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C Bharath
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Suma S Biradar
AICRP on Wheat, MARS, University of Agricultural Sciences, Dharwad, Karnataka, India

Rudra Naik V
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Uday G
AICRP on Wheat, MARS, University of Agricultural Sciences, Dharwad, Karnataka, India

Desai SA
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Mahalaxmi K Patil
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Karnataka, India

KD Lamani
AICRP on Wheat, MARS, University of Agricultural Sciences, Dharwad, Karnataka, India

Sewa Ram
Principal Investigator (Quality), IIWBR, Karnal, Haryana, India

Corresponding Author:
Suma S Biradar
AICRP on Wheat, MARS, University of Agricultural Sciences, Dharwad, Karnataka, India

Investigation on heterosis for grain micronutrients Zn, Fe and identifying heterotic single cross hybrids in tetraploid wheat

C Bharath, Suma S Biradar, Rudra Naik V, Uday G, Desai SA, Mahalaxmi K Patil, KD Lamani and Sewa Ram

Abstract
The present investigation was conducted at AICRP on Wheat, Dharwad, during *rabi* 2018-19. A comprehensive analysis of various yield and yield-related components and grain nutrients was carried out among 45 single cross hybrids. Three popular cultivated varieties DDK-1029, HW-1098, and NP-200 employed as lines, while local germplasm of dicoccum with high grain nutrients as testers. Highly significant differences were observed among the F1 for all the traits studied. Significant heterosis, heterobeltosis, and standard heterosis were observed in the cross HW 1098 × GPM DIC 66 with a value 63.95, 62.63, 61.00, respectively, and it was adjudged best heterotic cross combination for grain yield per plant. The cross combination NP-200 × GPM DIC 25 exhibited significant positive standard heterosis for Zn content over mid parent (20.62), better parent (7.82), and check (28.47). The cross HW-1098 × GPM DIC 105 exhibited the highest and significant positive heterosis over better parent and mid parent for grain protein content. These crosses can be used in developing high yielding cultivar with good quality traits.

Keywords: Heterobeltosis, heterosis, lines, tester, wheat

Introduction
Wheat (*Triticum* spp.) is the most widely grown and consumed food crop of the world. The importance of wheat as a staple food is well known as nearly 35 per cent of the world population depends on wheat. Wheat is the second most important crop after rice in India and occupying 31 million hectares, with a production of 101.2 million tones with a verage productivity of 3295 kg ha-1 (Anon., 2019) [3].

Worldwide, wheat provides nearly 55 per cent of the carbohydrates and 20 per cent of food calories consumed globally. Wheat grain contains carbohydrates (60-80% mainly asstarch), proteins(8-15%), fats(1.5-2%), minerals(1.5-2%), traces of vitamins and crude fibers (2-3%).Malnutrition, which is a global issue, afflicts more than 52 per cent of the world's population (Hwalla *et al*., 2017) [8]. Currently, over two billion people suffer from ‘‘hidden hunger’’ (micronutrient deficiency) (Anon., 2013) [1]. The World Health Organization estimates about 30 per cent of world population suffers from anemia (Anon., 2013a) [2] and that Fe deficiency anemia led to the loss of 46,000 disability-adjusted life years (DALS) in 2010 alone (Murray and Lopez, 2012) [10]. Wessells and Brown (2012) [14] reported that 17per cent of people worldwide are at risk of inadequate Zn intake in developing countries.

Micronutrient intake in the human diet can be done through many possible ways namely, post-harvest food fortification, dietary diversification, and mineral supplementation. These strategies however require high investment and infrastructure. These problems can be solved by improving the micronutrient content of the crops by increasing mineral levels and bioavailability in thee dibleparts. Agronomic biofortification is a complimentary, short term approach and a quick solution to counter micronutrient deficiency in cereal grains (e.g., fertilizer strategy) (Cakmak, 2008) [5]. A plant breeding strategy (e.g., genetic biofortification) is along-term process requiring substantial efforts and resources, however, is a sustainable and cost-effective approach inimproving micronutrient concentrations. This method is however a sustainable and cost-effective approach for improving micronutrient concentration.

Tetraploids considered being one of the most promising donors to improve Zn and Fe concentrations of wheat (Cakmak *et al*., 2004) [4]. Wild emmer wheat (*Triticum dicoccoides*) showed significantly more variation and the highest concentrations of micronutrients, such as Zn and Fe, as compared to cultivated wheat (Çakmak *et al*., 2004).

The concentrations of Zn and Fe among *Triticum dicoccoides* genotypes varied from 14 to 190 mg kg per dryweight for Zn and from15to109 mg kg per dry weight for Fe.

Heterosis corresponds to the superiority of the hybrids. For obtaining a better picture of this measure, the superiority was measured concerningmid-parent (mid-parentheterosis), better parent (heterobeltosis), and the check used under particular conditions (standard heterosis).

Material and methods

The present experiment was conducted to assess the genetic analysis for grain yield, yield attributes, micronutrients and quality parameters in tetraploid wheat. The present investigation was carried out during 2018-2019 at All India Coordinated Wheat Improvement Project, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India. The three cultivated popular high yielding genotypes used as lines (recipients) crossed with the 15 donor parents as testers which are rich in micronutrients (Fe and Zn) are represented in Table 1. The crosses were attempted in Line × Tester design as postulated by Kempthrone, during *rabi*, 2017- 18 to produce the 45 straight single cross hybrids. The list of lines and testers employed in the present study are furnished in Table 2. All the resultant 45 F1's, along with their parents were evaluated using RCBD design with two replications. In the present investigation efforts were made to explore utilization of local germplasm of dicoccum which are rich in micronutrients to improve popularly cultivated varieties of the region.

Table 1: The list of lines and testers used in the hybridization programme during *rabi*, 2017-18

S. No	Recipient parents	Pedigree	Source
1	DDK1029	DDK-1012/HW-1093/276-15	UAS, Dharwad
2	HW1098	NP201//200Gray	ICAR, IARI regional station, Wellington
3	NP200	Selection of local Rishi Valley	ICAR, IARI regional station, Wellington
Donar Parents			
1	GPM DIC 66	DDK-50383	Belagali
2	GPM DIC 87	DDK-50404	No details
3	GPM DIC 74	DDK-50391	Mahalingpur
4	GPM DIC 49	DDK-50366	Gokak
5	GPM DIC 71	DDK-50388	No details
6	GPM DIC 89	DDK-50406	No details
7	GPM DIC 105	DDK-50422	No details
8	GPM DIC 54	DDK-50371	Belagali
9	GPM DIC 46	DDK-50363	No details
10	GPM DIC 47	DDK-50364	No details
11	GPM DIC 90	DDK-50366	Teeradal
12	GPM DIC 27	DDK-50344	Belagali
13	GPM DIC 25	DDK-50342	No details
14	SEL SET 16	DDK-50527	No details
15	GPM DIC 02	DDK-50319	Yadawad

Table 2: List of crosses attempted during *Rabi* 2017-18 at AICRP on Wheat, Dharwad centre

S. No.	Cross Name	Sl No.	Cross Name		
1	DDK-1029 × GPM DIC 66	20	HW-1098 × GPM DIC 71	39	NP-200 × GPM DIC 46
2	DDK-1029 × GPM DIC 87	21	HW-1098 × GPM DIC 89	40	NP-200 × GPM DIC 47
3	DDK-1029 × GPM DIC 74	22	HW-1098 × GPM DIC 105	41	NP-200 × GPM DIC 90
4	DDK-1029 × GPM DIC 49	23	HW-1098 × GPM DIC 54	42	NP-200 × GPM DIC 27
5	DDK-1029 × GPM DIC 71	24	HW-1098 × GPM DIC 46	43	NP-200 × GPM DIC 25
6	DDK-1029 × GPM DIC 89	25	HW-1098 × GPM DIC 47	44	NP-200 × SEL SET 16
7	DDK-1029 × GPM DIC 105	26	HW-1098 × GPM DIC 90	45	NP-200 × GPM DIC 02
8	DDK-1029 × GPM DIC 54	27	HW-1098 × GPM DIC 27		
9	DDK-1029 × GPM DIC 46	28	HW-1098 × GPM DIC 25		
10	DDK-1029 × GPM DIC 47	29	HW-1098 × SEL SET 16		
11	DDK-1029 × GPM DIC 90	30	HW-1098 × GPM DIC 02		
12	DDK-1029 × GPM DIC 27	31	NP 200 × GPM DIC 66		
13	DDK-1029 × GPM DIC 25	32	NP 200 × GPM DIC 87		
14	DDK-1029 × SEL SET 16	33	NP 200 × GPM DIC 74		
15	DDK-1029 × GPM DIC 02	34	NP 200 × GPM DIC 49		
16	HW 1098 × GPM DIC 66	35	NP-200 × GPM DIC 71		
17	HW 1098 × GPM DIC 87	36	NP-200 × GPM DIC 89		
18	HW 1098 × GPM DIC 74	37	NP-200 × GPM DIC 105		
19	HW 1098 × GPM DIC 49	38	NP-200 × GPM DIC 54		

Heterosis expressed as per cent increase or decrease of F1 hybrid over mid parent (average or relative heterosis), better parent (heterobeltiosis), and the best commercial check (standard heterosis) were computed for each character (Turner, 1953 and Hayes, *et al.*, 1955) [12, 7]. Out of four checks, the mean performance of the best check for a given character was considered to work out the standard heterosis.

$$\text{Heterosis over mid parent} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterosis over better parent} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Heterosis over check (Standard heterosis)} = \frac{F_1 - CC}{CC} \times 100$$

Where,
F1 = Mean performance of F1
MP = Mean mid-parental value = (P1 + P2)/2
P1 = Mean performance of parent one
P2 = Mean performance of parent two
BP = Mean performance of better parent
CC = Mean performance of the best commercial check.

Results and discussion

The analysis for variability was carried out by growing the parental genotypes in Randomized Complete Block Design. The mean sum of squares along with table values are presented in Table3. Perusal of results indicated that morpho-physiological, agronomic traits and grain nutrients exhibited highly significant results, suggesting the existence of sufficient variability among the parents and hybrids. The exploitation of heterosis for increased yield was largely attributed to cross-pollinated crops however, Freeman (1919) [6] reported the presence of heterotic effects in self-pollinated crops like wheat. A positive direction of heterosis as well as heterobeltosis is desirable in case of the trait grain yield. The single cross hybrid of the cross HW-1098 × GPM DIC 66 recorded the highest mean value for grain yield per plant. The F1 of the cross HW 1098 × GPM DIC 74 recorded the highest iron content with respect to mean values. Based on the per se performance of the hybrid, NP-200 × GPM DIC 25 recorded the highest value for the Zn content. Based on the per se performance, HW-1098 × GPM DIC 105 registered the highest value for protein content. Promising single cross hybrids based on the per se yield, Fe content, Zn content, protein content and heterosis are presented in Table 4.

Table 3: ANOVA for randomized block design for yield, micronutrients and protein content

	DF	SS	MSS	F value	Mean	SE
G Y	21	171.04	8.14*	2.28	23.18	1.33
Fe (ppm)	21	521.14	24.81*	2.82	43.40	2.09
Zn (ppm)	21	1222.69	58.22**	5.82	44.35	2.22
Protein (%)	21	24.50	1.17*	7.81	15.40	0.45

* - Significant at 5% probability
** - Significant at 1% probability GY- Grain yield per plant (g), Fe-iron content in ppm, Zn- Zinc content in ppm, Protein in percentage.

Table 4: Promising single cross hybrids based on the *per se* yield, Fe content, Zn content, protein content and heterosis

S. No.	Cross name	Mean (g)	Heterosis			Grain nutrients		
			Mid parent	Better Parent	HW 1098	Fe (ppm)	Zn (ppm)	Protein (%)
1	HW 1098 × GPM DIC 66	40.25	63.95**	62.63**	61.00**	41.09	48.47	16.57
2	DDK-1029 × GPM DIC 66	35.95	48.55**	47.64**	43.80**	39.86	46.59	16.71
3	HW-1098 × GPM DIC 71	35	41.27**	41.13**	40.00**	40.55	49.67	16.79
4	HW-1098 × GPM DIC 90	34.77	43.40**	40.51**	39.10**	41.44	49.5	16.34
5	DDK-1029 × GPM DIC 87	33.35	44.45**	38.67**	33.40*	39.05	45.24	15.91
Fe Content								
S. No.	Cross name	Fe Mean (ppm)	Heterosis			Grain Yield (g)		
			Mid parent	Better parent	HW 1098			
1	HW 1098 × GPM DIC 74	43.56	-2.66	-11.10**	1.54	21.16		
2	NP-200 × GPM DIC 27	43.53	1.44	-1.74	1.47	21.9		
3	NP 200 × GPM DIC 49	43.52	0.64	-3.19	1.43	30.2		
4	HW-1098 × GPM DIC 46	43.24	3.57	0.56	0.79	31.07		
5	HW 1098 × GPM DIC 49	43.11	0.91	-4.08	0.5	24.77		
Zn content								
S. No.	Cross name	Zn Mean (ppm)	Heterosis			Grain Yield (g)		
			Mid parent	Better parent	HW 1098			
1	NP-200 × GPM DIC 25	52.35	20.62**	7.82*	28.47**	22.63		
2	NP 200 × GPM DIC 66	52.3	25.63**	16.21**	28.33**	17.25		
3	HW-1098 × GPM DIC 02	52.11	12.99**	1.2	27.88**	20.75		
4	NP 200 × GPM DIC 74	52.02	12.18**	-4.54	27.67**	22.85		
5	NP-200 × GPM DIC 71	51.6	26.70**	19.43**	26.64**	15.99		
Protein content								
S. No.	Cross name	Protein content Mean (%)	Heterosis			Grain Yield (g)		
			Mid parent	Better parent	HW 1098			
1	HW-1098 × GPM DIC 105	17.95	16.35**	13.21**	20.88**	30.56		
2	DDK-1029 × GPM DIC 27	17.09	15.24**	12.77**	15.05**	31.57		
3	NP-200 × GPM DIC 90	17.04	7.39**	5.77*	14.75**	25.59		
4	NP-200 × GPM DIC 02	16.94	9.59**	8.45**	14.11**	31.34		
5	DDK-1029 × GPM DIC 25	16.88	8.38**	5.50*	13.67**	19.75		

* - Significant at 5% probability
** - Significant at 1% probability

Significant positive heterosis, as well as heterobeltosis for grain yield, was displayed by the crosses namely, DDK-1029 × GPMDIC66, DDK-1029 × GPMDIC87,DDK-1029 × GPMDIC02, HW1098 × GPMDIC66, HW-1098 × GPMDIC 71,HW-1098 × GPMDIC90, HW-1098 × GPMDIC27 and NP-200 × GPM DIC 02 whereas, positive significant heterosis but a non- significant positive heterobeltosis was observed in case of crosses *viz*., DDK-1029 × GPMDIC27, DDK-1029 × GPMDIC90, HW-1098 × GPMDIC46, NP-200 × GPMDIC46 and NP-200 × GPMDIC49 and seven crosses showed positive significant heterosis over the check HW-1098. Heterosis over standard check for grain yield ranged from-36.06 (NP-200 × GPMDIC71) to 61.00 (HW-1098 × GPMDIC66).Others promising crosses which recorded significantly higher values areDDK-1029 × GPMDIC66, HW-1098 × GPMDIC66, HW-1098 × GPMDIC71, HW-1098 × GPMDIC90 and DDK-1029 × GPMDIC87.Similar findings are reported by Menon and Sharma (1997) [9], Vanpariya *et al*. (2006) [13] and Singh *et al*. (2004) [11] (Table 5).

None of the crosses exhibited positive heterosis over the standard check HW 1098 for the trait Fe content. The cross HW1098×GPMDIC74reportedthe highest mean value among all the crosses *i.e*., 43.56ppm (Table 5).

Table 5: Estimates of mid-parent heterosis, heterobeltosis and standard heterosis for the trait grain yield per plant and Fe among 45 single crosses hybrids in tetraploid wheat

S. No.	F1 Cross	Heterosis (%)							
		GY (grain yield per plant)				Fe (ppm)			
		Mean	Mid parent	Better Parent	HW-1098	Mean	Mid parent	Better Parent	HW-1098
1	DDK-1029 X GPM DIC 66	35.95	48.55**	47.64**	43.80**	39.86	-5.94	-9.41**	-7.09
2	DDK-1029 X GPM DIC 87	33.35	44.45**	38.67**	33.40*	39.05	-6.75*	-9.19*	-8.97*
3	DDK-1029 X GPM DIC 74	21.78	-8	-9.44	-12.88	40.83	-9.03**	-16.68**	-4.84
4	DDK-1029 X GPM DIC 49	24.61	1.1	-0.1	-1.56	41.96	-2.09	-6.66	-2.2
5	DDK-1029 X GPM DIC 71	23.66	-3.13	-4.6	-5.36	42.26	-2.36	-7.74*	-1.5
6	DDK-1029 X GPM DIC 89	22.27	-0.48	-7.38	-10.9	42.67	-1.64	-7.25*	-0.55
7	DDK-1029 X GPM DIC 105	20.22	-19.98	-23.68	-19.1	41.75	-3.15	-8.16*	-2.69
8	DDK-1029 X GPM DIC 54	26.69	13.13	10.96	6.74	39.86	-3.37	-4.53	-7.09
9	DDK-1029 X GPM DIC 46	22.72	4.68	-5.55	-9.14	42.67	1.89	-0.78	-0.55
10	DDK-1029 X GPM DIC 47	22.96	-7.42	-10.14	-8.16	40.89	-6.16*	-11.88**	-4.69
11	DDK-1029 X GPM DIC 90	27.5	15.06	14.35	10	41.47	-4.06	-9.26**	-3.33
12	DDK-1029 X GPM DIC 27	31.57	27.66*	24.27	26.26	40.38	-5.06	-8.86*	-5.89
13	DDK-1029 X GPM DIC 25	19.75	-10.53	-17.88	-21	41.01	-9.17**	-17.22**	-4.42
14	DDK-1029 X SEL SET 16	19.82	-15.46	-17.57	-20.7	41.78	2.2	1.89	-2.62
15	DDK-1029 X GPM DIC 02	31.77	47.28**	32.12*	27.10*	42.80	-2.06	-8.25*	-0.23
16	HW 1098 x GPM DIC 66	40.25	63.95**	62.63**	61.00**	41.09	-2.75	-6.61	-4.22
17	HW 1098 x GPM DIC 87	28.18	20.21	13.84	12.7	38.83	-6.99*	-9.70**	-9.49*
18	HW 1098 x GPM DIC 74	21.16	-11.9	-14.48	-15.34	43.56	-2.66	-11.10**	1.54
19	HW 1098 x GPM DIC 49	24.77	0.33	0.1	-0.9	43.12	0.91	-4.08	0.5
20	HW-1098 X GPM DIC 71	35	41.27**	41.13**	40.00**	40.55	-6.04	-11.47**	-5.49
21	HW-1098 X GPM DIC 89	24.32	7.01	-1.72	-2.7	42.34	-2.12	-7.97*	-1.32
22	HW-1098 X GPM DIC 105	30.56	19.28	15.34	22.26	38.88	-9.53**	-14.46**	-9.37*
23	HW-1098 X GPM DIC 54	29.72	24.16	20.08	18.88	40.03	-2.66	-4.12	-6.69
24	HW-1098 X GPM DIC 46	31.07	40.93**	25.56**	24.3**	43.24	3.57	0.56	0.79
25	HW-1098 X GPM DIC 47	16.07	-36.12**	37.12**	-35.74*	39.71	-8.61**	-14.42**	-7.44*
26	HW-1098 X GPM DIC 90	34.77	43.40**	40.51**	39.10**	41.44	-3.86	-9.33**	-3.41
27	HW-1098 X GPM DIC 27	32.55	29.81*	28.15*	30.20*	39.78	-6.19	-10.21**	-7.28*
28	HW-1098 X GPM DIC 25	20.84	-7.07	-15.8	-16.64	42.94	-4.63	-13.32**	0.08
29	HW-1098 X GPM DIC 16	20.13	-15.44	-18.69	-19.5	39.90	-2.09	-2.68	-6.99
30	HW-1098 X GPM DIC 02	20.75	-5.36	-16.16	-17	39.80	-8.66**	-14.68**	-7.23*
31	NP 200 X GPM DIC 66	17.25	-26.12*	-29.16*	-31.00*	40.02	-6.41*	-9.05*	-6.71
32	NP 200 X GPM DIC 87	25.07	12.76	12.19	0.3	42.57	0.73	-1.00	-0.77
33	NP 200 X GPM DIC 74	22.85	0.11	-1.93	-8.6	42.08	-7.03*	-14.12**	-1.91
34	NP 200 X GPM DIC 49	30.2	28.55*	22.59	20.8	43.52	0.64	-3.19	1.43
35	NP-200 X GPM DIC 71	15.99	-32.20*	-35.54*	-36.06**	43.01	-1.49	-6.09	0.26
36	NP-200 X GPM DIC 89	23.72	10.14	6.11	-5.14	41.73	-4.64	-9.28**	-2.73
37	NP-200 X GPM DIC 105	25.32	3.68	-4.43	1.3	42.11	-3.18	-7.37*	-1.85
38	NP-200 X GPM DIC 54	16.25	-28.53*	-29.73*	-35.00*	40.90	-1.78	-2.05	-4.67
39	NP-200 X GPM DIC 46	28.8	38.13**	28.86	15.2	41.01	-2.98	-4.64	-4.42
40	NP-200 X GPM DIC 47	27.74	15.8	8.55	10.94	40.28	-8.38**	-13.19**	-6.11
41	NP-200 X GPM DIC 90	25.59	11	7.73	2.34	41.06	-5.85	-10.15**	-4.29
42	NP-200 X GPM DIC 27	21.9	-8.27	-13.78	-12.4	43.53	1.44	-1.74	1.47
43	NP-200 X GPM DIC 25	22.63	6.62	1.25	-9.48	39.61	-13.00**	-20.04**	-7.67*
44	NP-200 X SEL SET 16	19.91	-11.88	-12.84	-20.34	40.33	-2.26	-2.88	-5.99
45	NP-200 X GPM DIC 02	31.34	51.19**	40.20**	25.34	38.97	-11.61**	-16.46**	-9.16*
	S.E.d		2.0747	2.395	2.395		1.29	1.49	1.49
	CD @ 95%		4.181	4.828	4.828		2.60	3.00	3.00
	CD @ 99%		5.585	6.44	6.44		3.47	4.01	4.01
No. of positive heterosis			12	8	7		0	0	0

Crosses revealed a positive direction of heterosis as well as heterobeltosis for the trait Zn content under the experimental conditions. A significant positive heterosis as well as heterobeltosis was displayed by the crosses namely, DDK-1029 × GPM DIC46, DDK-1029 × GPMDIC90, HW-1098 × GPMDIC66, HW-1098 × GPMDIC71, HW-1098 × GPMDIC54, HW-1098 × GPMDIC46, HW-1098 × GPMDIC47, HW-1098 × GPMDIC90, NP200 × GPMDIC66, NP200 × GPMDIC87, NP200 × GPMDIC71, NP200 × GPMDIC89, NP200 × GPMDIC54, NP200 × GPMDIC46, NP200 × GPMDIC90 and NP200 × GPMDIC25**.** All the 45 crosses, showed positive significant heterosis over the check, maximum was registered in the cross NP-200 × GPM DIC25 (28.47), and the minimum was registered in DDK-1029 × GPM DIC90 (8.37) (Table 6).

The protein content is one of the important desirable qualitative traits of wheat, which not only helps to avert malnutrition but also very much desired for good bread and chapati making quality. The estimate for grain protein contentfor heterobeltiosis, mid parent heterosis, and standard heterosis over check HW-1098 was16.35, 13.21, 20.88 respectively, and recorded in the cross HW-1098 × GPMDIC105 (Table 6).The findings corroborate with the results reported by Singh *et al*. (2004) [11].

Table 6: Estimates of mid-parent heterosis, heterobeltiosis and standard heterosis for the trait Zn and protein content among 45 single crosses hybrids in tetraploid wheat

S. No.	F1 Cross	Heterosis (%)							
		Zn (ppm)				Protein (%)			
		Mean	Mid parent	Better Parent	HW-1098	Mean	Mid parent	Better Parent	HW-1098
1	DDK-1029 X GPM DIC 66	46.59	14.54**	3.53	14.33**	16.71	8.07**	5.93*	12.53**
2	DDK-1029 X GPM DIC 87	45.24	9.10*	-2.88	11.01**	15.91	2.61	0.35	7.10**
3	DDK-1029 X GPM DIC 74	51.25	12.82**	-5.96	25.77**	16.39	4.95*	1.93	10.34**
4	DDK-1029 X GPM DIC 49	48.50	17.19**	4.48	19.02**	15.79	4.36	4.19	6.30*
5	DDK-1029 X GPM DIC 71	44.56	12.00**	3.11	9.34*	15.78	0.56	-2.8	6.26*
6	DDK-1029 X GPM DIC 89	46.67	15.04**	4.21	14.52**	15.40	-0.73	-2.96	3.67
7	DDK-1029 X GPM DIC 105	47.89	10.72**	-4.53	17.52**	16.73	7.92**	5.52*	12.66**
8	DDK-1029 X GPM DIC 54	48.03	17.38**	5.61	17.85**	15.65	0.97	-1.26	5.39*
9	DDK-1029 X GPM DIC 46	46.96	24.34**	19.86**	15.23**	16.85	7.84**	4.66	13.47**
10	DDK-1029 X GPM DIC 47	44.97	9.69**	-1.47	10.34*	15.78	2.07	0.10	6.23*
11	DDK-1029 X GPM DIC 90	44.16	17.72**	14.18**	8.37*	16.10	3.01	-0.06	8.42**
12	DDK-1029 X GPM DIC 27	48.00	9.83**	-5.99	17.79**	17.09	15.24**	12.77**	15.05**
13	DDK-1029 X GPM DIC 25	44.85	5.65	-7.63*	10.06*	16.88	8.38**	5.50*	13.67**
14	DDK-1029 X SEL SET 16	46.80	5.52	-10.60**	14.85**	15.06	1.59	-0.59	1.41
15	DDK-1029 X GPM DIC 02	44.71	1.80	-13.17**	9.72*	15.32	0.62	0.13	3.16
16	HW 1098 x GPM DIC 66	48.47	13.04**	7.70*	18.93**	16.58	7.72**	5.07*	11.62**
17	HW 1098 x GPM DIC 87	46.66	6.87*	0.18	14.50**	14.79	-4.15	-6.72**	-0.44
18	HW 1098 x GPM DIC 74	48.00	0.79	-11.93**	17.79**	16.70	7.45**	3.86	12.42**
19	HW 1098 x GPM DIC 49	47.35	8.64*	2.00	16.20**	16.12	7.08**	6.72*	8.52**
20	HW-1098 X GPM DIC 71	49.67	18.32**	14.95**	21.89**	16.79	7.48**	3.39	13.03**
21	HW-1098 X GPM DIC 89	47.15	10.25**	5.29	15.71**	15.12	-2.06	-4.73	1.78
22	HW-1098 X GPM DIC 105	49.01	7.81*	-2.30	20.26**	17.95	16.35**	13.21**	20.88**
23	HW-1098 X GPM DIC 54	50.26	16.58**	10.52**	23.34**	14.79	-4.15	-6.72**	-0.44
24	HW-1098 X GPM DIC 46	47.85	19.74**	17.42**	17.42**	16.58	6.62**	2.98	11.65**
25	HW-1098 X GPM DIC 47	49.72	15.10**	8.94*	22.00**	16.57	7.70**	5.11*	11.55**
26	HW-1098 X GPM DIC 90	49.50	24.65**	21.47**	21.47**	16.34	5.05*	1.43	10.03**
27	HW-1098 X GPM DIC 27	48.90	6.51*	-4.24	19.99**	16.33	10.68**	8.83**	9.93**
28	HW-1098 X GPM DIC 25	47.98	7.45*	-1.18	17.74**	16.65	7.42**	4.06	12.12**
29	HW-1098 X GPM DIC 16	48.90	5.05	-6.59*	20.00**	15.36	4.1	2.37	3.4
30	HW-1098 X GPM DIC 02	52.11	12.99**	1.20	27.88**	14.13	-6.73**	-7.65**	-4.85
31	NP 200 X GPM DIC 66	52.30	25.63**	16.21**	28.33**	15.74	0.25	-0.22	5.99*
32	NP 200 X GPM DIC 87	50.35	18.72**	8.11*	23.56**	16.27	3.38	2.65	9.56**
33	NP 200 X GPM DIC 74	52.03	12.18**	-4.54	27.67**	15.77	-0.54	-1.93	6.16*
34	NP 200 X GPM DIC 49	49.00	15.74**	5.56	20.25**	14.95	-2.69	-4.32	0.67
35	NP-200 X GPM DIC 71	51.61	26.70**	19.43**	26.64**	16.01	0.47	-1.42	7.78**
36	NP-200 X GPM DIC 89	49.40	18.99**	10.32**	21.23**	16.46	4.51*	3.72	10.81**
37	NP-200 X GPM DIC 105	47.16	6.67*	-5.99	15.72**	15.78	0.22	-0.50	6.23*
38	NP-200 X GPM DIC 54	49.05	17.16**	7.85*	20.36**	16.40	4.21	3.47	10.44**
39	NP-200 X GPM DIC 46	51.01	31.75**	30.20**	25.17**	16.85	6.19**	4.63	13.43**
40	NP-200 X GPM DIC 47	48.08	14.62**	5.35	17.98**	16.08	2.47	2.03	8.28**
41	NP-200 X GPM DIC 90	51.56	34.04**	33.30**	26.52**	17.04	7.39**	5.77*	14.75**
42	NP-200 X GPM DIC 27	49.45	10.74**	-3.15	21.35**	16.76	11.24**	7.23**	12.83**
43	NP-200 X GPM DIC 25	52.35	20.62**	7.82*	28.47**	16.13	2.01	0.81	8.62**
44	NP-200 X SEL SET 16	49.85	10.04**	-4.78	22.33**	15.65	3.90	0.16	5.39*
45	NP-200 X GPM DIC 02	49.00	9.19**	-4.85	20.23**	16.95	9.59**	8.45**	14.11**
	S.E.d		1.29	1.49	1.49		0.33	0.38	0.38
	CD @ 95%		2.60	3.00	3.00		0.67	0.77	0.77
	CD @ 99%		3.47	4.01	4.01		0.9	1.03	1.03
	No. of positive heterosis		40	16	45		21	12	36

The findings of the present investigation revealed the presence of a good amount of genetic variability among the parents and hence, there exists ample possibility for the exploitation of heterosis for grain yield and quality traits. The cross HW-1098 x GPM DIC 66 was recognized as the best heterotic cross for grain yield and it exhibited highly significant positive heterosis over the standard check HW1098. Therefore, this cross can be further evaluated and used in the hybrid breeding programme to boostup the grain yield. Moreover, the cross HW-1098 x GPM DIC 105 exhibited the highest and significant positive heterosis over the standard check for protein content while, the cross NP 200 x GPM DIC 25 showed the best positive heterosis over better parent, mid parent and standard check for Zn content. Besides, the results of the present study also revealed ample scope for finding transgressive segregants involving some of the crosses in developing high yielding wheat genotypes with good quality attributes.

Conclusion

In the present study, among the out yielding single cross hybrids, three crosses namely, HW1098 x GPMDIC66, HW-1098 X GPMDIC71, HW-1098 X GPMDIC90 exhibited superior grain nutrients, so these crosses can be further advanced to isolate superior recombinants with dense micronutrients and higher yield. The superior performance of these hybrids was attributed to additive and non-additive genes. Further, superior single cross hybrids concerning mean performance of iron, zinc, and protein content were identified and presented in Table 6. Unfortunately, all of them were inferior with respect to grain yield, therefore the results obtained in the present study suggest that simultaneous improvement of yield and grain nutrients is relatively different. However, interpopulation intermating can be followed to improve these traits simultaneously. On the contrary, superior recombinants for individual traits can be registered as genetic stocks and can be further used in durum and bread wheat bio fortification programme.

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