

Research Article

Borlaug 2016: a high yielding wheat variety for the rainfed/irrigated areas of Pakistan

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Abstract

Drought, heat and rusts are the major stresses of wheat crop in Pakistan that leads to yield losses from almost 30 to 40%. Hence, rusts resistant and climate resilient wheat varieties are needed to exploit the potential yield in the country. The occurrence of the Ug99 race of stem rust in different areas of the world is also a potential threat for Pakistani wheat varieties. Keeping in view the above scenario, scientists at Wheat Program, NARC, Islamabad, conducted this study to develop the wheat variety Borlaug 2016. Borlaug-2016 is a cross of SOKOLL/3/PASTOR//HXL7573/2*BAU. It was selected from 17th Semi-arid wheat Yield Trial of CIMMYT. It was tested for disease, adaptability, yield and quality traits for two years at station and for one year at regional yield trials. It was also tested at different locations in National Uniform Wheat Yield Trials under both irrigated and rain-fed conditions for two consecutive years and it showed good performance. It carries desirable resistance against all three wheat rusts. It also carries Adult Plant Resistance against stem rust race 'Ug99'. It has good quality traits that are required for chapatti making. Borlaug-2016 was approved by Punjab Seed Council for cultivation in irrigated areas of Punjab. Hence, as a commercial wheat variety, Borlaug 2016 will help farming community of Pakistan to get increased grain yield with long-lasting rust resistance that will assist to boost their per capita income. It will also be helpful in future breeding programs aimed at rusts resistance and high grain yield in wheat.

Keywords: Crop; Diversity; Irrigated; Nutrition; Wheat; Yield

Introduction

Wheat as a human food, is valued for its taste and nutrition in the form of calories, proteins, certain vitamins and minerals. Wheat is the staple food grain of Pakistan. Agriculture

contributes about 18.5 percent in the total Gross Domestic Production (GDP) out of which 1.6 percent is from wheat and it contributes 8.9 percent to the value added in agriculture [1]. In terms of acreage, wheat is

most important crop in Pakistan. After green revolution, increased agricultural productivity is considered, largely due to the development of high-yielding wheat crop cultivars and better crop management through improved agronomic practices i.e. efficient use of fertilizers, timely planting and better weed control. During the wheat cropping season 2018-19, area under wheat crop has been reported 8.740 million hectares with the production of 25.195 million tons and average yield of 2883 Kg/ha [2]. Drought, heat and rusts (mainly yellow rust) are the major problems of wheat in Pakistan. Most of the wheat varieties are replaced overtime due to their susceptibility to yellow rust [3]. Therefore, continuous efforts of developing new varieties with multiple genes for resistance and adaptation to the changing climate with high yields are inevitable to cope with the global warming and growing population needs. Borlaug-2016, a newly developed wheat variety is an addition to this directory by the scientists of Wheat Program, National Agriculture Research Centre, Islamabad, Pakistan. It is high yielding, rust resistant and good quality wheat for the people of Pakistan.

Materials and Methods

Borlaug-2016 (registered with name of NR-399) is a cross of SOKOLL/3/PASTOR//HXL7573/2*BAU having pedigree PTSS02B00015S-0Y-0B-0Y-0B-1Y-0M-0SY-0ID which was received from CIMMYT, Mexico during the year 2009-10 through national coordinator wheat, Pakistan Agricultural Research Council (PARC) (Anonymous, 1984). It was first evaluated for yield and adaptability in 17th Semi-Arid wheat Yield Trial (17th SAWYT) during the year 2009-10 along with NARC-09 as a local check. The design of the experiment was alpha lattice with two replications [4]. Upon

selection, it was re-evaluated for yield and other morpho-agronomic traits in Preliminary Yield Trials (PYT) in 2010-11 and after that in Advance Yield Trial (AYT) during year 2011-12, using alpha lattice design in rain-fed ecology of Potohar region against NARC-09 as local check, following the recommended agronomic practices. NR 399 (Borlaug-2016) was compared to BARS-09 on 6 different locations during year 2012-13 in Micro Wheat Yield Trial-rainfed (MWYT). Similarly, MWYT irrigated was conducted over 19 different locations under two sowing dates (normal and late) using Punjab-11 as check variety. NR-399 was tested in National Uniform Yield Trials (NUYT) for rain-fed during 2011-12 and 2012-13 at 15 rainfed and 36 irrigated sites of Pakistan by using Randomized Complete Block design (RCBD) with four replications [5]. Seed rate experiment was also performed in 2014-15 using 6 seeding densities to figure out optimum seed rate requirement per hectare. Analysis of variance was run using MSTAT-C computer software package. Differences among means of each trait were measured by the least significant difference (LSD) test at 5% probability level [5]. For yellow rust (*Puccinia striiformis*) and brown rust (*Puccinia recondita*) screening, NR-399 was tested in National Wheat Disease Screening Nursery (NWDSN) during two consecutive years 2011-12 and 2012-13 by Crop Diseases Research Institute (CDRI), NARC Islamabad. The Coefficient of Infection (CI) was estimated following the formula used by CIMMYT and United States Department of Agriculture (USDA) [6]. Rust scoring scale for cereals by [7] was adopted by Pakistan Agricultural Research Council in 1982 with slight modifications that were later accepted by ARC of Great Britain [8].

Coefficient of infection (CI) = response value X intensity of infection %

Average Coefficient of Infection (ACI) = $\frac{\text{sum of CI values of each entry}}{\text{Number of locations}}$

The maximum ACI of a candidate entry was set at 100 and all other entries were adjusted accordingly to calculate Relative Percentage Attack (RPA) for each entry under observation. Country Averaged Relative Percentage Attack (CARPA) was estimated by taking average RPA for each entry under observation. CARPA was used to score between 0-9, where 0 being most susceptible and 9 the highly resistant.

Relative Rust Index (RRI) = $(100 - \text{CARPA}) \times 9$ (100 set as maximum value for CARPA)

Results and Discussion

Borlaug-2016 was selected from 17th Semi-Arid wheat Yield Trial (17th SAWYT). This yield trial was acquired from CIMMYT through National Coordinator Wheat, PARC. This line was tested at National Agriculture Research Centre (NARC), Islamabad under rainfed condition for consecutive three years. It gave 3100 kg/ha grain yield during first year (2009-2010) which was 35% higher than the standard check variety NARC 2009 (2300 kg/ha). During second year (2010-2011), in Preliminary Yield Trial (PYT) it produced 22% higher yield (3388 kg/ha) than the check variety NARC 2009 (2774 kg/ha) as shown in (Table 1). NR-399 (Borlaug-2016) was tested in the third year (2011-2012) in Advance Yield Trial (AYT) under rainfed condition and it produced 22% higher yield (7204 kg) than NARC 2009 (5918 kg).

NR 399 had an average yield of 3242 Kg/ha as compared to BARS-09 (2559 Kg/ha) when tested on 6 locations during year 2012-13 in Micro Wheat Yield Trial-rainfed (MWYT) as shown in (Table 2). The MWYT rainfed was managed by Barani Agriculture Research Institute (BARI) Chakwal. Whereas, MWYT-irrigated was managed by Wheat Research Institute (WRI) Faisalabad that was conducted on 19 locations under two sowing dates. In MWYT Normal (irrigated) it produced 2% higher yield than local Check (Punjab 2011) and in MWYT Late (irrigated)

it was at par with check cultivar Millat 11.

Borlaug-2016 was tested for its yield performance at different locations in National Uniform Wheat Yield Trials (NUWYT) under both irrigated and rainfed conditions for two years (Table 3). During the first year of testing (2011-12) under irrigated condition, it stood 4th on all Pakistan basis (4452 Kg/ha) when yield of both late and normal planting was combined. Consequently, it gave 4762 Kg/ha and 4141 Kg/ha yield in normal and late planting, respectively, at Pakistan level. During 2012-13 under irrigated condition at Pakistan level, production was 4115 Kg/ha in normal planting, 3572 Kg/ha in late planting and 3843 Kg/ha when both seeding dates were pooled (Table 4). In both years of test it showed a good performance in late planting. Under rain-fed condition, during the second year of testing (2012-13), production was 3312 kg/ha at Pakistan level, 3296 Kg/ha in Punjab and 3511 Kg/ha in Khyber Pakhtunkhwa and it got 1st, 4th and 1st position, respectively. Results are in accordance with [9, 10].

Seed rate experiment was also performed to check the optimum seed rate (Kg/ha). At 100kg/ha, NR-399 produces maximum yield (2660 kg/ha) as shown in (Table 5). Maximum number of tillers/m² (239.75), chlorophyll content (49.550) and biological yield (7125.0 kg/ha) were observed when 100 kg/ha seed rate was used. NR 399 was also analyzed for desirable quality traits of chapatti making (Table 6). Thousand grain weight of NR-399 ranged from 40-48g. Protein content ranged from 11.72-12.5 percent. NR 399 and NARC 09 had significantly higher grain yield under normal and late planting that may be attributed to their cooler canopies, higher flag leaf chlorophyll retention, lower spike sterility and better grain weight under high temperature stress at reproductive growth

stage (Table 7). Genetic potential of wheat productivity under stressed genotypes to tolerate environmental stress environment. proved to be more important factor for better

Table 1. Performance of Borlaug-2016 at different Trials (Yield Kg/Ha)

Trial	NR 399	L. Check (NARC 09)	% increase over Check	¥
17 th SAWYT Entry # 43 (2009-10)	3100	2300	35%	1/1
Preliminary Yield Trial (2010-11)	3388	2774	22%	1/1
Advance Yield Trial (2011-12)	7204	5918	22%	1/1
Micro Wheat Yield trial (Rainfed)	3242	2559	27	5/6
Micro Wheat Yield trial Normal (irrigated)	3670	3594	2	11/21
¥ Number of locations in which NR 399 performed better than local check				

Table 2. Consolidated Yield Data (kg/ha) of Micro Wheat Yield Trial Rainfed 2012-13

S. No.	Varietal Code	BARI, Chakwal	GRS, Attock	CRS, Mianwali	NARC, Islamabad	WRI, Faisalabad	BARS, F. Jhang	Avg. (Kg/ha)
1	9172	3170	2670	2781	3632	5430	3567	3542
2	NR-399	3307	1993	1648	4621	5379	2504	3242
3	V-12001	3144	1978	1778	3873	5621	2750	3191
4	11C022	3241	2174	2419	3856	4495	2681	3144
5	11C023	3470	2244	1878	4297	4760	2164	3136
6	09FJ34	3341	2211	2178	2700	4453	3518	3067
7	V-11168	2715	2067	1830	3937	4951	2873	3062
8	11C021	3463	2270	2081	3235	4579	2551	3030
9	NR-391	3367	1541	1452	4200	5126	2315	3000
10	V-10287	3422	2022	1622	3990	4245	2591	2982
11	V-11172	2156	2119	1796	3629	5251	2481	2905
12	08BT005	3444	2026	1322	3068	4243	2286	2732
13	09BT043	2100	2056	1933	3091	4418	2146	2624
14	09FJ21	2019	2096	2119	2455	3992	2857	2590
15	BARS-09	2619	1537	1419	3747	3360	2671	2559

*BARI= Barani Agriculture Research Institute, GRS= Research Station, CRS= Cereal Research Station, NARC= National Agricultural Research Centre, WRI= Wheat Research Institute, BARS= Barani Agriculture Research Station

Table 3. Performance of NR 399 in NUYT-Irrigated (Yield Kg/ ha)

Year	Locations	Yield (t/ha)	Check Yield
2011-12	Pakistan(11)	3153	3091
	Khyber Pakhtunkhwa (7)	3698	3442
	Punjab (15)	2888	2954
2012-13	Pakistan (1)	3312	3008
	Khyber Pakhtunkhwa (1)	3511	3122
	Punjab (4)	3296	3050

Table 4. Performance of NR 399 in NUYT-Irrigated (Yield Kg/ha)

Year	Location (Sites)	Sowing dates (Sites)	Yield (t/ha)	Check Yield
2011-12	Punjab (25)	Normal	4958	4947
2011-12		Late	4308	4119
2011-12		Pool	4633	4533
2011-12	Sindh (6)	Normal	4572	4007
2011-12		Late	3865	3439
2011-12		Pool	4218	3723
2011-12	Khyber Pakhtunkhwa	Normal	4362	4950
2011-12		Late	3966	3664
2011-12		Pool	4164	4307
2011-12	Pakistan (36)	Normal	4762	4128
2011-12		Late	4141	3901
2011-12		Pool	4452	4317
2012-13	Punjab	Normal (26)	4062	4110
2012-13		Late (25)	3520	3356
2012-13		Pool (25)	3812	3745
2012-13	Sindh	Normal (7)	3991	3774
2012-13		Late (6)	3556	3787
2012-13		Pool (6)	3749	3845
2012-13	Khyber Pakhtunkhwa	Normal (4)	4529	4431
2012-13		Late (3)	4037	3509
2012-13		Pool (3)	4296	4102
2012-13	Pakistan (34)	Normal	4115	4143
2012-13	Punjab (25)	Late	3572	3446
2012-13		Pool	3843	3794

() Number of locations

Table 5. Performance of NR 399 at various seeding rates during 2014-15

Seed rate kg/ha	Plant Height (cm)	Spike Length (cm)	No of Tillers/m ²	Leaf Area (cm ²)	Chlorophyll Contents	Biological Yield kg/ha	Grain Yield kg/ha
50	90.475	11.950	170.25bc	27.050	48.175ab	5375.0b	2030.0b
75	88.675	12.125	152.75c	27.425	47.700ab	6250.0ab	2342.5ab
100	90.500	11.700	239.75a	27.800	49.550a	7125.0a	2660.0a
125	89.475	11.575	223.75ab	27.850	46.900b	6625.0ab	2552.5a
150	89.950	11.275	209.00abc	28.025	47.325ab	6375.0ab	2420.0ab
175	90.300	11.175	203.25abc	27.375	47.150ab	6875.0a	2557.5a
LSD(5%)	NS	NS	60.949	NS	2.5414	1323.8	515.31

*NS = non-significant

Table 6. Quality Characteristics of NR 399 in National Uniform Wheat Yield Trials

S. No.	Quantity Traits	Irrigated		Rainfed	
		2011-12	2012-13	2011-12	2012-13
1	1000-Kernel weight(g)	40.04	48	41.5	46.9
2	Test weight(kg/hl)	76.95	75	70.6	72
3	PSI	51	41	54	37
4	Ash (%)	1.21	1.50	1.24	1.49
5	Dry Gluten content (%)	7.72	7.62	8.08	9.27
6	Wet Gluten (%)	19.18	20.58	20.78	22.75
7	Grain Protein(% d. b)	12.67	11.72	12.65	12.5

*PSI= Particle size index

Table 7. Physio-agronomic traits evaluation of NR-399

Genotype	Average (canopy temperature(°C)	Average chlorophyll (SPAD value)	Days to maturity (No.)		Grain yield (kg/ha)	
			Normal	Late	Normal	Late
NR-399	23.7	48.5	164	140	4550	2830
NARC-09	23.8	48.3	165	141	4450	2550

The advanced line (NR 399) carries desirable resistance against yellow rust (YR), leaf rust (LR) and stem rust (SR) with RRI 9.0 for YR and 8.93 for LR during the year 2011-12. During 2012-13 RRI was 9 for both YR and SR and 8.95 for LR as reported by CDRI

(Table 8). Similar results were also reported by [11]. Moreover, CIMMYT/ Njoro Kenya disease data showed that it carries adult plant resistance against stem rust race of Ug99 which is a potential threat to global wheat production.

Table 8. Disease reaction of NR 399 in National Trials (data provided by CDRI-NARC)

Location	Year	Yellow Rust		Leaf Rust		Stem Rust	
		TR	RRI	TR	RRI	TR	RRI
Irrigated	2011-12	0	9.00	TMS	8.93	0	
	2012-13	0	9	TMS	8.95	0	9
Rainfed	2011-12	5RMR	5.79	TMS	8.78	0	
	2012-13	0	9	5MSS	7.97	5M	8.71

*TR= type of reaction, RRI= Relative Rust Index

Conclusion

Based on its yield performance in national, regional and station trials, resistance against wheat rusts and better quality traits, the advance line NR 399 was presented to Variety Evaluation Committee (VEC). It was recommended by VEC to release as a variety during its meeting held on February 23, 2015 at PARC. The candidate variety was also

recommended by Expert Sub-Committee of Punjab Seed Corporation (PSC) during its 72th meeting held at Ayub Agriculture Research Institute (AARI) Faisalabad under chairmanship of Director General, AARI on 02-06-2016. Finally, it was approved by Punjab Seed Corporation for cultivation in irrigated areas of Punjab during its 47th meeting held at Agricultural House Lahore under chairmanship

of the Minister of Agriculture, Punjab/Chairman PSC, on 15-07-2016. The release of this new variety (Borlaug-2016) will complement the existing diversity in wheat germplasm and the farmers can make decision to choose and pick the higher yielding variety. Farmers, will get benefit through its higher yield and resistance against prevalent races of wheat rusts along with added resistance against the Ug99 stem rust race. In this way, the individual farmer will gain the optimum benefit. Moreover, with the possession of these resistance genes Borlaug-2016 will also help plant breeders in future breeding programs planned to increase grain yield, better quality and rust resistance in wheat.

Authors' contributions

Conceived and designed the experiments: M Qamar, RU Din & S Waqar, Performed the experiments: M Qamar, RU Din & S Waqar, Analyzed the data: M Qamar, RU Din, S Waqar & MS Ahmed, Contributed materials/ analysis/ tools: SK Tanveer, SH Abbas, Z Mehmood, I Hussain, AUR Rattu & M Imtiaz, Wrote the paper: M Qamar & S Waqar.

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