

**PEARL-21: SIX ROWED, HIGH YIELDING, HEAT STRESS RESISTANT, AND EARLY MATURING BARLEY CULTIVAR**

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**Abstract** Pearl-21, an early maturing barley cultivar that was developed keeping in view the fluctuating climatic scenarios as drought stress is severely impairing the yield of crops in Pakistan. The exquisite genotypes were received from the International Center for Agricultural Research in the Dry Areas (ICARDA), Lebanon. The superior line was screened out from the international barley segregating population received from ICARDA. It was evaluated under code B-14035 in station yield trails for two years (2014-15 & 2015-16). It excelled by 15.26% and 7.38% in provincial barley yield trials during 2017-18 and 18.77% and 10.18% in national barley yield trials during 2018-19 in contrast to commercial checks Haider-93 and Sultan-17, respectively over four locations. It also presented encouraging results in rainfed yield trials. Pathological studies depicted that the proposed cultivar had exceptional resistance against rust diseases. Pearl-21 has plant height ranging from 95-99 cm with semi-erect growth habit both at the seedling and booting stage. It has a high tillering trend (140 productive tillers per meter). It took only 99-101 days to head while, 123-130 days for maturity. It bears 60-70 seeds per ear and has 34-38g thousand-grain weight. The prominent features it encompasses are drought and lodging tolerance and short duration. Due to encouraging steady performance for better grain yield, resistance against rusts, and quality Punjab Seed Council approved it in 2021 with the name "Pearl-21" for general cultivation in Punjab, Pakistan.

**Keywords:** Barley; short duration; early maturity;  $\beta$ -Glucan; rainfed areas; agro-climatic conditions

### Introduction

Pakistan is known as an agricultural country and agriculture is the backbone of its economy but still, more than 60% population is food insecure, and 50% of women and children are malnourished (FAO/WHO, 2003). The expected global warming and climate alteration will upsurge the incidence of drought which consequently causes agricultural crop output losses (Sallam *et al.*, 2019).

This needs to explore options to increase agricultural produce, such as the usage of marginal land and incorporation of more stress-tolerant crops (Iqbal, 2015). Barley is an annual crop grown under a range of environments from deserts to Himalayan peaks (Hayes *et al.*, 2003). In Pakistan, barley is mainly grown for grain and fodder purposes (Abbas *et al.*, 2016). But it is gaining popularity because of its nutritional profile as its usage helps to prevent type-2 diabetes and several chronic cardiovascular diseases due to a dietary fiber  $\beta$ -glucan.  $\beta$ -glucan lowers the postprandial glucose response and improves blood cholesterol levels. (Izydorczyk *et al.*, 1998; Henrion *et al.*, 2019). Studies have reported that barley had the highest proportion (2-20g) of  $\beta$ -glucan 65% of which is a water-soluble fraction

followed by oats that have 3-8g of  $\beta$ -glucan and 82% is water soluble. Other cereals contain a very low proportion of  $\beta$ -glucan like sorghum has 1.1-6.2 g, maize 0.8-1.7 g, wheat 0.5-1.0 g, *Triticum Turgidum* (Durum) 0.5-0.6 g, and the least is present in rice 0.13 g (Bacic *et al.*, 2009; Khoury *et al.*, 2012).

Barley can better withstand severe environments like drought, heat, and salinity (Rowe and Johnson, 1995; Kumar *et al.*, 2020). Barley is more salt tolerant among all cereals as it can use all the available soil water even in high salt concentrations. (Munns *et al.*, 2006; Gurel *et al.*, 2016). Furthermore, drought is one of the key challenges that hampers the yield and development of crops world-wide. However, barley can combat drought in a better way than other cereals. Early flowering in barley is the main reason for inbuilt tolerance in barley against abiotic stresses, which ensures the completion of reproductive phases like pollination, seed formation, and maturity at the proper time (Turner *et al.*, 2005; Zitzewits *et al.*, 2011).

Six-rowed barley tends to have higher protein contents than two-row barley which is generally better for food and feed. The newly developed

advanced line B-14035 is six-rowed barley which can grow and ripen in a shorter time than any other cereal. It also has a relatively short growth period and it is especially effective for late planting. Plant height is also not very tall which provides it comparable tolerance against lodging.

#### MATERIALS AND METHODS

Pearl 2021 was developed in 2020 at Wheat Research Institute, Faisalabad. The proposed genotype has parentage “Lignee527 / Aths // Lignee527 / NK1272 /6/ JLB70-01 /5/ DeirAlla106 // DL70 / Pyo /3/ RM1508 /4/ Arizona 5908/Aths // Avt /Attiki /3/ Ager” and pedigree ICB07-0050-0AP-0A-1A-0A-0A. This line was received from ICARDA’S nursery of International Barley Segregating Population (IBSP) and planted as 3<sup>rd</sup> filial generation during 2009-10 cropping season. In the subsequent years, this genotype was advanced to the next generations following the modified bulk pedigree method. From the F7 generation a uniform and stable line was selected based on high yield, resistance against rust and smut diseases and lodging, short stature, drought tolerance, and most significantly short duration and promoted in preliminary yield trials during 2014-15 coded as B-14035. In preliminary yield trials, genotypes were planted following a randomized complete block design keeping the plot size of 6 rows of 5-meter length and 30cm row-to-row distance (Steel *et al.*, 1997) During 2015-2018, regular yield trials, sowing date trials, and multi-locational yield trials throughout Punjab (PUBYT) were completed for the selected barley genotype. In sowing date trials, each genotype was planted on three different dates with an interval of 15 days from 5<sup>th</sup> November to 5<sup>th</sup> December 2016-17, 2017-18, and 2018-19. It was further tested in different agro-climatic conditions of Pakistan under National uniform barley yield trial and rainfed yield trial during 2018-2020 to evaluate its stability and wider adaptability over a range of environments. In rainfed yield trials, one set was planted under normal irrigation while the other set was planted under rainfed conditions where only one irrigation was applied for pre-sowing irrigation throughout the sowing time. Besides these trials, pathological studies were also conducted at different locations in Pakistan to screen against leaf and yellow rust during the respective years. Rust scoring was carried out according to the modified Cobb Scales (Peterson *et al.*, 1948). For quality parameter analysis, standard procedures of the International Association for Cereal Science and Technology (Anonymous, 1994) and the American Association of Cereal Chemists (Anonymous, 2000) were pursued at the Cereal Technology Laboratory, Wheat Research Institute. To conduct the analysis grain samples were collected from PUBYT. A brief history of Pearl-21 development is presented in Table 1.

#### Results and discussion

The prospective B-14035 line was further screened by in-station (A-trial, B-trial), outstation (PUBYT & NUBYT), Rainfed, and agronomic yield trials (Table-1) after evaluating in segregating generation from F3 to F7.

##### Station Yield Trials 2014-16

Twenty-six entries were studied in the preliminary yield trial (A-trial) during 2014-15 against local check Jau-83 at WRI, Faisalabad (Table 2). Proposed advanced line B-14035 yielded 3728 kg/ha surpassing the check Jau-83 (3614 kg/ha) by 3.15%. For further evaluation and to verify its stability it was again studied in a regular yield trial (B-Trial) during 2015-16 against Haider-93 a promising local check at WRI, Faisalabad (Table-2). The advance line excelled by 13.6 and 3.15 % over Haider-93 and Jau-83, respectively.”

##### Provincial Uniform Barley Yield Trials (PUBYT)

After gauging in-station yield trials, B-14035 was then advanced to PUBYT during 2017-18 and was planted over five different locations in Punjab to scrutinize its versatility and stability in different climatic conditions. The proposed cultivar established its significance by yielding 15.26 % and 7.38% higher than the provincial check cultivars Haider-93 and Sultan-17, respectively (Table 3).

##### National Uniform Barley Yield Trials (NUBYT)

For consecutive two years (2018-19 and 2019-20) B-14035 surpassed NUBYT conducted by the National Agricultural Research Centre, Islamabad over four different locations in different provinces to explore its wider adaptability. During 2018-19, B-14035 proved its worth by yielding 3106 kg/ha in contrast to 2615 kg/ha and 2819 kg/ha of Haider-93 and Sultan-17, respectively is 18.77% and 10.18% higher than both checks (Table 4). In the second year of NUBYT (2019-20), it was again planted at four different locations. The proposed cultivar outclassed the checks Jau-87 and Jau-17 by yielding 4.18% and 7.87% higher (Table 4).

##### Agronomic yield Trials

Sowing date trials were carried out for three cropping seasons of 2016-17 to 2018-19 at Wheat Research Institute, Faisalabad (Table 5) to find its optimum sowing date. The promising line B-14035 was assessed against commercial checks Haider-93 and Jau-87 in sowing date trials with 15-day intervals D1 (5<sup>th</sup> November), D2 (20<sup>th</sup> November), and D3 (5<sup>th</sup> December). Data demonstrated that D2 was the optimum sowing date as the maximum grain yield 3194kg/ha, 4514 kg/ha, and 4453 kg/ha from 2016-17 to 2018-19 sequentially, was produced when planted in the fourth week of November. However, minute yield reduction was observed when planted in December which is due to the reduced growth period available for vegetative and

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reproductive stages still making it profitable in comparison to wheat as its yield reduced drastically when suffering from delayed planting (Okosun *et al.*, 2006; Ram *et al.*, 2010; Amarjeet *et al.*, 2020).

**Rainfed Yield Trials**

The performance of B-14035 was also examined in rainfed yield trials for two cropping seasons 2018-19 and 2019-20. Data demonstrated that the production of the proposed line under water conditions was comparable to normal irrigation in contrast to checks. The higher yield under water stress conditions depicts the stability of B-14035 to better cope with the stress environment. Abdullah *et al.*, 2021; Ahmad *et al.*, 2022; Riaz *et al.*, 2022 also shared similar findings.

**Disease Screening Studies**

Rust scoring was done by using a modified Cobb scale (Peterson et al. 1948). During 2017-18, leaf rust was recorded as Traces moderately susceptible (TMS), Traces moderately resistant (TMR), and traces susceptible (TS) in Islamabad, Peshawar, and Pirsabak, respectively while it was zero in other locations (Faisalabad, Kotnaina, Bahawalpur and Khanewal). Similarly, yellow rust appeared as traces resistant (TR) and traces susceptible (TS) at Peshawar and Pirsabak, respectively while it was zero in other locations (Faisalabad, Kotnaina, Bahawalpur, Khanewal, and Islamabad) on B-14035. During 2018-19, leaf rust was recorded as 5 moderately resistant (5MR), TMS, TS, and TR in Islamabad, Peshawar, Pirsabak, and Faisalabad while it was zero in other locations (Kotnania, Bahawalpur, and Khanewal). Similarly, yellow rust appeared as TMR, TR, and TMS at Islamabad,

Peshawar, and Pirsabak while it was zero in other locations (Faisalabad, Kotnaina, Bahawalpur, and Khanewal) on B-14035. In the two described years, disease reaction for both diseases ranged from 0-5S on check variety (Haider-93) in disease screening nurseries planted at these locations.

**Quality parameters**

To fulfill the Punjab Seed Council (PSC) protocols for the approval of a cultivar, quality analysis was also carried out for the estimation of 1000 grain weight, test weight, and protein content. B -14035 had a bold grain size with 1000 grain weight ranging from 33.63 g to 38.3g (Table 8). Test weight ranged from 49.4 kg/hl to 50.3 kg/hl while, protein contents ranged from 13.5 to 21.8 %. The data (Table 5) depicted that the proposed cultivar has higher ranges of quality parameters than the commercial check Haider-93 thus meeting the quality yardstick for the general cultivation.

**Botanical attributes of Pearl-21**

Uniform and homogenous advanced line B-14035 was approved as Pearl-21 to increase genetic diversity in the fields thus providing a cushion against rust disease. The complete detail of botanical attributes has been described in Table 6. Pearl-21 has short stature (95-99cm) with semi-erect growth habit and erect flag leaf orientation. It had yellowish-white straw color at maturity and amber colored seed of elliptical shape. Its ear emerges in 99 days and matures relatively early in 123-130 days. Pearl-21 expressed high tillering capacity which is about 140 productive tillers per meter. Quality analysis showed higher protein contents ranging from 12.8% to 13.5%. The potential yield of Pearl-21 is 4800 kg ha<sup>-1</sup>.

**Table 1. Development History of B-14035**

S.No.	Year	Generation/trial
1	2009-10	F3 (ICARDA segregating generation IBSP 2009-10, Entry no 19)
2	2010-11	F4
3	2011-12	F5
4	2012-13	F6
5	2013-14	F7
6	2014-15	Preliminary Yield Trial (A-trial)
7	2015-16	Barley Regular Yield Trial (B-trial)
8	2016-17	Sowing Date Trial
9	2017-18	Punjab Uniform Barley Yield Trial (PUBYT), Rainfed Yield Trial
10	2018-19	National Uniform Barley Yield Trial (NUBYT)
11	2019-20	National Uniform Barley Yield Trial(NUBYT)

**Table 2. Yield Performance of “B-14035” in Station Yield Trials**

S.No.	Year	Type of trial	Yield kg/ha			% increment over check
			B-14035	Jau-83	Haider-93	
1	2014-15	A-TRIAL	3728	3614	-	3.15
2	2015-16	B- TRIAL	2616	-	2302	13.6

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**Table 3. Yield Performance of Barley Cultivar “B-14035” in PUBYT during 2017-18**

S.No.	Locations	Yield (kg/hac)		
		B-14035	Haider-93	Sultan-17
1	Wheat Research Institute, Faisalabad	4161	2238	3073
2	Govt Seed Farm, Dhakar Pakpattan	2769	2619	2939
3	Maize and Millets Research Institute Sahiwal	4065	3471	3133
4	Adaptive Research Farm, Gujranwala	2898	2264	2304
5	Rice Research Institute, Kala Shah Kaku	2606	3720	3914
	Average Yield (kg/hac)	3300	2863	3073
	% inc over check		15.26	7.38

**Table 4. Yield Performance of Barley Cultivar “B-14035” in NUBYT.**

S.No.	NUBYT 2018-19			
	Locations	B-14035	Haider-93	Sultan-17
1	Wheat Research Institute, Faisalabad	3927	3239	3647
2	Govt. Seed Farm Dhakkar, Pakpattan	4223	3609	3696
3	Agriculture Research Institute, D.I. Khan	2709	2341	2565
4	Quaid-e-Awam Agriculture Research Institute, Larkana	1567	1272	1369
	Average Yield	3106	2615	2819
	% inc over check	-	18.77	10.18
NUBYT 2019-20				
S.No.	Locations	B-14035	Jau-87	Jau-17
1	Wheat Research Institute, Faisalabad	4398	3678	3918
2	Arid Zone Research Institute, Bhakkar	1611	1604	1854
3	Govt. Seed Farm Dhakkar Pakpattan	4059	3915	3282
4	Agriculture Research Institute, D.I. Khan	1398	1805	1575
	Average Yield	2866	2751	2657
	% inc over check	-	4.18	7.87

**Table 5. Quality Characteristics of “B-14035” from 2016-17 to 2018-19**

Year	2016-17		2017-18		2018-19	
	B-14035	Haider-93	B-14035	Haider-93	B-14035	Haider-93
<b>Quality Characteristics</b>						
<b>1000 Grain wt. (g)</b>	35.6	31.2	38.3	30.4	33.63	30.9
<b>Test wt. (kg/hl)</b>	50.3	58.3	50	44.2	49.4	50.3
<b>Protein (%)</b>	13.5	12.5	13	13.3	12.8	13.4

**Table 6. Botanical Description of Pearl-21**

S.No.	Character	Range
1	Plant height	95-99 cm
2	Growth habit	Semi erect
3	Flag leaf attitude	Semi erect
4	Straw color	Yellowish white
5	Seed color	Amber
6	Days to heading	99
7	Days to maturity	123-130
8	Productive tillers/ m	140
9	1000 Kernel weight	34-38 g
10	Protein contents	12.8-13.5 %
11	Lodging	Tolerant
12	Stem rust, Leaf rust, Stripe rust	Resistant
13	Yield potential	4800 Kg ha <sup>-1</sup>

**Table 7. Yield Performance of “B-14035” in Sowing Date Trials**

Year	2016-17			2017-18			2018-19			
	Name	B-14035	Haider-93	Jau-87	B-14035	Haider-93	Jau-87	B-14035	Haider-93	Jau-87
<b>D1</b>		2773	2807	2991	3900	4392	4575	4047	3181	4047

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<b>D2</b>	3194	2998	2823	4514	3659	3828	4453	3346	3599
<b>D3</b>	2899	2242	2088	3898	2380	3746	4018	2792	3435
<b>Avg. Yield</b>	2955	2682	2634	4104	3477	4049	4173	3106	3694

**Table 8. Yield Performance of “B-14035” in Rainfed Yield Trials**

Year	2018-19			2019-20		
Name	<b>B-14035</b>	<b>Haider-93</b>	<b>Jau-83</b>	<b>B-14035</b>	<b>Jau-87</b>	<b>Jau-17</b>
<b>Normal Irrigation</b>	4800	3318	3305	4043	4077	3903
<b>Rainfed conditions</b>	3855	3087	2881	3437	3258	3258
<b>Average Yield</b>	4327	3203	3093	3740	3668	3581
% inc over check	-	<b>35.09</b>	<b>39.89</b>	-	<b>1.96</b>	<b>4.44</b>

**Conclusions**

Pearl-21 is higher yielding than the previously available commercial cultivars like Jau-83, Jau-87, and Haider-93. It flaunted resistance to rust, lodging, and shattering. It matures relatively early. As a result, it can better escape terminal heat stress and evacuate the field timely. The experiments depict that Pearl-21 has a higher yield in rainfed conditions. So, it is suitable for marginal lands and also for Barani areas. Its quality characteristics make it suitable for diabetic patients and people suffering from heart disease due to the dietary fiber  $\beta$ -Glucan being present in barley.

**Key findings**

Pearl-21 is a unique barley cultivar for general cultivation in irrigated and rainfed areas of Punjab. It is a short-duration early maturing cultivar best suitable to combat terminal heat stress.

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## Statements and Declarations

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### Author contributions

All authors contributed equally.

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N/A

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Current study is approved from concerned ethical review committee

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### Data availability statement

All data has been given in manuscript.

### Submission declaration and verification

The work is not been published previously, and it is not under consideration for publication elsewhere.



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