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SAEED-2023: A High-Yielding, Early-Maturing New Sorghum Hybrid Tailored for Punjab's Agro-Ecological Conditions

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Abstract

SAEED-2023 (YSH-134) is a dual-purpose sorghum hybrid developed at MMRI–Yusafwala Sahiwal, characterized by early maturity, medium plant height, high grain and stover yield, and resistance to foliar diseases. It was derived from a CMS-10 × YSS-98 cross using ICRISAT germplasm, the parental lines were developed through pedigree selection from Kharif 2007 to 2017, followed by the generation of 54 hybrid combinations in 2017–18 and their rigorous evaluation at MMRI and SRSS, D.G. Khan. Preliminary yield station trials conducted in Kharif 2018 and 2020 showed grain yield advantages of 3.01% (3520 vs. 3417 kg ha^{-1}) and 15.17% (4175 vs. 3625 kg ha^{-1}), respectively, over the check hybrid Fakhar-e-Punjab. Under natural *Helminthosporium* infection, SAEED-2023 scored 1.00 vs. 1.84 for the check, indicating 46% improved tolerance. Multi-location National Uniform Sorghum Yield Trials conducted at five sites across Punjab in 2019 and 2020 demonstrated average yield gains of 19.71% and 36.11%, respectively, with an overall increase of 18.50% (3705 vs. 3150.4 kg ha^{-1}) over the check. Agronomic optimization identified 75 cm × 15 cm spacing under irrigation yielding 5404 kg ha^{-1} and a fertilizer regime of 225:112:50 kg N:P:K ha^{-1} producing 3056 kg ha^{-1}. Proximate analysis confirmed competitive grain quality 9.69% protein and 84.1% NFE suitable for feed and industrial uses. Medium height (180–190 cm) reduced lodging risk, while 110–115-day maturity offered terminal heat escape. These findings recommend SAEED-2023 for broad cultivation across Punjab and similar environments to enhance sorghum productivity, sustainability and resource-use efficiency.

Keywords: *Sorghum bicolor*, Hybrid development, High grain yield, Disease tolerance, ICRISAT germplasm

Introduction

Sorghum (*Sorghum bicolor* L. Moench) ranks fifth among global cereals and is indispensable in Pakistan's semi-arid and arid zones, providing both grain and stover for feed and industrial uses (Liaqat *et al*., 2025; Rather *et al*., 2023). In the 2023–24 season, sorghum occupied 47000 ha nationwide yielding 39000 tons at 800 kg ha^{-1} (Pakistan Bureau of Statistics, 2024). Its stover, containing up to 16% soluble sugars (Brix), is highly valued as livestock fodder, while its grain serves as a suitable substitute for maize in poultry feed (Malabadi *et al*., 2022; Revilla Temiño *et al*., 2021). Despite this importance, yield stability remains hampered by heat stress, foliar diseases (*Helminthosporium* spp.), lodging and the limited availability of high-performing, locally adapted hybrids (Prasad *et al*., 2021). Addressing the yield gap in cereals due to heat stress requires both the introduction of exotic germplasm and the

development of breeding materials under high-temperature conditions to identify and produce heat-tolerant lines or hybrids (Yousaf *et al*., 2021; Mallhi *et al*., 2025)

Historically, Pakistan has released only one dual-purpose sorghum hybrid and many imported lines show inconsistent performance under Punjab's conditions (Mumtaz *et al*., 2018). Heterosis in hybrids enhances per-unit yield and promotes uniformity in maturity and plant height which are essential for mechanized harvesting and optimal market timing (Begna, 2022; Shehzad *et al*., 2019). However, the availability of locally bred sorghum hybrids has been limited, leading to a heavy reliance on exotic germplasm and imposing a significant economic burden (Pinho *et al*., 2022; Mumtaz *et al*., 2017). Therefore, there is a pressing need for a sorghum hybrid that combines early maturity, medium plant stature, strong disease resistance and high grain and stover yields to perform reliably across Punjab's diverse agro-ecological conditions (Mumtaz *et al*., 2019).

Pakistan is far behind in per hectare yield from major sorghum producers due to unavailability of high grain yield hybrids (Mumtaz *et al*., 2018). Therefore, it needs to bring high yielding hybrid cultivars along with tolerance to biotic and abiotic stresses in changing climate scenario (Ghani *et al.,* 2020). The current study carries out to share the success story of conventional breeding for development of high grain yield hybrid SAEED-2023 by MMRI, Yusafwla, Sahiwal.

Materials & Methods

Breeding and Developmental History

SAEED-2023 was developed at the Maize & Millets Research Institute (MMRI), Yusafwala, by crossing the cytoplasmic male-sterile line CMS-10 with the restorer line YSS-98 using diverse sorghum germplasm sourced from ICRISAT, India. Parental lines were planted in the institute's Kharif–2007 nursery and subjected to continuous pedigree selection through 2017 to attain uniformity in key agronomic traits. In Kharif 2017 and 2018, 23 and 31 crosses, respectively, were made; F_1 progenies were advanced into station yield trials at MMRI and the Sorghum Research Sub-Station (SRSS), DG Khan, using Fakhar e Punjab as the standard check. Promising hybrids were carried forward into adaptability trials under rainfed and irrigated conditions in Kharif 2019 and 2020, coordinated by the National Agricultural Research Centre (NARC), Islamabad.

Station Yield Trials

Preliminary evaluation of SAEED-2023 versus Fakhar e Punjab was conducted at the MMRI research farm in Kharif 2018 and 2020. A randomized complete block design (RCBD) with four replications was employed; each plot measured 5×3 meter and was sown at the recommended seed rate. Standard crop management (irrigation, weed control) was applied. At physiological maturity, panicles from the central 3 m² of each plot were hand-harvested, sun-dried, threshed and grain yield per plot was recorded and converted to kg ha^{-1} as described in below formula.

$$Grain\ weight\ kg\ (12\%) = Grain\ Wt\ (kg) \times \frac{100 - Grain\ Moisture}{88}$$

$$\text{Grain Yield (kg ha}^{-1}\text{) at 12\%} = \frac{Grain\ Weight\ (kg) of\ harvested\ plot\ at\ 12\%}{Harvested\ PLot\ Area\ (m2)} \times 10000$$

Disease Reaction

Foliar disease resistance was assessed under natural epiphytotic pressure of *Helminthosporium maydis* and *H. turcicum*. Twenty plants per plot were rated on a 1–5 severity scale (1 = highly resistant, 5 = highly susceptible) at the grain-fill stage. Disease scores were averaged across replications and seasons to obtain a mean severity value for each entry.

Agronomic Studies

Spacing Trials (Kharif 2017): To determine optimal plant population, an RCBD with four replications evaluated five plant spacing (5, 6, 7, 8 and 9 inches). Under irrigation, line sowing on raised beds used 75 cm row spacing × 15 cm intra-row; rainfed trials used 60 cm × 20 cm geometry.

Fertilizer Trials: An RCBD with four replications tested four N:P:K levels 0:0:0, 75:37:25, 150:75:50 and 225:112:50 kg ha^{-1}. Nitrogen (urea) was split 50% at sowing and 50% at tillering; full rates of P (SSP) and K (MOP) were applied at sowing.

National Uniform Sorghum Yield Trials

SAEED-2023 was advanced to multi-location trials under NARC coordination. In 2019, two locations were tested; in 2020, three locations, each following NUSYT protocols (RCBD with three replications, 5 m × 3 m plots, recommended agronomy), with Fakhar e Punjab as the check in all sites.

Quality Analysis

Grain samples from both station and national trials were cleaned, milled (1 mm sieve) and analysed for crude protein (Kjeldahl N × 6.25), crude fat (Soxhlet extraction), crude fibre (Weende method), ash (muffle furnace) and nitrogen-free extract (by difference) following AACC standard procedures.

Results

Grain Yield in Station Trials

In the preliminary station trials at MMRI–Yusafwala, SAEED-2023 consistently outperformed the standard hybrid Fakhar e Punjab. In Kharif 2018, under the RCBD with four replications, SAEED-2023 produced a mean grain yield of 3520 kg ha^{-1} compared to 3417 kg ha^{-1} for Fakhar e Punjab, representing a 3.01% advantage. In the subsequent Kharif 2020 trial conducted under the same design and management, SAEED-2023 achieved 4175 kg ha^{-1} versus 3625 kg ha^{-1} for the check, a 15.17% increase. This increase was consistent across all four replications, indicating robust performance under station agro-climatic conditions (Table 1).

Table 1: Comparative Grain Yield Performance of SAEED-2023 (YSH-134) with Checks (Kharif 2018 & Kharif 2020)

Year	Name of trial	Locations	Saeed-2023 (YSH-134)	Fakhar e Punjab (YSH-95) Check	Percent increase over check
Kharif 2018	Sorghum Hybrid Yield Trial	MMRI	3520	3417	**+3.01**
Kharif 2020	Sorghum Hybrid Yield Trial	MMRI	4175	3625	**+15.17**

Disease Tolerance

Under natural epiphytotic pressure from *Helminthosporium maydis* and *H. turcicum*, disease severity was assessed on a 1–5 scale. Across two seasons, SAEED-2023 exhibited a mean severity score of 1.00 (highly resistant), whereas Fakhar e Punjab averaged 1.84 (moderately susceptible), reflecting a 46% improvement in foliar disease tolerance. This enhanced resistance was observed consistently across all plots and both years, suggesting stable genetic defence against key sorghum foliar pathogens (Table 2).

Table 2: Disease Reaction of SAEED-2023 (YSH-134) in Two Years

Entry	Year 2018	Year 2019	Mean	Percent Tolerance
SAEED-2023 (YSH-134)	1	1	1	46
Fakhar e Punjab (Check)	2	1.67	1.84	-

Optimal Spacing & Fertilizer

Agronomic trials identified the best planting geometry (Table 3) and various nutrient doses (Table 4) for maximizing SAEED-2023 grain yield. In irrigated conditions, line sowing on raised beds at 75 cm row and 15 cm plant spacing delivered the highest grain yield of 5404 kg ha^{-1}. Under rainfed conditions, a configuration of 60 cm row and 20 cm plant spacing was adopted based on comparable performance. In fertilizer rate trials (Table 4), the highest yield (3056 kg ha^{-1}) was obtained with an N:P:K application of 225:112:50 kg ha^{-1} split between sowing and tillering for nitrogen demonstrating significant nutrient responsiveness (four replications).

Table 3: Determination of Optimum Plant Spacing for Sorghum Hybrid SAEED-2023 (YSH-134)

Treatment	Stand count (ha^{-1})	Plant height (cm)	Days to anthesis	No. of heads /ha	Total head weight (kg/ha)	Grain yield (kg/ha)
5inches	86667 a	173.5 c	71.25	52500ab	5908c	4321bc
6 inches	**71250 b**	**183.5 ab**	**70.50**	**56250a**	**7579a**	**5404a**
7 inches	58750 c	188.8 a	70.50	51250bc	6231bc	4671b
8 inches	53333 cd	186.5 a	72.50	47083c	6267b	3575d
9 inches	47500 d	177.3 bc	72.0	47917bc	6327b	417c
$LSD_{0.05}$	7467.9	8.32	NS	4872	329.57	358

Table 4: Various Fertilizer Doses Effect on Grain Yield of New Sorghum Hybrids SAEED-2023 (YSH-134) during Kharif 2017

Sr. No.	Treatments (kg/ha)			Grain yield (kg/ha)	Stand count	Days to 50% Silking	Plant Height
	N	P	K				(cm)
1	0	0	0	1300	80	86	174

2	125	62	50	2200	81	84	189
3	150	74	50	2433	81	84	192
4	175	87	50	2800	81	83	193
5	200	100	50	2756	81	82	200
6	**225**	**112**	**50**	**3056**	**80**	**82**	**199**
CV %				6.4	2.47	0.75	2.17
LSD %				126.69	N.S	1.134	7.532

National Trials Performance

SAEED-2023 was tested in the National Uniform Sorghum Yield Trials, coordinated by NARC–Islamabad, alongside 12 and 16 entries across multiple locations in Punjab during 2019 and 2020. In 2019 (Table 5), across two sites, it achieved an average yield of 3234 kg ha^{-1}, outperforming Fakhar-e-Punjab, which yielded 2701.5 kg ha^{-1}, a 19.71% advantage. In 2020 (Table 6), it evaluated at three sites, SAEED-2023 recorded 3891 kg ha^{-1} compared to 2858.7 kg ha^{-1} for the check, reflecting a 36.11% increase. Overall, across both years and all sites, SAEED-2023 maintained a strong performance with an average yield of 3705 kg ha^{-1}, surpassing the check's 3150.4 kg ha^{-1} and showing a consistent 18.50% improvement under standard trial protocols involving three replications per site (Table 7).

Table 5: National Uniform Sorghum Yield Trial Kharif 2019

Entries	Name	Grain Yield (kg/ha)			Percent Increase
		Bahawalpur	Yusafwala	Average	
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**
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	--	

Table 6: National Uniform Sorghum Yield Trial Kharif 2020

Entries	Name	Grain Yield (kg/ha)				Percent Increase
		Yusafwala	Bahawalpur	D.G Khan	Mean	
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	39.71
4	Q.S-499	986	2467	711	1388	180.33
5	16GS2670	2884	3956	1511	2783.67	39.78
6	YSH-134	3651	4022	4000	3891	0
7	YSS-10	5389	4822	--	5105.5	-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	**Fakhar-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	40.72
15	YSH-132	5250	4356	2667	4091	-4.89
16	YSS-42	5649	3778	3778	4401.67	-11.6
CV%		12.45	16.11	8.29	-	-
LSD (0.05%)		867.33	927.35	333.97	-	-

Table 7: Overall Summary of Grain Yield Performance of SAEED-2023 (YSH-134) in National Trials

Year	Name of trial	Locations	Saeed-2023 (YSH-134)	Fakhar e Punjab (YSH-95) Check	Percent increase over checks
Kharif 2018	Sorghum Hybrid Yield Trial	MMRI	3520	3417	3.01
Kharif 2020	Sorghum Hybrid Yield Trial	MMRI	4175	3625	15.17
Kharif 2019	National Uniform Yield Trial	Yusafwala & Bahawalpur	3234	2701.5	19.71
Kharif 2020	National Uniform Yield Trial	Yusafwala & Bahawalpur, DG khan	3891	2858.67	36.11

Grain Quality

Proximate analysis of grain samples from station and national trials revealed that SAEED-2023 matches or exceeds the nutritional profile of Fakhar e Punjab. SAEED-2023 contained 9.69% crude protein, 2.50% crude fat, 1.40% crude fibre, 2.25% ash and 84.1% nitrogen-free extract (NFE), whereas Fakhar e Punjab registered 9.46% protein, 2.81% fat, 1.77% fibre, 1.86% ash and 84.1% NFE. These results indicate that SAEED-2023 delivers competitive grain quality for feed and industrial uses (Table 8).

Table 8: Quality parameters of SAEED-2023 (YSH-134) and local and commercial checks

Varieties	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrates (NFE %)
SAEED-2023 (YSH-134)	9.69	2.50	1.40	2.25	84.1
Fakhar e Punjab	9.46	2.81	1.77	1.86	84.1

Evaluation of Different Weedicides for Weed Control in Sorghum

Herbicides were evaluated for better weed control in sorghum (Table 9). Treatments consisted of post emergence spray of Mesotrione + Atrazine (Flisto gold 550SC) @ 250, 300, 350 ml acre-1 and Atrazine + S-metolachlor (Primextra gold 720 SC) @ 250 and 300 ml acre-1. Control (no herbicide) treatment was maintained for comparison.

Table-9: Impact of weed control in sorghum through post emergence herbicide spray (Kharif 2018)

Treatments acre-1	Plant Stand ha-1	Weed DM (14 days of spray)	Weed DM (6 weeks of spray)	Heading (days)	Plant height (cm)	Grain yield kg/ha
Flisto Gold 250 ml	66667	191	102	74.7	183	4728 b
Flisto Gold 300 ml	62222	195	84	74.7	177	5306 a
FlistoGold 350 ml	63333	187	75	74.3	176	4222 cd
Primextra Gold 200 ml	62222	140	110	74.7	188	4356 c
Primextra Gold 250 ml	65556	137	123	74.3	187	3911 d
Control	62778	215	292	75	176	3039 e
LSD (5%)	NS	25.39	38	NS	3.58	313

Analysis of the data presented disclose that plant stand ha-1 was not affected by different treatments (P>0.05). After 14 days of the spray weed DM was minimum with Primextra gold @ 300 ml acre-1 while after 6 weeks of spray minimum weed DM was recorded with Flisto gold @ 350 ml acre-1. Maximum grain yield (5306 kg/acre was recorded at Flisto gold @ 350 ml/acre followed by Flisto gold @ 250 ml acre-1with grain yield of 4728 kg/ha. Lowest yield was recorded in the control treatment gave 3039 kg/ha.

Entomological Studies

Sorghum is vulnerable to several insect pests, including shoot fly, stem borer and aphids. These infestations can effectively be controlled through timely interventions such as (1) seed treatment (2) targeted insecticide applications (3) the use of insecticidal granules.

DESCRIPTION OF HYBRID

SAEED-2023 (YSH-134) is a medium-tall sorghum hybrid with a plant height of 180–190 cm and head length of 35–36 cm (Table 10). It flowers in 64–67 days and reaches maturity in 110–115 days, making it suitable for timely harvest. The hybrid has dark green leaves, a juicy stem and sweet taste, indicating its dual-purpose potential for grain and fodder. It shows a good Brix content of 15–16%, reflecting high sugar accumulation. With an average grain yield of 3,602 kg/ha and a potential yield of up to 6,250 kg/ha, it also delivers an impressive stalk yield potential of 30,540 kg/ha.

Table 10: Key Agronomic and Morphological Features of SAEED-2023

Features	**SAEED-2023 (YSH-134)**
Plant height (cm)	180-190
Head length (cm)	35-36
Days to 50% anthesis	64-67
Brix %	15-16
Maturity Days	110-115
Leaf color	Dark Green
Taste	Sweet
Stem Type	Juicy
Av. Grain Yield (kg/ha)	3602
Yield Potential (kg/ha)	6250

Stalk Yield Potential	30540

Recommended Production Technology for Sorghum Hybrid SAEED-2023

Summary of standard recommendations regarding irrigation, seed rate, plant population and other agronomic practices for this cultivar are given in Table 11.

Table 11: Key Agronomic Recommendations of SAEED-2023

Agronomic Recommendations	**Irrigated areas**	**Rain fed areas**
Sowing time	20th July to 8th August	21st June to 31st July
Sowing method	Line/bed sowing	Line sowing
Seed rate (kg/ha)	12 to 15	15 to 20
Row spacing (cm)	75	60
Plant spacing (cm)	15	20
Irrigations	6-May	-
Fertilizer Application	225-112-50	200-100-50

Discussion

SAEED-2023 exhibited a consistent and significant grain yield advantage over the standard hybrid Fakhar e Punjab (Hussain *et al.,* 2020) across both station and multi-location trials. In the MMRI station trials, SAEED-2023 out-yielded the check by 3.01% in 2018 and by 15.17% in 2020, demonstrating strong performance under controlled research-farm conditions. This superiority was further confirmed in National Uniform Sorghum Yield Trials, where SAEED-2023 averaged 3 705 kg ha^{-1} 18.50% above the check across five Punjab locations over two seasons. Hussain *et al*., (2020) revealed 33.1 % higher grain yield for the approved variety compared to the check in Adaptability/National Uniform Yield Trials. Such gains underscore the hybrid's genetic potential for enhanced productivity and suggest a robust capacity to capitalize on both optimal and variable environments (Begna, 2022; Pinho *et al*., 2022).

Key morphological and phenological traits of SAEED-2023 contribute to its agronomic success. The hybrid matures in 110–115 days, escaping terminal heat stress prevalent in Punjab's late Kharif season, while maintaining a moderate stature of 180–190 cm that minimizes lodging risk. A high stem-juice sugar content (Brix 15–16%) not only enhances

fodder palatability but also supports stay-green characteristics, ensuring photosynthetic activity during grain fill (Vermerris *et al*., 2024). Mumtaz *et al*., (2019) detected brix values ranging 8% to 18% in various sorghum hybrids. Lodging assessments confirmed NIL lodging in SAEED-2023 versus low incidence in Fakhar e Punjab, further safeguarding yield stability under wind and rain.

Enhanced foliar disease tolerance is another hallmark of SAEED-2023. Under natural infection by *Helminthosporium maydis* and *H. turcicum*, SAEED-2023 recorded a mean severity score of 1.00 (highly resistant) versus 1.84 (moderately susceptible) for the check a 46% improvement. This genetic resistance reduces dependency on fungicide applications (Khaskheli *et al*., 2025), lowers production costs and mitigates yield losses in disease-prone environments (Pandian *et al*., 2022) which are common under Punjab's warm, humid microclimates.

Optimized agronomic practices further unlock SAEED-2023's yield potential. Line sowing on raised beds at 75 cm × 15 cm under irrigated conditions yielded 5404 kg ha^{-1}, while the recommended 60 cm × 20 cm geometry performed well under rainfed trials. Nutrient response trials identified 225:112:50 kg N:P:K ha^{-1} split for nitrogen as the optimum fertilizer regime, delivering 3056 kg ha^{-1} and demonstrating efficient nutrient use. A similar recommendation regarding fertilizer dosage, sowing time, irrigation practices and suitable soil type for the sorghum variety YS-16 was also revealed by Hussain *et al*. (2019). Standardized production technology (sowing dates, seed rates, irrigation frequency) ensures farmers to get reliably good grain yield.

Grain quality analyses showed SAEED-2023 matches or exceeds the nutritional profile of Fakhar e Punjab, with 9.69% crude protein and 84.1% nitrogen-free extract (carbohydrates). Such quality parameters are critical for poultry and livestock industries, enabling the hybrid to serve both feed and industrial starch markets without compromise (Utama *et al*., 2023).

Given its high yield stability, disease resistance, favourable agronomic traits and grain quality, SAEED-2023 is well-suited for widespread cultivation. It is recommended for general cultivation not only in Punjab but also in Sindh, Khyber Pakhtunkhwa, Balochistan and Gilgit-Baltistan, where its early maturity and adaptability can address local production constraints. Overall, SAEED-2023 represents a significant advance in dual-purpose sorghum breeding for Pakistan's agro-climatic diversity.

Conclusion

SAEED-2023 (YSH-134) integrates early maturity (110–115 days), medium height (180–190 cm) and robust foliar disease resistance, resulting in consistent yield advantages over Fakhar-e-Punjab in both station (3.01% in 2018; 15.17% in 2020) and national uniform trials (18.50% overall) across Punjab's agro-ecologies. The hybrid's high Brix content and optimized agronomy (75 × 15 cm spacing; 225:112:50 kg N:P:K ha^{-1}) further contribute to its dual-purpose value for grain and fodder, achieving yields up to 5 404 kg ha^{-1} under irrigated conditions. A mean disease severity score of 1.00 versus 1.84 underscores its 46% greater tolerance to *Helminthosporium* spp. Given its agronomic stability, disease resilience and grain-fodder synergy, SAEED-2023 is recommended for broad adoption in Punjab and similar environments to enhance sorghum productivity and resource-use efficiency.

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Conflicts of Interest

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

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