

THE NEW WHEAT VARIETY “JAUHAR-16”: AN ADDITION IN LOCAL HIGH YIELDING AND RUST RESISTANT GERMPLASM

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ABSTRACT

‘Jauhar-16’ is the new wheat (*Triticum aestivum* L.) variety possessing high yield potential and resistance against rusts. It was released in 2016 for general cultivation in irrigated as well as rainfed areas of Punjab. The variety was developed through a local cross attempted and preceded for subsequent stages of variety evolution through pedigree method at Regional Agricultural Research Institute, Bahawalpur Pakistan. The variety possesses high yield potential (>7.6 t/ha), resistance against yellow rust (10MS to 30M), leaf rust (5MSS to 10MSS) and stem rust (0 to 40M). It possesses some new major \pm and minor gene combinations, other than the resistant genes known so far, which confer resistance/tolerance against TTKSK (a new virulent race of stem rust, synonymously known as Ug-99). The variety has better tolerance against moisture stress, therefore, can be adapted to barani areas of the country as well. It has 1000-grain weight of 38-40g, high test weight (76-80 kg/hl), medium height (98-105cm) and white chaff. It is less attractive to wheat aphids and good responsive to fertilizers. The grain colour is amber containing high protein, starch and gluten percentage (14.3-15.7%, 54.1-55.7% and 26.3-32.0%, respectively). It has good chapati making quality. It expresses good yield potential when planted during first fortnights of November by keeping seed rate of 100-120kg/ha and fertilizer dose of 150-120-60 NPK kg/ha. Thus, it appears that Jauhar-16 has high yield potential and resistance against biotic and abiotic stresses prevailing in the region.

Keyword: *Triticum aestivum*, variety, rusts resistance, Ug-99, quality.

M=MRMS=moderately resistant to moderately susceptible; MS=moderately susceptible; MSS=moderately susceptible to susceptible; hl=hectolitre

INTRODUCTION

Bread wheat (*Triticum aestivum*) is the most widely grown crop in the world. It is the most important food and cereal crop serving as staple food of 35% of the world’s population (Ogbonnaya *et al.*, 2013) which is being cultivated on an area of 217.2 Mha producing 729 MT grain yield with an average of 2906 kg/ha (USDA- FAO, 2014). It is one of the most traded commodities in the world markets (Curtis and Halford, 2014).

Wheat is the staple food of Pakistan which was cultivated on an area of 8.8 Mha during 2015-16 with a production of 25.5 MT which accounted 2.9% increase over the last year’s crop (Anonymous, 2015-16). It contributes 13.7% to the value added in agriculture and 4.51% to GDP (Anonymous 2015-16). Punjab occupies the maximum area i.e. 6.9Mha (>78% of the total area under wheat crop). Most of the area (91%) under wheat in Punjab is irrigated while 9% comes under rainfed conditions. Southern Punjab comprising of Bahawalpur, Multan and D.G. Khan divisions, contributes about 39.9% of the total wheat production of the Punjab (Anonymous, 2015-16).

Rust diseases of wheat including yellow rust (*Puccinia striiformis*), leaf rust (*Puccinia triticina*) and stem rust (*Puccinia graminis*) are serious production hazards all over the world (McIntosh *et al.*, 1997). Under favorable climatic conditions these diseases can cause epidemics and considerably reduce yield, but this reduction depends upon the time of infection and intensity of the disease (Hussain *et al.*, 2004; Afzal *et al.*, 2007; Anonymous, 2013-14). Rust epidemic can reduce the wheat yield up to 50% (Muhammad *et al.*, 2015) and sometimes results in complete calamity of the crop.

Chemical control of rust pathogens is neither economical nor recommendable due to direct use of wheat grain/flour as food (Coelho *et al.*, 2016). Therefore, development and broad cultivation of rust resistant varieties is of supreme significance (Hussain *et al.* 2010a, b, c; Anonymous, 2013-14). Continual release of rust resistant varieties in Pakistan has abridged the losses caused by rust (Khan, 1987, Hussain *et al.*, 2010 a, b, c). Due to rapid recombination and/or mutations in causal organisms, new rust races also develop which become virulent for newly released rust resistant varieties also. Plant breeders and plant pathologists, therefore, have to be very cautious of pathogen dynamics.

Keeping in view the numerous constraints, continuous release of wheat varieties devouring the higher yield potential, resistance against diseases and insect pests, better quality and wider adaptability is a dreadful need. Jauhar-16, a newly released high yielding and rust resistant wheat variety, is a result of enthusiastic and determined efforts of the researchers' team consisting of breeders, pathologists, agronomists, entomologists and soil chemists working at Regional Agricultural Research Institute, Bahawalpur. It is suitable for early to late planting in irrigated as well as rainfed areas of the Punjab. The variety possesses improved genetic potential along with resistance to biotic and abiotic stresses prevailing in the country.

MATERIALS AND METHODS

Hybridization and development of filial generations

Jauhar-16 was developed through pedigree method (Alam, 1994) from a cross (KAUZ/PASTOR//V.3009) attempted at Regional Agricultural Research Institute (RARI), Bahawalpur during 2003-04. All the filial generations and yield trials were conducted at RARI, Bahawalpur. F₁ generation was sown in single row of 2m length with single row hand drill during the succeeding year. F₂ population was developed (from the bulked seeds of F₁ plants) through space plantation of seed done by dibbler keeping plant to plant and row to row distances of 12cm and 30cm, respectively. The first segregating population was kept at its maximum so as not to lose any segregant. Keeping in view the desirable traits, selection of individual superior plants was made in every cycle from F₂ to F₅. A plot size of four rows each 5m length was kept through F₃ to F₅ generation. Universally reported rust susceptible check "*Morocco*" was planted along and across the field beds so as to provide maximum disease (leaf rust and yellow rust) pressure in natural conditions. In F₅ generation a superior family of the cross was harvested as bulk on attaining maximum homozygosity. The selected family was coded as 099172 and put up in yield assessment trials.

Yield assessment

The strain 099172 was then tested in replicated preliminary (A-trials), regular (B-trials), regional (RWYT) and Punjab (PUWYT) yield trials from 2009-10 through 2012-13. The layout for preliminary, regular and regional trials was RCBD while PUWYT was laid out following alpha lattice due to relatively large number of genotypes to be tested. Each trial was replicated thrice while plot size was kept 1.8m × 5m maintaining 30cm row to row distance. Sowing was done with single row hand drill. Two or more commercial cultivars were included in every experiment as checks for comparison. Finally, the selected line was evaluated in national uniform wheat yield trials (NUWYT). These trials were conducted by the National Coordinator Wheat, NARC Islamabad, at 45 locations in 2013-14 and at 34 locations during 2014-15 throughout the country. These experiments were also laid out in alpha lattice with 3 replications keeping plot size of 1.8m × 5m maintaining 30cm apart rows. Sowing time and crop management practices, soil and climatic conditions were varying at all the locations. The replicated data of individual locations were averaged and converted to kg/ha for comparison as reported by Mustafa *et al.* (2007 and 2008). Various steps from hybridization to final approval of Jauhar-16 are summarized in table 1.

Development of production package

To estimate the most suitable planting time, fertilizer dose and seed rate, a succession of replicated yield trials were conducted for three years from 2013-14 through 2015-16. One or more commercial varieties were included in the trials for comparison. The strain was also tested for tolerance against insect pests especially aphids in replicated yield trials along with check varieties Fareed-06 and FSD-08.

Pathological and entomological studies

To ascertain disease reaction of the strain, separate experiments were conducted at RARI (with the collaboration of scientists from pathological section of the institute) and national agricultural research centre (NARC) Islamabad with collaboration of scientists from crop disease research institute (CDRI) for three years. The reaction was noted under artificial inoculation conditions every year. The target entries were planted in two rows each 2-meter long, 30cm apart. Two rows of *Morocco* and *Local White*, which are vulnerable to rusts, universally, were planted around the test entries. In addition, a row of each susceptible check (*Morocco* and *local check*) was also planted after every 10 entries. Artificial inoculations with a mixture of field collection/national bulk inoculums of known prevalent races/virulences of the rusts were carried out during the month of March. Initially inoculations of spreaders (3-5 tillers in a row) were carried out by hypodermic syringe method using aqueous uredospore suspension to which 1-2 drops of Tween-20 were added to break the surface tension. Subsequently all the material was sprayed 2-3 times by turbo-air sprayer using aqueous spore suspension with fortnightly intervals to obtain heavy rust development. The data were recorded on leaf and yellow rusts as percent infection on the plants according to the modified Cobb's

Scale (Peterson *et al.*, 1948) during the first week of April. Relative Resistance Index (RRI) was calculated according the formula of Hussain *et al.* (1999).

The variety was also tested at Kenya (Ug-99 prone area) for resistance against stem rust (TTKSK/Ug-99, the most virulent newly emerged race). Further genotyping of the variety was done at The Minnesota University, USA to identify the genes conferring resistance.

Quality evaluation

Physio-chemical properties of the grain were studied at Bio-Chemistry Lab. at AARI, Faisalabad (Mustafa *et al.*, 2007).

Various steps from hybridization till final approval of Jauhar-16 are summarized in Table 1.

The yield data were subjected to ANOVA using statistical software ‘Statistix 8.1’ and the means were compared using LSD (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

On-station yield trials

After passing through filial generations (F₁-F₆), Jauhar-16 was tested in replicated preliminary (A) and regular (B) yield trials at RARI, Bahawalpur during 2009-10 through 2010-11. The data on grain yield shows that the variety gave 4833kg/ha and out yielded both the checks, Sehar-06 and Mairaj-08 with grain yield of 4733kg/ha and 4500kg/ha, respectively. In B trials, Jauhar-16 performed even better showing a grain yield of 5200kg/ha as compared to 4678kg/ha and 4888kg/ha grain yield produced by Sehar-06 and Mairaj-08, respectively resulting in 7.5% to 7.9% increase in comparative yield of the test variety. While averaging both the trials (A and B), Jauhar-16 gave 6% more yield than both the check varieties (Table 2). The differences were significant in both the trials. Earlier released varieties like Sehar-06, although possessed high yield potential but those appeared to be susceptible to rusts as revealed in the results reported by Anonymous (2013-14, 2015-16). Consequently, these are being banned for general cultivation to avoid epidemic of rust. Since the major emphasis was placed on incorporation of rust resistance in the target variety aimed for release in irrigated areas of Punjab, Jauhar-16 appeared to be a promising genotype with respect to this major trait wanted for wheat cultivation in rust prone areas.

Table 1. Summary of various steps in evolution of Jauhar-16.

Year	Trials	Description
2003-04	Hybridization	KAUZ/PASTOR//V.3009
2004-09	Filial Generations	Selection of desirable families from F ₁ to F ₅ .
2009-11	A & B trials	On-station replicated yield trials at RARI, Bahawalpur.
2011-12	RWYT	Multi-locations yield testing in southern Punjab through the Director RARI, Bahawalpur.
2012-13	PUWYT	Multi-locations yield testing on provincial basis through the Director WRI, Faisalabad.
2013-15	NUWYT	Multi-locations yield testing on national basis through the National Coordinator Wheat, Islamabad.
2009-15	Pathological studies	These studies were conducted at RARI-Bahawalpur, NARC-Islamabad and The Minnesota University USA.
2014-16	Entomological studies	These studies were conducted at RARI-Bahawalpur.
2012-15	Agronomic studies	These studies were conducted at RARI-Bahawalpur and Agronomic Research Station Bahawalpur.
2013-15	Physio-chemical studies	These studies were conducted at physio-chemical Lab at Wheat Research Institute, Faisalabad.

Multi-locational yield trials

To assess the adaptability and stability of the variety, multi-location/multi-environment testing was done through regional, Punjab and national yield trials.

Regional yield trials were conducted at 8 locations in southern Punjab by Director RARI, Bahawalpur during 2011-12. Results showed that Jauhar-16 out yielded both or either of the two check varieties Mairaj-08 and FSD-08 at all the locations. Grain yield of the test genotype ranged from 2937-5570kg/ha while range of grain yield for check varieties was recorded as 3092-4966kg/ha (for Mairaj-08) and 2580-5635kg/ha (for FSD-08). Averaging all the localities showed that the target variety exhibited non-significant increase (1.65%) over FSD-08 while significant increase (7%) over Mairaj-08 (Table 3).

Table 2. On-station yield trials at RARI, Bahawalpur.

Year	Trial	Grain yield (kg/ha)			LSD (0.05)
		Jauhar-16	Sehar-06	Miraj-08	
2009-10	A1-Trial	4833	4733	4500	212
2009-10	A2-Trial	3575	3280	3155	235
2010-11	B1-Trial	5200	4672	4888	325
2010-11	B2-Trial	4470	4235	4210	215
Mean		4520	4206	4188	
Increase over check			7.5%	7.9%	

Table 3. Regional yield trials.

Sr.No.	Location	Grain yield (kg/ha)		
		Jauhar-16	Mairaj-08	FSD-08
1	R.Y. Khan	4322	4400	4540
2	Khanpur	3855	3650	3762
3	Bahawalpur	5164	4250	5000
4	Lodhran	4600	4325	4590
5	Muzaffargarh	5570	4966	5635
6	Bahawalnagar	2937	3092	2580
7	Multan	4855	4372	4830
8	D.G. Khan	4723	4600	4505
Mean		4503	4207	4430
Increase over check			7.04%	1.65%

The variety was further tested in Punjab uniform yield trials (PUYT). These trials were conducted by Director Wheat Research Institute, Faisalabad during 2012-13 at 21 locations on whole Punjab basis both under normal and late sown conditions. Average data of grain yield per hectare across the 14 locations in southern Punjab revealed that Jauhar-16 showed at par performance with Millat-11 while 6.0% increase over Punjab-11 (Table 4).

The target variety was also tested in national uniform yield trials (NUYT) for two consecutive years (2013-14 and 2014-15) across the country. Comparison of grain yield of Jauhar-16 and check varieties (Punjab-11, Aas-11 and Galaxy-13) is given in Table 5 & 6. The results (average of 40 locations) revealed that the new variety gave 6% increase over Punjab-11 while 3% increase over each of Galaxy-13 and Aas-11 in normal sowing conditions. Under late planting conditions, Jauhar-16 showed 5.2 and 4.7% increased yield as compared to Punjab-11 and Aas-11, respectively while it showed at par performance with Galaxy-13 (Table 5). During the succeeding year (2014-15), Jauhar-16 was tested at 34 sites in whole Pakistan basis, average of 9 locations in southern Punjab revealed that the variety showed significantly increased yield (2.6%) over the local check, Aas-11, and highly significant increase in grain yield (15.4%) over the national check (FSD-08).

Testing of Jauhar-16 under multi soil and environmental conditions (RYT, PUYT and NUYT) revealed that the variety possesses better adaptability and stability in addition to its higher yield potential. Adaptability and stability of a variety, to varying agro-climatic conditions, are of prime importance for its successful and long-lasting adaptation over a major area.

Several earlier researchers like Khan and Din (1999), Saleem *et al.* (2002), Ahmad *et al.* (2002a, b), Tariq *et al.* (2003), Siddiqi *et al.* (2001), Ahmad *et al.* (2005), Sarwar and Ahmad (2003), Bakhsh *et al.* (2005) and Hussain *et al.* (2010a, b, c) reported higher yield and adaptability in new sesame, mungbean, chickpea, guar, wheat and cotton varieties than the checks.

Table 4. Punjab uniform yield trials.

Sr.No.	Location	Grain yield (kg/ha)		LSD (0.05)
		Jauhar-16	Punjab-11	
A. Normal sowing (1st to 15th November)				
1	Khanewal	4172	4750	310
2	Vehari	4210	3909	255
3	Bahawalnagar	3473	2871	225
4	Bahawalpur	3717	4383	325
5	Khanpur	2900	2428	320
6	Muzaffargarh	3617	2961	345
7	R.Y. Khan	6180	5203	335
Mean		4038	3786	
Increase over check			6.00%	
B. Late sowing (1st to 15th December)				
8	Khanewal	1981	2250	195
9	Vehari	3421	2903	215
10	Bahawalnagar	2938	3167	190
11	Bahawalpur	3511	3169	280
12	Khanpur	3533	3267	210
13	Muzaffargarh	2256	2439	250
14	R.Y. Khan	3111	3742	305
Mean		2964	2991	
Increase over check			-0.91%	
Overall mean (14 locations)		3501	3388	
overall increase over check			3.34%	

Production technology

To estimate most suitable planting time, fertilizer doses and seed rate, a series of experiments was conducted for three years from 2012-13 through 2014-15 at RARI, Bahawalpur.

Results pertaining to planting time during 2014-15 revealed that the variety showed the highest yield when planted on 1st November as compared to rest of the dates. It is also clear from the results presented in Table 7 that Jauhar-16 showed at par performance with Aas-11 and Galaxy-13 while better than FSD-08 and Fareed-06 on the basis of average performance across all the dates.

During 2014-15, Jauhar-16 gave the highest grain yield when planted on 11th November. The variety performed at par with Aas-11 while better than FSD-08 and Galaxy-13 when averaged across all the dates. So, it can be concluded that the most suitable planting time for the variety is first fortnights of November (Table 7).

Average data of three years from 2012-13 through 2014-15 regarding fertilizer (NPK) doses are presented in Table 7. It is clear from the results that Jauhar-16 gave the highest yield when fertilized with 150:120:60 kg NPK/ha, respectively. Results of experiments regarding seed rate revealed that the most economical seed rate for the variety was 125kg/ha.

It can be concluded that Jauhar-16 expresses yield potential to its maximum when sown on 1st to 15th November, keeping 150:120:60 kg NPK/ha and with seed rate of 125kg/ha. Similar results were reported by Ahmad *et al.* (2002a, b) and Hussain *et al.* (2010a, b, c) for newly released wheat varieties of the time.

Table 5. National uniform wheat yield trial 2013-14.

Sr. No.	Site/ location	Jauhar-16	Punjab-11	Galaxy-13	Aas-11	LSD (0.05)
A. Normal sowing (1st to 15th November)						
1	Moza Jalla Araein Distt. Lodhran	5435	4929	4739	4821	371
2	ORS Khanpur	4083	3913	3950	4163	408
3	CRS Multan	4783	4677	5378	5182	506
4	Moza Kikri R. Y.Khan	5247	5327	5360	4827	415
5	Moza Sarwar Wali D.G.Khan	4356	4075	4328	4404	328
6	Bahawalpur RARI	4978	4845	4395	4643	522
7	PSCF Khanewal	4783	4677	5378	5182	213
8	Takht Mahal Bahawalnagar	6159	5140	5965	6138	325
9	Makhdoom Rasheed, Multan	4147	4024	3456	3061	360
10	Mad Wala Alipur	5670	5314	4642	6041	398
11	Garh Mor Vehari	7633	6167	6167	6337	372
12	RRC Bahawalnagar	4038	3804	4102	4292	338
13	CRS Vehari	3820	4041	4622	3814	323
14	AZRI Bhakkar	5583	5805	6166	5721	433
Mean		5051	4767	4903	4902	
Increase over checks			6%	3%	3%	
B. Late sowing (1st to 15th December)						
15	Moza Jalla Araein Distt. Lodhran	4874	5229	5296	4523	539
16	ORS KhanPur	3699	3432	3457	3465	455
17	Moza Kikri RYK	4510	3870	4157	3900	486
18	Moza Sarwar Wali DG Khan	3383	3882	3952	3798	316
19	RARI Bahawalpur	3571	3361	3325	3386	505
20	PSCF Khanewal	4353	3568	4816	3997	257
21	Takht Mahal Bahawalnagar	3639	3419	3938	3486	240
22	Multan, Makhdoom Rasheed	3575	3071	3061	3123	330
23	Mad Wala Alipur.	3673	3582	3833	3815	467
24	Garh Mor Vehari	4933	5093	4773	5220	449
25	RRC Bahawalnagar	2330	2461	2222	2320	220
26	CRS Vehari	3907	3678	3712	3364	226
27	AZRI Bhakkar	4750	4000	4639	4500	388
Mean		3938	3742	3937	3761	
Increase over check			5.2%	-	4.7%	
Overall mean		4515	4273	4438	4353	
Overall increase over check			5.7%	1.7%	3.7%	

Resistance against diseases and insect pests

The response of Jauhar-16 to various foliar diseases remained under regular study from 2009 to 2015 at RARI, Bahawalpur. The variety was also tested by experts of Crop Diseases Research Institute (CDRI) NARC, Islamabad through national wheat diseases screening nursery (NWDSN) trials throughout Pakistan. The disease score of Jauhar-16 recorded throughout the period is presented in Table 8. The variety showed rust score from 0 to 10R for leaf rust and 5R to 10M for yellow rust as compared to 60S to 80S for leaf rust and 70S to 90S for yellow rust of the check variety i.e. Morocco under agro-climatic conditions of Bahawalpur. In NWDSN, Jauhar-16 proved to be resistant to leaf and yellow rust as compared to Morocco. The new variety showed reaction of 5MSS to 10MSS for

leaf rust, 10MS to 30M for yellow rust and 0 to 40MR for stem rust (RRTTF, a local race). The target variety had RRI value of 7.9-8.4 and 7.3-8.4 for leaf and yellow rust, respectively, which is above the desirable limit.

Table 6. National uniform wheat yield trial 2014-15.

Sr. No.	Site/ location	Jauhar-16	Aas-11)	FSD-08	LSD (0.05)
1	Moza Jalla Araein Lodhran	4701	4450	3728	265
2	Jhanian Multan	4025	3565	2446	432
3	Moza Kikri R.Y.Khan	5368	5075	4727	464
4	Moza Sarwar Wali D.G.Khan	4034	4112	4667	390
5	Fortabbas Marrot	5334	5611	4000	326
6	RARI Bahawalpur	3573	2819	2546	426
7	PSC Khanewal	3774	3737	3609	385
8	Alipur Muzaffargarh	4689	4500	4278	317
9	RSS Bahawalnagar	3348	3987	3670	370
Mean		4316	4206	3741	
Increase over check			2.6%	15.4%	

Table 7. Average grain yield (kg/ha) performance of Jauhar-16 under various planting times (2 years), fertilizer doses (3 years) and seed rate (2 years) trials.

Varieties	1 st Nov.	11 th Nov.	21 st Nov.	1 st Dec.	11 th Dec.	21 st Dec.	1 st Jan.	11 th Jan.	Means
Planting time trial (2013-14)									
Jauhar-16	5276	4612	4410	4459	3590	3526	3048	2486	3926
FSD-08	4867	4306	4299	4500	3495	3306	2691	2177	3705
Galaxy-13	5136	4704	4244	4496	3584	3489	2935	2431	3877
Planting time trial (2014-15)									
Jauhar-16	4890	4918	5029	4890	3598	3515	3209	2845	4112
FSD-08	4653	4584	4847	4862	3518	3195	3070	2730	3932
Galaxy-13	4862	4917	4875	4886	3486	3334	2958	2786	4013
Fertilizer doses trials (Kg/ha, 2012-13 to 2014-15)									
Tr. No.	N	P ₂ O ₅		K ₂ O		Yield			LSD (0.05)
1	0	0		0		2018			110
2	0	120		60		2420			
3	75	120		60		3880			
4	150	120		60		4650			
5	225	120		60		4704			
6	150	0		60		3565			
7	150	60		60		4278			
8	150	180		60		4850			
9	150	120		0		4430			
10	150	120		30		4535			
11	150	120		90		4730			
Seed rate trials (2012-13 to 2013-14)									
Tr.No.	Seed rate (kg/ha)			Yield					LSD (0.05)
1	100			4435					230
2	125			4870					
3	150			4955					
4	175			4930					

Table 8. Disease studies by crop disease research institute, CDRI, Islamabad.

RARI Bahawalpur						
Genotype	2009-10		2010-11		2011-12	
	Lr	Yr	Lr	Yr	Lr	Yr
Jauhar-16	0	0	10R	5R	5R	10M
Morrocco	60S	70S	80S	70S	80S	90S

CDRI, NARC, Islamabad through NWDSN							
Disease	Genotype	2012-13		2013-14		2014-15	
		TR	ACI (%)	TR	RRI	TR	RRI
Leaf Rust	Jauhar-16	5 MSS	1	10MS	8.4	10MSS	7.9
	Morrocco	90S	88	90S	-	90S	-
Yellow Rust	Jauhar-16	10R	0.7	30M	7.3	10MS	8.4
	Morrocco	90S	93	90S	-	90S	87ACI
Stem Rust	Jauhar-16	0	0	60M	-	40MR	6.7
	Morrocco	80S	70	100S	-	100S	-

TR = Terminal Reaction.

RRI = Relative Resistance Index.

CDRI = Crop Disease Reporting Institute.

NARC = National Agricultural Research Centre.

ACI = Average Coefficient Infection.

Table 9. Genotyping data of Jauhar-16 revealed by various markers.

Seedling analysis			Primers used									
TTKSK (Ug-99)	RRTTF Local Race	Yemen race	Sr 31	Sr 2	Sr 9a	Sr 24	Lr 19+	Yr 18+	Lr 37+-	Yr 15	Lr 9	Sr 36
MR 2+3 LIF	R 2	R 2	-	-	-	-	-	-	-	-	-	-

Table 10. Entomological studies.

Sr. No	Variety/ Strain	Average Aphid/ Tiller	
		2014-15	2015-16
1	Jauhar-16	12	14
2	Fareed-06	21	23
3	FSD-08	22	19

Resistance against rusts (leaf and yellow rust) makes Jauhar-16 a better genetic source for rust prone areas. Leaf and yellow rusts of wheat, beside yield reduction, damages the quality of grain as well. Therefore, the grains obtained from susceptible varieties grown under diseased conditions are of inferior quality, whereas, the resistant varieties produce better yield and grains of better quality. This phenomenon was recorded in the case of Jauhar-16 as well when grown in disease conditions. Ahmad *et al.* (2002 a, b and 2005) and Hussain *et al.* (2010a, b, c) reported new varieties of wheat to be more resistant to rust diseases compared to checks.

The variety showed MR reaction against the newly emerged, most virulent race of stem rust (Ug-99) and other virulent races when evaluated at Kenya (the rust race prone area). Mostly mega wheat varieties in Pakistan carry Yr.18+Lr.34 gene combinations but Jauhar-16 possesses some novel combination of genes conferring resistance as is evident from genotyping results received from Minnesota University, USA (Table 9). Further genotyping and QTL studies are needed to identify and locate the linkage group governing resistance.

Entomological studies revealed that the variety Jauhar-16 was less attractive to aphids as compared to Fareed-06 and FSD-08 (Table 10). The research trials were carried out at RARI, Bahawalpur from 2013 to 2015. Ahmad *et al.* (2002a, b and 2005), Siddiqi *et al.* (2001) and Hussain *et al.* (2010a, b, c) reported similar results for new wheat varieties.

Table 11. Evaluation of physio-chemical traits.

Variety	1000. K.W (g)	Test Wt. (Kg/hl)	Starch (%)	Moisture %	Protein (%)	Gluten Dry (%)	Gluten Wet (%)	Flour (%)	Chapati quality
NUYT, 2013-14									
Jauhar-16	34.9	77.9	55.7	10.7	14.3	9.1	32.0	67.4	Good
Galaxy-13	36.1	719	55.6	10.5	11.8	6.5	19.5	67.6	Good
Aas-11	31.7	75	54.1	10.8	13.5	8.1	24.3	67.8	Good
NUYT, 2014-15									
Jauhar-16	39.6	79.8	56.5	10.5	15.7	9.3	26.3	67.7	Good
FSD-08	36.9	77.3	52.5	10.6	15.2	7.8	26.8	66.8	Good

Quality traits

Seed quality traits are important parameters that determine the acceptability of a commodity among the consumers (Bhatty, 1988). The comparison of quality parameters showed that seed of Jauhar-16 contains protein up to 15.7% and gluten up to 32.0%. It has good chapati making quality (Table 11). The quality traits revealed that the new variety is better than the existing checks. Gluten consistency of the variety is strong to medium strong, while gluten percentage of the variety is also acceptable. Mustafa *et al.* (2007, 2008) and Hussain *et al.* (2010a, b, c) reported similar results for new wheat varieties.

Conclusion

Jauhar-16 is not only a high-yielding cultivar possessing resistance/tolerance to diseases and insect pests and better-quality traits but it is also best suited in wheat-cotton-wheat rotation. It is resistant to stem rust (RRITF i.e. local race and TTKSK i.e. Ug-99) which is a serious emerging threat to wheat crop in south Asia. Due to its better adaptability, it has the potential to cover maximum area under wheat. This variety was unanimously approved and released by Punjab Seed Council during its 47th meeting held on 15th July 2016 in Agriculture House Lahore under the Chairmanship of Minister for Agriculture, Government of the Punjab, under the name of "Jauhar-16" for general cultivation in whole Punjab especially hot and drought prone areas of the province.

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REFERENCES

Afzal, S.N., M.I. Haque, M.S. Ahmedani, S. Bashir and A.R. Rattu (2007). Assessment of yield losses caused by *Puccinia striiformis* triggering stripe rust in the most common wheat varieties. *Pak. J. Bot.*, 39: 2127-2134.

- Ahmad, M., L.H. Akhtar, M. Hussain, G. Hussain, A. Rashid, M. Aslam, M. Safdar, M.M. Akhtar and S.Z. Siddiqi (2002a). "Bahawalpur-2000": A new wheat variety of new millennium for southern Punjab. *Sci. Tech. Dev.*, 21: 38-43.
- Ahmad, M., L.H. Akhtar, M. Arshad, A.H. Tariq, S.Z. Siddiqi, M. Hussain, A. Rashid, G. Hussain, M. Aslam, M. Safdar and M.M. Akhtar (2005). Development of a high yielding wheat variety "Bahawalpur-97" for southern Punjab, Pakistan. *Pak. J. Sci. Ind. Res.*, 48: 42-46.
- Ahmad, M., S.Z. Siddiqi, L.H. Akhtar, M. Hussain, A. Rashid, G. Hussain, M. Aslam, M. Safdar, M.M. Akhtar and M. Arshad (2002b). A high-yielding variety of wheat "Derawar-97" released for general cultivation in southern Punjab. *Sci. Tech. Dev.*, 21: 32-36.
- Alam, K. (1994). Breeding methods in self pollinated crops. In: *Plant Breeding*. (Ed.): A.K. Manzoor. National book foundation of Pakistan, Islamabad. 67-82.
- Anonymous (2013-14). Economic Survey of Pakistan. Ministry of Food and Agriculture, Division (Economic Wing) Government of Pakistan, Islamabad.
- Anonymous (2015-16). Economic Survey of Pakistan. Ministry of Food and Agriculture, Division (Economic Wing) Government of Pakistan, Islamabad.
- Bakhsh, A., M. Arshad and S.M. Iqbal (2005). Development of chickpea blight resistant variety (Dasht) using combination of bulk population and pedigree breeding method. *Pak. J. Bot.*, 37: 325-335.
- Bhatty, R.S. (1988). Composition and quality of Lentil (*Lens culinaris* Medik): A Review. *Can. Ins. Food Sci. Tech. J.* 21: 144-160.
- Coelho, M.A.O., G.A.M. Torres, P.R. Cecon and F.M. Santana (2016). Sowing date reduces the incidence of wheat blast disease. *Pesq. Agro. Bras.* 51(5): 631-637.
- Curtis, T. and N.G. Halford (2014). Food Security: The challenge of increasing wheat yield and the importance of not compromising food safety. *Ann. App. Bio.*, 164: 354-372.
- Hussain, M., G. Hussain, L.H. Akhtar, A.H. Tariq, M. Rafiq, M.Z. Aslam, M. Aslam, M. Arshad, S. Ahmad and S.T. Sahi (2010b). New wheat variety "Fareed-06" for irrigated areas of Punjab, Pakistan. *Pak. J. Bot.*, 42: 3285-3297.
- Hussain, M., I. Ahmad, M.I. Haque, M.A.S. Kirmani, J.S. Hamid, E.U. Haque, M.A. Akhtar, A.U.R. Rattu, J.I. Mirza, S.A.J. Khan, A.A. Hakro and A.H. Jaffery (1999). Evaluation of candidate lines against stripe and yellow rusts under uniform wheat and barley yield trial (1997-98). Proceedings of 2nd national Conference of Plant Pathology, 112-119.
- Hussain, M., L.H. Akhtar, A.H. Tariq, M. Rafiq and M. Nasim (2010c). Manthar-03: A high-yielding cultivar of wheat released for general cultivation in southern Punjab. *Pak. J. Agri. Sci.*, 47: 1-8.
- Khan, M.A. (1987). Wheat variety development and longevity of rust resistance. Government of the Punjab, Agriculture Department, Lahore, 197.
- Hussain, M., L.H. Akhtar, M. Rafiq, M.Z. Aslam, A.H. Tariq, M. Aslam, M. Arshad and S. Ahmad (2010a). Mairaj-08: New wheat (*Triticum aestivum*) variety released for general cultivation under normal and late planting in Punjab province, Pakistan. *Int. J. Agri. Bio.*, 12: 341-347.
- Hussain, M., M.A.S. Kirmani and E. Haque (2004). Pathotypes and man-guided evolution of *Puccinia striiformis* of Sp. tritici in Pakistan. In: Abstracts. Second regional yellow rust conference for central & west Asia and north Africa, Islamabad, Pakistan.
- Khan, N.I. and F. Din (1999). TS-3: A new sesame white seed cultivar. *J. Agri. Res.*, 37: 123-128.
- McIntosh, R.A., C.R. Wellings and R.F. Park (1997). *Wheat Rusts. An atlas of resistance genes*. CSIRO Publications, East Melbourne, Victoria, Australia.
- Muhammad, S., A.I. Khan, A. Rehman, F.S. Awan and A. Rehman (2015). Screening for leaf rust resistance and association of leaf rust with epidemiological factors in wheat (*Triticum aestivum* L.). *Pak. J. Agri. Sci.*, 52: 691-700.
- Mustafa, S.Z., M.A. Khan, S. Yasmin, N.S. Kisana, M.Y. Mujahid, M. Asif and M. Asim (2007). Results of the national uniform wheat yield trials (2006-07). Coordinated Wheat-Barley and Triticale Program, Pakistan Agricultural Research Council, Islamabad.
- Mustafa, S.Z., S. Yasmin, N.S. Kisana and M.Y. Mujahid (2008). Results of the national uniform wheat yield trials (2007-08). Coordinated Wheat Barley and Triticale Program, Pakistan Agricultural Research Council, Islamabad.
- Ogbonnaya, F., A. Mujeeb-Kazi, A.G. Kazi, E.L. Lagudah, S.S. Xu and D. Bonnett (2013). Synthetic hexaploid in wheat improvement. In: J. Janick (ed.), *Plant Breeding Reviews*; pp.35-122. John Wiley & Sons Inc.
- Peterson, R.F., A.B. Campbell and A.E. Hannah (1948). A diagrammatic scale for estimating rust severity on leaves and stems of cereals. *Canad. J. Res.*, 26: 496-500.

- Saleem, M.I., S.A.H. Shah and L.H. Akhtar (2002). "BR-99": A new guar cultivar released for general cultivation in Punjab province. *Asian J. Plant Sci.*, 1: 266-268.
- Sarwar, G. and M. Ahmad (2003). Development of a new high yielding mungbean variety "AEM96" through induced mutations. *SAARC J. Agri.*, 1: 173-180.
- Siddiqi, S.Z., M. Ahmad, L.H. Akhtar, M. Hussain, G. Hussain, A. Rashid, M. Aslam, M. Safdar and M.M. Akhtar (2001). "PUNJNAD-1": A new wheat variety for southern Punjab (Pakistan). *Ann. Wheat News*, 47:131-133.
- Steel, R.G.D., J.H. Torrie and D.A. Dickey (1997). *Principles and Procedures of Statistics. A biometrical approach.* 3rd Ed., McGraw Hill Book Co., New York, USA.
- Tariq, M.A., S.A. Rana, R.A. Shah, S.M. Shah, S. Ali, M. Zafar and L.H. Akhtar (2003). BH-118: A new cotton variety released for general cultivation in southern Punjab. *Sci. Tech. Dev.*, 22: 15-19.
- USDA (2015). *Foreign Agriculture Service. World Agricultural Production.* Circular Series WAP 12-13. Washington, DC, USA: USDA.

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