INSIGHTS-JOURNAL OF
LIFE AND SOCIAL SCIENCES

INSIGHTS-JLSS
Insights-Journal of Life and Social Sciences

GUAR VARIETY "BR-22": A STEP TOWARDS MAXIMIZING AGRICULTURAL POTENTIAL

Original Article

Rashid Minhas[1], Mashal Rehman*[1], Muhammad Zubair[2], Muhammad Shah Jahan Bukhari[1], Muhammad Imran Akram[2], Rahmat Ullah[1], Abdul Jabbar[3], Ahmad Hussain[3], Sana Ullah[4], Mahreen Khalid[2]

[1]Agricultural Research Station, Bahawalpur, Punjab, Pakistan.
[2]Regional Agricultural Research Institute, Bahawalpur, Punjab, Pakistan.
[3]Fodder Research Institute, Sargodha, Punjab, Pakistan
[4]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Punjab, Pakistan.

Corresponding Author: Mashal Rehman, Agricultural Research Station, Bahawalpur, Punjab, Pakistan, mashal.rehman2210@gmail.com

Conflict of Interest: None

Grant Support & Financial Support: None

Acknowledgment: Funds from ADP project scheme No. 6598, "Exchange and development of fodder germplasm resistant to biotic and abiotic stresses," are acknowledged by the authors. For their assistance and support in conducting multi-location studies at respective Institutes, we are grateful to the Research Institutes listed in Tables 4, 5, and 6. Additionally, we appreciate the germplasm provided for this experiment by the BCI-PGRI, NARC Islamabad.

ABSTRACT

Guar is a summer annual legume that blooms in drought conditions and is well-suited to the arid as well as semi-arid regions of Pakistan. Guar gum, derived from guar seeds, is a vital product with diverse applications across various industries worldwide. Due to more importance of guar crop and its guar gum contents, there was a need to develop a high-yielding, short-duration, and early-maturing guar variety which will combats the present climatic conditions of the grown area and will be able to maintained the yield stability. The Agricultural Research Station in Bahawalpur is engaged in developing new crop varieties. The recently developed BR-22 (strain S-5885) is a high- yielding guar variety with broad genetic adaptability. Over a period of eleven years (2011–2022), guar varietal performance experiments were used to gather data on grain yield. Using a commercial variety as the standard, this strain outperformed the commercial variety in seven different yield performance experiments from 2013 to 2019. Additionally, the BR-22 variety consistently outperformed the check variety in agronomic trials involving planting date, fertilizer requirements, row spacing, and irrigation levels throughout the period of several study years. Distinguished character of BR-22 is that this variety has one main compacted stem same like BR-17 but also included 6-8 branches which enhances its biomass resulted in more fodder and seed yield. In comparison to earlier produced types, it also has a higher gum content (34.9%). Because of its early maturity and relative resistance to diseases and insect pests, this type is better suited for timely seeding of rabi crops such as chickpeas, wheat, and raya.

Keywords: Sustainable Agriculture, Climate Friendly, Soil Health, Early Maturing, High Guar Gum.

INTRODUCTION

Guar (*Cyamopsis tetragonoloba*), a drought-resistant summer annual legume, has become a crop of considerable commercial significance in arid and semi-arid areas. Historically regarded as a source of food, fodder, and green manure (Abidi *et al.,* 2015), guar has increasingly acquired significance in recent decades owing to its industrial uses, especially in guar gum manufacturing. This natural polymer serves as a lubricant, binder, thickener, and emulsifier, making it a crucial component in many industries. Guar gum's global economic significance has increased because to the oil and gas industry's growing need for it in hydraulic fracturing (Khan, 2024). Guar gum and its derivatives, which are used in the production of paper, medications, cosmetics, and food processing, are most commonly consumed and imported in the United States (Thombare *et al.,* 2016).

The agronomic importance of the crop surpasses its industrial uses. Guar, a leguminous plant, establishes symbiotic associations with rhizobia bacteria, enabling air nitrogen fixation. This trait not only lowers the need for nitrogen fertilizer but also enhances soil fertility for succeeding crops in the rotation system. The crop's capacity to flourish in water-scarce circumstances makes it especially important in areas experiencing heightened climatic uncertainty and water shortages.

Pakistan and India together produce 95% of the world's guar, with India contributing 80% and Pakistan 15% (Thombare *et al.,* 2016). In Pakistan guar cultivation is most extensive in Punjab (27%) and Sindh (25%) especially in Thal and Tharparker areas which contributes 75% guar production of total Pakistan. Current research showed that Bahawalpur, one of the main guar-growing regions, is witnessing a gradual increase in temperatures and a decline in the rainfall received, hence the need for drought-enduring crops (Sher *et al.,* 2022). These environmental factors point to the need for the release of guar cultivar's suited for the current climatic conditions.

Pakistan's exporters contribute almost one-third of the global guar production, and the following factors hamper the production of guar in Punjab: These include farming on substandard soils, bad seeds to plant on, poor information on better techniques, use of poor rich type seeds and poor capital. One main concern is that private sector has been largely inactive in seed production where the Punjab Seed Corporation is the only source of improved varieties. These challenge still exits despite a constantly rising global demand for guar and its derivatives. Three critical factors drive the development of new crop varieties: potential yield, detection of suitable practices and variety management and contours in various environments (Cobb *et al.,* 2013). Plant breeding is a continual process that uses different methods in order to develop improved cultivars, while targeting specific characteristics and consolidating the expression of such characteristics (Moose & Mumm, 2008).

Multi-location trials are very important in establishing new varieties. These trials dissect the genotype structures and explore which cultivar is stable under variable environments. Thus, such evaluations are vital for guar, for which flexibility to marginal environments and climate stability are major selection priorities (Braun *et al.,* 2010; Kundu *et al.,* 2022). These challenges have been overcome by the Agricultural Research Station, Bahawalpur by introducing a new guar variety known as BR-22 whose agronomic behaviors are desirable. Selected from the gene pool PGRI- 24285, through single plant selection, the variety BR-22 was developed with high yield potential, drought tolerance and disease resistance.

This study gives a detailed assessment of BR-22 based on the extended field test carried out for several years across various areas. Agronomic performance, management practices and quality standards for industrial processes all fall under analysis by this tool. The outcome of this study suggests that BR-22 possesses the potential to address the existing limitations in the production systems and fulfill the needs of stakeholder farmers and industries; the research, therefore, represents a major advancement in terms of improving the yield and sustainability of guar crop in Pakistan.

MATERIAL AND METHODS

The original site of the experiment was Agricultural Research Station, Bahawalpur, Pakistan that is situated in the Southern region of Punjab Province, the institute covers an area of 24,730 square kilometres, with latitudes between 27°48′N and 29°49′N and longitudes between 70°55′E and 72°49′E. The climate of Bahawalpur district is severe, with summer temperatures as high as 49 °C and dry, frigid winters that drop below 6 °C. It is situated in one of the driest areas of Pakistan. The plain area, desert area, and riverain area are the three distinct physiographic units that make up the district. pH, EC, and Zn values of the sandy loam-textured soil under investigation were 8.4, 2.6 dS m^{-1}, and 1.42 ppm, respectively (Mahmood *et al.,* 2024).

Breeding history: Guar variety "BR-22," coded as "S-5885," was selected from a single plant from the guar gene pool Line No. "PGRI 24285" of Agricultural Research Station, Bahawalpur based on factors such as plant structure, number of branches per plant, days to maturity, 1000 seed weight (g), drought, disease, and insect pest resistance. The development lineage of the BR-22 guar variety is shown in Table-1(g), drought, disease, and insect pest resistance. The development lineage of the BR-22 guar variety is shown in Table-1.

Table 1. The development lineage of the BR-22 Guar variety

Sr. No.	Year	Generation / Trial	V. Code
1	2011-12	Single Plant Selections	S-5885
2	2012-13	Selection of superior progeny lines of guar	-do-
3	2013-14	Preliminary Yield Trials (A-Trial)	-do-
4	2014-15	Regular Yield Trials (B-Trial)	-do-
5	2016-17	Advance Yield Trials (C-Trial)	-do-
6	2017-18	Zonal Trials, NUGYT, DUS	-do-
7	2018-19	Zonal Trials, NUGYT, DUS	-do-
8	2021-22	Spot Examination	-do-

Breeding Method and Procedure: Single plant selections were made using the pure-line selection approach, which vast quantities of unimproved material as the breeder's resources. From the seeds of each chosen plant, a progeny row was sown. Rows with higher performance were chosen. Based on yield and other characteristics, the chosen rows were examined in duplicated trials. For additional testing, the rows with higher yielding and better-performing characters were chosen. Procedure of pure-line selection method is shown in Fig 1.

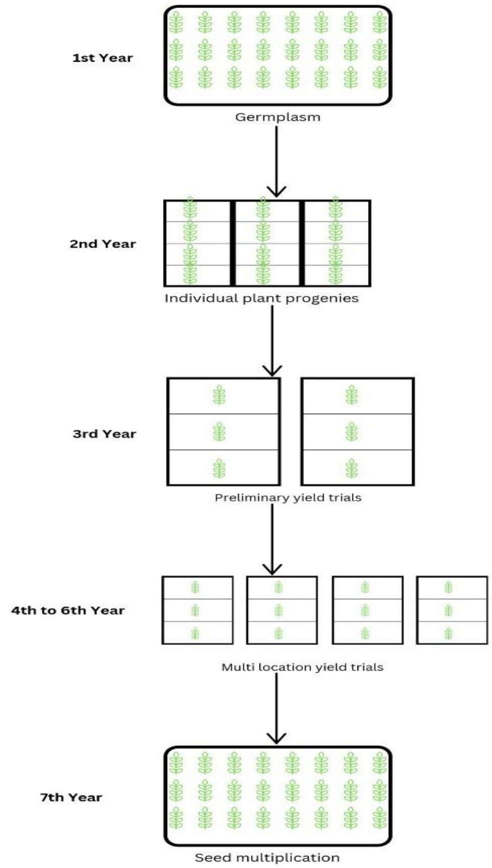

Figure 1Pure-line selection method in Guar

Evaluation Trials: The guar varietal performance trials, which lasted for eleven years in a row (2011–2022), provided yield statistics (grain yield). Commercial cultivar (check variety) and advance lines were evaluated in the initially conducted trials which involved 120 genotypes at 9 different locations. Agronomic trials were also conducted to determine the potential of new guar variety via different trials which included i.e. Trial of the sowing dates, Water regimes testing of genotypes (which includes irrigated or drought experiments), Fertilizer's requirement, Row spacing trials, The experiment was either done for grain exclusively or for both grain and grazing purposes.

Trials for this investigation were carried out at Agricultural Research station, Bahawalpur and in farmers' fields. The salient traits of the variety in comparison of check variety are given as in Table 2. The difference of plant structure of BR-22 & BR-17 (Check) variety is shown is Figure 2 and 3.

Table 2. Salient characters of Guar variety "BR-22"

Characters	BR-22	BR-2017 (Check)
Plant surface	Hairy	Hairy
Plant height (cm)	130-140	150-160
No. of branches per plant	06-Aug	01-Jan
Days to 50% flowering	55-60	50-55
Days to maturity	115-125	110-120
Pods plant^{-1}	250-280	200-230
Seed size(boldness)	Bold	Medium bold
No. of Seeds per pod	8-10	6-7
1000 seed weight (g)	32	30
Seed Yield Potential Kg ha^{-1}	2700	2400
Guar Gum (%age)	35.29	33.71
Crude Protein (%age)	32.25	30.75

=

	
BR-22	**(BR-17 Check Variety)**

Figure 2 Difference of Plant structure of BR-22 & BR-17(check) variety.

Figure 3 Difference of plant structure of BR-22 & BR-17(check) variety at maturity.

RESULTS AND DISCUSSION

Station Yield Trials

The variety was tested in Preliminary Guar Yield Trial (A-Trial), Regular Guar Yield Trial (B-Trial) and Advance Guar Yield Trial (C-Trial) at Agricultural Research Station, Bahawalpur from 2013-14 to 2015-16 and the results are given (Table 3). In the 2013-14 A-Trial, S-5885 yielded 2550 kg/ha, marking a 64.94% increase over BR-99 (1546 kg/ha) (Figure 4). . This trend continued in 2014-15 B-Trial (2599 kg/ha vs. 1845 kg/ha, 41.25% increase) and 2016-17 C-Trial (2703 kg/ha vs. 1740 kg/ha, 55.34% increase) (Table 3). The LSD (0.05) values confirmed the statistical significance of these differences.

The enhanced performance of BR-22 can be attributed to its improved morphological traits. Its compact main stem with 6–8 branches likely contributed to higher biomass and harvest efficiency (Minhas *et al.,* 2021). The stable and superior performance across years indicates its adaptability and higher productivity potential, especially valuable under fluctuating climatic conditions prevalent in semi-arid regions like Bahawalpur.

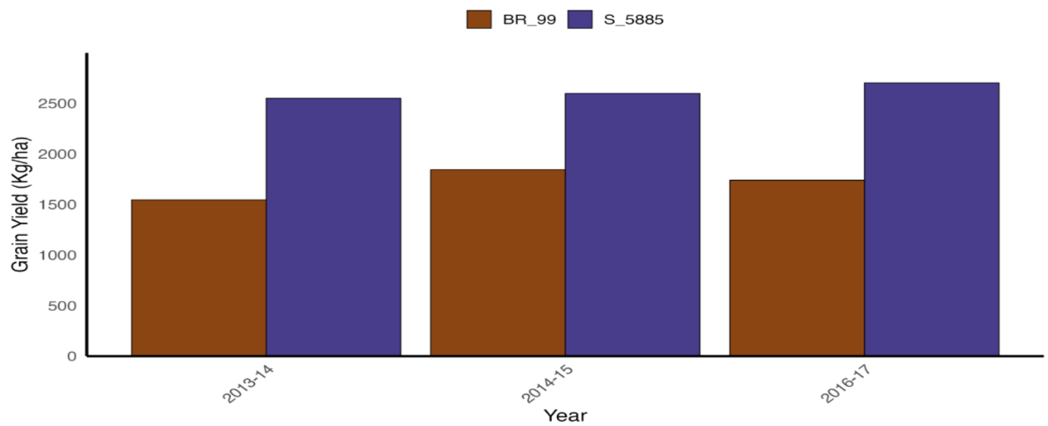

Figure 4 Station Yield Trials from year 2013-14 to 2016-17

Zonal Yield Trials

In the two-year zonal trials (2017-18 and 2018-19) across ARS Khanewal, Karor, and Bahawalpur, BR-22 consistently out-yielded BR-2017. In 2017-18, BR-22 averaged yield of 1766 kg/ha-21.21% more than the check variety. In 2018-19, it maintained superiority with 1910 kg/ha, a 17.25% increase (Table 4). The highest yield was recorded at ARS Bahawalpur, indicating BR- 22's adaptability and strong yield stability (Figure-5).

This consistent performance across locations supports BR-22's broad adaptability and suitability for large-scale cultivation. The stable yields across agro-climatic zones highlight the variety's potential under varied environmental stresses and its reliability for

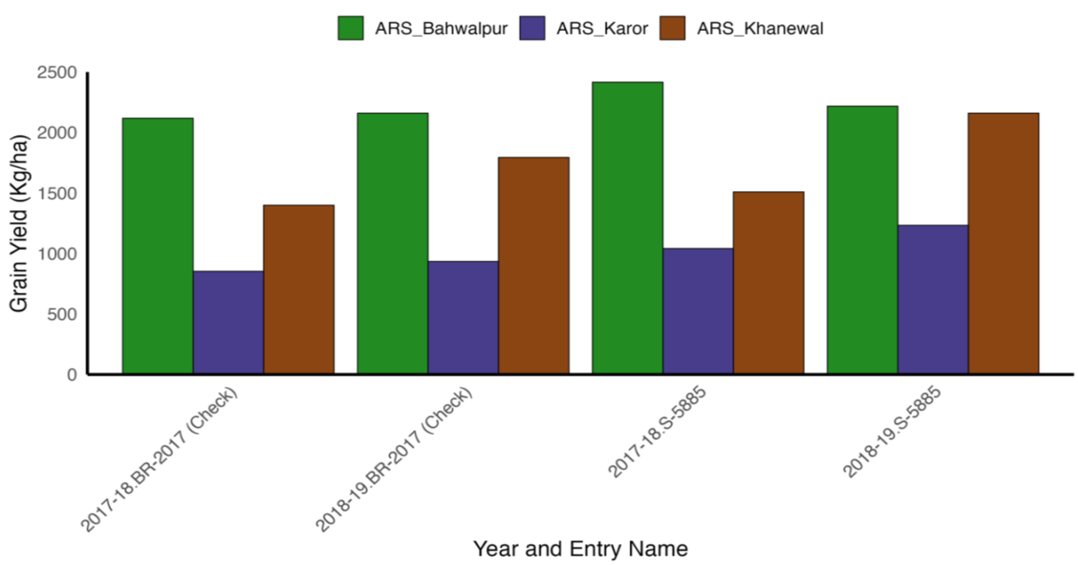

Figure 5 Zonal Yield Trial from year 2017-18 to 2018-19

farmers.

National Uniform Guar Yield Trials (2017–2018)

Evaluations across diverse agro-ecological regions (Table 5 and 6) revealed BR-22's yield advantages ranging from 1.44% to 18.23% over BR-2017. In 2017, BR-22 averaged 1816 kg/ha compared to BR-2017's 1536 kg/ha. In 2018, although the yield advantage was lower (2043 vs. 2014 kg/ha), it still showed performance consistency across locations. (Figure 6 & 7).

These results emphasize BR-22's flexibility and yield resilience under diverse agro- environmental conditions. Multi-location trial success strengthens the case for its adoption under varying climatic and soil conditions, crucial for ensuring food security amid climate variability (Khalid *et al.,* 2017).

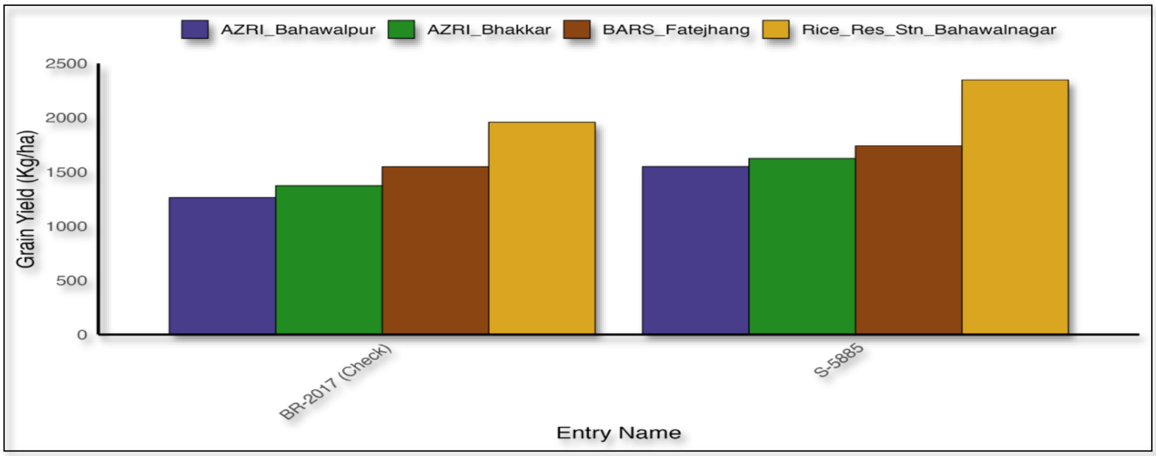

Figure 6 National Uniform Guar Yield Trial (2017)

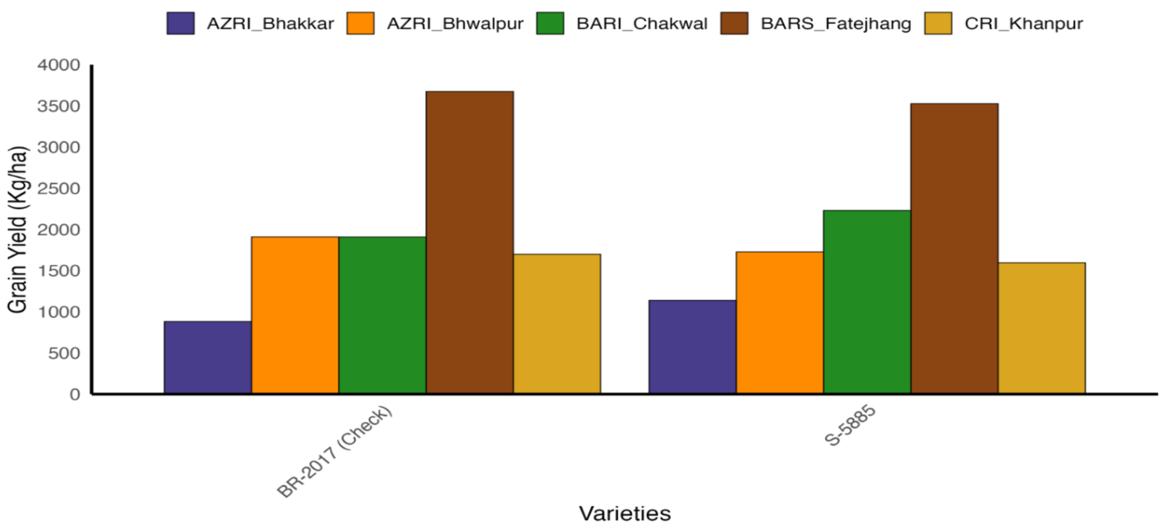

Figure 7 National Uniform Guar Yield Trial (2018)

Sowing Dates Trials

The sowing date trials from 2017–18 and 2018–19 revealed that sowing on June 1st and June 15th yielded the highest grain outputs (2685 and 2592 kg/ha respectively) (Table 7). Although the statistical variation between these two dates was negligible, sowing between May 15 and June 15 significantly outperformed than other sowing dates (Figure-8).

Optimal performance during this gap indicates BR-22's sensitivity to planting time, which aligns with regional climate trends of increasing temperatures and reduced rainfall. Sowing during this gap ensures optimal vegetative growth and flowering synchronization with favorable environmental conditions (Minhas *et al.,* 2021).

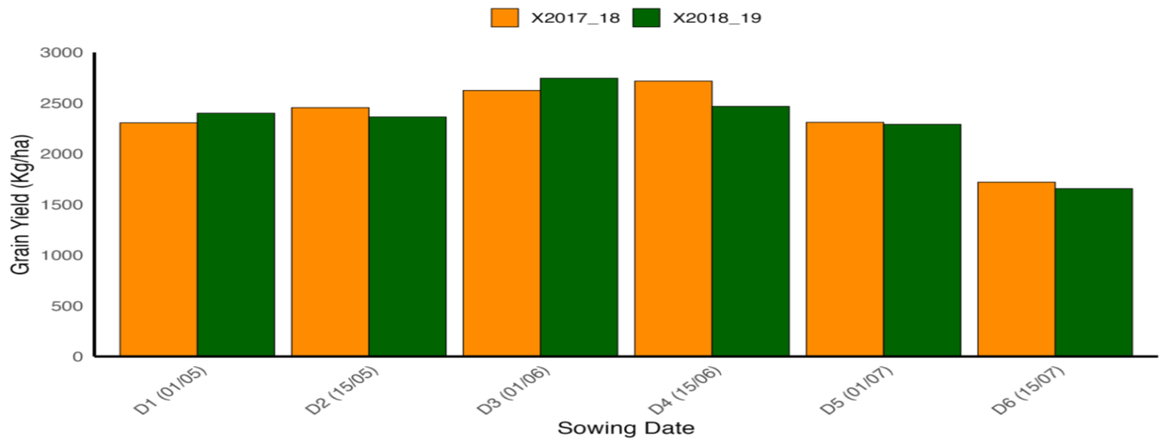

Figure 8 Effect of Planting/Sowing Dates on yield of S-5885

Fertilizer Dose Trials

Ten NPK combinations tested over two years showed that BR-22 produced the highest average yield (2699 kg/ha) under the 30:60:60 kg ha^{-1} regime (Table 8) (Figure-9). Lower or higher doses showed either reduced efficiency or yield penalty. This optimal nutrient requirement reflects BR- 22's efficient nutrient use capacity. Balanced fertilization at 30:60:60 ensures maximum biomass accumulation and pod development while preventing resource wastage—important for sustainable crop production (Vara,

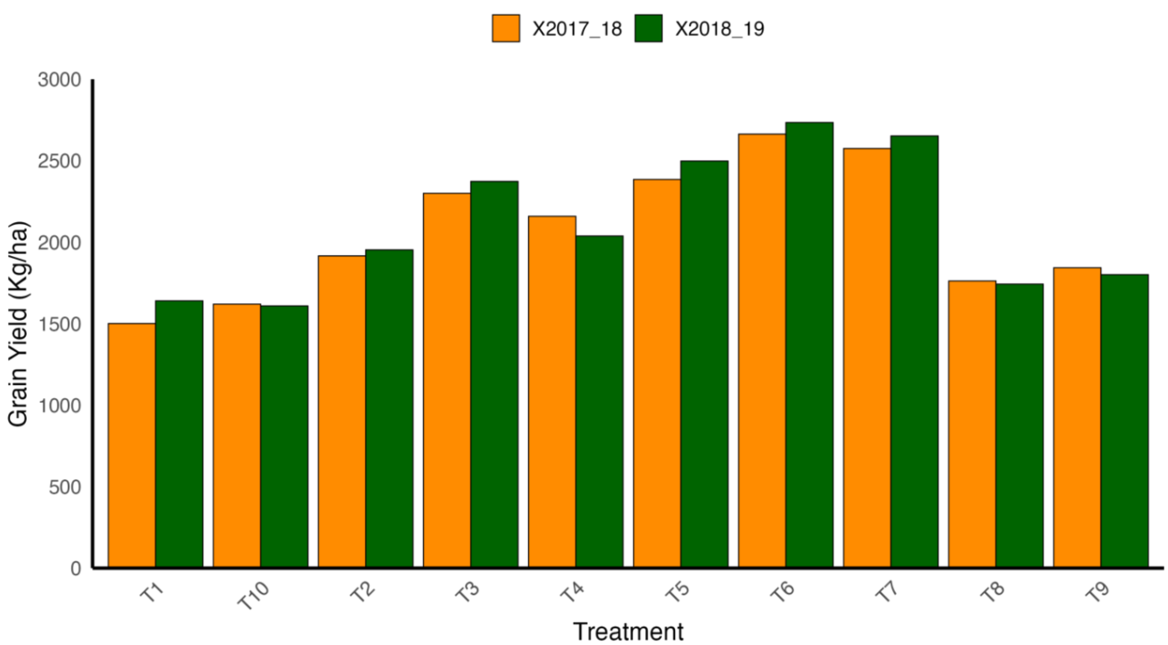

Figure 9 Results of NPK fertilizer trial

2021).

Row Spacing Effects Trials

Row spacing trials revealed the best grain yield (2710 kg/ha average) was achieved with 45 cm spacing (Table 9) (Figure-10). Wider or narrower spacing reduced yield due to suboptimal canopy architecture and inter-plant competition.

This spacing ensures ideal plant population, canopy light interception, and aeration, which are critical for photosynthetic efficiency and disease avoidance (Brightwood *et al.,* 2023). Recommendations for 45 cm row spacing offer farmers a simple

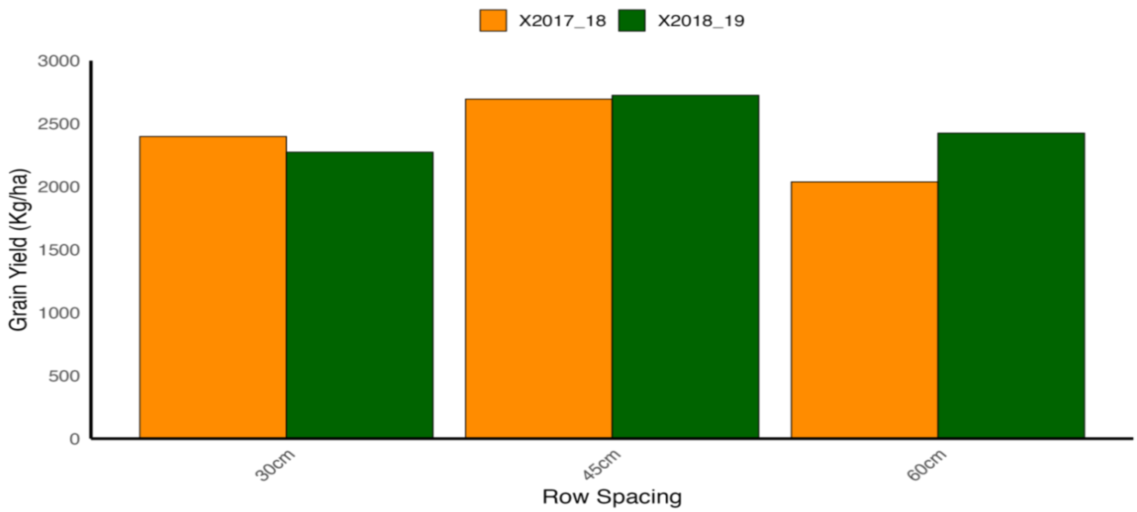

Figure 10 Effect of Row Spacing on yield of S-5885

agronomic adjustment for maximizing productivity.

Irrigation Requirement Trials

The findings of this study underscore the critical role of irrigation timing in maximizing the yield potential of Guar variety BR-22, particularly in semi-arid regions where water scarcity is a prevailing constraint. The three-irrigation schedule applied at 35 days after sowing (DAS), flowering, and pod formation stages resulted in the highest average yield (2670 kg/ha), significantly outperforming both the single-irrigation and rainfed (no-irrigation) treatments (Table 10) (Figure-11). This highlights the importance of meeting the crop's water demand during its most sensitive growth stages.

The superior performance of BR-22 under this schedule can be attributed to enhanced water availability during the crop's critical physiological phases, particularly flowering and pod formation, which are directly linked to reproductive success and seed development. Adequate moisture during these periods likely supported better flower retention, pod setting, and seed filling, ultimately leading to increased biomass and grain yield.

Insect Pest Incidence Trials

Entomological assessments during 2017–18 and 2018–19 indicated low infestation levels for sucking pests on BR-22, especially jassids and whiteflies (Table 11) (Figure-11). Compared to BR-2017, BR-22 exhibited better tolerance. Improved pest resistance reduces the need for chemical interventions, contributing to environmental safety and cost savings for farmers. This trait enhances BR-22's appeal as a low-input, sustainable variety.

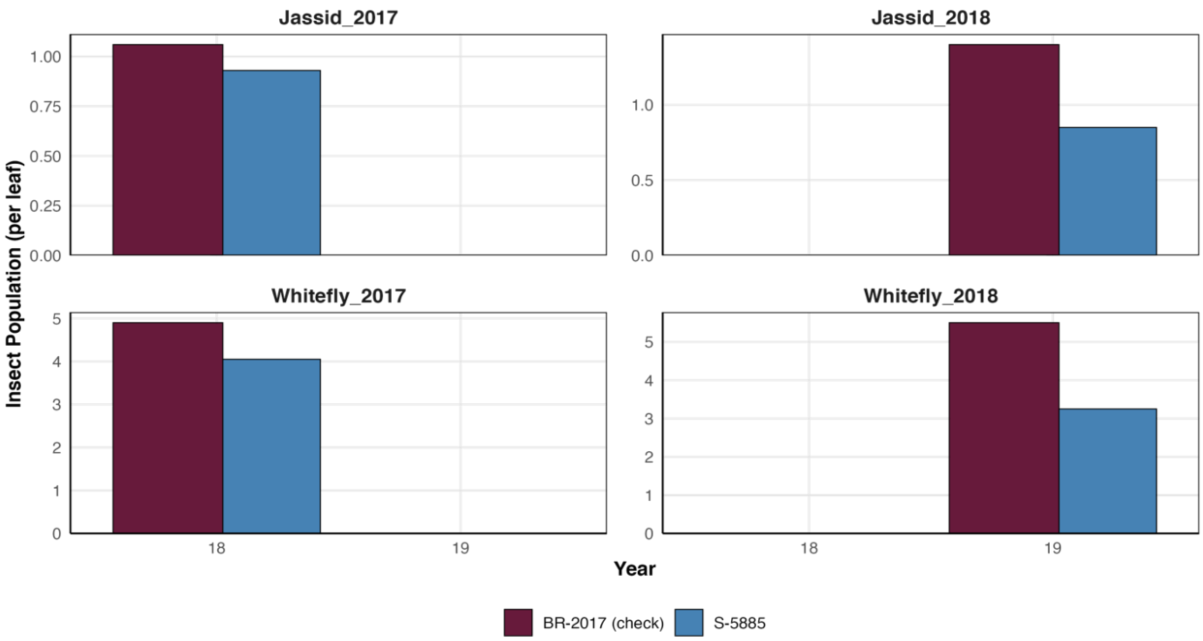

Figure 11 Response of S-5885 against insect pests attack

Pathological Studies

Pathology data revealed that BR-22 had moderate resistance to bacterial blight and alternaria blight, whereas BR-2017 was moderately susceptible to bacterial blight (Table 12) (Figure-12). The disease resilience of BR-22 provides additional yield stability, particularly under humid or disease-prone conditions. Moderate resistance reduces disease management costs and improves the environmental footprint of crop production systems.

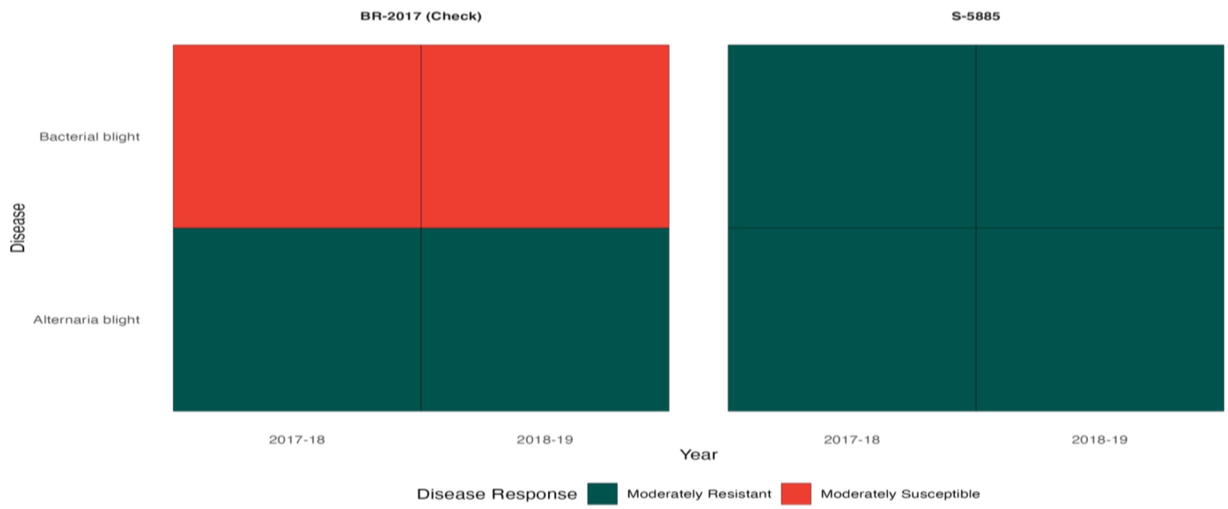

Figure 12 Response of S-5885 against diseases

Quality Analysis

Chemical analysis by the Post-Harvest Research Centre (AARI, Faisalabad) confirmed that BR-22 has a higher gum content (35.29%) compared to BR-2017 (33.71%), along with superior protein (32.25%) and carbohydrate content (40.16%) (Table 13).

The increased gum content enhances BR-22's value for industrial applications, while high protein makes it suitable as a feed source, confirming its dual-purpose utility. This adds a strong economic incentive for adoption by growers (Minhas *et al.,* 2021).

Table.3 Station Yield Trials Results (2013-14 to 2016-17)

Year	Trial	Yield Kg/ha BR-22	Yield Kg/ha BR-99 (Check)	% increase over check	LSD (0.05)
2013-14	A-Trial	2550	1546	64.94	216.0
2014-15	B-Trial	2599	1845	41.25	185.3
2016-17	C-Trial	2703	1740	55.34	286.0

BR-22 was evaluated three year as A-Trial: Preliminary Yield Trial, B-Trial: Regular Yield Trial, C-Trial: Advance Yield Trial

Table 4. Zonal Yield Trial Results (2017-18 to 2018-19)

Years	Entry Name	Locations Yield (Kg ha^{-1}) ARS, Karor	ARS, Khanewal	ARS, Bahwalpur	Average Kg ha^{-1}	%age increase over check
	BR-22	1041	1509	2416	1766	21.21%
2017-18	BR-2017	853	1399	2118	1457	-
	BR-22	1233	2160	2218	1910	17.25%
2018-19	BR-2017	934	1794	2160	1629	-

Table 5. National Uniform Guar Yield Trial Results (2017)

Entry Name	Grain Yield ($Kg\ ha^{-1}$) BARS, Fatejhang	AZRI Bahawalpur	AZRI Bhakkar	Rice Res.Stn.BWP	Avg.	%age Increase over check
BR-22	1741	1550	1624	2348	1816	**18.23%**
(BR-17 Check)	1549	1263	1373	1958	1536	-

Table 6. National Uniform Guar Yield Trial Results (2018)

Entry	Locations/GrainYield ($Kg\ ha^{-1}$)						%age
Name	BARS, Fatejhang	AZRI Bhakkar	BARI, Chakwal	CRI, Khanpur	AZRI Bhwalpur	Avg.	Increase Over check
BR-22	3525	1139	2230	1595	1726	2043	**1.44%**
(BR-2017 Check)	3674	1908	1698	1909	2014	-	
LSD (0.05)	299.4	379.3	351.4	151.1	216.3	-	-

Table 7. Effect of Planting/Sowing Dates on Grain Yield of BR-22

Sr. No.	Sowing Dates	Grain Yield ($Kg\ ha^{-1}$) 2017-18	2018-19	Average
1	D1 (01/05)	2305	2400	2353
2	D2 (15/05)	2455	2363	2409
3	D3 (01/06)	2625	2745	2685
4	D4 (15/06)	2717	2467	2592
5	D5 (01/07)	2310	2290	2300
6	D6 (15/07)	1720	1656	1688
	LSD (0.05)	**193.60**	**245.5**	

Table 8. Results of NPK fertilizer trial of BR-22 variety

Treatments	N ($Kg\ ha^{-1}$)	P ($Kg\ ha^{-1}$)	K ($Kg\ ha^{-1}$)	Grain Yield 2017-18	($Kg\ ha^{-1}$) 2018-19	Average
T-1	0	0	0	1501	1640	1571
T-2	15	30	30	1916	1953	1935
T-3	15	60	30	2300	2373	2337
T-4	15	90	30	2159	2038	2099
T-5	30	30	60	2385	2498	2442

T-6	30	60	60	2663	2734	2699
T-7	30	90	60	2575	2652	2614
T-8	45	30	90	1762	1743	1753
T-9	45	60	90	1843	1801	1822
T-10	45	90	90	1620	1609	1615
			LSD (0.05)	**167.56**	**323.9**	

Table 9. Impact of Row Spacing on the Yield Performance of BR-22

Sr. No	**Treatment (Row Spacing)**		**Average Yield (Kg ha^{-1})**		**Average Yield (kg ha^{-1})**
			2017-18	2018-19	Kg ha^{-1}
1	T1	30cm	2398	2274	2336
2	T2	45cm	2695	2725	2710
3	T3	60cm	2038	2425	2232
		LSD (0.05)	**231.92**	**337.26**	

Table 10. Response of BR-22 under various irrigation levels

Sr. No.	**Treatments/ Irrigation levels**		**Grain Yield 2017-18**	**Kg ha^{-1} 2018-19**	**Average**
1	T1	01 irrigation at 35 days of sowing	1915	1825	1870
2	T2	01irrigation at flowering stage	1795	1700	1748
3	T3	02 irrigations at 35 days of sowing & at flowering stage	2245	2078	2162
4	T4	T3+ 01 irrigation at pod formation stage	2710	2630	2670
5	T5	No irrigation (Control)	1667	1589	1628
	LSD (0.05)		**325.0**	**287.0**	**-**

Table 11. Insect pest incidence per leaf on Guar varieties (2017–2019)

Year	**Variety**	**Jassid per leaf**	**Whitefly per leaf**
2017–2018	**BR-22**	0.93	4.05
	BR-2017 (Control)	1.07	4.92
	LSD (0.05)	0.23	1.21
2018–2019	**BR-22**	0.85	3.25
	BR-2017 (Control)	1.4	5.5
	LSD (0.05)	0.36	1.89

Table 12. Pathological/ Disease Resistance Observations (2017–2019)

Year	Variety	Bacterial Blight	Alternaria Blight
2017–2018	**BR-22**	Moderately Resistant	Moderately Resistant
	(BR-2017 Check)	Moderate Susceptible	Moderate Resistant
2018–2019	**BR-22**	Moderately Resistant	Moderately Resistant
	(BR-2017 (Check)	Moderately Susceptible	Moderately Resistant

Table 13. Results of Chemical Analysis of Guar

Entry Name	Gum (%)	Protein (%)	Carbohydrates (%)
BR-22	35.29	32.25	40.16
BR-2017 (Check)	33.71	30.75	38.90

Source: Post-Harvest Research Centre, Ayub Agricultural Research Institute, Faisalabad.

CONCLUSION

Guar variety BR-22 exhibits a high gum content of up to 35.29% and a crude protein level of 32.25%, surpassing the check variety. It also demonstrates a higher yield potential compared to existing guar varieties. Due to its greater biomass, it can be cultivated for dual purposes—both seed and fodder production. Additionally, it shows relative resistance to insect pests and diseases. As an early maturing crop, it allows for the timely sowing of subsequent Rabi crops such as wheat, raya, and chickpea.

Conflict of Interest: The Authors declare that there is no conflict of interest

Author's Contribution Statements: RM, MR, IAKN, MZ, MSB, MIA, RU conducted and evaluated the experimental trial in field and selected the best genotype which later became approved from FSC & RD also from PSC for general cultivation in all over Punjab. MR & SU contributed to writing of this manuscript and editing of overall manuscript.

Acknowledgement: Funds from ADP project scheme No. 6598, "Exchange and development of fodder germplasm resistant to biotic and abiotic stresses," are acknowledged by the authors. For their assistance and support in conducting multi-location studies at respective Institutes, we are grateful to the Research Institutes listed in Tables 4, 5, and 6. Additionally, we appreciate the germplasm provided for this experiment by the BCI-PGRI, NARC Islamabad.

AUTHOR CONTRIBUTION

Author	Contribution
Rashid Minhas	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mashal Rehman*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Zubair	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Shah Jahan Bukhari	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Imran Akram	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Rahmat Ullah	Substantial Contribution to study design and Data Analysis

Author	Contribution
	Has given Final Approval of the version to be published
Abdul Jabbar	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Ahmad Hussain	Writing - Review & Editing, Assistance with Data Curation
Sana Ullah	Writing - Review & Editing, Assistance with Data Curation
Mahreen Khalid	Writing - Review & Editing, Assistance with Data Curation

REFERENCES

Abidi, N., S. Liyanage, D. Auld, R. Imel, L. Norman, K. Grover, S. Angadi, S. Singla and C. Trostle. 2015. Challenges and opportunities for increasing guar production in the United States to support unconventional oil and gas production. Hydraul. Fract. Impacts Technol. 207–226.

Braun, H.J., G. Atlin and T. Payne. 2010. Multi-location testing as a tool to identify plant response to global climate change. In: Clim. Change Crop Prod. 115–138. Wallingford UK: CABI.

Cobb, J.N., G. DeClerck, A. Greenberg, R. Clark and S. McCouch. 2013. Next-generation phenotyping: requirements and strategies for enhancing our understanding of genotype–phenotype relationships and its relevance to crop improvement. Theor. Appl. Genet. 126: 867–887.

Khalid, M.A.U.R., L.H. Akhtar, R. Minhas, S.J. Bukhari, M. Zubair and M.A. Iqbal. 2017. Screening of guar accessions [Cyamopsis tetragonoloba (L.) Taub.] for higher yield potential under irrigated conditions. Afr. J. Agric. Res. 12(37): 2788–2794.

Khan, M. 2024. Chemical and physical architecture of macromolecular gels for fracturing fluid applications in the oil and gas industry; current status, challenges, and prospects. Gels. 10(5): 338.

Kundu, B.C., S. Naznin, M.A. Kawochar, M.M. Islam, A. Al-Mahmud, M.N. Amin and K.D. Hossain. 2022. Selection of processing potato varieties through multi-location trials. Malays. J. Sustain. Agric. 6(2): 65–71.

Akhtar, M.S. and A.W. Chughtai. 2021. Evolution of new guar variety "BR-21" with high yield potential through pure-line selection. Egypt. J. Agron. 43(2): 207–214.

Mahmood, K., M. Rehman, I. Ali, R.I. Ahmed, A. Zafar, N. Kanwal and N. Manzoor. 2024. Analyzing wheat variety nawab-21 for agronomic, pathological and zinc biofortification attributes under multilocational trials. Agric. Sci. J. 6(2): 37–49.

Minhas, R., L.H. Akhtar, M. Zubair, M.S. Bukhari, M. Akram, R. Ullah and A.W. Chughtai. 2021. Evolution of new guar variety "BR-21" with high yield potential through pure-line selection. Egypt. J. Agron. 43(2): 207–214.

Moose, S.P. and R.H. Mumm. 2008. Molecular plant breeding as the foundation for 21st century crop improvement. Plant Physiol. 147(3): 969–977.

Sher, A., R. Calone, A. Sattar, M. Ijaz, B. Sarwar, A. Qayyum and L. Barbanti. 2022. Growth, yield and quality attributes of guar (*Cyamopsis tetragonoloba* L.) genotypes grown under different planting dates in a semi-arid region of Pakistan. Pak. J. Agric. Sci. 59(5): 757–763.

Thombare, N., U. Jha, S. Mishra and M.Z. Siddiqui. 2016. Guar gum as a promising starting material for diverse applications: a review. Int. J. Biol. Macromol. 88: 361–372.

Vara, M. 2021. Evaluation of guar varieties and guar production in Pakistan - Flood-Based Livelihoods Network. https://floodbased.org/download/guar-finding-report_sep2019-pdf/.

