-1900M had the smallest head size of 17.5 cm which was non-significantly different from the head size of the check hybrid Hysun-33 (17.9 cm). Larger head size (20-30 cm) with more or less convex shape and some inclination is recommended because it has a close connection with level of sun burn, bird damage and head rot incidence (Kaya, 2015). Highest 100-GW was recorded by hybrid combination SMH-1900X (6.85 g) indicating that this hybrid has the largest seed size. Increase in sunflower seed size has already been reported as a result of breeding efforts (Wills & Burke, 2007; Burke *et al*., 2005). The check hybrid Hysun-33 was in the category of hybrids having comparatively lower 100-GW of less than 6.00 g.

Disease incidence: The most devastating disease causing huge economic losses to sunflower growers is *Sclerotinia* stalk and head rot (Talukder *et al*., 2017). This research study was carried out at Islamabad which has hot humid climate during summer providing favorable conditions for *Sclerotinia* attack (Vear, 2016) but even here, only 1 % of plants showed slight *Sclerotinia* attack. Generally in Pakistan, sunflower is grown in hotter and drier regions in the south of the country, where this disease is not likely to cause any significant yield losses to the crop. Protection of the crop from insect attack especially during reproductive stage is required as injuries caused by insect attack gives entry to different pathogens particularly the one causing head rot. In addition to cultural practices, an in-built disease resistance developed through breeding against major sunflower diseases would go a long way in making sunflower production profitable (Radanovic *et al*., 2018).

Conclusion

The aim of this study was to develop local sunflower hybrids with good genetic potential for high seed and oil yield, wide adaptability and resistance against major prevailing sunflower diseases specially head and stem rot. The laborious efforts for the development of A/B and R lines with highest level of stability and phenotypic uniformity led to development of 12 new inbred lines. The new cross combinations developed using the above mentioned newly developed inbred lines gave impressive agronomic performance. Almost all the hybrids have out-performed the currently grown commercial hybrids. The next step is nationwide testing of the best of these hybrids in national uniform yield trials (NUYTs). One hybrid SMH-1900M had already out-yielded all other hybrids in the national uniform yield trials (NUYT) of Spring-2020 and has been sent to NUYT again for second year testing. Other hybrids exhibiting better performance relative to the standard check will also go to NUYT in next 2-3 years. Good performance in the NUYT is must for seed registration and marketing in the county. Our next paper will be on the performance of these hybrids in the NUYTs. It is also being planned to study, using molecular markers on our hybrids, the impact of genetic distance on the level of heterosis.

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