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HYBRID DEVELOPMENT PROGRAMME OF SUNFLOWER IN PAKISTAN: A REVIEW

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ABSTRACT

Just, 40 years back around, a non-traditional crop of sunflower is introduced in Pakistan as the chief source of edible oil. Keeping in view the quality of edible oil, research activities in sunflower crop was initiated grudgingly due to be deficient in trained expertise in Pakistan. Therefore, only few hybrids uptill now have been developed by public and private sectors in the country. Farmers took this new but emerging crop by reluctantly in their cropping pattern during first decade of this new century. However, hybrid developmental program remained the main issue in the country due to non-availability of proper staff and infrastructures. Therefore, sunflower hybrids are totally depends upon private sector to import. Because, however, the procedure is very fiddly for the development of new hybrid as the requirement of parents is necessary on each season to maintain and restore its fertility. Uptill now, the entire area of 106 thousand hectare of sunflower crop in Pakistan is still under the cultivation of exotic hybrids. However, the role of Oilseeds Research Institute, Faisalabad in this regard, is commendable as developed first National Hybrid of sunflower (FH 331) some years back in the country. Now, with the trained expertise, numerous upcoming hybrids are in the pipelines, waiting to release for general cultivation by public sector. On the other hand, budding hybrids of FH 516 and FH 648 are expected to release soon being top yielder by 24 and 7% higher yielder, respectively than the check AG SUN-5264 in National Uniform Sunflower Yield Trials conducted by National Coordinator (Oilseeds), Islamabad during 2018-19 on public level for the replacement of exotic hybrids in the country.

KEYWORDS: *Helianthus annuus;* hybrid; line; oil; seed; Pakistan.

INTRODUCTION

Sunflower (*Halianthus annuus* L.) cultivation was introduced by Ghee Corporation of Pakistan (GCP) during eighty's in Pakistan (Anonymous, 2019). Its importance is enhancing by farming community due to short duration crop and can be easily being grown in between two major crops. Its oil promotes the human health in numerous ways and having excellent quality for cooking. It considered to be stable for frying the natural taste and invigorating the flavor of kitchen items (Kalukhe *et al*., 2010; Haghi *et al*., 2012; Zuil *et al.,* 2012; Zia-Ullah *et al*., 2013; Dzisiak, 2014; Rigon *et al*., 2014; Zielinska and Nowak, 2014). Impurity of edible oil is a big issue by spending huge money to import it in Pakistan. No doubt, expansion in sunflower crop is fluctuating due to various production and socioeconomics constraints. However, research work on this crop has shown adaptability potential of growing it under moisture stressed and irrigated farming systems in different ecological zones in the Pakistan (Mudassar *et al.,* 2009; Hassan *et al*., 2012; Amjad, 2014; Aqsa *et al.,* 2019).

The purpose of this manuscript is to introduce the research activities on hybrid development program of sunflower crops in public and private sectors in Pakistan for research scholars, academicians, and research institutes. Now, the swiftness of research in hybrid development program is no doubt, still in preliminary stages due to non-availability of proper staff and infrastructures. Therefore, sunflower hybrids are totally depends upon directly to the private sector to import. Private sector has taken an interest to cultivate sunflower crop in order to get edible oil locally by importing the seed of exotic sunflower hybrids because the procedure to develop new hybrid is very fiddly as the requirement of parents is necessary on each season to maintain and restore its fertility.

It is, therefore, a dire need of today to develop sunflower hybrids locally, that eventually, not only to save the foreign exchange of the nation but quality of the edible oil is also enhanced by releasing local hybrids (Ahmad *et al*., 2012; Zuil *et al.,* 2012; Zia-Ullah *et al.,* 2013; Amjad, 2014; Baloch *et al*., 2016; Anonymous, 2018; Anonymous, 2019). At present the national average yield of sunflower is recorded as 1.3 tons per hectare whereas (Table 5) Punjab attained 1.89 tons per hectare. (Anonymous, 2018; Anonymous, 2019; Oilseed, 2019).

Global sunflower

On global level, sunflower contribute significant role in value addition of the products especially confectionary purpose (Tyagi, 2010; Nasreen *et al*., 2011; Zuil *et al*., 2012; Van *et al*., 2013; Zia-Ullah *et al*., 2013; Safavi *et al*., 2011; Zielinska and Nowak, 2014; Oilseed, 2019). Its getting attention by the people across the world to take roasted and snake seed. It also generates huge revenue in bird seed market. The production of sunflower in the world is 54.45 million tons in 2018-19 on an area of 26.42 million hectare descript as in Table 1. Ukrain is the top yielder country by yielding 15.50 million tons production and followed by Russia, China and Argentina but a negligible portion is contributed by Pakistan with 0.14 million tons production only in the world (Table 1).

Table 1. Area, production and yield of sunflower crop of different countries in the world during 2018-19.

S. No.	Country	Area Mh	Production mt	Yield t/h
1	Ukraine	6.20	15.50	2.50
2	Russia	8.40	15.30	1.82
3	Argentina	1.60	3.20	2.00
4	China	1.25	3.25	2.60
5	Turkey	0.73	1.75	2.40
6	USA	0.50	0.88	1.75
7	S. Africa	0.61	0.75	1.23
7	Moldova	0.40	0.90	2.25
8	Serbia	0.22	0.60	3.00
9	Burma	0.60	0.39	0.65
10	India	0.23	0.17	0.76
11	Brazil	0.08	0.12	1.50
12	**Pakistan**	**0.11**	**0.14**	**1.33**
13	Bolivia	0.12	0.09	0.75
14	Canada	0.03	0.06	2.17
15	Others	5.31	11.34	2.13
	Total	**26.42**	**54.45**	**2.06**

Source: FAO web page. http://www.fao.org

National sunflower

Alongwith rapeseed and mustard, sunflower has also a prospective oilseed crop in the country. Earlier, sunflower was introduced by Ghee Corporation of Pakistan (GCP) during 1980's. Due to the importance of this crop and farmers friendly Government policies, the area increased continuously during first decade of new century in country. However, horizontal expansion in sunflower crop in Pakistan is taken placed almost one fifty (150) time more in the recent year as compare to 1970-71 whereas about 300 time expansion is recorded on vertical aspect (Table 2). However, average yield of sunflower is filled the bag over double during the mentioned span (Aleem *et al.,* 2015; Amin *et al*., 2016; Anonymous, 2018; Anonymous, 2019).

In the Table 2, it revealed that maximum area of 397.31 thousand hectare under sunflower crop was observed during 2007-08 with the production of 603.8 thousand tons in the country (Ilahi *et al*., 2009; Bonciu *et al.,* 2010; Nasreen *et al*., 2011; Jalil *et al*., 2014; Anonymous, 2018; Anonymous, 2019). It's the ever-highest area and production of sunflower recorded in the country. Afterward decreasing trend in area, production was observed reasoning there by the availability of hybrids with high cost of imported seed, storage facility, proper marketing system (Kholghi *et al*., 2011; Nasreen *et al.,* 2011; Anonymous, 2018; Anonymous, 2019) and increasing price of wheat and demolishing the Ghee Corporation of Pakistan (GCP). However, during 2017-18, due to the campaign of sunflower cultivation initiated by Government of Punjab, Oilseeds Research Institute, Faisalabad taken step on warm footing to interact all stakeholders of sunflower crop. Government also has given subsidy of Rs. 5000/= per acre maximum upto 20 acres to the farming community of oilseed i.e sunflower crop (Anonymous, 2018; Anonymous, 2019; Aqsa *et al*., 2019). Farmer of Southern Punjab, has taken special interest to cultivate sunflower in specific land vacant for 120 days before sowing the major crop like cotton.

Table 2. Area, production and yield of sunflower in Pakistan during 1970-71 to 2018-19.

Year	Area (000, ha)	Production (000, tons)	Yield (t/h)
1971-72	1.25	0.87	0.70
1981-82	7.24	5.86	0.81
1991-92	63.33	83.31	1.32
2001-02	63.24	73.96	1.17
2005-06	325.08	348.28	1.07
2006-07	323.07	407.22	1.26
2007-08	397.31	603.89	1.52
2008-09	319.74	420.49	1.32
2009-10	256.12	325.48	1.27
2010-11	300.61	404.39	1.35
2011-12	236.00	282.92	1.20
2017-18	82.20	104.00	1.27
2018-19	106.90	142.00	1.33

Source: Agriculture Statistics of Pakistan, Economic survey of Pakistan

Provincial sunflower

Regarding provincial history, area of sunflower under the province of *Khaiber Pakhtoon Khaw* (KP) is observed remarkably declined from 2.81 thousand hectare to only 0.14 thousand hectare during last 2 decades. (Table 3). However, in contrary with KP, area of sunflower under Sindh province increased from 37.37 thousand hectare to 76.59 thousand hectare during 2000-01 to 2018-19 (Anonymous, 2018; Anonymous, 2019; Aqsa *et al*., 2018; Aqsa *et al*., 2019).

Similarly, province Sindh ranked the most producing sunflower production (84.63 thousand tons) in the country during the current year (Table 4), whereas Punjab declared as the top producing province in the homeland being executed the maximum average yield as 1.89 ton/ha followed by KP of 1.68 t/h during 2018-19 (Table 5).

Table 3. Area of sunflower crop of different provinces in Pakistan

Year	Area (000, ha)				
	Punjab	Sindh	KP	Baluchi-stan	Total
2000-01	18.27	37.37	2.81	0.55	58.99
2001-02	21.44	38.53	0.61	2.66	63.25
2002-03	37.30	63.91	0.36	6.15	107.72
2003-04	84.11	171.31	0.09	0.18	255.68
2004-05	56.91	206.39	0.18	0.54	264.01
2005-06	75.10	248.98	0.47	0.58	325.08
2006-07	90.45	231.66	0.35	0.60	323.07
2007-08	152.10	243.97	0.52	0.72	397.31
2008-09	64.81	253.71	0.52	0.69	319.74
2009-10	34.11	220.96	0.56	0.49	256.12
2010-11	32.54	266.96	0.50	0.61	300.61
2011-12	46.24	188.66	0.49	0.61	236.00
2012-13	51.70	143.63	0.27	0.51	196.10
2013-14	27.23	124.74	0.32	0.42	152.72
2014-15	22.08	118.58	0.24	0.35	141.25
2015-16	16.20	65.90	0.20	0.30	82.60
2016-17	19.50	67.30	0.10	0.30	87.20
2017-18	19.50	62.20	0.20	0.20	82.10
2018-19	29.92	76.59	0.14	0.25	106.90

Source: Agriculture Statistics of Pakistan, Economic survey of Pakistan

Table 4. Production of sunflower crop of different provinces in Pakistan

Year	Production (000 t)				
	Punjab	Sindh	KP	Baluchistan	Total
2000-01	24.92	39.74	3.40	0.60	68.65
2001-02	28.88	40.83	1.34	2.92	73.96
2002-03	54.89	66.27	0.67	6.71	128.53
2003-04	122.49	235.68	0.17	0.19	358.53
2004-05	86.37	240.52	0.24	0.54	327.65
2005-06	122.84	224.20	0.65	0.58	348.28
2006-07	156.26	249.78	0.58	0.61	407.22
2007-08	324.97	277.33	0.79	0.80	603.90
2008-09	130.51	288.40	0.81	0.77	420.49
2009-10	65.05	259.20	0.90	0.33	325.48
20010-11	61.25	341.64	0.80	0.70	404.39
2011-12	94.05	187.38	0.78	0.72	282.92
2012-13	92.24	150.14	0.38	0.62	243.38
2013-14	54.59	137.60	0.38	0.54	193.10
2014-15	37.02	130.74	0.39	0.48	168.63
2015-16	31.00	54.10	0.30	0.50	85.90
2016-17	36.30	69.30	0.30	0.40	106.30
2017-18	36.30	64.70	0.40	0.30	101.70
2018-19	56.78	84.63	0.24	0.35	142.00

Source: Agriculture Statistics of Pakistan, Economic survey of Pakistan

Although due to prioritization of oilseeds cultivation by the Government and promotional campaign of Agriculture (Extension wing), normally oilseeds crops and particularly sunflower crop has been significantly enhanced as an impact of this crusade. However, in this regards, avowal of procurement of sunflower crop on reasonable price considering cost production is important to maintain the sustainability of oilseeds cultivation. However, in addition to development of industry related to oilseed crops which would emphatically may steps towards self sufficiency in edible oil (Riaz *et al*., 2017; Anonymous, 2018; Anonymous, 2019).

It is depicted in the Table 6 that the main regions of sunflower crop were DG Khan, Bahawalpur and Multan in the province of Punjab during 2018-19. Maximum area of this crop was sown in the region of DG Khan of Punjab province with 18.33 thousand hectare producing 36.58 thousand tons followed by 4.12 thousand hectare of Bahawalpur with the production of 7.84 thousand tons in the province. However, the average yield of DG Khan, Faisalabad and Rawalpindi regions was recorded as 2.00 ton per hectare (Anonymous, 2019).

Table 5. Yield of sunflower crop of different provinces in Pakistan

Year	Yield (t/h)				
	Punjab	Sindh	KP	Baluchistan	Total
2000-01	1.36	1.06	1.21	1.09	1.16
2001-02	1.35	1.06	2.18	1.10	1.17
2002-03	1.47	1.04	1.83	1.09	1.19
2003-04	1.46	1.38	1.92	1.06	1.40
2004-05	1.52	1.17	1.35	1.00	1.24
2005-06	1.64	0.90	1.39	1.01	1.07
2006-07	1.73	1.08	1.66	1.01	1.26
2007-08	2.14	1.14	1.52	1.11	1.52
2008-09	2.01	1.14	1.54	1.12	1.32
2009-10	1.91	1.17	1.61	0.68	1.27
20010-11	1.88	1.28	1.60	1.14	1.35
2011-12	2.03	0.99	1.57	1.18	1.20
2012-13	1.78	1.05	1.42	1.23	1.24
2013-14	2.00	1.10	1.18	1.27	1.26
2014-15	1.68	1.10	1.60	1.36	1.19
2015-16	1.91	0.82	1.50	1.67	1.04
2016-17	1.86	1.03	3.00	1.33	1.22
2017-18	1.86	1.04	2.00	1.50	1.24
2018-19	1.89	1.06	1.68	1.40	1.33

Source: Agriculture Statistics of Pakistan, Economic survey of Pakistan

Table 6. Area, production and yield of growing regions of sunflower in the Punjab province during 2018-19

S. No.	Region	Area (000, h)	Production (000 t)	Yield (t/h)
1	DG Khan	18.33	36.58	2.00
2	Bahawalpur	4.12	7.84	1.90
3	Multan	3.30	6.01	1.82
4	Sargodha	2.90	3.92	1.35
5	Faisalabad	0.41	0.82	2.00
6	Gujranwala	0.38	0.67	1.76
7	Lahore	0.24	0.45	1.88
8	Sahiwal	0.23	0.45	1.96
9	Rawalpindi	0.01	0.02	2.00
	Punjab	**29.92**	**56.78**	**1.90**

Source: Crop Reporting Service, Punjab, Lahore. 2018-19

Climatic requirement

Sunflower crop is planted in two seasons in the country under spring and autumn cultivation, but it need specific environment under which the pace of breeding program may enhance and multiply actively. Sunflower plant requires warmer days alongwith cooler nights. It can be grown under wide range of temperature of 8°C to 34°C, but 25-28°C is referred as optimum temperature under which each floral parts of sunflower plant bloom in full swing (Schwertner *et al.,* 2009; Anandhan *et al*., 2010; Zia *et al.,* 2013; Adare, 2014; Zielinska and Izabela, 2014; Amin *et al.,* 2016; Tyagi and Dhillon, 2016; Anonymous, 2018).

As for as concerning the performance of male and female part of the flower regarding breeding work, more than 30˚C is proved to be fatal and leads to damage

the anthesis, resultantly, empty seed observed on the capitulum. If temperature around the environment prevails less than 5° C during seed developmental stage or grain filling stage designated the head by empty seeded (Anandhan *et al*., 2010; Martin*et al.*, 2012; Baloch *et al*., 2016; Aqsa *et al*., 2018; Oilseed, 2019). Similarly, under range of 45 to 65 % humidity, vegetative growth, flowering and pollination processes occurred pleasantly (Hu *et al*., 2010; Echarte *et al*., 2013; Hladni *et al*., 2014; Golabadi *et al*., 2015; Hassan *et al.,* 2012). Humidity beyond the limit of 80%, vegetative expansion considered as low. A normal pollen growth and pollination process is also observed deleterious, if humidity prevails less than 45% in the environment (Kaya *et al*., 2007; Said and Azam, 2008; Singh, 2010; Hladni *et al*., 2011; Safavi *et al*., 2011; Hassan *et al*., 2012; Echarte *et al*., 2013; Zia *et al.,* 2013; Hladni *et al.,* 2014; Memon *et al*., 2014; Rigon *et al.,* 2014; Golabadi *et al.,* 2015; Aqsa *et al.,* 2018). The main feature of hybrid is referred as homogeneous population (Andarkhor *et al.,* 2011; Hansen, 2011; Jockovic *et al*., 2012; Deengra *et al*., 2013; Amjad 2014; Tyagi and Dhillon, 2016; Aqsa *et al.,* 2018). The maturity of all individual plants of hybrid is uniformed alongwith high yield potential but hybrid seeds needed every year to develop for the farmers for the cultivation as compare to open pollinated crop varieties (Radic *et al.,* 2009; Ilahi *et al.,* 2009; Kalukhe *et al*., 2010; Chandra *et al*., 2011; Jockovic *et al*., 2012; Radic *et al*., 2013; Jalil *et al.,* 2014; Chambo *et al*., 2017; Biradar *et al.,* 2018).

Sunflower hybrid program in Pakistan

Like other field crops, breeding work on sunflower crop is also being practiced in public and private sectors concurrently in the country. The cadence of research work and acreage under sunflower crop is very slow, however, efforts to import hybrids seed by the private sector to get advantage of this crop is appreciated by the growers.

Private sector

Various companies in private sector are involved directly or indirectly in the research activities of sunflower's seed to import from reputable institutes of the world but 11 companies are attaining much attention in private sector to import sunflower hybrids in the country, enlisted in Table 7.

Multi-national companies have taken much interest to import hybrid seeds in Pakistan. Therefore, the hybrid seeds of Pioneer Seeds, ICI seeds, Syngenta Seeds, Umer Seeds and Seethi Seeds were much popularized among farmers in Pakistan. However, seven hybrid seeds of the following three companies apparently are available in the market for the farmers during 2019-20.

Table 7. List of private companies alongwith their imported sunflower hybrids in Pakistan.

S. No.	Private	Year	Hybrid
1	Sandoz/Syngenta	1991	NK-265
2	Cargill/Monsento	1991	SF-187
3	Cargill pvt Ltd hi-Shell	1995	SF-177
4 i	Pioneer Seeds	1991	PI-6480
ii	Pioneer Seeds	2004	PI-64 A 93
5 i	ICI Seeds	1993	Hysun-33/T-40318
ii	ICI Seeds	2004	Hysun-38
6 i	Syngenta Seeds	2002	NK-S-278
ii	Syngenta Seeds	2008	NK-Melody, NK-Armony
7	The Seeds	2006	LG 56-60
8	Farm Services Syndicate	2010	FSS-64
9	Umer seeds	2016	US-666
10	Ali akbar	---	---
11	Seethi Seeds	2018	Aguara 5264,5270
i	Seethi Seeds	2019	AG Sun 5264

Table 8. Available sunflower hybrids to cultivate during 2019-20

S. No.	Company	Hybrid
1 i	ICI Pakistan	Hysun-33
ii	-do-	Hysun-39
iii	-do-	Aguara-4
iv	-do-	T-40318
2	Sethi seeds	Augsun-5264
3 i	Umer seeds	US-666
ii	-do-	US-777

Public sector

Breeding program was initiated in the country by the inclusion of Russian's germplasm of sunflower at Agriculture College and Research Centre at Lyallpur during 1958-59. However, regular work on this special crop began during next decade of 1961-70 at National Agriculture Research Centre (NARC), Islamabad. Breeders were very much enthusiastic to work on this special type of cross pollinated crop by maintaining male sterile (A), male fertile (B) and restorer line (R) in ABR system and sooner two types viz *Noor* and *Shamsh* were developed during next decade of seventies. However, regular work on variety testing program started in NARC Islamabad, having 745 imported germplasm of sunflower during 1981-86.

In public sector, efforts are being made in seven institutes for the development of sunflower hybrids but the fleetness to prepare hybrids is not appreciable. It's urgently needed to accelerate research activities in Pakistan for the production of local oil. In this regards, oilseeds section, NARC, Islamabad made an effort for the production of sunflower hybrids and contributed significant role for releasing sunflower hybrids (Table 9), but these hybrids did not attain much attention by the farmers to cultivate in their own farms due to lowering the yield. Hence, Oilseeds Research Institute, Faisalabad started its breeding program on regular basis during 1993.

Table 9. Organizations in public sector alongwith their sunflower hybrids developed in Pakistan.

S. No.	Public institute	Year	Variety/Hybrid developed
1	Agriculture Research Institute, (ARI), Tandojam, Sind	---	---
2	Agriculture Research Institute, (ARI), Tarnab, KP	---	---
3	Agriculture Research Institute, (ARI), Sariab, Quetta	---	---
4	University of Agriculture, Faisalabad	---	---
5	Board of Oilseed Development (BOD), Regional Offices, Lahore, Punjab	---	---
6	Oilseed Section, National Agriculture Research Centre (NARC), Islamabad	1975	Noor, Shamash
		1993	PARC-92E, SMH-9706 SMH-0907, SMH-0917
7	Oilseeds Research Institute (ORI), Faisalabad, Punjab	2009	FH-331

Oilseeds Research Institute, Faisalabad

In Punjab, being one of the leading oilseed institute of the province, Oilseeds Research Institute, Faisalabad, Punjab started breeding work on sunflower and grown different necessary stakeholders of hybrids like cytoplasmic male sterility line (A), male fertility line (B), and restorer (R) lines, separately for developing hybrids as a provincial research being the regular feature of the institute during 1993. Sooner, scientists achieved the target and made first restorer line in 1996 and first CMS line prepared during the following year in 1997 (Table 10).

Table 10. Preparation of stakeholders for hybrid development of sunflower at ORI, Faisalabad

S. No.	Stakeholder for hybrid	Year
1	A,B & R system started	1993
2	First restorer line developed	1996
3	First CMS inbred developed	1997

The main objective of ORI, Faisalabad for developing sunflower hybrid is to improve seed yield, oil content, early maturing hybrids with increased seed setting in the head (flower) of sunflower. Tolerance to biotic and abiotic stresses is necessary feature for developing sunflower hybrid under the scenario of global warming conditions.

Procedure to develop sunflower hybrid

Hybrid seed production in sunflower is initiated at ORI, Faisalabad by using cytoplasmic male sterile (CMS) in ABR system, where A, B and R is designated as A- line, B-line and Restorer-lines (Fig.1), respectively (Said and Azam, 2008l; Schwertner *et al*., 2009; Singh, 2010; Andarkhor *et al.,* 2011; Haghi *et al.,* 2012; Safavi *et al.,* 2011; Radic *et al*., 2013; Tyagi and Dhillon, 2016).

Restorer line is developed by crossing plants with dominant restorer gene to a cytoplasmic male sterile line. Elaboration is depicted in Fig 2. Male sterile line for example (ORI-1), A line is maintained primarily by crossing for example ORI-1B as male fertile line (B line). Later, male sterile line ORI-1 (A line) is crossed with for example restorer line (RL-2) as male fertile parent for executing fertile hybrid F_1, namely for example FH-1000 as revealed in the Fig. 3 (Kaya *et al*., 2008; Ilahi *et al*., 2009; Kumar *et al.,* 2010; Echarte *et al.,* 2012; Deengra *et al.,* 2013; Echarte *et al*., 2013; Golabadi *et al.,* 2015).

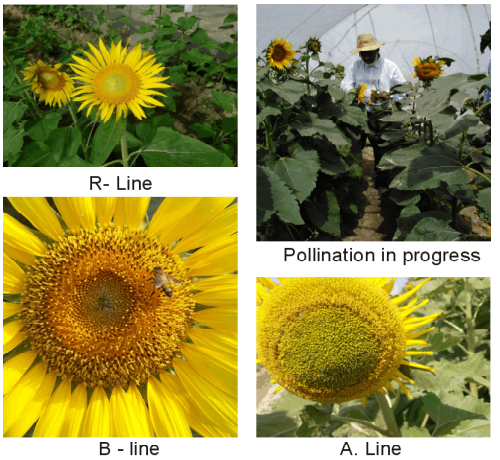


Fig. 1. Pollination procedure of sunflower

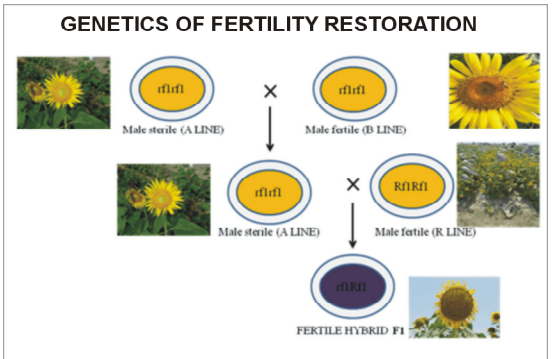


Fig. 2. Procedure to develop fertility restoration in sunflower hybrid.

Period of 4 years comprising 8 seasons is basically required to develop pure inbred line alongwith incorporation of cytoplasmic male sterility at Oilseeds Research Institute, Faisalabad. Similarly, only one year comprising 2 seasons is necessary for the development of new hybrid combination. If targeted required hybrid, once developed, it is then tested against the commercial hybrid regarding the parameters of yield and oil content at locally as well as in the yield trial on multi-locations in the province which required one and a half year period for establishing the facts (Kaya *et al.,* 2008; Khan *et al.,* 2009; Mudassar *et al.,* 2009; Pakistan Bureau Statistics, 2019). For upcoming hybrids, the period of two years is necessary phase for checking its acclimatization, adaptability, on national

level regarding yield and oil content under biotic and abiotic stresses. National Coordinator Oilseeds, Pakistan Agriculture Research Council, Islamabad conduct the trials with decoding entries for comparing yield data against national check hybrids throughout the country.

Inbred line development program

As depicted in Table 10, the work to develop the CMS A, B & restorer line initiated in 1993 and it is continuous nature and being run at ORI, Faisalabad till to date (Kaya *et al.,* 2008; Khan *et al*., 2009; Anandhan *et al*., 2010; Bukhsh *et al.,* 2011; Darvishzadeh *et al.,* 2011; Kholghi *et al*., 2011; Machikowa *et al.,* 2011; Chigeza *et al.,* 2012; Deengra *et al.,* 2013; Baloch *et al*., 2016; Dhillon and Tyagi, 2016; Anonymous, 2018; Aqsa *et al*., 2019). Hence, the total CMS A line, maintainer B line were 97 in number whereas 76 fertility restorer-lines have been executed and pasted on the face of ORI, Faisalabad successfully since 2020. However, CMS A & B lines developed are mentioned year-wise in Table 11.

Table 11. CMS development program at ORI Faisalabad

S. No	Year	CMS A & B developed
1	1997	ORI-1 to ORI-39
2	1998	ORI-40 to ORI-78
3	2000	ORI-79 to ORI-100
4	2001	ORI-101
5	2002	ORI-102
6	2003	ORI-103
7	2004	ORI-104
8	2005	ORI-105

The constituents for making hybrids are necessarily maintained after its development with efficient staff at ORI, Faisalabad. Seventy-five (75) restorer lines developed at the institute in the seasons of spring and autumn during 1996 are maintained regularly. However, at present 112 male fertile restorer lines are kept in the cold room at ORI, Faisalabad and ready for making hybrids (Table 12).

Table 12. Restorer lines developed at ORI, Faisalabad.

S. No.	Year	Restorer developed	Totalrestorer
1	Spring-1996	RL-1 to RL-34	34
2	Autumn-1996	RL-35 to RL-75	41
	Subtotal		**75**
3	Spring-1997	RL-76 to RL-106	31
4	Spring -2000	RL-108 to RL-109	2
5	Spring-2003-04	RL-111 to RL-114	4
	Total		**112**

Plant breeders must know the flowering attitude to open in full bloom on the sunflower plant. The information regarding days to 50% flowering of an individual A-line is very much helpful for crossing the required restorers. Without synchronization the counterpart of A-line with restorer line, one cannot achieve the successful target of hybridization. In this regards, Table 13, 14, 15 and 16 got attention by sunflower breeders being keeping valuable information by making in the early and late group of days to 50% flowering and days to maturity of all breeding material in sunflower crop.

Table 13. Days to 50% flowering of various inbred lines in early, medium and late group of sunflower

S. No.	Groups	Days	A & B lines	Total
1	Early	60-65	A-1,3,4,5, 6,7,8,9,10,12,13, 14, 16,18,19,20, 21, 22, 25,26, 27,29, 33,35,38, 39,48, 53,54,55, 56,57, 58, 59,61,62,70,79, 80, 81,86,88	41
2	Medium	66-70	A-2,11,23,28,30,31,46,47,49,50,5 1,52,63, 64,65 ,66, 69, 71,72,73, 74,75,77,78,83,87,88,89,90,93,9 4,98,99, 100,102,103	35
3	Late	>71	A-34,37,39,42,43,44,45,68,76,8 2,84,85, 91,92,95, 96, 97, 101, 104,105,106	21
	Total			**97**

Table 14. Days to maturity of various inbred lines in early, medium and late group of sunflower

S. No.	Groups	Days	A& B Lines	Total
1	Early	94-99	A-1,2,3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 37, 38, 39, 42, 43, 44, 45, 46,47,48, 49,50,52,53,54, 55,56,57,58, 61, 65, 68, 70,71,73,75,76, 77,78,79, 80,86,87, 88,94,98, 100, 102, 103	69
2	Late	100 & above	A-36,42,51,59,62,63,64,66,69, 72,74,81,82,83,84, 85, 89 ,90, 91,92,93,95,96,97,99,101,104 ,105,106	28
	Total			**97**

Table 15. Days to 50% flowering of various restorer lines in early, medium and late group in sunflower at ORI, Faisalabad.

S. No.	Group	Days	Restorer lines	Total
1	Early	60-65	RL-26, 37, 39, 43, 44, 48, 49, 51, 52, 57, 64, 77, 83, 97, 103	15
2	Medium	66-70	RL-6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 27, 28, 35, 36, 38, 40, 41, 45, 46, 50, 55, 61, 62, 66, 67, 68, 69,70, 72, 81,82, 84, 87, 89, 93, 95, 96, 98, 99,100, 101,102,107, 108, 109, 110	50
3	Late	71 & above	RL-7, 23, 25, 42, 58, 60, 86, 111, 112, 114, V-214	11
	Total			**76**

Out of 76 male fertile, 15 lines were earmarked to include in early group of restorer lines. Fifty percent flowering occurred in theses lines by 60 to 65 days. Similarly, medium (66-70 days) and late group (more than 71 days) of restorer lines are mentioned in Table 15.

Regarding days to maturity, early and late group are formulated in restorer lines. Mostly lines were matured by 90 to 99 days depicted in the Table 16. Both kinds of head types viz. mono and multi heads are produced naturally in the plant of restorer lines. Out of 76 restorer lines, mono heads are appeared in 24 lines only (Table 17), which are preferred to promote and incorporate genetically while making in hybrids.

Table 16. Days to maturity of various male fertile restorer lines in early and late group in sunflower at ORI, Faisalabad.

S. No.	Group	Days	Restorer line	Total
1	Early	90-99	RL-6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 21, 23, 26, 27, 29, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 55, 57, 60, 61, 62, 64, 66, 68, 69, 70, 77, 81, 82, 83, 84, 87,92, 93, 97, 101, 102, 103, 107, 110, 111	65
2	Late	>100	RL-12, 25, 58, 86, 95, 96, 108, 109, 112, 114, V-214	11
	Total			**76**

Table 17. Characterization of restorer lines according to heads type in sunflower at ORI, Faisalabad.

S. No	Group	Restorer line	Total
1	Mono head	RL- 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 57, 108, 09, 110, 114, V-214	24
2	Multi head	RL-6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 23, 25, 26, 27, 29, 45, 55, 58, 60, 61, 62, 64, 66, 67, 68, 69, 70, 71, 72, 77, 81, 82, 83, 84, 86, 87, 92, 93, 95, 96, 97, 98, 99, 100, 101, 102, 103, 107, 111, 112	52
	Total		**76**

In the Table 18, the profile of the oil of CMS-A Line is depicted. Actually, sunflower oil contained 2 types of fatty acids viz saturated fatty acid and unsaturated fatty acid. Saturated fatty acids are semi-liquid at room temperature that is referred as undesirable for human health. On the other hand, unsaturated fatty acids are desirable for human body being liquid at room temperature and easily pass on through human body (Said and Azam, 2008; Mudassar *et al*., 2009; Schwertner *et al.,* 2009; Kalukhe *et al*., 2010; Singh, 2010; Andarkhor *et al*., 2011; Ahmad *et al*., 2012; Adare, 2014; Aleem *et al*., 2015). Moreover, unsaturated fatty acids comprise omega 9 and omega 6, where omega 9 is mono unsaturated fatty acid in which oleic acid of fine quality by ranges of 20-80% present. On the other hand, linoleic acid is present in poly unsaturated fatty acid which also referred as omega 6. The maximum value (63%) of linoleic acid was recorded by ORI-74.

As for as concerning oil content, it normally present upto 42% in the sunflower hybrids, but ORI, Faisalabad, kept the CMS lines of 46% (ORI-38) and 44% (ORI-26) in her stock to utilize them for making hybrids of sunflower crop (Table 18).

Similarly, maximum oil content of 47% was observed in RL-67 and RL-114. Oleic acid in a range of 47 to 92% was recorded in 13 restorer lines at ORI, Faisalabad. Other quality content, Linoleic acid with maximum value of 87% was observed in RL-114 (Table 19). Uptill now, 868 hybrids were synthesized at ORI, Faisalabad so for. The pace of synthesizing the hybrids was noticed maximum in number (176) during 2002 at the institute followed by 100 hybrids in 2001and 60 hybrids in the year of 2019 (Table 20).

Table 18. The quality profile (%) of CMS A- Line at ORI, Faisalabad

S. No.	CMS A-line	Oil content	Oleic acid	Linoleic acid
1	ORI-2	37	63	38
2	ORI-10	35	67	60
3	ORI-25	43	45	39
4	ORI-26	44	66	50
5	ORI-30	41	57	55
6	ORI-34	38	77	24
7	ORI-38	46	52	13
8	ORI-42	35	71	42
9	ORI-43	42	65	18
10	ORI-44	41	64	27
11	ORI-46	40	56	26
12	ORI-74	35	62	63
13	ORI-88	40	64	29
14	ORI-92	35	65	2
15	ORI-94	38	86	18
16	ORI-97	41	54	26
17	ORI-99	43	60	31
18	ORI-101	41	69	34

Table 19. The quality profile (%) of restorer line at ORI, Faisalabad

S. No.	Restorer line	Oil content	Oleic acid	Linoleic acid
1	RL-14	38	72	10
2	RL-15	32	69	13
3	RL-38	39	70	18
4	RL-39	38	92	3
5	RL-66	38	64	0.14
6	RL-67	47	53	16
7	RL-68	37	65	24
8	RL-69	42	48	35
9	RL-86	34	61	61
10	RL-108	44	57	28
11	RL-109	36	58	42
12	RL-112	36	47	17
13	RL-114	47	47	87

Table 20. Hybrids synthesized at ORI, Faisalabad (1997-2019)

S. No.	Year	No. of hybrids	S. no.	Year	No. of hybrids
1	1997	11	13	2009	38
2	1998	13	14	2010	15
3	1999	10	15	2011	25
4	2000	30	16	2012	30
5	2001	100	17	2013	22
6	2002	176	18	2014	18
7	2003	10	19	2015	32
8	2004	14	20	2016	55
9	2005	16	21	2017	55
10	2006	20	22	2018	55
11	2007	22	23	2019	60
12	2008	41		**Total**	**868**

As the hybrid established, it included then on farm or station yield trials for testing yield potential. Now, 868

hybrids of sunflower crop have been decorated and pasted on the canvass of ORI, Faisalabad (Table 20). It means, the handsome stock of established hybrids is readily available for day to day testing in upper levels of hybrid development program. However, among these, the potential yield of newly established hybrid of FH-730 produced maximum yields of 3617 kg/ha. However, FH-675 yielded 3483 kg/ ha followed by FH-680 with 3460 kg/ha. Similarly, FH-648, FH-678 and FH-624 remained high yielder hybrids with 3333, 3310, and 3273 kg/ha, respectively (Table 21).

Table 21. The potential yield of Sunflower Hybrids synthesized at ORI, Faisalabad during 2014-15 to 2018-19

S. No.	Hybrid	Yield (Kg/h)	S. No.	Hybrid	Yield (Kg/h)
1	FH-572	2800	15	FH-693	2990
2	FH-593	2810	16	FH-702	2917
3	FH-624	3273	17	FH-714	2817
4	FH-632	2563	18	FH-719	2800
5	FH-648	3333	19	FH-720	2850
6	FH-659	2980	20	FH-721	2983
7	FH-669	3083	21	FH-723	3133
8	FH-673	2883	22	FH-728	2800
9	FH-675	3483	23	FH-729	2667
10	FH-676	2533	24	FH-730	3617
11	FH-677	2650	25	FH-731	3083
12	FH-678	3310	26	FH-732	2990
13	FH-680	3460	27	FH-741	2861
14	FH-691	2817	28	FH-751	2635

Table 22. Contribution of ORIan's hybrid into NUSYT during 2010 to 2019

S. No.	Year	Hybrid	Total
1	2010	FH-372, FH-415, FH-419, FH-385, FH-352	5
2	2011	FH-417, FH-693	2
3	2012	-	0
4	2013	-	0
5	2014	FH-465	1
6	2015	-	0
7	2016	FH-693	1
8	2017	FH-654, FH-688, FH-689	3
9	2018	FH-516, FH-610, FH-624,FH-648	4
10	2019	FH-516, FH-648, FH-673, FH-675, FH-701,FH-790	6

First national hybrid

Although some varieties/hybrids prepared at oilseed section, National Agriculture Research Centre (NARC), Islamabad but FH-331 a short duration sunflower hybrid developed at Oilseeds Research Institute, Faisalabad (Anonymous 2019) is considered to be the first national hybrid of Pakistan (Table 9). Soon after releasing, this National Hybrid (FH-331) was sold to *Zamindara* Seed Company, *Depalpure, Okara* in a private sector during 2011 by the Government at the price of Rupee Twenty-two hundred thousand (Rs. 22,00,000). Now all rights to multiply and disseminate the hybrid seeds to the farmers was reserved by *Zamindara* Seed Company till today.

Sunflower tract in Pakistan

More than 88% of sunflower crop has been cultivated in cotton belt of Southern Punjab after the late cotton picking (Anonymous, 2019). It will not only give high return to the farmers but also allow timely sowing of cotton in the next season. Some newly high yielding sunflower hybrids are in pipelines for approval. Cities like Multan Rajanpur, Mailsi, Vehari, Lodhran, Muzaffar Garh, Layyah, Bahawalpur, and DG Khan are the potential areas in Southern Punjab. Another approach to expand sunflower area is the rotation of Sunflower-Rice-Sunflower. After harvesting the rice crop, this area can be utilized for sunflower cultivation. Similarly, tracts in Sialkot, Gujranwala, Narowal, Kasoor , Okara and Sheikupura are the potential areas for sunflower cultivation in Rice belt. *Sahiwal*, potato growing area has also a good budding area for sunflower as potato is harvested in December and January. In Sindh province, limited areas in Hyderabad division , Larkana and Mirpurkhas can be utilized for this purpose. However, there is a great potential to increase the area under sunflower crop in river belts, Silaba and Khushkaba areas. Moreover, adjustment of this crop in different cropping patterns will also help increase areas under oilseed productivity.

Some tribulations in making hybrids

However, during preparation of hybrids, it was keenly noticed that isolation places was very much necessary to not only maintain all stakeholder parents like CMS A, B & R lines but without isolation locality, synthesis of hybrids would not be in pure form, so non availability of isolation would be the main issue. It was also observed the stickiness attitude of the pollen of sunflower. In contrary with other pollen of field crops, sunflower's pollen can not move by air. Its fell down from heads just after development, so pollination totally depends upon insects. Without insect pollinators, heads or capitulum of sunflower may not be filled properly, hence yield declining occurred. Moreover, inbreeding depression or self incompatibility would also be main hurdle for proper filling the capitulum. Similarly, just after cultivation, picking sunflower seeds from the soil and un-ripened seed from the flower head by the birds during morning/ evening was also main obstacle for proper yield.

Diseases like charcoal rot, head rot, downy mildew while insect infestation of termite, whitefly, jassid, cutworm and armyworm remained the main bottlenecks in yield maximization in sunflower field. Last but no means the least, rains during blossoming period of sunflower plant also deteriorated yield significantly.

Hybrid: A final product

After threshing the yield potential of newly established hybrids at station as well as micro yield trial, the

Table 23. Results of sunflower hybrids in national uniform sunflower yield trials during 2018.

S. No.	Hybrid	NARC, Id	RARI, Br	ORI, Fd	AZRI, Bhk	UOS Sg	ICI, Hd	Syngenta, Multan	ARI, TJ	Syngenta, Hd	Ave yield (kg/ha)
1	AGSUN-5270	2617	1680	2919	2466	2355	2830	2805	1693	2160	2392
2	STWS	2021	2244	2679	2607	2510	2655	2679	1893	2074	2374
3	Hysun-33	1627	2467	2613	2489	2523	2618	2621	1644	2057	2295
4	FH-516	1986	1609	2832	2249	2230	3296	2526	1782	1945	2273
5	US-777	2076	2089	2779	2050	2306	2585	2642	2049	1528	2234
7	L121TC	2309	1764	2381	2863	2336	1560	2259	2000	1968	2160
8	L126TI	2037	2013	2271	2221	2168	2774	2768	1222	1861	2148
9	ESF-H-3391	1933	1920	2102	2070	2031	2731	2305	2066	2149	2145
10	KQS-HSF-1	2096	1773	2400	2141	2305	2170	2398	1962	1969	2135
11	FH-648	1956	1844	2065	2340	2120	2405	2679	1606	1959	2108
12	FH-624	1969	1444	2631	2242	2106	2071	2362	1679	1564	2008

NARC,Id: National Agricultural Research Center, Islamabad, RARI, Br: Regional Agricultural Research Institute, Bahawalpur, ORI, Fd: Oilseeds Research Institute, Faisalabad, AZRI, Bhk: Arid Zone Research Institute, Bhakkar, UOS,Sg: University of Sargodha, Sargodha, ICI, Hd: Imperial Chemical Institute, Hyderabad, ARI, TJ: Agriculture Research Institute, Tando Jam, Syngenta Hd: Syngenta Hyderabad

Table 24. Results of sunflower hybrids in national uniform sunflower yield trials during 2019

S. No.	Hybrid	NARC ID	ORI, FD	RARI. BR	ICI, HD	ICI-MN	AZRC-DIK	Yield (Kg/Ha)
1	FH-701	2616	3004	2662	3078	2374	3279	2836
2	FH-516	2506	3133	2493	3154	2092	3202	2763
5	S-278 (Check)	2790	2668	1462	3074	2398	4083	2746
6	AG-SUN-5264 (Check)	3376	2446	2026	2610	1732	3669	2643
7	FH-675	2902	2998	2302	2737	1837	1697	2412
8	FH-648	2178	2533	2146	2601	1978	2771	2368

NARC, ID: National Agricultural Research Center, Islamabad, ORI,FD: Oilseeds Research Institute, Faisalabad, RARI, BR: Regional Agricultural Research Institute, Bahawalpur, ICI,HD: ICI, Hayderabad, ICI, MN: ICI, Multan, AZRC DIK: Arid Zone Research Center, Dera Ismail Khan

Table 25. Results of sunflower hybrids with completed two years in national uniform sunflower yield trials in 2019

S. No.	Hybrid	ORI, FD	RARI, BR	ICI, MN	Mean, 3 Loc	% inc. /dec. over check	
						NK-S 278	AG SUN-5264
1	FH-516 (ND)	3133	2493	2092	2573	18	24
2	FH-648 (SD)	2533	2146	1978	2219	2	7
3	NK-S 278 (Check)	2668	1462	2398	2176	-	-
4	AG SUN-5264 (Check)	2446	2026	1732	2068	-	-
	Mean loc.	**2695**	**2031**	**2050**			

ND: Normal Duration, SD: Short duration, ORI, FD: Oilseeds Research Institute, Faisalabad, RARI,BR: Regional Agriculture Research Institute, Bahawalpur, ICI, MN: Imperial Chemical Institute, Multan

promising one were sent to National Coordinator (Oilseeds), Pakistan Agriculture Research Council, Islamabad for the inclusion in National Uniform Sunflower Yield Trial (NUSYT) on each year for testing its yield potential on national level. Some dropping years were also observed at ORI, Faisalabad due to non-availability of sufficient seed of the hybrids. However, maximum hybrids in six numbers were sent to NUSYT during 2019 depicted in Table 22.

National Coordinator (oilseeds), Islamabad, Government of Pakistan conducted National Uniform Sunflower Yield Trial (NUSYT) across country on each year (Table 23, 24) for imminent hybrid. Sixteen hybrids belong to public and private institutes were planted under randomized complete block design on national level during 2019. Result depicted that two hybrids viz FH 516, a normal duration hybrid and FH 648 a short duration hybrid of ORI, Faisalabad remained top yielder on the basis of Punjab province (Table 25). According to the results, mentioned in the Table 25. Hybrid like FH 516 of normal duration (125 day) excelled the yield (2573 kg/ha) by 24% more than the national check of AG SUN 5264 (2068 kg/ha) and 18% more yield than the other national check NKS 278 (2176 kg / ha). Similarly, another hybrid of ORI, Faisalabad designated as short duration hybrid (110 days) as FH 648 produced 7 and 2% more yield than the national check of AG SUN 5264 and NKS 278, respectively. Moreover, these hybrids completed their journey of two compulsory years in NUSYT and expected to release FH-516 as normal duration and FH-648 as short duration hybrid for general cultivation very soon in near future after fulfilling the necessary requirements.

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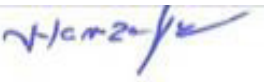
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S. No.	Author's name	Contribution	Signature
1.	Muhammad Ijaz Tabassum	Conduced research, collected data and prepared write-up	
2.	Muhammad Aslam	Assisted to write up the mansucript keenly regarding sunflower history	
3.	Muhammad Ishaq Javed	Collected and reviewed the literature	
4.	Jafar Salim	Reviewed the manuscript along with latest sunflower data	
5.	Muhammad Sarwar	Proof read the manuscript	
6.	Hamza Rafiq	Collected material from different sources and prepared figures of the manuscript	