

Screening and Characterization of Wheat Germplasms for Phytic Acid and Iron Content

R. K. Gupta¹, S. S. Gangoliya¹, and N. K. Singh^{1*}

ABSTRACT

Phytic acid is a major storage form of phosphorous in cereals that acts as food inhibitor by chelating micronutrients and prevents it to be bioavailable for monogastric animals, including humans. Ninety three wheat (*Triticum aestivum* L.) germplasms, including cultivars from India, were characterized for phytic acid and Fe contents. Phytic acid contents ranged from 0.59 (IITR 92) to 2.08% (IITR 25). The Fe contents of all wheat germplasms ranged from 9.97 (IITR 25) to 45.77 mg kg⁻¹ (IBW 1133) while historical cultivars from India contain an average of 21.7 mg kg⁻¹ Fe. This initial screening facilitated the identification of diversity in germplasms for this trait that can be exploited for genetic improvement in wheat. Forty eight F₂ wheat lines from (WL711×IITR 19) were also evaluated, which demonstrated considerable variation in phytic acid content. Phytic acid contents ranged from 0.58 to 2.01% in F₂ lines with an average of 1.52%. The genotypes showed significant differences in phytic acid and Fe contents. F₂ lines of WL711×IITR19 also illustrated variation in phytic acid content that were significant. The progenies having lower phytic acid content compared to parents are useful for further crop improvement. A relatively high broad sense heritability (93.4%) and genetic advance (32.3%) of phytic acid showed that progenies of this cross would be useful for reducing phytic acid.

Keywords: Food and nutrition, Genetic improvement, Wheat genotypes.

INTRODUCTION

Wheat (*Triticum aestivum*) is the most important food crop of the world and is the cheapest source of protein and calories. Wheat contributes approximately with 30% of the total cereal production worldwide and is a major source of minerals for many people (McKevith, 2004). There are many human diseases that are related to micronutrition (Guo *et al.*, 2012), hence it is important to improve the micronutrient in foods. In bread wheat, Fe content range from 21–32 mg kg⁻¹ and Zn content 15–22 mg kg⁻¹ (Rawat *et al.*, 2009), but a very small portion of the existing amount is retained during processing and has low bioavailability due to the presence of phytic acid food inhibitors. Compared to cultivated wheat, wild and primitive wheat are a better genetic

resource for high Fe and Zn concentrations. Wild emmer wheat, *Triticum turgidum* ssp. *dicoccoides*, showed prominent genetic variation in the concentrations of Zn ranging from 14 to 190 mg kg⁻¹ (Cakmak *et al.*, 2010; Gupta *et al.*, 2013). Phytic acid is the major storage form of phosphorous in cereals. Approximately 65 to 85% of total seed phosphorus is stored as phytic acid (Vats and Banerjee, 2004). Phytic acid chelates micronutrients and prevents it to be bioavailable for monogastric animals, including humans, because they lack phytic acid hydrolyzing enzyme in their digestive tract (Schroder *et al.*, 1996; Boling *et al.*, 2000; Singh *et al.*, 2011). Reducing the amount of phytic acid in seed is one way to increase the micronutrient in diet and develop cultivars with low phytic acid content. Selection among the existing low phytic acid wheat varieties is the simplest approach for a plant breeder, but non-lethal recessive

¹ Department of Biotechnology, Motilal Nehru National Institute of Technology, Allahabad, (U. P.) 211004 India.

*Corresponding author; e-mail:singhnand@gmail.com



mutations can also be used to decrease seed phytic acid concentration. Low phytic acid mutations have been isolated in barley (Larson *et al.*, 1998; Rasmussen and Hatzack, 1998), maize (Raboy and Gerbasi, 2000), rice (Larson *et al.*, 2000) and soybean (Wilcox *et al.*, 2001; Hitz *et al.*, 2002; Guttieri *et al.*, 2004). Hence, screening genetically low phytic acid trait in wheat and afterward development of low phytate varieties is very important. Low phytic acid varieties can be used to fulfill the deficiencies caused by iron, zinc, and other micronutrients (Khan *et al.* 2007). Wheat breeding in most world regions is mainly focused on improving grain yields, decrease farming cost, increasing resistance to diseases, and lodging (Rengel and Romheld, 2000; Bouis and Welch, 2010; Hussain *et al.*, 2012).

Molecular markers can be used in breeding programs, especially to improve traits relating to wheat grain (Goutam *et al.*, 2013). Ram *et al.* (2011) reported the importance of Glu-3 alleles in evaluation of wheat germplasm and breeding. They identified most of low molecular weight (LMW) glutenin alleles by combined SDS-PAGE and PCR based methods. One hundred eighty two Indian bread wheat cultivars were characterized using allele specific marker for

LMW-GS for quality breeding.

Improvement in crop plants mostly depends on the magnitude of genetic variability. Selection of germplasms having groups of desired traits can be obtained by study of associations among various traits. In this work, variability of phytic acid and Fe contents were evaluated for 93 wheat genotypes from India.

MATERIALS AND METHODS

Plant Materials

The study was carried out at experimental field of Biotechnology Department, Motilal Nehru National Institute of Technology, Allahabad U.P. The experimental material of the study comprised 85 hexaploid wheat wild germplasms and eight cultivars. The germplasms were collected from Department of Biotechnology, IIT Roorkee and Department of Genetics and Plant Breeding, Sam Higginbotton Institute of Agriculture Technology and Science Allahabad, India. (Table1)

Table 1. List of cultivars and germplasms studied.

| Cultivars | | | | | |
|------------|--------------|--------------|---------|---------|----------|
| Lok1 | | | WL711 | | |
| Halna | | | S701 | | |
| K7 | | | Kedar | | |
| HD2733 | | | PBW343 | | |
| Germplasms | | | | | |
| AAI 13 | IBW 1050 | AAI/IBW 1035 | IITR 17 | IITR 33 | IITR 82 |
| AAI 15 | IBW 1074 | AAI/IBW 1033 | IITR 18 | IITR 34 | IITR 83 |
| AAI 16 | IBW 1078 | AAI/IBW 1084 | IITR 19 | IITR 38 | IITR 88 |
| AAI 23 | IBW 1103 | AAI/IBW 1083 | IITR 20 | IITR 65 | IITR 89 |
| AAI 25 | IBW 1113 | K-9533 | IITR 21 | IITR 66 | IITR 91 |
| AAI 28 | IBW 1133 | GW-03-12 | IITR 22 | IITR 67 | IITR 92 |
| AAI 29 | IBW 1115 | GAW-94 | IITR 23 | IITR 69 | IITR 95 |
| AAI 47 | AAI/IBW 1081 | WR-1451 | IITR 24 | IITR 70 | IITR 96 |
| AAI 344 | AAI/IBW 1075 | CS | IITR 25 | IITR 71 | IITR 102 |
| AAI 347 | AAI/IBW 1064 | IITR 8 | IITR 26 | IITR 72 | IITR 103 |
| IBW 1038 | AAI/IBW 1097 | IITR 9 | IITR 27 | IITR 73 | |
| AAI-03-12 | AAI/IBW 1016 | IITR 10 | IITR 28 | IITR 74 | |
| IBW 1014 | AAI/IBW 1104 | IITR 11 | IITR 29 | IITR 75 | |
| IBW 1026 | AAI/IBW 1129 | IITR 13 | IITR 30 | IITR 76 | |
| IBW 1046 | AAI/IBW 1036 | IITR 15 | IITR 31 | IITR 79 | |

The experiment was laid out in a randomized block design with three replications. The standard agronomical practices were used to grow the plants. The genetic study was conducted utilizing a cultivar, the WL711 having 1.71% phytic acid and a genotype IITR 19 having 0.68% phytic acid. Morphological characters such as seed color, seed structure, days of flowering and maturity were also taken in consideration. WL-711 has amber color bold seed and early maturity while IITR 19 has red color shrink seed with late maturity. Crosses were made between WL711 and IITR 19; the resulting F₁ plants were grown in field during 2010-2011 growing season, while the resulting F₂ plants were grown in 2011-2012 and F₃ plants in 2012-2013. Data from plants recorded for days upto 50 percent flowering, days to maturity, plant height, peduncle length, number of tillers per plant, spike length, number of spikelet per spike, 1,000 grain weight, grain color, grain size and phytic acid contents. A sub-sample of seed from each plant was analyzed for phytic acid concentration. Triplicate estimates were made for each sample. The determination of phytic acid was based on the modified Wade assay.

Statistical Analysis

The statistical analyses were carried out by analysis of variance (ANOVA) for all characters to test the level of significance among the 93 genotypes. The phytic acid content was also measured. Basic statistics for

all parameters of 48 F₂ lines were determined. The Data obtained from plants were subjected to statistical analysis to calculate heritability and genetic advance. Heritability in broad sense (H) was computed according to Lush (1940).

$$H = \sigma_g^2 / \sigma_p^2$$

Where, σ_g^2 = Genotypic variance, σ_p^2 = Phenotypic variance.

Genetic advance (GA) was calculated following Johnson *et al.* (1955).

$$GA = (\sigma_g / \sigma_p) \times K$$

Where, σ_p = Phenotypic standard deviation; σ_g^2 = Genotypic variance, K = Selection intensity

(The value of K = 1.755 in this study at 10% selection pressure).

Genetic advance percent = (GA/Mean) × 100

RESULTS AND DISCUSSION

Screening of Wheat Genotypes

Phytic acid content, in the 93 wheat germplasms, ranged from 0.59% (IITR 92) followed by IITR19 (0.68) to 2.08% (IITR25). Lok1, WL711, Halna, K7, Kedar and S701 are some popular cultivars in India which contain phytic acid in between 1.52-1.71%, but there are great variations in phytic acid content in wheat germplasms. Phytic acid content in grains of 93 wheat genotypes showed that the maximum phytic acid was in the range of 1.3-1.5% (Figure 1). Two genotypes i.e. IITR 92 and IITR 19 were initially identified as having low phytic

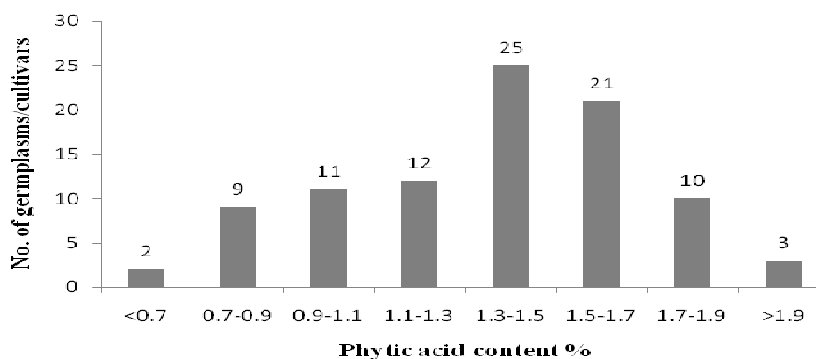


Figure 1. Range of phytic acid content in grains of 93 wheat germplasms and cultivars.



acid (< 0.7%). Khan *et al.* (2007) reported frequency distribution for phytic acid content in the range of 1.43-1.72% in 66 wheat genotypes. Ahmad *et al.* (2013) reported 1.06 to 3.67% phytic acid in parental wheat genotype while the value among F₁ hybrids ranged from 0.56% to 3.43%. The analysis of variance showed that the difference among germplasms for phytic acid content was highly significant (Table 2). The great variation in phytic acid content among the wheat germplasms indicates that there are possibilities of identifying and developing cultivars with low phytic acid contents in grain. The Fe content of all wheat germplasms ranged from 9.97 (IITR25) to 45.77 mg kg⁻¹ (IBW 1133) while popular Indian cultivars contain an average of 21.7 mg kg⁻¹ iron (Table 3).

Genetic Study of Low Phytic Acid Wheat Genotypes

The segregation result of F₂ population shows that there are wheat plants which contain low phytic acid with better morphological traits. The result of segregation analysis revealed that, out of 48 F₂ lines, lines no. 2, 7, and 41 had lower phytic acid content. Phytic acid content in all lines ranged from 0.58 to 2.01%. Seeds of line no.2 had 0.58% phytic acid, lower than both parents with amber color (Figure 2). Therefore, this line may be used further for breeding programs (Table 4). The characters can be used as morphological marker for phytic acid content

Table 2. Analysis of variance (ANOVA) of phytic acid in grains of 93 genotypes.

| Source | df | SS | MS | F |
|-------------|-----|-------|-------|----------|
| Genotypes | 92 | 46.08 | 0.501 | 40.937** |
| Replication | 2 | 0.01 | 0.005 | 0.388 |
| Error | 184 | 2.25 | 0.012 | |
| Total | 278 | 48.34 | | |

** at 5% *P* value.

Table 3. Analysis of variance (ANOVA) of Fe in grains of 93 genotypes.

| Source | df | SS | MS | F |
|-------------|-----|----------|--------|-----------|
| Genotypes | 92 | 22696.54 | 246.70 | 1035.85** |
| Replication | 2 | 546.13 | 273.06 | 1146.55 |
| Error | 184 | 43.82 | 0.238 | |
| Total | 278 | 23286.49 | | |

** at 5% *P* value.



Figure 2. Grain color of F₂ population of wheat.

Table 4. Morphological and chemical characteristic of 48 F₂ lines of wheat (WL711× ITR19).

| Line No. | Days of flowering | Days of maturity | Plant height cm | No. of tillers | Peduncle length cm | Spike length cm | No. of spikelet per spike | 1000 grain weight | Phytic acid (%) | Grain color | Grain structure |
|-------------------|-------------------|------------------|-----------------|----------------|--------------------|-----------------|---------------------------|-------------------|-----------------|----------------|-----------------|
| 1 | 68 | 104 | 116 | 19 | 53 | 10 | 14 | 39.75 | 1.18 | R ^a | B ^b |
| 2 | 84 | 119 | 126 | 21 | 46 | 15 | 24 | 29.80 | 0.58 | A ^c | S ^d |
| 3 | 70 | 103 | 121 | 14 | 65 | 12 | 18 | 34.90 | 1.44 | R | B |
| 4 | 71 | 106 | 118 | 12 | 48 | 11 | 16 | 30.60 | 1.25 | R | S |
| 5 | 83 | 119 | 131 | 17 | 45 | 15 | 24 | 24.50 | 1.44 | R | S |
| 6 | 84 | 121 | 119 | 14 | 46 | 18 | 21 | 21.71 | 1.58 | A | S |
| 7 | 87 | 122 | 118 | 24 | 47 | 15 | 20 | 36.84 | 0.79 | R | B |
| 8 | 64 | 99 | 120 | 6 | 57 | 12 | 18 | 46.57 | 1.44 | A | B |
| 9 | 70 | 100 | 109 | 4 | 52 | 8 | 16 | 31.08 | 1.31 | R | S |
| 10 | 68 | 104 | 122 | 5 | 65 | 13 | 18 | 38.42 | 1.64 | R | B |
| 11 | 72 | 106 | 119 | 25 | 59 | 13 | 20 | 42.86 | 1.58 | R | B |
| 12 | 74 | 110 | 126 | 6 | 54 | 12 | 16 | 34.17 | 1.25 | R | B |
| 13 | 73 | 106 | 128 | 12 | 58 | 10 | 14 | 43.13 | 1.71 | A | B |
| 14 | 62 | 97 | 102 | 16 | 50 | 12 | 18 | 35.63 | 1.51 | R | B |
| 15 | 67 | 103 | 105 | 4 | 50 | 9 | 14 | 37.27 | 1.58 | R | B |
| 16 | 75 | 107 | 123 | 5 | 51 | 11 | 16 | 36.35 | 1.55 | R | B |
| 17 | 70 | 105 | 118 | 6 | 52 | 12 | 14 | 40.31 | 1.58 | R | B |
| 18 | 76 | 110 | 118 | 5 | 50 | 10 | 16 | 42.50 | 1.64 | A | B |
| 19 | 84 | 119 | 129 | 19 | 47 | 13 | 20 | 27.50 | 1.31 | A | S |
| 20 | 68 | 105 | 117 | 14 | 46 | 12 | 16 | 44.86 | 1.71 | R | B |
| 21 | 64 | 99 | 115 | 12 | 58 | 11 | 16 | 30.00 | 1.44 | R | S |
| 22 | 74 | 109 | 114 | 16 | 42 | 15 | 22 | 37.91 | 1.98 | R | B |
| 23 | 72 | 106 | 134 | 13 | 49 | 16 | 22 | 36.35 | 1.71 | R | B |
| 24 | 69 | 103 | 110 | 10 | 44 | 13 | 20 | 39.55 | 1.58 | R | B |
| 25 | 72 | 106 | 119 | 4 | 52 | 12 | 16 | 45.75 | 1.84 | A | B |
| 26 | 78 | 111 | 141 | 16 | 50 | 12 | 18 | 45.90 | 1.64 | A | B |
| 27 | 79 | 112 | 128 | 11 | 49 | 11 | 16 | 45.75 | 1.67 | R | B |
| 28 | 81 | 110 | 120 | 15 | 55 | 12 | 18 | 40.24 | 1.97 | R | B |
| 29 | 64 | 99 | 118 | 13 | 51 | 12 | 18 | 42.56 | 1.51 | R | B |
| 30 | 78 | 110 | 132 | 11 | 54 | 14 | 20 | 30.20 | 1.64 | R | S |
| 31 | 79 | 110 | 131 | 12 | 56 | 13 | 18 | 40.00 | 2.01 | R | B |
| 32 | 66 | 102 | 118 | 15 | 46 | 16 | 18 | 29.41 | 1.67 | R | S |
| 33 | 76 | 110 | 134 | 14 | 57 | 13 | 18 | 39.15 | 1.71 | R | B |
| 34 | 70 | 105 | 115 | 11 | 43 | 12 | 18 | 33.00 | 1.91 | R | S |
| 35 | 67 | 100 | 108 | 5 | 50 | 10 | 16 | 43.64 | 1.66 | R | B |
| 36 | 70 | 105 | 127 | 8 | 58 | 12 | 16 | 37.14 | 1.58 | R | B |
| 37 | 71 | 106 | 117 | 14 | 56 | 14 | 22 | 34.81 | 1.64 | R | B |
| 38 | 76 | 108 | 133 | 23 | 60 | 14 | 18 | 37.92 | 1.84 | A | B |
| 39 | 72 | 107 | 90 | 3 | 43 | 10 | 14 | 34.55 | 1.18 | R | B |
| 40 | 68 | 104 | 102 | 15 | 46 | 12 | 18 | 36.88 | 1.44 | R | B |
| 41 | 84 | 120 | 125 | 24 | 35 | 15 | 24 | 28.91 | 0.88 | R | S |
| 42 | 70 | 105 | 118 | 23 | 52 | 12 | 20 | 34.09 | 1.25 | R | B |
| 43 | 72 | 105 | 125 | 22 | 40 | 10 | 18 | 29.71 | 1.18 | R | S |
| 44 | 63 | 96 | 98 | 6 | 39 | 11 | 18 | 29.26 | 1.31 | R | S |
| 45 | 68 | 105 | 116 | 10 | 51 | 12 | 18 | 42.59 | 1.91 | A | B |
| 46 | 74 | 106 | 112 | 25 | 44 | 11 | 18 | 31.75 | 1.74 | R | S |
| 47 | 70 | 104 | 100 | 4 | 48 | 9 | 14 | 39.32 | 1.51 | A | B |
| 48 | 86 | 119 | 138 | 24 | 36 | 14 | 22 | 29.75 | 1.64 | R | S |
| (P ₁) | 65 | 104 | 100 | 15 | 40 | 11 | 18 | 45.00 | 1.71 | A | B |
| (P ₂) | 82 | 119 | 130 | 9 | 57 | 14 | 18 | 34.42 | 0.68 | R | S |

^a Red ; ^b Bold; ^c Amber; ^d Shrink.



in wheat grain after further confirmation.

The mean value of phytic acid content of F₂ lines was recorded and it was found 1.52% (Table 5). In the maximum plants of F₂ segregation lines, days of flowering, days of maturity, no. of tillers per plant, no. of spikelet per spike were in between 70-75 days, 105-110 days, 10-15, and 18-20, respectively. Plants height, peduncle length, and spike length were in between 110-120, 50-55, and 12-14 cm, respectively, in the maximum number of segregants in F₂ population. Variations in spike length of F₂ lines wheat are shown in Figure 3. There are great variations between spikes of F₂ population. The spike of WL711 is amber color, compact, and small, while the spike of IITR19 is red and comparatively large. The spikes of some F₂ segregants are larger than both parents with red or amber color (Table 4). In maximum no. of F₂ lines, 1000 grain weights were recorded between 35-40 g (Table 6).

The F₂ progeny from WL711×IITR19 indicated the 93.4% heritability in broad sense with 32.3% genetic advance for phytic acid. A quite high heritability and genetic advance of phytic acid indicated that progenies of this cross would be useful for reducing phytic acid. These results are in accordance with the findings of Ahmad *et al.* (2013).

In correlation study, a correlation between PA and Fe content in grain was not observed ($r = -0.07$). Among 93 genotypes, some contained higher concentration of phytic acid and low concentration of Fe (data not shown). Lower concentration of Fe may be due to the presence of high concentration of phytic acid, which is a chelating agent that binds minerals making them unavailable for dietary absorption (Akond *et al.*, 2011; Hirschi, 2009). A negative correlation between phytic acid and Fe contents was also reported in common bean by Akond *et*

Table 5. Range, mean, and standard error of means for nine quantitative characters of 48 wheat F₂ lines.

| Character | Range | Mean | SE |
|-----------------------|-------------|--------|------|
| Days of flowering | 62-87 | 72.97 | 0.93 |
| Days of maturity | 96-122 | 107.22 | 0.92 |
| Plant height (cm) | 90-141 | 119.22 | 1.53 |
| No. of tillers/plant | 3-25 | 13.06 | 0.95 |
| Peduncle Length (cm) | 35-65 | 50.10 | 0.96 |
| Spike Length (cm) | 8-18 | 12.31 | 0.29 |
| No. of spikelet/spike | 14-24 | 18.06 | 0.39 |
| 1000 grain weight | 21.71-46.57 | 36.35 | 0.86 |
| Phytic acid % | 0.58-2.01 | 1.52 | 0.04 |



Figure 3. Variability in spike length of F₂ population of wheat.

Table 6. Frequency distribution of morphological characters for F₂ progeny wheat.

| Days of flowering | No. of plants | Days of maturity | No. of plants | Plant height | No. of plants | Peduncle length | No. of plants | No. of tillers/plants | No. of plants | Spike length | No. of plants | 1000 grain weight | No. of plants | No. of spikelet/F spike | No. of plants |
|-------------------|---------------|------------------|---------------|--------------|---------------|-----------------|---------------|-----------------------|---------------|--------------|---------------|-------------------|---------------|-------------------------|---------------|
| 60-65 | 5 | 95-100 | 5 | 90-100 | 2 | 35-40 | 3 | 0-5 | 5 | 08-10 | 3 | 20-25 | 2 | 14-16 | 6 |
| 65-70 | 9 | 100-105 | 9 | 100-110 | 6 | 40-45 | 7 | 05-10 | 9 | 10-12 | 12 | 25-30 | 7 | 16-18 | 11 |
| 70-75 | 18 | 105-110 | 19 | 110-120 | 19 | 45-50 | 11 | 10-15 | 16 | 12-14 | 21 | 30-35 | 11 | 18-20 | 17 |
| 75-80 | 8 | 110-115 | 7 | 120-130 | 13 | 50-55 | 15 | 15-20 | 9 | 14-16 | 10 | 35-40 | 14 | 20-22 | 7 |
| 80-85 | 6 | 115-120 | 5 | 130-140 | 7 | 55-60 | 9 | 20-25 | 7 | 16-18 | 2 | 40-45 | 10 | 22-24 | 4 |
| 85-90 | 2 | 120-125 | 3 | 140-150 | 1 | 60-65 | 3 | 25-30 | 2 | 18-20 | 1 | 45-50 | 4 | 24-26 | 3 |

al. (2011). Nair and Iyenger (2009) reported that iron availability was negatively correlated with phytate content. The recommended level of phytate: Fe molar ratio is < 1.0 in food products (Roos *et al.*, 2013). Lopez *et al.* (2002) reported that phytic acid accumulation was correlated with phosphorus accumulation, but not with total mineral content in seeds. Chiangmai *et al.* (2011) studied the correlation between phytic acid (PA) content and yield. They reported that there was positive correlation between PA content and yield that may be a hindrance to discover new high yielding potential corn varieties with reduced phytic acid content in F₁ hybrids.

CONCLUSIONS

The present study revealed that germplasms, cultivars, and inbred lines show significant differences in phytic acid and Fe content. Such variants of germplasms can be used for plant breeding programs for further improvement of wheat grain. F₂ lines of parents WL711 and IITR19 also illustrate variation in phytic acid content and are significant. Few progenies showed phytic acid content less than both parents and are useful for further crop improvement. A relatively high heritability and genetic advance of phytic acid showed that progenies of this cross would be useful for reducing phytic acid.

ACKNOWLEDGEMENTS

This work is financially supported by Ministry of Human Resource Development (MHRD) and Department of Science and Technology (DST), New Delhi, India. The authors sincerely acknowledge the coordination of Dr S. Marker, Genetics and Plant Breeding, SHIATS, Allahabad, India, and Prof. H. S. Dhaliwal for providing the breeding material for this study.



REFERENCES

1. Ahmad, I., Mohammad, F., Zeb, A., Noorka, I. R., Farhatullah, and Jadoon, S. A. 2013. Determination and Inheritance of Phytic Acid as Marker in Diverse Genetic Group of Bread Wheat. *Am. J. Mol. Bio.*, **3**:158-164.
2. Akond, A. G. M., Crawford, H., Berthold, J., Talukder, Z. I. and Hossain, K. 2001. Minerals (Zn, Fe, Ca and Mg) and Antinutrient (Phytic acid) Constituents in Common Bean. *Am. J. Food Tech.*, **6**(3):235-243.
3. Boling, S. D., Douglas, M. W., Johnson, M. L., Wang, X., Parsons, C. M. and Koelkebeck, K. W. 2000. The Effects of Dietary Available Phosphorus Levels and Phytase Performance of Young and Older Laying Hens. *Poultry Sci.*, **79**:224-30.
4. Bouis, H. E. and Welch, R. M. 2010. Biofortification: A Sustainable Agricultural Strategy for Reducing Micronutrient Malnutrition in the Global South. *Crop Sci.*, **50**:S20-S32.
5. Cakmak, I., Wolfgang, H. P. and Bonnie, M. 2010. Biofortification of Durum Wheat with Zinc and Iron. *Cereal Chem.*, **87**:10-20.
6. Chiangmai, P.N., Yodmingkhwan, P., Nilprapruck, P., Aekatasanawan, C. and Kanjanamaneesathian, M. 2011. Screening of Phytic Acid and Inorganic Phosphorus Contents in Corn Inbred Lines and F₁ Hybrids in Tropical Environment. *Maydica*, **54**: 331-339.
7. Goutam, U., Kukreja, S., Tiwari, R., Chaudhury, A., Gupta, R. K., Dholakia, B. B. and Yadav, R. 2013. Biotechnological Approaches for Grain Quality Improvement in Wheat: Present Status and Future Possibilities. *AJCS*, **7**(4): 469-483.
8. Guo, Z., Xu, P., Zhang, Z. and Guo, Y. 2012. Segregation Ratios of Colored Grains in F₁ Hybrid Wheat. *Crop Breed. Appl. Biotechnol.*, **12**: 126-131.
9. Gupta, R. K., Gangoliya, S. S. and Singh, N. K. 2013. Reduction of Phytic Acid and Enhancement of Bioavailable Micronutrient in Food Grains. *J. food Sci. Tech.*, **52**: 676-684.
10. Guttieri, M., Bowen, D., Dorsch, J. A., Raboy, V. and Souza, E. 2004. Identification and Characterization of Low Phytic Acid Wheat. *Crop Sci.*, **44**:418-424.
11. Hirschi, K. D. 2009. Nutrient Biofortification of Food Crop. *Annu. Rev.Nutr.*, **29**:401-421.
12. Hitz, W. D., Carlson, T. J., Kerr, P. S. and Sebastian, S. A. 2002. Biochemical and Molecular Characterization of a Mutation That Confers a Decreased Raffinosaccharide and Phytic Acid Phenotype on Soybean Seeds. *Plant Physiol.*, **128**: 650-660.
13. Hussain, S., Maqsood, M. A., Renge, Z. and Khan, M. K. 2012. Mineral Bioavailability in Grains of Pakistani Bread Wheat Declines from Old to Current Cultivars. *Euphytica*, **186**:153-163.
14. Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of Genetic and Environmental Variability in Soybean. *Agron. J.*, **47**:314-318.
15. Khan, A. J., Ali, A., Farooq-i-Azam and Zeb, A. 2007. Identification and Isolation of Low Phytic Acid Wheat (*Triticum aestivum* L.) Inbred Lines/mutants. *Pakistan J. Bot.*, **39**:2051-2058.
16. Larson, S. R., Rutger, J. N., Young, K. A. and Raboy, V. 2000. Isolation and Genetic Mapping of Non-lethal Rice (*Oryza Sativa* L.) Low Phytic Acid Mutation. *Crop Sci.* **40**:1397-1405.
17. Larson, S. R., Young, K. A., Cook, A., Blake, T. K. and Raboy, V. 1998. Linkage Mapping of Two Mutations That Reduce Phytic Acid Content of Barley Grain. *Theor. App. Genet.*, **97**:141-146.
18. Lopez, H. W., Leenhardt, F., Coudray, C. and Remesy, C. 2002. Minerals and Phytic Acid Interactions: Is It a Real Problem For Human Nutrition? *Int. J. Food Sci. Tech.*, **37**: 727-739.
19. Lush, J. L. 1940. Intra-sire Correlation and Regression of Offspring in Rams as a Method of Estimating Heritability of Characters. *Proc. American Soc. Animal Product*, **33**: 292-301.
20. McKevith, B. 2004. Nutritional Aspects of Cereals. *Nutrition Bull.*, **29**: 111-142
21. Nair, K. M. and Iyengar, V. 2009. Iron Content, Bioavailability and Factors Affecting Iron Status of Indians. *Indian J. Med. Res.*, **130**: 634-645
22. Raboy, V., Gerbasi, P.F., Young, K. A., Stoneberg, S. D., Pickett, S. G., Bauman, A. T., Murthy, P. P. N., Sheridan, W. F. and Ertl, D. S. 2000. Origin and Seed Phenotype of Maize Low Phytic Acid 1-1 and Low

- Phytic Acid 2-1. *Plant Physiol.*, **124**: 355-368.
23. Ram, S., Sharma, S., Verma, A., Tyagi, B. S. and Pena, R. J. 2011. Comparative Analyses of LMW Glutenin Alleles in Bread Wheat Using Allele-Specific PCR and SDS-PAGE. *J. Cereal Sci.*, **54(3)**:488-493
 24. Rasmussen, S. K. and Hatzack, F. 1998. Identification of Two Low Phytate Barley (*Hordeum Vulgare* L.) Grain Mutants by TLC and Cereal Genetic Analysis. *Hereditas*, **129**:107-112.
 25. Rawat, N., Tiwari, V. K., Singh, N., Randhawa, G. S., Singh, K., Chhuneja, P. and Dhaliwal, H. S. 2009. Evaluation and Utilization of *Aegilops* and Wild *Triticum* Species for Enhancing Iron and Zinc Content in Wheat. *Genet. Resour. Crop. Evol.* **56**:53-64.
 26. Rengel, Z. and Romheld, V. 2000. Differential Tolerance to Fe and Zn Deficiencies in Wheat Germplasm. *Euphytica* **113**: 219-225.
 27. Roos, N., Sorensen, J. C., Sorensen, H., Rasmussen, S. K., Briend, A., Yang, Z. and Huffman, S. L. 2013. Screening for Antinutritional Compounds in Complementary Foods and Food Aid Products for Infants And Young Children. *Maternal Child Nutrition*, **9**: 47-71
 28. Schroder, B., Breve, G. and Rodehutsord, M. 1996. Mechanisms of Intestinal Phosphorus Absorption and Availability of Dietary Phosphorus in Pigs. *Dtsch Tieraerztl Wochenschr*, **103**: 209-214.
 29. Singh, B., Kunze, G. and Satyanarayana, T. 2011. Developments in Biochemical Aspects and Biotechnological Applications of Microbial Phytases. *Biotechnol. Mol. Biol. Review*, **6**: 69-87.
 30. Vats, P. and Banerjee, U. C. 2004. Production Studies and Catalytic Properties of Phytases (Myo-inositol-hexakisphosphate Phosphohydrolases): An Overview. *Enzyme Microb. Technol.*, **35**: 3-14.
 31. Wilcox, J., Premachandra, G., Young, K. and Raboy, V. 2000. Isolation of High Seed Inorganic P, Low-phytate Soybean Mutants. *Crop Sci.*, **40**:1601-1605.

غربال گری و تشخیص ویژگی های ژرم پلاسما های گندم برای اسید فیتیک و آهن موجود در آنها

ر. ک. گوپتا، س. س. گانگولیا، و ن. ک. سینک

چکیده

اسید فیتیک یک شکل عمده فسفر در غلات است که با کلات کردن (chelating) مواد غذایی کم مصرف و کاهش زیست دسترسی (bioavailability) آنها، به عنوان بازدارنده جذب بعضی مواد غذایی در حیوانات تک معده ای (از جمله انسانها) شناخته می شود. در این پژوهش، ۹۳ ژرم پلاسما گندم (*Triticum aestivum* L.) که شامل کولتیوارهایی از هندوستان بود از نظر محتوای اسید فیتیک و آهن بررسی شدند. مقدار اسید فیتیک در آنها بین ۰.۵۹٪ (در مورد IITR 92) تا ۲.۰۸٪ (در مورد IITR 25) تغییر میکرد. در این ژرم پلاسما ها مقدار آهن بین $9/97 \text{ mg kg}^{-1}$ (در IITR 25) تا $45/77 \text{ mg kg}^{-1}$ (در IBW 1133) بود در حالی که کولتیوار های قدیمی هند به طور میانگین $21/7 \text{ mg kg}^{-1}$ آهن دارند. این غربالگری اولیه شناسایی تنوع این صفات را در ژرم پلاسما های گندم تسهیل کرده و می توان از آن برای بهبود ژنتیکی گندم استفاده کرد. همچنین، ۴۸ رگه F2 حاصل از



(WL711 x IITR 19) ارزیابی شد که تنوع زیادی در مورد اسید فیتیک نشان داد. محتوی اسید فیتیک آن ها بین ۰/۵۸٪ تا ۲/۰۱٪ با میانگین ۱/۵۲٪ بود. این ژنوتیپ ها تفاوت معنی داری در مورد مقدار اسید فیتیک و آهن داشتند. نیز، رگه های F2 حاصل از تلاقی WL711 x IITR19 تفاوت های معنی داری در فیتیک اسید نشان دادند. فرزندان و نتاجی که اسید فیتیکی کمتر از والد ها دارند برای اصلاح ژنتیکی مفید هستند. توارث پذیری زیاد (۹۳٪) و عریض و پیشرفت ژنتیکی (genetic advance) معادل ۳۲٪ گواهی داد که فرزندان این تلاقی برای اصلاح ژنتیکی در مورد اسید فیتیک مناسب اند.