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Research Article

ANALYZING WHEAT VARIETY NAWAB-21 FOR AGRONOMIC, PATHOLOGICAL AND ZINC BIOFORTIFICATION ATTRIBUTES UNDER MULTILOCATIONAL TRIALS

Khalid Mahmood[1,*], Mashal Rehman[1,2], Imtiaz Ali[1], , Rana Imtiaz Ahmed[1], Akash Zafar[1], Natasha Kanwal[1], Abdul Majid Khan[1], Muhammad Arshad Hussain[1], Abid Ali[1], Naeem Arshad Maan[1], Muhammad Imran Akhtar[1], Asad-ur-Rahman Ch. [1], Wajiha Anum[1], Madiha Mobeen Khan[1], Nadia Manzoor[1]

[1]*Regional Agricultural Research Institute, Bahawalpur, Pakistan.*
[2]*Rice Program, Crop Science Institute, NARC, Islamabad, Pakistan.*
**Corresponding author: khalidbully@gmail.com*

Abstract

Wheat variety *Nawab-21* is one of the elite genotypes of CIMMYT germplasm *Harvest plus yield trial* (7-HPYT, 2016-17) with high zinc contents and more yield potential as compared to earlier evolved biofortified and non-biofortified wheat varieties. The variety was initially screened out at the Regional Agricultural Research Institute, Bahawalpur, Pakistan in station yield trials, where it gave 5537 kg ha^{-1}grain yield which was 11% higher than the check varieties. In multi-locational yield trials, the variety's yield potential was recorded as 7007 kg ha^{-1} in Alipur region. The variety also came-up when tested in National Wheat Disease Screening Nursery's (NWDSN) for disease (rusts) resistance in both years of national uniform wheat yield trials (NUWYT 2019-20 and 2020-21). Nawab-21 is medium in maturity with head emerging from the flag leaf between 90-95 days and matures within 140-145 days.

Keywords: Sustainable agriculture; Nutrient uptake; Disease resistance; Agronomic analysis; Soil health.
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1. INTRODUCTION

Wheat (Triticum aestivum L.) is a primary food in numerous developing and developed countries such as India, Pakistan, Afghanistan, Nepal, China, Turkey, Egypt, and Iran, playing a significant role in global food consumption. With a worldwide production of 790.6 million tons in 2022-23, it ranks as the second most cultivated cereal crop globally, just behind maize, which yielded 1155.6 million tons (Erenstein et al., 2022). It is being consumed globally , with an average of 65.5 kg per capita annually [1]. Asian countries account for most of the global wheat consumption, 375.1 million metric tons, followed by Europe 186.8 million metric tons. While American and African countries consume 711.5 metric tons of wheat. In Pakistan, wheat covered one third portion of the area of cultivated land across the country by contributing 8.2% of the value addition in agriculture and 1.9% of the GDP (Islam et al., 2021; Mehta, 2023). Whereas, Punjab, being the main food hub, shares 73.5% of area and 76.6% of production of wheat (Anonymous 2021).

A major and increasing concern of the modern world, in addition to quantity, is the quality of the product. The population of developing countries have been found Zinc (Zn), Iron (Fe), and Vitamin A deficient (WHO, 2022). Zn deficiency is indeed a significant public health concern that plays a crucial role in various physiological processes including growth, immunity and development, especially in developing countries like Pakistan. According to the

Ministry of Health, Government of Pakistan (2018), high prevalence of Zn deficiency is found in every third child and 40% of the mothers (Annonymous, 2018). One of the major causes of Zn malnutrition is the excessive utilization of wheat-based foodstuffs. The bioavailability of Zn is limited in wheat inherently. Additionally, the decrease in the Zn level in wheat grain is due to the cultivation of 50% of wheat crops on Zn deficit soils (Stangoulis and Knez, 2022). Improving the biofortification of wheat with zinc is the most important objective for breeders in Pakistan, given its position as the most widely consumed grain. This endeavour seeks to address the challenge of hidden hunger and malnutrition by ensuring a steady supply of economically viable, zinc-enriched wheat domestically.

2. Materials and Methods

2.1. Germplasm selection

Nawab-21 wheat variety is one of the elite genotypes of CIMMYT germplasm Harvest plus yield trial (7-HPYT, 2016-17). The parentage of this line is HG094.7.1.12/2*QUAIU#1/3/VILLA JUAREZ F2009/SOLALA//… with pedigree CMSS11B01126S-099M-099Y-8M-OWGY. The variety was subjected to different selection cycles for ensuring global food security and sustainable agriculture. The standard breeding approach was adapted for the development of said variety (Irshad et al., 2018; Ali et al., 2019).

2.2. Experimental site

The experiment was initially carried out in the Regional Agricultural Research Institute in Bahawalpur, Pakistan. The institute is located in the southern part of Punjab Province and spans 24,830 square kilometers, with latitudes ranging from 27°48′N to 29°50′N and longitudes from 70°54′E to 72°50′E. Bahawalpur District's climate is harsh, with summers reaching up to 48 °C and cold, dry winters below 7 °C. It is located in one of Pakistan's most arid regions. The district is physically separated into three separate physiographic units: the plain area, the desert area, and the river area. The soil under study had a sandy loam texture and had pH, EC, and Zn levels of 8.2, 2.8 dS m^{-1}, and 1.43 ppm, respectively.

2.3. Station Trials

2.3.1. *Preliminary yield trial*

During 2016-2017, this variety was tested in a preliminary wheat yield trial in a randomized complete block design (RCBD) replicated thrice for its yield performance against Jauhar-16 and Zincol-16 at the Regional Agricultural Research Institute, Bahawalpur, Pakistan keeping a plot size of $6m^2$.

2.3.2. Regular yield trial

During 2017-2018, variety was evaluated in a regular wheat yield trial against two check varieties Jauhar-16 and Zincol-16 in RCBD design replicated thrice. Standard agronomic practices were adopted to ensure consistent and healthy crop growth. We selected 10 plants from each plot to calculate the average values for various morphological and grain yielding parameters to understand the crop's performance and potential yield under different conditions.

2.4. Multilocational Yield Trials

2.4.1. *Punjab Uniform Wheat Yield Trials (PUWYT)*

The performance of wheat variety was evaluated in PUWYT at twenty-eight diverse locations of Punjab province during 2018-2019 in alpha lattice design with two replications having plot size of 5m × 1.2 m. The two check varieties included in PUWYT were FSD-08 and Jauhar-16.

2.4.2. *National Uniform Wheat Yield Trial (NUWYT)*

The National Coordinated Wheat Program, under the Pakistan Agricultural Research Council, Islamabad, conducted multi-location trials in 2019-2020 and 2020-2021 for rigorous testing. The trials followed a robust experimental design, using an alpha lattice design with two replications, and plot sizes of 5m × 1.8m.

2.5. Zn biofortification trials

The wheat variety was evaluated for Zn biofortification in comparison with other check varieties (Jauhar-16 & Zincol-16). Three treatments were applied; (T1)

Genetic evaluation of wheat strain under control/natural condition, (T2) $ZnSO_4$ applied at the rate of 10 kg ha^{-1} in soil at the time of sowing, and (T3) 0.3% solution of $ZnSO_4$ applied at booting stage. Grain samples were sent to the Soil and Water Testing Lab, Bahawalpur for Zn (ppm) contents analysis.

2.6. Production technology trials

2.6.1. *Sowing dates Experiment*

A rigorous approach was adopted for determining ideal sowing time of "Nawab-21", by planting yield trials on eight different dates, spanning from October 20th to January 1st, with a 10-day interval between each sowing date for two consecutive years (2019-2010 and 2020-2021).

2.6.2. *Drought Tolerance Evaluation*

The variety was also tested under absolute rainfed conditions/planting under absolute drought conditions (with no artificial irrigation except double rounds for seedbed preparation). The total rainfall during the crop growth periods i.e., emergence to physiological maturity was recorded as 103mm in 2018-19 and 167mm in 2019-20.

2.6.3. *Fertilizers Doses Evaluation Trial*

A thorough investigation was done to determine the most effective and economical fertilizer dosage for the variety. For that purpose a split-plot design with three replications to evaluate 11 different combinations of Nitrogen (N), Phosphorous (P), and Potash (K) under irrigated conditions was employed through Urea, DAP (DiAmmonium Phosphate), and MOP (Muriate of Potash), respectively.

2.7. Pathological studies

Pathological studies were conducted under the National Wheat Disease Screening Nursery (NWDSN) during 2019-2020 and 2020-2021 by the Crop Diseases Research Institute NARC, Islamabad.

Observations were made at all sites regarding the response and severity of stripe, leaf, and stem rusts, following the methodology described by Cobb scale. The severity of rust infection on plants was assessed using the modified Cobb scale (Peterson et al., 1948) expressed as a percentage. Due to the subjective nature of visual observation, readings may not be entirely precise. Therefore, for severity below 5%, intervals ranging from trace (T) to 2 were used. For severity levels between 5% and 20%, 5% intervals were employed, and for higher severity readings, 10% intervals were used. Varietal responses were categorized based on the type of infection followed by Fayyaz et al.2021.

2.8. Entomological studies

Entomological studies on the Aphid attack on wheat were conducted in normal and late sown trials for two years 2019-20 and 2020-21 at Regional Agricultural Research Institute, Bahawalpur in which infestation of aphids on Nawab-21 variety and Check varieties were compared.

2.9. Grain quality analysis

A comprehensive analysis of Nawab-21 variety's quality attributes such as test weight, protein percentage, starch percentage, gluten percentage and bread-making quality were studied at the cereal quality Laboratory, Wheat Research Institute, Faisalabad. To ensure reliability and accuracy the tests were conducted over two consecutive years (2019-20 and 2020-2021) at 0.05 probability level.

3. Results:

3.1. Wheat trials at Regional Agricultural Research Institute, Bahawalpur

The study involve two types of necessary trials such as preliminary and regular yield trials to evaluate the potential of the wheat variety Nawab-21 from 2016 to 2018. In the preliminary yield trial, which are initial evaluation type of trials the Nawab-21 gave 5537 kg ha^{-1}grain yield in comparison to the check varieties Jauhar-16 (5310 kg ha^{-1}) and Zincol-16 (4970 kg ha^{-1}) during the year 2016-2017. In the regular yield trial, the grain yield of Nawab-21 was 5064 kg ha^{-1}, whereas the two checks Jauhar-16 & Zincol-16 yielded 4977 and 4695 kg $ha^{-1,}$ respectively (Table 1).

Table 1. Comparison of average grain yield of Nawab-21 with commercial checks in Station Yield Trials (2016-18)

Year	Trial Name	Average grain yield (kg ha^{-1})			
		Nawab-21	**Jauhar-16 (Check)**	**Zincol-16 (Check)**	**LSD**
2016-17	Preliminary Yield Trial (7-HPYT)	5537	5310	4970	185
	% Increase over checks		**4**	**11**	
2017-18	Regular Yield Trial	5064	4977	4695	120
	% Increase over checks		**2**	**8**	

Table 2. Comparison of average grain yield of Nawab-21 with commercial checks in Punjab Uniform wheat yield trial 2018-2019

	Yield (kg ha^{-1})		
	Nawab-21	**FSD-08 (Check)**	**Jauhar-16 (Check)**
Mean (28 sites)	4455	4066	3769
% increase over checks		**10**	**18**

Table 3. Performance (Average grain yield) of Nawab-21 at South Punjab level (2018-2019).

Locations	Nawab-21	FSD-08 (Check)	Jauhar-16 (Check)	LSD
RARI, Bahawalpur (Normal Time Planting)	5500	5417	5042	105
Jahanian	5125	4084	2708	245
MNSUA, Multan	4083	4333	3167	295
ARF, Vehari	4600	3858	3017	172
ORS, Khanpur	4584	3167	3167	215
Alipur	4903	4611	3639	190
RRS, Bahawalnagar	4141	4008	3268	135
PSC, Khanewal	4723	3848	3566	230
RARI, Bahawalpur (Late Time Planting)	3333	3000	2250	205
Average	4555	4036	3314	190
% Increase over checks		**12**	**37**	

Table 4. Performance of Nawab-21 in NUWYT at provincial and national levels (2019-20)

Average grain yield (kg ha^{-1})				
Varieties	**Punjab** (20 locations)	**Increase/decrease over checks(%)**	**Pakistan** (33 locations)	**Increase/decrease over checks(%)**
Nawab-21	4537		4252	
Pakistan-13(Check)	4285	**6.0**	4099	**4.0**
Ghazi-19(Check)	4639	**-2.0**	4368	**0.3**

3.2. Punjab Uniform Wheat Yield Trial (PUWYT)

Nawab-21 was tested at 28 locations in all-over Punjab (2018-2019). The average yield of all 28 locations was 4455 kg ha^{-1} in comparison to other standard checks FSD-08 (4065 kg ha^{-1}) and Jauhar-16 (3768 kg ha^{-1}). The gain in yield over checks FSD-08 and Jauhar-16 was recorded as 10% and 18%, respectively (Table 2). The yield performance (kg ha^{-1}) of "Nawab-21" was also evaluated in South Punjab with a comparison of two other local checks (Table 3). The strain showed a 12% better grain yield over the check variety FSD-08 and a 37% increased yield over the local check (Jauhar-16) across 9 locations in South Punjab (PUWYT, 2019).

Table 5. Performance of Nawab-21 in NUWYT at the South Punjab Level (2019-20).

Location	Nawab-21	Pak-13 (Check)	Ghazi -19 (Check)	LSD
RARI, Bahawalpur	3056	3833	3278	320
MNSUA, Multan	5056	4167	4112	315
R.Y. Khan	4722	4334	5723	205
AliPur	7007	5685	5583	380
Jahanian	6472	4028	5861	270
ORS, Khanpur	6137	6217	6147	110
RSS, Bahawalnar	4922	5289	5114	180
PSC, Khanewal	4011	4022	5057	450
AZRI Bhakkar	4078	4740	4142	340
Average	**5051**	**4701**	**5002**	
% Increase over checks		**7**	**1**	

Table 6. Performance of Nawab-21 in NUWYT (Rainfed) 2019-20.

Strains/Varieties	Average grain yield (kg ha^{-1})			
	Punjab (6 locations)	**Increase/decrease over checks(%)**	**Pakistan** (10 locations)	**Increase/decrease over checks(%)**
Nawab-21	**4491**		**4141**	
Pakistan-13(Check)	4130	**9**	3854	**7**
Ghazi-19(Check)	4296	**5**	3827	**8**

Table 7. Performance of Nawab-21 in NUWYT at all Punjab and Pakistan Levels (2020-21)

Average grain yield (kg ha^{-1})				
Varieties	**Punjab** (21 locations)	**Increase/decrease over checks(%)**	**Pakistan** (31locations)	**Increase/decrease over checks(%)**
BF-1705	4043		4203	
Pakistan-13(Check)	4039	**0.12**	3991	**5.3**
Ghazi-19(Check)	4154	**-2.7**	4280	**-0.02**

Table 8. Performance of Nawab-21 in NUWYT at South Punjab Level (2020-21).

Locations	Nawab-21	Pak-13 (Check)	Ghazi -19 (Check)	LSD
Regional Agri.Res.Inst. Bahawalpur	5445	4790	4729	320
Khanewal	5586	5832	5191	155
Rahim.Yar Khan	4778	4112	4390	105
Neelam Seed, Jahanian	5834	4721	5305	265
Alipur (Muzzafargarh)	6206	5835	5962	110
Mailsi (Vehari)	6111	5722	5999	190
Arid Zone Res. Inst. Bhakkar	3627	4526	4741	130
Punjab Seed Corp. Khanewal	4805	3654	4802	450
MNS Univ. Agri. Multan	2624	3913	3513	180
Average	**5001**	**4789**	**4959**	
% Increase over checks		**4**	**1**	

Table 9. Performance of Nawab-21 in NUWYT 2020-21 (Rainfed)

Strains/Varieties	Average grain yield (kg ha^{-1})			
	Punjab (6 locations)	**Increase/decrease over checks(%)**	**Pakistan** (15 locations)	**Increase/decrease over checks(%)**
Nawab-21	**4455**		**4013**	
Pakistan-13(Check)	4303	4	3570	12
Ghazi-19(Check)	4502	-1	3859	4

Table 10. Evaluation of Nawab-21 under three different treatments (genetic, soil & foliar application) at RARI, Bahawalpur.

Treatments	Nawab-21		Jauhar-16 (Check)		Zincol-16 (Check)	
	Grain yield (kg ha^{-1})	Zn (ppm)	Grain yield (kg ha^{-1})	Zn (ppm)	Grain yield (kg ha^{-1})	Zn (ppm)
Station Yield Trial (2017-18)						
T1	4561	32.6	4511	32.2	4311	32.7
T2	4988	42.8	5066	36.6	4688	38.5
T3	5645	43.5	5355	41.3	5088	42.9
Average	**5064**	**39.6**	**4977**	**36.7**	**4695**	**38.0**
Station Yield Trial (2018-19)						
T1	4233	32.2	4266	29.2	4161	31.5
T2	4661	41.7	4600	35.6	4289	38.8
T3	4817	42.6	4666	38.0	4572	41.8
Average	**4570**	**38.8**	**4510**	**34.2**	**4340**	**37.3**
Average of 2 years	**4817**	**39.2**	**4743**	**35.4**	**4517**	**37.6**

Table 11. Performance of Nawab-21 against different fertilizer doses sowing at RARI, Bahawalpur.

Nutrients (kg ha^{-1})			Grain Yield (kg ha^{-1})	
N	**P_2O_5**	**K_2O**	**Nawab-21**	**Jauhar-16(Check)**
0	0	0	1885	1720
0	120	60	2270	2140
75	120	60	3580	3420
150	**120**	**60**	**4570**	**4460**
225	120	60	4590	4530
150	0	60	3535	3460
150	60	60	4130	4050
150	180	60	4799	4660
150	120	0	4250	4050
150	120	30	4470	4410
150	120	90	4610	4520

Table 12. Disease data recorded at RARI Bahawalpur for three years.

Genotypes	2018-19		2019-20		2020-21	
	Lr	**Yr**	**Lr**	**Yr**	**Lr**	**Yr**
Nawab-21	0	20MR	0	20MR	0	10MR
Morrocco (Check)	90S	100S	100S	100S	100S	100S

MR= Moderately Resistant; S= Susceptible

Table 13. Disease data recorded and published by CDRI, NARC, Islamabad.					
Disease	**Genotypes**	**2019-20**		**2020-21**	
		TR	**RRI**	**TR**	**RRI**
Leaf Rust	**Nawab-21**	**0**	**9.0**	**5MSS**	**8.6**
	Morrocco (Check)	90S	-	100S	-
Yellow Rust	**Nawab-21**	**40MR**	**8.6**	**10MRMS**	**8.3**
	Morrocco (Check)	100S	-	100S	-
Stem Rust	**Nawab-21**	**20MSS**	**6.9**	**-**	**-**
	Morrocco (Check)	100S	-	-	-

TR= Terminal Reaction; MR= Moderately Resistant; MRMS= Moderately Resistant to Moderately Susceptible; MSS= Moderately Susceptible to Susceptible; S= Susceptible

Table 14. Testing under absolute drought conditions (2018-20)

Average grain yield (kg ha^{-1})		
Nawab-21	**Jauhar-16 (Check)**	**Barani-17 (Check)**
2748	2560	2410
% Increase over check	**7**	**14**

Table 15. Testing under various irrigation levels.

No. of irrigations (after sowing)	**Yield kg ha^{-1}(Average of 2 years)**			
	Nawab-21	**Jauhar-16 (Check)**	**FSD-08 (Check)**	**LSD**
1	3028	2865	2753	120
2	3380	3210	3160	105
3	4105	4030	4100	100
4	4415	4180	4390	130
Average	**3732**	**3571**	**3601**	
% Increase over checks		**5**	**4**	

3.3. National Uniform Wheat Yield Trials (NUWYT)

The target variety was also tested in national uniform wheat yield trials (NUWYT) for two consecutive years (2019-20 and 2020-21) across the country. A comparison of the grain yield of Nawab-21 and check varieties (Pak-13 and Ghazi-19) in the first year (2019-20) (average of 33 locations) revealed that the new variety gave a 4% increase in grain yield over Pak-13 while it showed at par performance with Ghazi-19 in irrigated areas of the country (Table 4). An average of 9 locations in South Punjab revealed that the variety showed 7 & 1% higher grain yield than Pak-13 and Ghazi-19 (National checks), respectively (Table 5). Under rainfed conditions, Nawab-21 showed 5% to 9% more yield as compared to Pak-13 and Ghazi-19, respectively (Table 6).

During the succeeding year (2020-21), Nawab-21 was tested at 31 sites all over the country and showed a 5% increased yield over Pak-13, but the economic yield remained at par with other check varieties Ghazi-19 (Table 7). The variety showed gain in yield by 4% and 1% over the national checks Pak-13 & Ghazi-19 in South Punjab (Table 8). While under rainfed conditions, Nawab-21 showed a 12% and 4% increased yield as compared to Pak-13 and Ghazi-19 (Table 9).

Testing of Nawab-21 under multi-soil and environmental conditions (PUWYT & NUWYT) ensured the varietal potential for better adaptability and stability in challenging environments where changes are more frequent (Ahmad et al., 2020; Rattu and Ikram, 2020).

3.4. Biofortification Trials

The two main methods of biofortification are genetic biofortification (increased uptake under natural conditions) & agronomic biofortification (enhanced uptake through the application of nutrients)

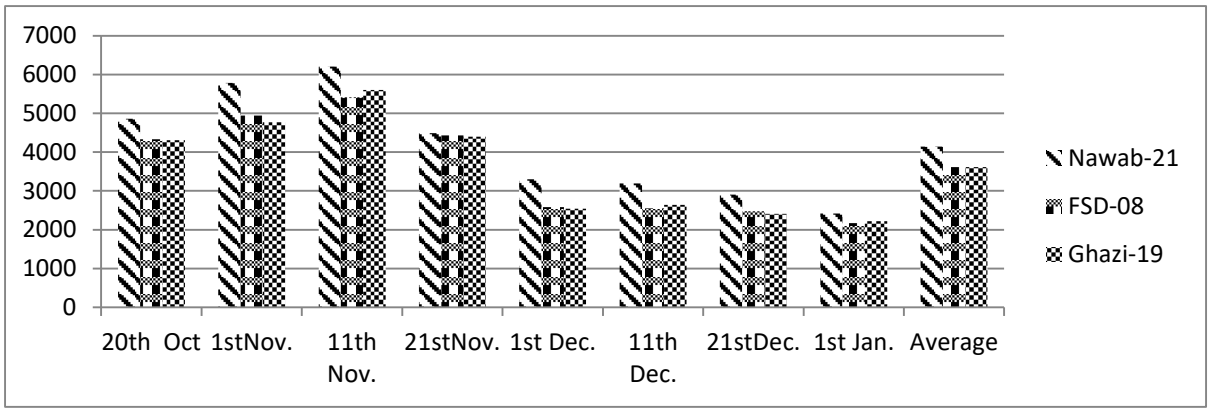

Figure 1. Performance of Nawab-21 on various sowing dates.

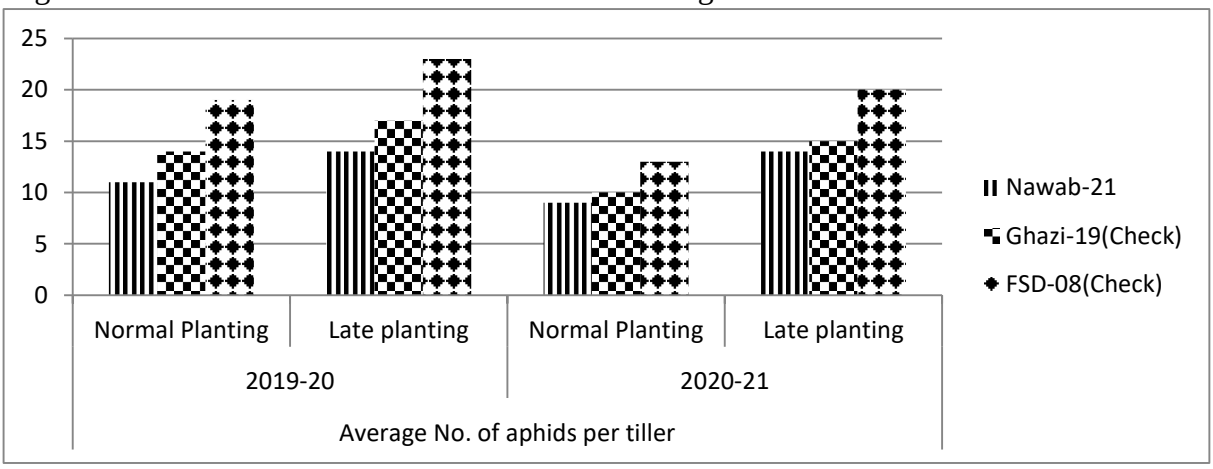

Figure 2. Assessment of attractiveness of Nawab-21 for aphids.

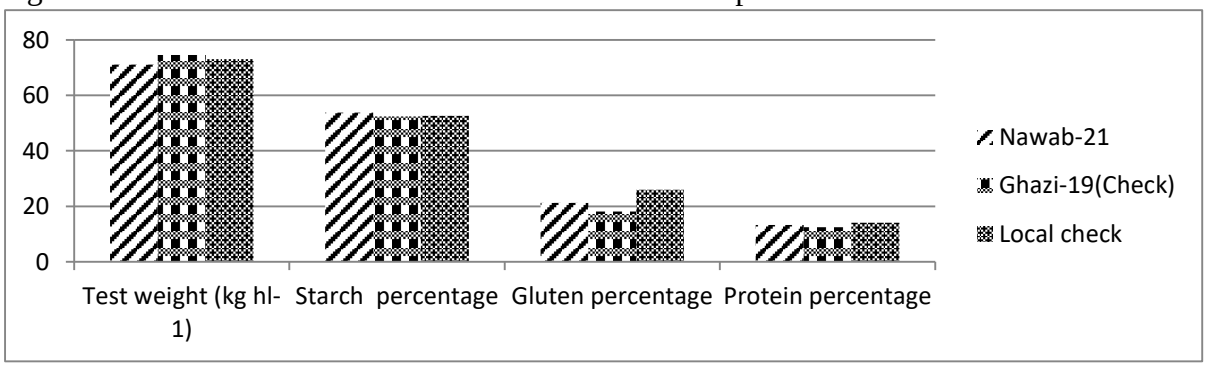

Figure 3. Assesment of grain quality traits of Nawab-21 in comparison with checks.

to increase the nutrient contents of the crop plant. Agronomic biofortification further includes soil fertilizer and foliar fertilizer application of desired micronutrients ($ZnSO_4$) to enhance its level/concentration in the crop (Bhardwaj et al., 2022).

Wheat biofortification trials conducted at RARI, Bahawalpur during 2019-2020 and 2020-2021 showed an overall increase in grain yield and quality under treated conditions as compared to untreated/control conditions. However, the results of grain yield and quality were significantly higher under foliar application as compared with soil-applied $ZnSO_4$. The pattern for yield and quality (Zn contents) traits was Foliar (T_3)> Soil (T_2)> Control (T_1).

As far as the performance of individual genotypes is concerned the average yield of Nawab-21 under all three treatments (T_1, T_2 & T_3) remained higher than Jauhar-16 & Zincol-16 (Table 10). Zn (ppm) contents in Nawab-21 ranged from 32.2 ppm to 43.5 ppm, and Jauhar-16 exhibited 29.2 ppm to 41.3 ppm Zn in grains. While, Zincol-16 had a range from 31.5 ppm to 42.9 ppm.

Nawab-21 was the only variety that maintained its yield as well as high Zn contents in grain in all three treatments during the field experimental trials. Zincol-16 has nearly equivalent Zn contents in grain but lower yield potential than Nawab-21, while Jauhar-16 fell in between the two varieties concerning grain yield but the lower Zn uptake. Nawab-21 variety remained on top in the trial for its higher yield (4817 kg ha^{-1}) and high Zn (39.2 ppm) contents, Jauhar-16 exhibited 4743 kg ha^{-1} yield and 35.4 ppm Zn contents in wheat grain, Zincol-16 showed 4517 kg ha-1 yield with 37.6 ppm Zn content (Table 10). Uptake of the nutrients by the subjected strain was better than both check varieties especially Zincol-16 which has been approved commercially for the same objective.

3.5. Agronomic Studies

The study was conducted at RARI, Bahawalpur to observe the crop performance in different sowing dates, and optimal nutrient requirements for Nawab-21 under natural environmental conditions during 2019-2021. Figure 1 is showing that the variety "Nawab-21" gave more yield on the 1st of November sowing date followed by 15th of November. Different doses of fertilizer were also studied at the time of sowing. The variety Nawab-21 gave 4570 kg ha^{-1} of yield with the NPK fertilizer at the rate of 150:120:60 kg ha^{-1} (Table 11).

3.6. Biotic Stress Studies

The "Nawab-21" variety was put through rigorous testing for the study of yellow and leaf rust in research trials at RARI, Bahawalpur (2018-2021). The variety was also sent to the Cereal Disease Research Institute (CDRI), Islamabad for its inclusion in the National Wheat Disease Screening Nursery (NWDSN) program for the years 2019-20 and 2020-21. In the experimental trials of RARI, Bahawalpur the variety showed that the terminal reaction for leaf rust was "0" while for yellow rust the terminal reaction was 10MR to 20MR for three consecutive years (Table 12).

From the results of CDRI, Islamabad it was revealed that the new genotype has an 8.3 to 9.0 Rust Resistance Index (RRI) for leaf rust, while the terminal reaction was 0 to 40MR during both two years of research (Table 13). The variety also showed better resistance against stem rust (6.9 RRI) even under inoculated conditions (Fayyaz et al., 2021). The results depicted its better adaptability in such challenging environmental conditions and hence this makes it an excellent candidate variety for general cultivation.

The response of variety against aphids was evaluated at RARI, Bahawalpur in normal and late sown trials in two years consecutively 2019-2020 & 2020-2021. The recorded data showed that 9 to 11aphids $tiller^{-1}$ in normal planting and 14 aphids' $tiller^{-1}$ were present in late plating trials during both years which is much less than check varieties (Figure 2).

3.7. Drought Tolerance

The low moisture stress tolerance of the strain was evaluated from 2018 to 2020 by planting under absolute drought conditions (with no artificial irrigation except double rounds for seedbed preparation) and also under different irrigation levels. The total rainfall during the crop growth periods i.e. emergence to physiological maturity was recorded as 103mm in 2018-19 and 167mm in 2019-20. Nawab-21 showed 7% & 14 % more yield under absolute drought conditions than the other two check varieties Jauhar-16 & Barani-17 (Table 14). The variety was also tested under different irrigation levels. The variety gave more economic yield under four irrigations after sowing as compared to a smaller number of irrigations. The average yield of the Nawab-21 under a different number of irrigations remained 5% & 4% more than check varieties (Jauhar16 & FSD-08) respectively (Table 15).

3.8. Quality Assessment Studies

A comprehensive testing protocol revealed that grains of Nawab-21 were medium bold (41.07 g/1000 grain). It contains high gluten contents (21%) along with high

protein content (13.3%). Moreover, it possesses very good "chapati-making" quality (Figure 3). These traits appreciably accomplish this variety as an excellent candidate which met all the quality standards for wheat grains when compared with other existing commercial standards i.e. FSD-08 (Hussain et al. 2014).

4. Discussion

The statics of population of Pakistan showed that it is growing at a rate of 1.2 % per annum. There is a need to increase the wheat yield by almost 20% by the end of 2050 (Duan et al., 2018). Therefore, the development of high-yielding and resilient varieties is the prime focus of wheat breeders of the institute. Nawab-21 is not only high-yielding but also resistant to biotic (disease) and abiotic stresses (heat and drought) of wheat variety.

For the development of new varieties, the major focus was given to the higher yield along with high zinc contents and better tolerance against diseases, drought, and heat. So, that variety not only performed well under normal conditions but also showed remarkable resilience against diverse environment when exposed to high temperature and disease pressure due to unique genetic recombinations (Sinha and Shukla, 2017; Ali et al., 2019). Nawab-21 showed this unique behavior in NUWYT trials over 33 locations in Pakistan during 2019- 20 and 31 locations in 2020-21 (Subhani et al., 2014). The variety maintained its average yield potential due to its wider adaptability. These results are in favor with the findings of Tariq et al. (2013) who found the same results for multi-locational yield trials (Tariq et al., 2013). The rigorous testing ensures accurate and reliable evaluation with significant differences for grain yield at each location (Rattu and Ikram, 2020). Moreover, it remained at the top for disease (rusts) resistance amongst all test lines in NUWYT during the year 2019-20, especially for yellow and leaf rust (NUWYT, 2019-20)

As a matter of concern with Zn biofortification in wheat crops, it is important to know that zinc is an essential micronutrient. It is found in the body cells. It is indeed an essential micronutrient for the body's defensive/immune system and various other physiological and biochemical process (Praharaj et al., 2021; Iqbal, 2022; Stangoulis and Knez, 2022).

The timely, foliar application of ZnSO4 not only increased the grain yield but also the Zn contents of the wheat grain which was also reported by Noreen and Kamran, 2019 and Azeem et al., 2023. Applying Zn fertilizer via foliar application during the grain filling stage is an important strategy to boost up the Zn content in grain (De-Valenca et al., 2017; Kour et al., 2020).

Favorable weather & adequate soil moisture at the time of sowing are some important factors for increased crop yield [14]. The rainfall pattern (amount, frequency) during the maturity period of a particular wheat variety also contribute toward high yield (Lan et al., 2017; Holdrege et al.. 2021; Appiah et al., 2023). From the research trials that were conducted at RARI, Bahawalpur it was recommended that15th -October to 15th November is the ideal time for sowing of Nawab-21 variety to gain its maximum potential yield. For most of the wheat varieties in Pakistan, particularly for the regions of Punjab/South Punjab areas, the optimum time for wheat varieties cultivation is mid-October to mid-November (Shaheen et al., 2020). The maximum yield (4460 kg ha-1) of the variety was attained with NPK fertilizer @ 150:120:60 kg ha-1 at sowing time. Significant results of increased fertilizer doses on grain yield and quality have also been observed (Akpinar and Ortas, 2023).

Seed quality is an important attribute for the acceptability of a commodity among consumers. The grains of Nawab-21 are medium to bold with amber color and high zinc content. The same results regarding quality characters have also been reported by Ahmad et al., 2020.

5. Conclusion

Nawab-21 is a high-yielding, zinc biofortified, diseases, drought, and heat-tolerant wheat variety possessing very good chapati/bread-making quality. On average Nawab-21 exhibited 2-10% higher grain yield, more Zn contents (32.2-43.5 ppm), and also showed excellent resistance against foliar diseases as compared to other commercial varieties. Due to its wider adaptability with good yield potential across the country, it is likely to replace the previous Zn biofortified varieties which have become susceptible to diseases. The more Zn contents (32.2-43.5 ppm) in this variety are beneficial for human health to overcome the problem of hidden hunger. Resultantly, more cultivation and consumption of this variety will help to overcome the threats of food insecurity and Zn deficiency problems.

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