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Original Research Article

ENHANCING PRE AND POST VEGETATIVE HEAT RESILIENCE AND YIELD POTENTIAL IN THE NEWLY RELEASED MAIZE VARIETY "SAHIWAL GOLD" THROUGH MODIFIED SELECTION

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Abstract *Maize is well-anchored crop across the globe due to its nutritional profile, multipurpose usage, and underlying financial benefits. Growing of open-pollinated maize varieties (OPVs) is a traditional trend and is still followed by a huge community of small farmers in most of the developing world. Improvement in yield potential is always inevitable and requires a purposeful and definite strategy. The current climate scenario loaded with heat escalation and extreme fluctuations is creating uncertainty and unsustainability through acute yield losses in domesticated crops. The breeding strategy of Sahiwal Gold (2008-2018) was comprised of four developmental phases i.e. enrichment phase, half-sib selection, pedigree selection, uniformity phase, and field evaluation at various agro-ecological zones of Pakistan. Each consecutive autumn and spring season was utilized to improve yield potential by exploiting pre and post-vegetative heat resilience. Half sib and pedigree selection improved plant features like height (12%), cob length (4.1%), seeds per cob (7.5%), grain (10%), and stalk yield (11.2%) from enrichment to uniformity phase. Sahiwal Gold maintained a high adaption profile across the tested locations and out-yielded the check variety (MMRI Yellow) by 18% and 26% on average in 6 stations and 16 national yield trials, respectively. National yield testing approved its suitability across provinces like Punjab, Khyber-Pakhtunkhwa (KPK), and Islamabad territory under a diverse range of temperatures. Analysis of variance revealed that highly significant interaction between season and genotypes work for plant height, grain, and stalk yield potential. Higher grain yield up to 95 mounds/acre was observed for spring season crop and batter stalk yield results (650 mounds/acre) were assessed during autumn plantation. Twelve (12) feet tall plants with 4 feet long leaves having 75-90% stay green ability provide a good opportunity fodder and grain yield potential at farmer's field. This work will provide a better understanding to researchers for designing breeding programs for the development of heat resilience germplasm in crops.*

Keywords*:* *Maize OPV; Heat Resilience; Yield Potential; Vegetative Stage; Breeding; Selection*

Introduction

Maize (*Zea mays* L.) is an important cereal crop known as "Queen of Cereals" with the highest yield per unit area and is cultivated worldwide to feed humans and animals (Preetha and Stalin, 2014). It serves as a good source of food and provides higher energy units about 6.9 million calories per hectare than wheat (3.7 million) and rice (4.9 million) (Ghani et al., 2017). It is a multipurpose crop used for food, feed, fodder, and fuel purposes in addition to industrial consumption (Afzal et al., 2009; Enyisi et al., 2014). Maize is grown as a major field crop in different agro-ecological zones of Pakistan between 24-37° latitude and stands at 3rd after wheat and rice among the important crops (Bhutto et al., 2023). It contributed 3.2 percent value addition towards Pakistan's agriculture and 0.7 percent in GDP.

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During 2021-22, maize covered 1.65 million hectares with production approaching 10.63 million tons and an average yield 5922 kg/ha. The area and production of maize have increased tremendously by 58.5% and 119% respectively in Pakistan during the last 10 years (Government of Pakistan, 2022) due to high profitability in maize (Murtaza et al., 2020). High profitability in maize is mainly associated with the introduction of hybrid seed technology which almost doubled the yield within the same area (Tahir et al., 2008). Maize seed availability is a major issue in Pakistan as only 55% of seed (32,868 MT) of total demand was available to farmers during 2021-22. Only 15% of available seed was locally produced while 85% was imported as multinational hybrids costing price rates at 7-8 US$ per kilogram which is highest in South Asia and unaffordable by small landholders (Akbar et al., 2008). About 80 percent of farmers are small landholders with limited resources and conventional farming approaches facing yield constraints due to low-quality inputs including seed (Ali et al., 2020). Only 30% of the maize area is under cultivation of high-yielding but costly hybrids while the remaining is utilized with growing OPVs.

Hence, the dire need of the time is to strengthen the local seed sector by developing new and climate-smart open-pollinated maize varieties with higher yield potential and sustainable productivity (Masuka et al., 2017). Seed production and proper dissemination of these varieties at a supported rate and with batter extension services can address the issue regarding timely availability and high seed prices (Takoutsing et al., 2014). To meet the needs of the time, the following work was started at Maize and Millets Research Institute Yusafwala-Sahiwal which is a pioneer institute working on the development of new maize varieties and hybrids. The new maize OPV "Sahiwal Gold" is high yielding stay green variety that stood ranked 1st three times during national testing. It is a heat tolerant season variety and performed well across the regions during both autumn and spring season.

Material and Methods

Development Phase

The newly approved maize variety "Sahiwal Gold" was derived from the base population of yellow maize verities "Yusafwala Pool-50" which was earlier developed at Maize and Millets Research Institute Yusafwala-Sahiwal through assimilation of vast genetic pool. The development history of Sahiwal Gold started in spring 2008 when Yusafwala Pool-50 was enriched by the incorporation of six new families of indigenous and exotic germplasm viz: Yusafwala-5098, Yusafwala hybrid, Nanning-8528, Pozarica-8624, Jardinoplis-8624, and CHTTY-1205. Bulk seed of Pool-50 was used to sow four rows of female lines (de-tasseled at flowering) and one male row. Open pollination (pollen of incorporated families) was allowed in Pool-50 for two consecutive seasons (spring 2008, and autumn 2008). Healthy, disease and pest-free tall plants with stay green stems and long cob size were selected during each season and the same criteria was adapted subsequently to improve the stalk and grain yield potential. Finally, 250 desirable plants were identified after field and table selection and their seed was bulked to proceed further. The resultant selection from Yusafwala Pool-50 was allowed to undergo four consecutive cycles of half sib selection (spring 2009, autumn 2009, spring 2010, and autumn 2010). Bulk seed of selected cobs was used to sow female and male lines in 4:1 ratio and open pollination was allowed at the time of flowering. 200 - 300 desirable plants in field were selected during each season and their cobs were harvested for table selection. Unhealthy, fungal-infected and undesirable cobs were removed and the remaining lot was bulked and used for next season. At the end of autumn 2010, a strict selection was opted based on stay green stem, plant height, root anchor, cob height, cob length, tassel size and disease aspect with grad I score (highly resistant type) and 50 plants were selected. Fifty selected cobs were further subjected to the development of their test progenies through ear to row method during spring 2011. Seed from each ear was sown in single and separate row. Four female rows (test progenies) with one male row (bulk of all selected cobs) were followed and open pollination was allowed. Cobs of 20 selected plants from each row were harvested and seed of each progeny was bulked and saved separately (Masuka et al., 2017). Performance regarding grain yield components, stalk yield and other characteristic features in each progeny was recorded. This procedure was exercised in next 3 seasons (autumn 2011, spring 2012 and autumn 2012) and ten best-yielding families were selected based on yield potential and phonological uniformity. Ultimately, bulk seed of 10 selected families was sown in isolation for free mixing through open pollination and procedure was adapted for four seasons (spring 2013, autumn 2013, spring 2014 and autumn 2014). Strict rouging of undesirable off type plants was applied in each mixing cycle to attain the maximum homogenization, yield stability and uniformity in new candidate variety.

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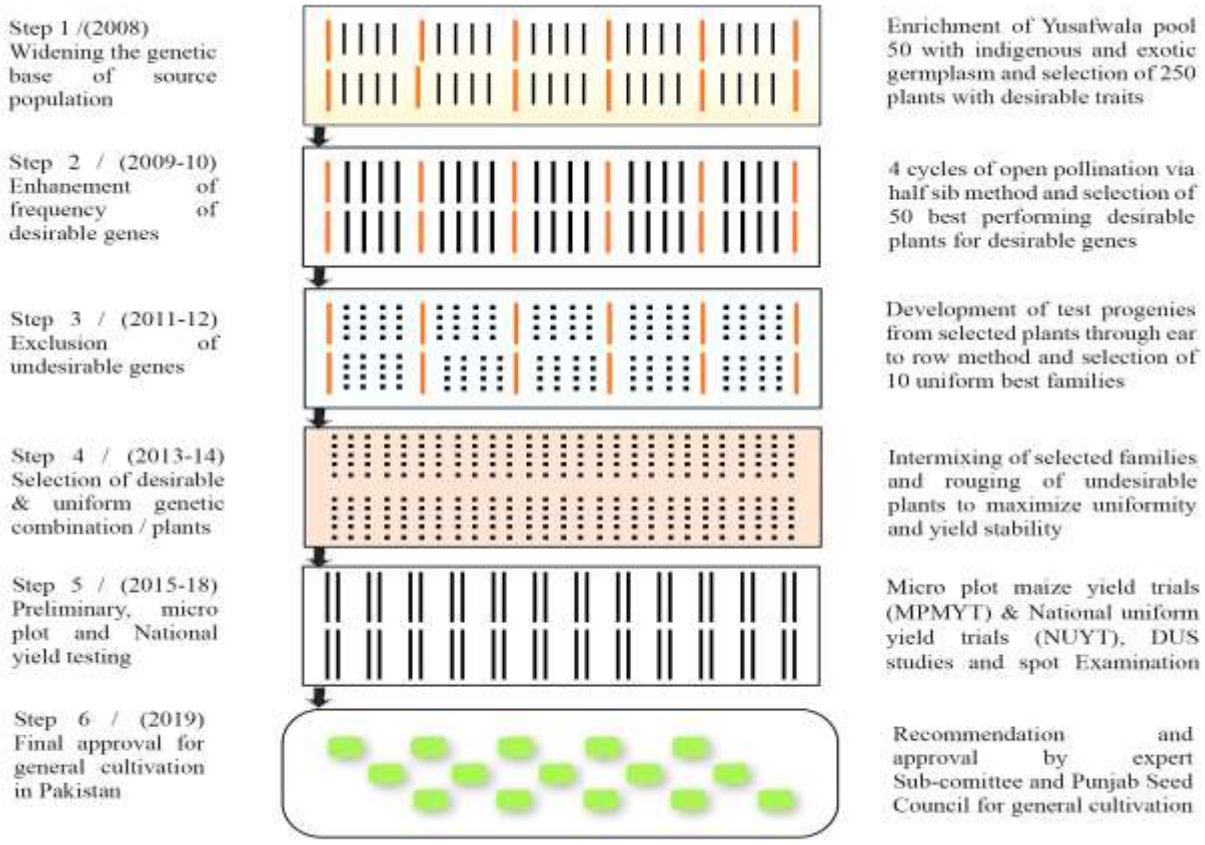

Fig.1 Breeding Flow Chart of Development of Maize Open Pollinated Variety "Sahiwal Gold"

Evaluation phase

The homogenized seed of the candidate variety was subjected to various types of evaluation trials from 2015 to 2018. Initially, performance regarding grain and stalk yield potential was assessed in comparison to check variety (MMRI Yellow) through preliminary, micro and macro yield trials from 2015 to 2017. Experiments were conducted following RCBD wherein experimental plots OPV entries were randomized incomplete blocks. Plot size in preliminary, micro and macro trials was 7.5 m² (2 rows of 5 m length and 0.75 m apart), 15 m² (4 rows) and 30 m² (8 rows) respectively. 12 to 16 irrigations were managed according to water requirements in spring and autumn season. Fertilizer was applied according to the recommended dose of 272-114-62 NPK (Kg/ha). Agronomic practices and plant protection measures were performed accordingly. After passing the station tests, a third party evaluation for candidates and check variety was conducted by National Coordinator, Pakistan Agriculture Research Council (PARC) Islamabad. Adaptability / National Uniform Yield Trials (NUYT) for yellow maize OPVs were performed during autumn 2016, spring 2017, autumn 2017 and spring 2018 at different locations of Punjab, KPK and Sindh. Distinctness, uniformity and stability studies were carried out by Federal Seed Certification and Registration Department (FSC&RD). Spot examination for characteristic features of candidate variety was examined by scientist of Experts Sub-Committee on 06.06.2018. Initially, the case for approval of new Yellow maize OPV "Sahiwal Gold (YY-15)" was presented before 78th meeting of Experts Sub-Committee on 09.01.2019 and after attaining recommendation by the Committee the final approval for general cultivation of a variety was granted by Punjab Seed Council during 2019.

Estimation of yield and other traits

Different morphological traits like plant height, cob height were measured through mearing tape. Grain yield per plot was estimated by counting number of cobs harvested per plot and shelling was performed to get the total grains. Dried grains at 12% moisture (measured through moisture meter at corn) were weighed and the resultant value of a single plot was multiplied with plot factor for hectare (1333.33 in case when 5 m long 2 rows and 0.75 m apart = 10000 / 7.5) to estimate the grain yield in kg / hac. Similarly, fresh weight of stalks per plot was measured and converted into stalk yield in kg/ha.

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Phonological data like days to 50% tasseling, days to 50% silking and total maturity duration was counted from date of sowing and inspecting the relevant stage of the plants in plot. Other plant characteristics like plant health, disease and pest attack were scored from 1 to 5 (resistant to susceptible) according to infestation and intensity of attack. Stay green trait was measured by visual inspection for percentage of dryness of plants at the time of harvesting.

2.4 Statistical analysis

The collected data were subjected to statistical analysis like "analysis of variance" to test the significant differences in yield performance of two maize OPVs, effects of Reps, Season and years. R software and packages like *tidyverse, ggplot2, emmeans* and *agriTutorial* were used for analysis and graphical presentation by following statistical techniques given in (Piepho and Edmondson, 2018).

Results

Characteristic Improvement during Developmental Cycles

Development of new maize variety Sahiwal Gold was the result of four breeding phases. Different plant attributes during 4 developmental cycles showed high variability and differential responses subject to the breeding strategy carried out at each phase (Table 1).

Table 1. Range and average of different plant traits at various developmental steps of sahiwal gold

	Enrichment Phase 2008		Half Sib Selection 2009-10		Progeny Selection 2010-12		Uniformity Phase 2013-14		% Difference
Plant Traits	Range1	Av.1	Range2	Av.2	Range3	Av.3	Range4	Av.4	Av.4/Av.1
Plant Height (cm)	230-315	250	255-290	277.0	245-305	265	260-295	280.0	12.00
Cob Height (cm)	125-210	150	155-180	172.0	145-190	158	160-175	169.0	12.67
Anthesis Days Sp.	56-68	64	58-64	62.0	54-66	60	60-64	62.0	-3.12
Silking Days Sp.	46-56	54	50-54	52.0	46-54	52	50-54	52.0	-3.70
Anthesis Days Aut.	58-70	66	60-66	64.0	56-68	62	62-66	64.0	-3.03
Silking Days Aut.	48-58	56	52-56	54.0	48-56	54	52-56	54.0	-3.57
Days to Maturity	95-125	116	110-120	115.0	100-125	118	105-115	112.0	-3.45
Leaf Length (cm)	80-120	105	90-110	100.0	85-115	94	95-110	104.0	-0.95
1000 Grain Weight (g)	230-295	270	265-295	278.0	240-285	259	260-280	272.0	0.74
Rows per Cob	14-18	16	14-18	16.0	14-20	16	14-18	16.0	0.00
Cob Length (cm)	8.5-15	12	11.5- 15.5	13.2	8.5-16	11	10.5- 5	12.5	4.17
Seeds Per Cob	570-810	665	630-820	745.0	550-840	680	600-800	715.0	7.52
Grain Yield per Cob	145-225	180	170-235	200.0	160-230	182	175-225	198.0	10.00
Stay Green %	55-90	80	75-95	86.0	50-95	70	65-90	78.0	-2.50
Stalk Weight (g)	750-1070	890	930-1140	1060.0	775-1125	935	850-1100	990.0	11.24

Both plant and cob height showed an overall 12% average increase from enrichment (Av.1 = 250 and 150 cm) to uniformity phase (Av.4 = 280 and 169 cm). Half sib selection instantly enhanced plant height (Av.2 = 277 cm) but subsequent reduction is observed during progeny selection (Av.3 = 265 cm) and ultimately improved during the uniformity phase. Similar incremental pattern of progression and positive response was observed for cob height, thousand grain weight (0.74%), cob length (4.1%), seeds per cob (7.5%), grain yield per cob (10%), and stalk weight (11.2%) during developmental phases. Phonological traits like flowering and maturity days were 3% reduced. Enrichment phase and progeny selection showed higher range and lower average for most of the traits while averages were improved during half sib selection and uniformity phase.

Station Yield Performance

Grain yield performance of a new variety “Sahiwal Gold” and check variety “MMRI Yellow” was tested in different station trials at Maize and Millets Research Institute Yusafwala-Sahiwal, Pakistan during 2015 to 2017. Results showed that Sahiwal Gold (8768.6 kg / ha) surpassed check variety MMRI Yellow (7468.8 kg / ha) in all six trials with an overall 18.2% grain yield increase. Minimum increase over check (6.1%) was obtained during spring 2016 while maximum increase (31.1%) was observed during autumn 2016. Sahiwal Gold showed its maximum yield potential (9954 kg / ha) up to 100 mound / acre during spring 2017.

Variability Studies

Variation under the effects of replication (REPS), season, genotypes and their interction was assesed throgh ANOVA for different morphological, phenological and yield traits (Table 2).

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Table 2. Results of ANOVA (Kenwar-Roger's method) on the effects of REPS, season and genotypes for morphological, phenological and yield traits of sahiwal gold and MMRI yellow

	DF	Grain Yield per hac	Maturity days	Plant height	Silking days	Stalk Yield per hac	Tasseling days
REPS	2	1408.75 ns	2.37 ns	57.04 ns	1.54 ns	1554877.07 ns	0.29 ns
Season	1	5908887.39 **	3876.04 **	1980.17 ns	962.67 **	223790711.65 *	975.38 **
Genotype	1	15648542.18 **	5.04 ns	7072.67 **	1.5 ns	1619902898.53 **	1.04 ns
Year	1	1691.76 ns	425.04 **	160.17 ns	104.17 **	1546171.09 ns	108.37 **
Season:Genotype	1	930431.26 **	35.04 ns	1700.17 *	6 ns	264391637.23 **	12.04 ns
Season:Year	1	472.59 ns	18.37 ns	486 ns	6 ns	647358.83 ns	3.37 ns
Genotype:Year	1	1828.76 ns	7.04 ns	160.17 ns	0.17 ns	2773244.61 ns	5.04 ns
Season:Genotype:Year	1	7193.34 ns	3.38 ns	216 ns	0.67 ns	14221787.43 **	1.04 ns

* * Significance at 5% probability, ** Significance at 5% probability, ns: non-Significant

The analysis of varience showed that replications effects made a non-significant impact on any of the studied trait and thus remained consistant with the basic assumption of non-significant REPS in block design. Significant to highly significant differences in studied traits came under seasonal and genotypic effects individually but their interection was found positive for plant height, grain yield and stalk yield. The joint action of seasonal trends and genotypic response generated significant variation in plant height and highly significant for grain and stalk yield. Phenological traits like Silking, tasseling and maturity days showed highly significant differences but only under seasonal effects. For both genotypes, average flowering and maturity time during autumn crop was 52 and 103 days, respectively while this duration extended to 64 and 129 days during spring season. Interective action of season and genotypes was further validated by contrast analysis and parameter estimates for genotypic and seasonal contrasts were measured (Table 3). All contrast estiamtes retained zero proabality values thus ennsuring that true differences were present among varieties and seasons. It showed that autumn and spring differences were true for both of the varieties and similarly both varieties behaved differently in spring and autumn season.

Table 3. Parameter estimates, Standard Error and P.value of contrast among Seasons, Gentypes and Years for Stalk Yield

Genotype	Season	Year	contrast	estimate	SE	df	t.ratio	p.value
MMRI Yellow	.	2016	Autumn - Spring	7522.19	1205.78	5.18	6.24	0.02
Sahiwal Gold	.	2016	Autumn - Spring	17719.37	1205.78	5.18	14.70	0.00
MMRI Yellow	.	2017	Autumn - Spring	5099.98	1205.78	5.18	4.23	0.09
Sahiwal Gold	.	2017	Autumn - Spring	21455.47	1205.78	5.18	17.79	0.00
.	Autumn	2016	MMRI Yellow - Sahiwal Gold	-20849.92	880.83	12.00	-23.67	0.00
.	Spring	2016	MMRI Yellow - Sahiwal Gold	-10652.74	880.83	12.00	-12.09	0.00
.	Autumn	2017	MMRI Yellow - Sahiwal Gold	-25288.79	880.83	12.00	-28.71	0.00
.	Spring	2017	MMRI Yellow - Sahiwal Gold	-8933.30	880.83	12.00	-10.14	0.00
MMRI Yellow	Autumn	.	Year2016 - Year2017	1383.33	880.83	12.00	1.57	1.00
Sahiwal Gold	Autumn	.	Year2016 - Year2017	-3055.54	880.83	12.00	-3.47	0.06
MMRI Yellow	Spring	.	Year2016 - Year2017	-1038.88	880.83	12.00	-1.18	1.00
Sahiwal Gold	Spring	.	Year2016 - Year2017	680.55	880.83	12.00	0.77	1.00

Variability analysis for stalk yield potential was also performed and Type I analysis of variance through Kenwar-Roger's method showed that Season x Genotype x Year interaction was the key factor for stalk yield response.

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Table 4. Type I Analysis of Variance Table with Kenward-Roger's method for Stalk Yield (Kg/hac)

	SumSq	MeanSq	NumDF	DenDF	Fvalue	Probability
REPS	3109754.1	1554877.1	2	2	1.34	**0.43**
Season	223790711.7	223790711.7	1	2	192.29	**0.01**
Genotype	1619902898.5	1619902898.5	1	12	1391.92	**0.00**
Year	1546171.1	1546171.1	1	12	1.33	**0.27**
Season:Genotype	264391637.2	264391637.2	1	12	227.18	**0.00**
Season:Year	647358.8	647358.8	1	12	0.56	**0.47**
Genotype:Year	2773244.6	2773244.6	1	12	2.38	**0.15**
Season:Genotype:Year	14221787.4	14221787.4	1	12	12.22	**0.00**

Fig. 2 dipicted grain yield performance for two open pollinated varieties in two growing seasons. It was observed that Sahiwal Gold out-yielded MMRI Yellow in both seasons (autumn and spring) and spring crop maintained more benificial edge for grain yield over autumn for both of the varieties. The interective response illustrated that Sahiwal Gold maintained a steeper slope than MMRI Yellow due to higher yield (9550 kg / hac) during spring season.

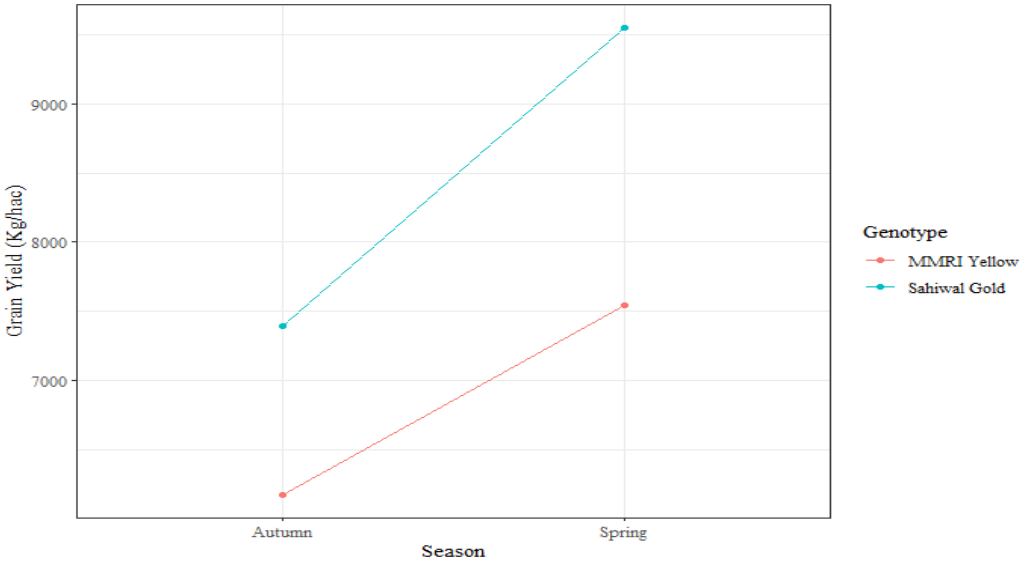

Figure 2: Grain Yield Response of two OPVs (Sahiwal Gold and MMRI Yellow) in Spring and Autumn Season

Fig. 3 illustrated the interactive response of two varieties over two seasons and years (2016 and 2017). It was observed that Sahiwal Gold produced more stalk yield over MMRI yellow in both of the years and autumn environment carried more stalk yield potential over spring season. Both years incorporated a differential response of stalk yield for both varieties and over both seasons. Stalk yield of Sahiwal Gold, on one side, enhanced during autumn 2017 but reduced for MMRI Yellow in same season in comparison to 2016. Steeper slop of Sahiwal Gold and slightly flatten slop of MMRI yellow during 2017 made a different interaction pattern than 2016.

Adaptability / National Uniform Maize Yield Trials

Grain yield performance of Sahiwal Gold was determined over check variety across the country under Adaptability / National Uniform Maize Yield Trials. Results showed (Table 5) that overall 26.2% yield increase of Sahiwal Gold was measured over check for all seasons and locations. All spring season showed more than 20% (range: 21-40%) yield increase while autumn 2017 registered the yield benefit of Sahiwal Gold up to 9%. Arifwala site with single data set showed highest yield enhancement (112%) over MMRI.

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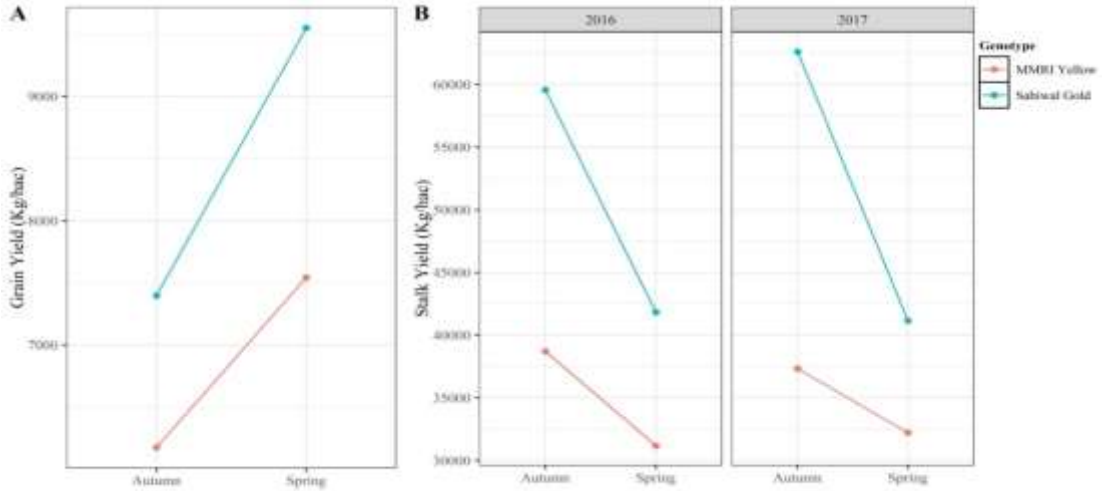

Fig.3: Grain and stalk yield of two OPVs sahiwal gold and MMRI yellow in spring and autumn season during 2016 and 2017

Faisalabad location was the most consistent performer in Punjab with 30% yield increase than check and followed by Yusafwala-Sahiwal. Islamabad and KPK locations also showed positive increment (up to 18%) over check variety. The only location with 7% lower in yield of candidate variety was Sangarh, Sindh. Maximum yield potential (11161 kg / ha) for Sahiwal Gold was achieved at Shergarh, KPK site during spring 2018. This season also showed highest average yield performance of Sahiwal Gold (8966 kg / ha) across the locations and followed by spring 2017 (6222 kg / hac). Sahiwal Gold was the only variety that not only exceeded its check variety but stood 1st for three times in yield performance during national testing.

Table 5. Performance of sahiwal gold and MMRI yellow (Kg/ha) across different location during national uniform maize (OPVs) yield trials during spring / autumn seasons (2016 to 2018)

National Uniform Maize (OPVs) Yield Trial	Varieties	Islamabad (Kg/ha)	Yusafwala Punjab (Kg/ha)	Faisalabad Punjab (Kg/ha)	Arfwala Punjab (Kg/ha)	Sangarh Sindh (Kg/ha)	Pirsbak KPK (Kg/ha)	Shergarh KPK (Kg/ha)	Average Yield (Kg/ha)	% Increase over Check
Spring 2016	Sahiwal Gold	1983	5558	7398	5995	-	-	-	5233.5	**40.07**
Spring 2016	MMRI Yellow	417	5790	5911	2827	-	-	-	3736.25	-
Spring 2017	Sahiwal Gold	6071	10951	1644.2	-	-	-	-	6222.06	**38.78**
Spring 2017	MMRI Yellow	5101	7431	918	-	-	-	-	4483.33	-
Autumn 2017	Sahiwal Gold	7237	1556	5465	-	4853	-	-	4777.75	**9.36**
Autumn 2017	MMRI Yellow	6646	1752	3853	-	5224	-	-	4368.75	-
Spring 2018	Sahiwal Gold	5068	10359	9724	-	-	8519	11161	8966.2	**21.51**
Spring 2018	MMRI Yellow	5034	7506	7887	-	-	7015	9450	7378.4	-
% Increase over Check	-	**18.38**	**26.44**	**30.49**	**112.06**	**-7.1**	**21.43**	**18.1**	**26.2**	-

Discussion

The development of new cultivars with higher yield potential and adaption flexibility is a dire need of the time under climate change scenario (Katsenios et al., 2021). Sahiwal Gold is newly developed maize open pollinated variety having superior plant characteristics than check variety. Seven years of developmental phase of Sahiwal Gold followed unique pattern of breeding procedure through enrichment phase, selection cycles and uniformity. Enrichment of germplasm with new genetic material widened the base of source population through formation of new and distant recombinants. Wide range and low average values of recorded plant features during enrichment phase is indicative a broad base line for selection. Improved averages of plant characteristics with narrow range are result of positive response of half sib selection method (Ludwig and Asseng, 2010).

This positive response is owing to right selection and increasing frequency of desirable genes during each selection cycle. Record of plant features with low averages and wide range during progeny selection cycles indicate the presence of some undesirable genes (Pandey et al., 1991). Ultimately, selection of only 10 best performing progenies among 50 caused the removal of undesirable genetic makeups and incorporated a potential for improvement of plants features through fixation desirable genes. In the end, uniformity phase stabilized the performance of variety through intermixing of only target recombinants. The resultant OPV when compared with check variety in field trials proved its superiority for yield and wide adaption. The exceeding capability of Sahiwal Gold over check

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variety (18-26%) across the years, locations and seasons in different yield trials proved its suitability for general cultivation with high adaptability potential. Highly significant yield variation for genotype and seasonal interaction indicated that both of the genotypes respond differently for environmental factors (Liu et al., 2021). Our results are coinciding with the findings that breeding for vegetative and cob trait improvement boost the grain and stalk yield potential in maize (Cagnola et al., 2021; Luque et al., 2006). of Sahiwal Gold and MMRI Yellow although followed grain yield increase during spring season and stalk yield enhancement during autumn season but positive and high incremental response of Sahiwal Gold than check variety is owing to its superior breed.

The newly developed open pollinated variety "Sahiwal Gold" is tall statured high yielding and heat tolerant variety with medium maturity duration. Broad leave stay green plant is resistant to stem rot and root lodging. It bears long cobs with average 16 rows per cob having pale yellow colored dented seed. It has high grain and stalk yield potential up to 9100 kg/ha and 65000 kg/ha, respectively. It was approved for general cultivation in Pakistan during 2019 and widely cultivated across the Punjab province during spring and autumn seasons.

Conclusion

Global warming is real threat to agricultural crop as significant losses were reported in almost all parts of world. Development of heat resilient verities is the need of time to cope the losses under heat effects. Sahiwal Gold is a maize open pollinated variety which was developed through a modified breeding methodology with double selection of requisite trait set. This enabled Sahiwal Gold to perform best across the locations and with batter grain and stalk yield potential. Dual season alternate breeding (spring and autumn) improved heat resilience for pre and post vegetative potential of maize plants in face of Sahiwal Gold. This variety is showing good and attractive results in term of grain and green yield on farmer field across the Punjab.

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Declaration

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Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

The study was approved by authors.

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Conflict of Interest

There is no conflict of interest among the authors regarding this case study.

Authors Contribution

JAVED HM and AKBAR W conducted this research work and all other authors assisted in writeup, data analysis, revision, editing and proof reading equally.

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