

YSH-134 A SWEET STALK SORGHUM HYBRID WITH HIGH POTENTIAL FOR SILAGE PRODUCTION IN PLAINS OF PUNJAB

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Abstract Ever-increasing population and the impact of high heat, a combination of both diminishing factors place agricultural productivity at risk. Food security is current alarming issue and ringing the bells on the door of stakeholders including breeders to devise appropriate strategies for future needs. The development of hybrids in crops is the only tool to enhance productivity by 2-3 times folds than current potential. The livestock industry is also increasing steeply to meet dairy-related needs and requires high fodder-yielding hybrids to fulfill its functional tasks. The constitution of new and dual-purpose high-yielding sorghum hybrids is a core need to boost production potential in fodder crops. Sorghum provides highly nutritious grain and green parts and requires a limited input supply when compared to other crops. A great improvement potential is present in sorghum crops in terms of hybrid development. Here, this work was performed for the development of a new sorghum hybrid through the ABR system. YSH-134 is a cross combination between CMS-10A and YSS-98 with a higher grain (5000 kg/ha) and fodder (45000 kg/ha) yield potential. This hybrid was tested against the previously released sorghum hybrid Fakhar-e-Punjab. It's the second of its lot and has yield superiority over check hybrid. YSH-134 maintained 3% and 15% yield enhancement at station trials during 2018 and 2020 over check hybrid. Under National Uniform Yield Testing, it showed more prominent and higher yield benefits (19% and 34% during 2019 and 2020, respectively) against its competitor. ANOVA and after ANOVA analysis showed its 14% grain yield increase and 26% fodder production than Fakhar-e-Punjab. This high productivity is owing to the exploitation of heterosis effects lying under this unique cross combination. High-yielding YSH-134 has a highly sweet and juicy stem (15% brix value) with green and broad which can be used as green fodder for the cattle and dairy industry. This work will pave the way to meet future targets through utilizing heterosis breeding and hybrid seed technology. This may help the researcher in designing breeding programs for the development of hybrids for higher yields in green fodder.

Keywords: Sorghum; Hybrid; Higher yields; Green Fodder; Vegetative Parts; Heterosis

1. Introduction

The need for dairy products is continuously increasing day by day due to the high population increase (Garcia et al., 2019; Grout et al., 2020). World's population is expected to be more than 9 billion in the middle of this century while estimated fodder requirements to feed the livestock are approaching 630 million tons (Dubey et al., 2017). The demand for high-yielding crop varieties to feed humans and animals is a great concern of the

researcher in this era (JABBAR et al., 2022). This scenario becomes more complex because of more supply from the same land resources. The livestock industry is steeply increasing in African and Asian countries but facing a shortage of feed in terms of quality and quantity (Erdaw, 2023). Sorghum stands at 5th position in the group of important crops and its worldwide production reached to 6.7 million tons from an area of 45.3 million hectares (Adebo, 2020).

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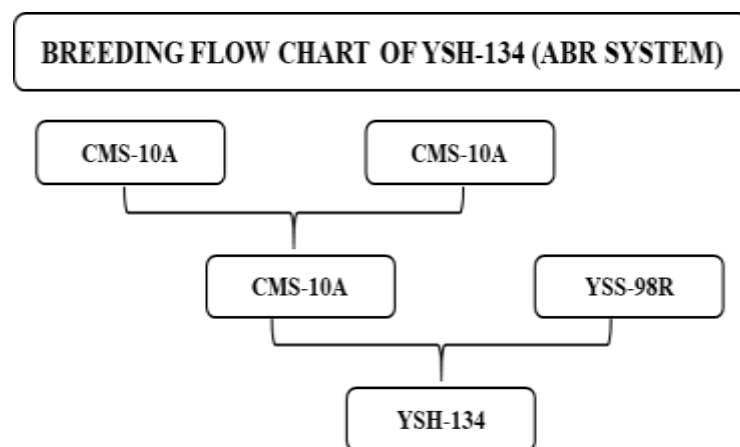
It is a nutritionally rich source for a proper diet of animals and provides protein, fiber, minerals, and other dietary ingredients. It has 7-8% protein content, 2-3% fats, 1-2% minerals, and about 90% carbs in its grain (Martínez-Villaluenga et al., 2020). It is widely adapted and grown in both irrigated and semi-arid regions with limited water resources and availability (Gregory, 1984). Under limitations imposed by global warming in each sector of agriculture, there is a need to prioritize our breeding programs focusing on industrial and farmer needs (Ligon and Sadoulet, 2018). Cattle and livestock industry in Pakistan holds large importance and big space, especially in terms of GDP sharing. It is contributing 62% in agriculture and about 14% to the total GDP of the country with a record growth rate of 3.26% during 2021-22 (Beckman and Countryman, 2021). Keeping a view on the pace of growth of this sector, there is a dire need to constitute new sorghum varieties for future needs (Pray, 1990). The development of sorghum lines with high and sustainable production potential both for grain and fodder yield will benefit the farmers inclusively (Fischer & Edmeades, 2010). This research paper will cover the developmental and breeding methodology of an early maturing, medium-heighted and high-yielding sorghum hybrid YSH-134 which was recently released for general in the fertile plains of Punjab.

The advantage of hybrids is not only higher yield but also uniformity in maturity and height, which is why they are preferred by farmer's community as farmers are very conscious to yield of the crop (Ostmeyer et al., 2022). Fakhar-e-Punjab released during 2020 for general cultivation, has good grain yield potential but is still unable to compete with exotic varieties due to less commercialization. A single hybrid cannot compete with multinational companies and exotic imported varieties or hybrids. Accordingly, a new hybrid named YSH-134 has been developed with high grain and fodder yields. It is early maturing, medium height, has a high brix value and has good tolerance to foliar diseases.

Material and Methods

This work is carried out at the Maize and Millet Research Institute (MMRI) Yusafwala Sahiwal, Punjab which has been contributing its services in terms of hybrid variety and development for maize, millet, and sorghum crops since 1958. Development of YSH-134 was carried out with a cross combination between two sorghum lines at MMRI (CMS 10A line * YSS98R). ABR system was utilized to develop YSH-134 for which A-line is maintained through pollination of B-line each time.

Multiple crosses were made with CMS10 in the past to identify the best combination with restoration ability. This cross was identified as a good yielder and restorer in 2017. Further evaluation was carried out to check the stability in this combination. After stability analysis under station trials, seed increase of CMS A-line and restorer YSS-98 was carried out to produce a higher amount of seed to send for national testing. The breeding flow chart of YSH-134 with ABR system is fetched in diagram.



Afterward, the pure seed of the new hybrid was used to evaluate its performance initially through station trialing during 2018 and 2019. After clearing the initial testing, third-party evaluation for the hybrid was conducted through National Coordinator, Pakistan Agriculture Research Council (PARC) Islamabad. The adaptability of the candidate line was checked under National Uniform Yield Trials (NUYT) during 2020 and 2021. National trials were conducted at Yousaf-wala, Renala Khurd, Bahawalpur, and D.G. Khan and results were shared after the completion of compilation. Different morphological traits like plant height, 50% silking, Plant leaf area, grain yield, and stalk yield were measured at respective crop stages. The collected data were subjected to "analysis of variance" to test the significant differences in yield performance between candidate line YS-18 and check hybrid YS-16 under factors like Reps, Years, and varietal makeup. 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

Variation Studies

Variation in plant and yield traits like plant height, 50% silking, Plant leaf area, grain yield and stalk yield under Reps, Years and varietal effects was estimated assessed through ANOVA (Table 1).

Table 1. ANOVA on the effects of reps, Years and varieties for morphological and yield traits of YSH-134 and check Fakhar-e-Punjab

	DF	Days to 50% silk	Flag Leaf Area (cm)	Grain Yield per hac	Plant Height (cm)	Stalk Weight per hac
Rep	2	6.17 ns	20.22 ns	13110.71 ns	193.17 ns	3091134.46 ns
Years	2	4.5 ns	43.56 ns	32184.59 ns	563.17 *	6206292 ns
Variety	1	0.06 ns	4449.39 **	717105.73 *	5904.22 **	496389092.21 **
Years:Variety	2	0.72 ns	20.22 ns	39924.35 ns	15.39 ns	4483372.65 ns
Residuals	10	6.97	39.89	115073	109.23	5529645.7

¹ * Significance at 5% probability, ** Significance at 1% probability, ns: non-Significant

The results showed that there was no silking time difference caused among the two hybrids by any of the factors while plant height, flag leave area, grain, and stalk yield were varied due to varietal differences. This indicated the YSH-134 and Fakhar-e-Punjab differed in their potential of the mentioned traits. Differences for while plan height and flag leave the area and stalk yield were highly significant with only 1% probability to vary while variations among grain yield were at significant levels.

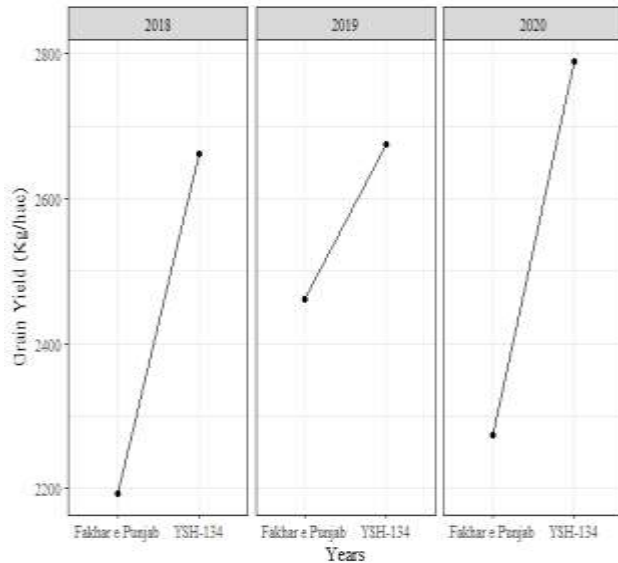


Figure 1: Grain Yield Response of YSH-134 and check Fakhar-e-Punjab during autumn 2018-20

Estimation of grain yield between the two hybrids was graphically illustrated in Figure 1. It was observed that higher grain yield was produced by YSH-134 in three consecutive years 2018-20 as compared to Fakhar-e-Punjab. The average yield potential of YSH-134 across the years was 2708 kg/ha and of Fakhar-e-Punjab with 2309 kg/ha, thus YSH-134 secured 14% more yield benefit in these trials. YSH-134 maintained a range between 2661-2790 kg/hac and Fakhar-e-Punjab stood between 2193-2462 kg/hac.

Similarly, stalk yield difference was estimated for two varieties and graphically illustrated in Figure 2. It was observed that higher Stalk yield was produced by YSH-134 in three consecutive years 2018-20 as compared to Fakhar-e-Punjab. The average yield potential of YSH-134 across the years was 40270 kg/ha and of YS-16 with 29705 kg/ha, thus YS-18 secured 26% more yield benefit in these trials. YSH-134 maintained a range between 338783-43506 kg/hac and Fakhar-e-Punjab stood between 28333-30540 kg/hac.

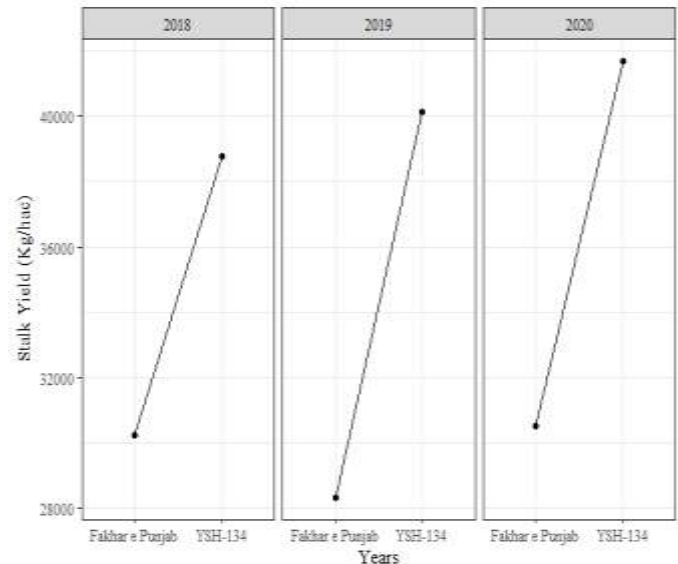


Figure 2: Stalk Yield Response of YSH-134 and check Fakhar-e-Punjab during autumn 2018-20

National Uniform Sorghum Yield Trial 2019

National Coordinator, Pakistan Agriculture Research Council (PARC) Islamabad convened this trial. National Uniform Sorghum Yield Trial 2019 was conducted at two locations in Punjab; Yousaf-wala and Bahawalpur with 12 candidate hybrids including YSH-134. The yield performance of these candidate hybrids is given table 2. YSH-134 maintained the 1st position in this trail and surpassed the check hybrids by sustaining 19 % yield increase. On an average of three locations, YSH-134 yielded 2701 kg / ha securing a maximum yield of 2950 kg / ha at the

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Yusafwala site. This hybridout yielded 12 other candidate varieties by maintaining a yield benefit

ranging from 10% to 253% on a cumulative average basis.

Table 2. National Uniform Sorghum Yield Trial Khairf 2019 (Grain Yield in Kg/ha)

Entries	Name	Bahawalpur	Yusawala	Average	% Increase
1	RARI. S-22	1460	2125	1792.5	80.42
2	MINTO	1256	838	1047	208.88
3	NAGINA	1738	3269	2503.5	29.18
4	LASANI	1569	3481	2525	28.08
5	EAGLE	2224	2181	2202.5	46.83
6	YSH-95 (check)	2453	2950	2701.5	19.71
7	YSH-134	1955	4513	3234	0.00
8	YSH-151	1729	2438	2083.5	55.22
9	YSH-132	2015	3819	2917	10.87
10	YSS-42	2627	2900	2763.5	17.03
11	SG-87	1336	494	915	253.44
12	GS-66	2938	2438	2688	20.31
CV%		9.63	18.08		---
LSD (0.05%)		316.55	802.19		---

National Uniform Sorghum Yield Trial 2020

National Uniform Sorghum Yield Trial 2020 was conducted at three locations in Punjab; Yousaf-wala, Bahawalpur, and D.G. Khan with 16 candidate varieties including YSH-134. The yield performance of these candidate lines is given in Table 3. YSH-134 maintained the 7th position in this trail and surpassed the other 11 candidate hybrids including check

hybrid (36 % yield increase). On an average of three locations, YSH-134 yielded 3891 kg / ha with securing a maximum yield 4022 kg / ha at the Bahawalpur site. This hybrid outyielded 11 other candidate varieties by maintaining a yield benefit ranging from 3.5% to 180% on a cumulative average basis.

Table 3: National Uniform Sorghum Yield Trial Kharif 2020 (Grain Yield Kg/ha)

Entries	Name	Yousafwala	Bahawalpur	D.G Khan	Mean	% Increase
1	Nagina	6500	3778	3067	4448.33	-12.53
2	R-3636	3622	3267	1333	2740.67	41.97
3	W-3535	4088	3067	1200	2785.00	39.71
4	Q.S-499	986	2467	711	1388.00	180.33
5	16GS2670	2884	3956	1511	2783.67	39.78
6	YSH-134	3651	4022	4000	3891.00	0.00
7	YSS-10	5389	4822	---	5105.50	-23.79
8	Eagle	5039	4311	2400	3916.67	-0.66
9	Sweet As	3590	2578	2000	2722.67	42.91
10	Omega-F1	6522	3733	2667	4307.33	-9.67
11	Fakhr-e-Punjab (CHECK)	3842	2556	2178	2858.67	36.11
12	14SB7001	2281	2467	2667	2471.67	57.42
13	YS-16 (CHECK)	4039	4089	3156	3761.33	3.45
14	Sweet Betty	3495	2000	2800	2765.00	40.72
15	YSH-132	5250	4356	2667	4091.00	-4.89
16	YSS-42	5649	3778	3778	4401.67	-11.60
CV%		12.45	16.11	8.29		
LSD (0.05%)		867.33	927.35	333.97		

YSH-134 was also tested in a total 9 trials from 2018 to 2020 against check Fakhar-e-Punjab. The candidate hybrid secured an overall benefit of 18 % in these entire trials and proved its supremacy over

check hybrid. The summary of trials is given in Table 4.

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Table 4. Overall Summary of Grain Yield Performance of YSH134 and Fakhar-e-Punjab in all 7 Trials

Year	Name of trial	Mumtaz-2022 (YSH-134)	Fakhar e Punjab (YSH-95) Check	% age increase over checks
Kharif 2018	Sorghum Station Yield Trial (MMRI)	3520.00	3417.00	+3.01
Kharif 2020	Sorghum Station Yield Trial (MMRI)	4175.00	3625.00	+15.17
Kharif 2019	National Uniform Yield Trial	3234.00	2701.50	+19.71
Kharif 2020	National Uniform Yield Trial	3891.00	2858.67	+36.11
Average		3705.00	3150.41	+18.50

Discussion

Sorghum is beneficial food and feed in many aspects its nutritional profile enriched with minerals, vitamins, fiber contents, and protein provides a good source of energy especially when used as cattle feed (Stefoska-Needham et al., 2015). Additionally, it can yield more with less input supply when compared to maize which is an exhaustive crop and thus provides an alternative opportunity for fodder production (Ndaru et al., 2020). New climate-smart and high-yielding varieties and hybrids with enhanced capability of adaption are the need of the hour to meet the food and feed in the face of challenges to food security issues (Hasan et al., 2018). Breeding of plant vegetative attributes and yield components provides an esteemed opportunity for betterment in many crops including sorghum plants (Ross et al., 1983). Our newly bred hybrid YSH-134 proved its adaptability to a diverse range of environments by maintaining a high grain yield and stalk yield benefits. Selection for medium plant height but with greater leaf area enabled this line to behave as dual-purpose hybrid (Dong et al., 2013).

This positive response is owing to the right selection and increasing frequency of desirable genes during each selection cycle (Anderson, 1971). Prominent improvement in grain and vegetative parts of YSH-134 was observed during station as well as national yield testing. This productivity enhancement is owing to fixed genetic improvements that were made during its breeding and this also validates the efficiency and accuracy of our breeding methodology. This early maturing hybrid with dark green and broad leaves has a good potential to penetrate a farmer's field. YSH-134 has a sweet juicy stem with 15-16% brix value and can increase milk production when used for cattle feed. It showed high adaptability across the regions with mild to hot environments.

The newly developed sorghum hybrid "YSH-134" is medium-statured grain and fodder-yielding and heat-resistant hybrid with medium maturity duration. Broad leaf along with stay green characters with palatable leaf structure furnish this hybrid with a hybrid of characters. It bears a long head with nutritionally enriched chalky grains and dark green

leaves set up grain and stalk yield potential up to 5000 kg/ha and 45000 kg/ha, respectively.

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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.

Funding Statement

Not applicable

Conflict of Interest

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

Authors Contribution

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



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