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Assessment of physico-chemical diversity and yellow rust resistance in commercial wheat varieties (*Triticum aestivum* L.)

Nosheen Kabir*[1], Fakhra Hafeez[1], Muhammad Freed Khan[1], Anisa Intikhab[1], Adnan Rasheed[1], Hussain Ahmed[1], Zahida Akhtar[1]

[1]*Department of Plant Breeding and Molecular Genetics, University of Poonch Rawalakot, AJK, Pakistan*

[2]*Department of Plant Breeding and Molecular Genetics, University of Agriculture, Faisalabad, Pakistan*

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Abstract

Wheat (*Triticum aestivum* L.) is one of the most important cultivated crops in the world. Research studies were carried out to evaluate the genetic diversity between wheat genotypes using morphological and biochemical traits and to assess the performance of wheat genotypes under elevated disease pressure and to distinguish genotypes having adult plant resistance, by evaluating them in a field trap nursery. Mean values revealed that two commercial cultivars Bathoor-08 and Zam-04 produced highest grain yield per plot. Whereas correlation and cluster analysis showed that plant height, days to 50 % heading, number of tiller per plant, peduncle length and harvest index have significant relationship with each other, hence these traits were responsible for most of variation among cultivars. Biplot and dendrogram verified that eight commercial cultivars like Pirsabak-2005, Zam-04, Td-01, Bathoor-08, Narc-2009, NIFA-Barsat-09, Meraj-08 and Seren as more diverse among all the cultivars. Similarly, in biochemical analysis antioxidant activity was recorded maximum for NIFA-Barsat-09 (44.09) and phenolic were found maximum in Atta-Habib (52.9 mg GAE/g).Yellow rust severity recorded for commercial cultivars of wheat indicated that cultivarsFaisalabad-08, NARC-2009, TD-1, Pirsabak-2008, KT-2000, Janbaz and Dharrabi-11 showed complete resistance. While Pirsabak 2005, Sehar -2006, Bathoor-08, NARC-2011, Seren, Pakistan-2013, Atta-Habib, Shahkar-13, NIFA-Barsat, Pirsabak-13 and NIFA-Lilma showed moderate resistance ranging from 5MR to 40MR.

* **Corresponding Author:** Nosheen Kabir ✉ nosheenkabir09@gmail.com

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of world's population. Wheat accounts for 9.6 percent of the value added in agriculture and 1.9 percent of GDP of Pakistan. During 2016-17, wheat crop was sown on an area of 9.05 million hectares witnessing a decrease of 1.9 percent compared to 9.22 million hectares during same period last year. Wheat production was estimated at 25.75 million tons during 2016 witnessing an increase of 0.5 percent over the last year production of 25.63 million tones. The production increased due to better supply of inputs which contributed in enhancing per hectare yield (Anonymous, 2016-17).

Production of wheat must increase with the increase in population. Various factors which hinder the production of wheat are diseases like rusts, weeds, drought, water shortage, salinity, acidity, insects, pests etc. A wide range of pathogens can infect wheat and resistant wheat varieties provide an efficient strategy to prevent crop losses(Singh *et al.,* 2016). Rust pathogens with worldwide prevalence and potential for long distance migration and invasions into new areas may pose a serious threat to food security regionally or globally (Beddow *et al.*, 2015) .Stripe rust caused by *Puccinia striiformis* f. sp. *tritici* is one of the most destructive diseases of wheat in Pakistan.

The reaction of wheat cultivars to stripe rust depends on two resistance forms 'seedling resistance' and 'adult plant resistance' (APR). Seedling resistance is presumed to be conditioned by a single gene; thus it is usually race-specific. Adult plant resistance develops as plants mature and is considered more durable than seedling resistance (Chen, 2014).

Genetic diversity exposes the genetic variability in diverse populations and provides justification for introgression and ideotype breeding program to enhance crop performance (Mustafa *et al.,* 2011). Breeding high yielding wheat cultivars which are an important strategy to withstand yield production draws the plant breeders' attention. Indirect selection through traits related to grain yield is one of the most important strategies in wheat breeding.

Genetic diversity can be analyzed on the basis of biochemical data by using DPPH and Phenolic compounds. The biological importance of phenolic compounds can largely be related to their characteristics, chemical properties and reactivity. They generally occur in the cell as fairly polar glycosides or esters. The total antioxidant activity of whole grain, fruit and vegetables is same (Miller *et al.*, 2001). Biological dynamic constituents and antioxidants in entire grains have not attracted more like phytochemicals found in fruits and vegetables although the risk of developing diseases has decreased by increased consumption of whole grains and whole grain products (Liu, 2007).

Radical scavenging is the main method through which antioxidants works in foods. Different mechanisms have been developed including 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 2-azinobis (3-ethylbenzothiazoline-6-sulphonicacid) radical scavenging methods. DPPH is mostly used to assess the free radical scavenging activity (Kumar *et al.*, 2011). The objectives were to find the genetic diversity among wheat varieties using morphological and biochemical studies and to recognize the extent of adult plant rust resistance in commercial wheat varieties.

Material and methods

Experimental material

Experimental material was sown in a trap nursery, acquired from Crop Disease Research Program (CDRP), National Agricultural Research Centre (NARC), Islamabad. A total of 30 commercial cultivars of wheat were used. Morroco was used both as spreader and check. Two rows of Morroco were sown around all the four sides of the trail. One meter long row was sown for each genotype and row to row distance was 30 cm.

Cultural practices

Recommended NPK fertilizers were applied, urea was applied in split doses. All cultural practices as well as weeding and hoeing were practiced right through the crop season.

Parameter studied

Observation on response and severity of stripe rust was noted according to Leogering (1959). Severity was recorded as percentage of rust infection on the plants according to the modified Cobb's Scale (Peterson *et al.,* 1948). The data was taken on following morphological traits like plant height, spike length, number of spikelets per spike, peduncle length, flag leaf area, days to 50 % headings, number of tillers per plant, grain yield per plant, 1000-grain weight, biological yield and harvest index. Following biochemical analysis were carried out; Antioxidant activity, Phenolics. The antioxidant activity of wheat seeds was measured using the stable 2, 2-diphenyl-1-picrylhydrazy (DPPH) radical as described by Hatano *et al.*, (1988). The activity was expressed as percentage scavenging of DPPHby the extracts and calculated as:

DPPH RSA=Absorbance of control- Absorbance of sample X 100

Absorbance of control

The total phenolic compounds were analyzed using the Folin-ciocalteau method with some modification (Ghafoor and Choi, 2009).

Results and discussion

Yellow Rust Severity on commercial cultivars of wheat

Yellow rust severity recorded for commercial cultivars of wheat indicated that cultivarsFaisalabad-08, NARC-2009, TD-1, Pirsabak-2008, Janbaz and Dharrabi-11 showed complete resistance.

Table 1. Yellow rust severity on commercial cultivars of wheat at Rawalakot, Azad Kashmir.

Commercial varieties	*Severity %*	*Commercial varieties*	*Severity %*
Pirsabak2004	20MR	Td 1	0
Pirsabak2005	10MR	Pirsabak 2008	0
Punjnad 1	90S	Punjab 2011	90S
Sehar 2006	20MR	Ufaq	90S
Lasani 08	90S	Janbaz	0
Meraj 08	10RMR	Dharrabi 11	0
Fareed 06	5RMR	Narc 2011	10MR
Faisalabad 08	0	Shahkar 13	20MR
Bathoor 08	10MR	Pirsbak 13	20MR
Aas 2009	20MS	Atta habib	10MR
Narc 2009	0	Seren	20MR
Aari 2010	40MSS	Pakistan 2013	5MR
Nifabarsat 09	20MR	Nifalilma	10MR
am 04	40MSS	Galaxy 2013	90S
Hashim 08	60MSS	Pirsabak 85	60MSS

The cultivars found highly susceptible included Punjnad-1 (90S), Lasani-08(90S), Punjab-2011(90S), Ufaq (90S) and Galaxy-2013(90S).

Mean values for morphological traits in 30 commercial wheat varieties

Mean values for morphological traitsin 30 commercial varieties are given in Table 2. For all commercial varieties mean values of flag leaf area varied greatly, ranging from minimum value of 11.35 cm^2 to33.67cm^2.

Maximum value was observed in Pirsabak 2008 which was 33.67cm^2 while the minimum value 11.35cm^2 was shown by Lasani 08. Mean values for number of tillers per plant were quite variable, ranging from 3 to 11 tillers. Higher number of tillers per plant was produced by Sehar 2006 and AARI 2010 with 11 no of tillers per plant, Commercial variety Pirsabak 2005 produced the lowest number of tillers with 3number of tillers per plant.

Mean values for grain yield per plot were extremely variable ranging from 15g to 230g. The maximum grain yield per plot was produced by Bathoor 08 with the value of 230g. Whereas, Meraj 08 showed minimum grain yield per plot was 15g.

Table 2. Mean values for morphological traits in 30 commercial wheat varieties.

Commercial Varieties	*PH*	*SL*	*DTH*	*NOS*	*PL*	*FLA*	*NOT*	*GY(g)*	*1000GW*	*BY*	*HI*
Pirsabak 2004	82.7	9.04	239	16.4	23.41	19.25	8	127	30.3	398.06	31.9
Pirsabak 2005	96.5	10.52	240	20	38.4	29.29	3	21	39.7	134.11	15.65
Punjnad 1	64.4	7.2	235	16.2	13.7	21.15	8	25	34.1	85.71	29.16
Sehar06	65.3	9.4	274	19.1	30.3	18.51	11	28	30.3	62.6	44.72
Lasani 08	73.2	7.53	239	16.1	32.1	11.35	6	22	27.7	95.5	23.03
Meraj 08	68	6.8	229	15.2	24.5	14.31	7	15	37	92.21	16.26
Fareed 06	75.2	7.4	235	15.3	25.1	20.70	6	35	36.6	57.71	60.64
Faisalabad 08	113.1	10.05	224	19.1	33.7	15.31	9	85	26	172.26	49.34
Bathoor 08	100.1	12.01	221	22	26.2	24.21	10	230	46	218.24	105.38
Aas 2009	82.6	10.3	236	20.3	31.1	25.06	8	19	30.5	140.2	13.55
Narc 2009	118.2	11.14	239	20.1	43	24.54	9	203	22.3	235.54	86.18
Aari 2010	77.3	8.02	228	18.02	25.2	22.64	11	32	28	147.27	21.72
Nifabarsat 09	79.6	7.05	225	14	24.7	15.42	8	92	32.5	49.52	185.78
Zam 04	93.2	12.01	235	18.3	31.13	32.31	8	210	45.2	621.72	33.77
Hashim 08	77.8	8.02	239	19.3	26.6	20.24	4	36	33.7	45.51	79.1
Td 1	95.6	12.4	230	20.2	29.5	33.30	5	205	36.4	460.64	44.5
Pirsabak 2008	79.22	10.8	239	21.3	30.7	33.64	10	192	28	470.52	40.8
Punjab 2001	86.4	11	235	20.2	34.4	32.34	9	77	35.2	123.35	62.42
Ufaq	78.1	11.26	230	20.5	28.1	30.57	7	99	39.1	120.04	82.47
Janbaz	73.4	10.42	235	19.2	25.04	26.47	8	63	35	148.51	42.42
Dharrabi 11	87.54	9.63	229	19.3	36.3	26.04	10	89	29.5	266.66	33.37
Narc 2011	86	9.12	270	17.1	29.4	30.03	5	27	36.4	74.1	36.43
Shahkar 13	81.24	11.06	231	19.6	25.53	21.32	9	114	33.2	270.63	42.12
Pirsabak 13	82.3	6.53	239	13.1	32.73	23.24	7	85	36.3	268.77	31.62
Atta habib	85.31	9.61	274	17.5	34.23	29.36	5	73	35.5	169.37	43.1
Seren	79.6	7.33	276	16.2	30.3	26.06	5	82	38.3	413.37	19.83
Pakistan 2013	77.02	9.26	276	16	35	29.77	10	24	41	74.77	32.09
Nifalilma	81.6	9.32	235	19.1	30	29.73	4	42	38	120.7	34.79
Galaxy 2013	83.4	10	235	18.6	23.2	25.04	5	32	32.5	75.1	42.6
Pirsabak 85	86.6	10.63	233	21.4	30.6	28.26	10	179	31.5	283.73	63.08

Where, PH= Plant height, SL= Spike length, NOS= Number of spikelet's/spike, PL= Peduncle length, FL=Flag leaf area, DTH=Days to 50% headings, NOT=Number of tillers per plant, GY= Grain yield per plant, 100GW= 1000-Grain weight, BY= Biological yield HI=Harvest index.

Simple correlation coefficients for morphological traits in 30 commercial wheat varieties

Yield is a complex trait and is linked with various yield related traits. Effective selection for improvement could not be made, if the yield affecting traits are not taken to consider. When selection pressure is applied for the enhancement of any trait, highly related with yield, it currently influences the number of other associated traits. Therefore, knowledge about association of yield and among themselves provides information to the plant breeder for making betterment through selection.

Table 3. Simple correlation coefficients for morphological traits in 30 commercial wheat varieties.

	P.H	S.L	N.O.S	P.L	F.L	DTH	N.O.T	G.Y.	1000GW	B.Y.	H.I
PH	1										
SL	0.564**	1									
NOS	0.417*	0.841**	1								
PL	0.604**	0.340	0.261	1							
FL	0.225	0.615**	0.477**	0.314	1						
DTH	-0.235	-0.181	-0.244	0.251	0.201	1					
NOT	0.023	0.204	0.223	0.040	-0.098	-0.133	1				
GY	0.571**	0.629**	0.450*	0.196	0.359	-0.300	0.317	1			
1000GW	-0.115	0.143	-0.064	-0.155	0.395*	0.124	-0.331	0.074	1		
BY	0.331	0.425*	0.211	0.167	0.412*	-0.074	0.141	0.753**	0.111	1	
HI	0.204	0.064	0.030	-0.076	-0.147	-0.290	0.128	0.346	0.003	-0.194	1

Where, PH= Plant height, SL= Spike length, NOS = Number of spikelet's/ spike, PL= Peduncle length, FL=Flag leaf area, DTH=Days to 50% headings, NOT=Number of tillers per plant, GY= Grain yield per plant, 1000GW= 1000-Grain weight, BY= Biological yield and HI=Harvest index.

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level.

Plant height has positive and highly significant correlation with spike length, number of spikelets per spike and grain yield. Number of spikelets per spike has positive correlation with flag leaf area and significant correlation with grain yield. Akram*et al.* (2008) also reported positive correlation of plant height with grain yield at genotypic level. Spike length has positive and highly significant correlation with plant height, number of spikelets per spike, flag leaf area, grain yield. Positive and significant correlation of spike length was observed with biological yield Results were supported by (Baloch *et al.*, 2013).

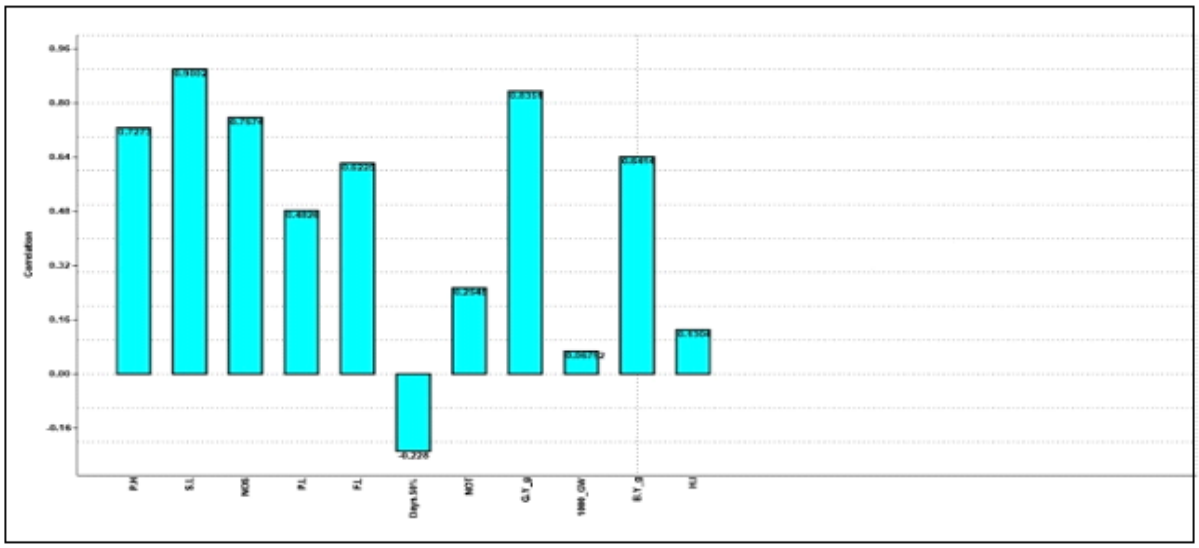

Fig. 1. Factor loading for Principal component 1 (PC1).

Flag leaf area has positive and significant correlation with 1000 grain weight and biological yield. Iftikhar *et al.* (2012) also reported positive and significant correlation of grain yield with flag leaf area. Grain yield has positive and significant correlation with biological yield. Ashfaq *et al.* (2014) also enlightened similar kind of relationships.

Loading for morph-physioological traits in 30 commercial wheat varieties

Factor Loadings for morphological traits

Factor loadings for some morphological traits invarious wheat genotypes are presented in the form of the following figures.

Loading for Factor 1: Loading for factor 1 is shown in Figure 1. Factor 1 has maximum positive load of the factors spike length (0.9002), followed by grain yield (0.8351), number of spikelet (0.7574), plant height (0.7273), biological yield (0.6414), flag leaf area (0.6229), peduncle length (0.4826), number of tiller (0.2545), harvest index (0.1304), 1000 grain weight (0.06792) indicating a strong association of these traits to produce higher grain yield while negative load was contributed by days to 50 % heading (-0.228).

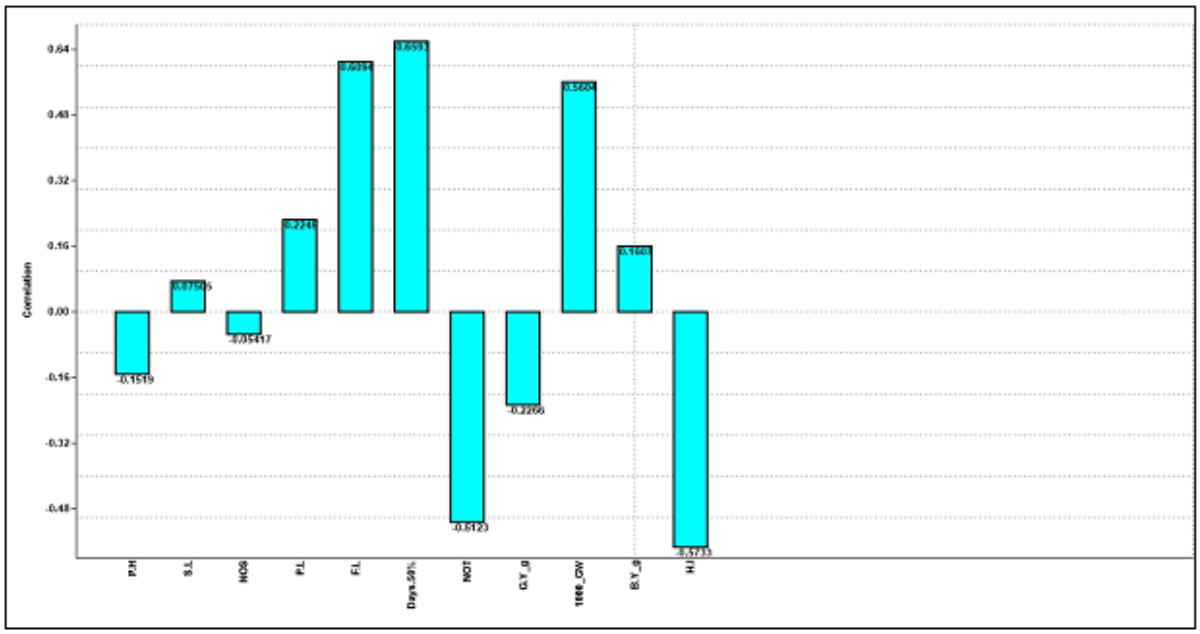

Fig. 2. Factor loading for Principal component 2 (PC2).

These studies are justified by correlation analysis. This PC can be called as effective PC for "Spike length". The results are supported by the findings of Mustafa *et al*., (2011) which disclosed that in the first factor, grain yield, number of spikes and spike length had significant importance and positively correlated.

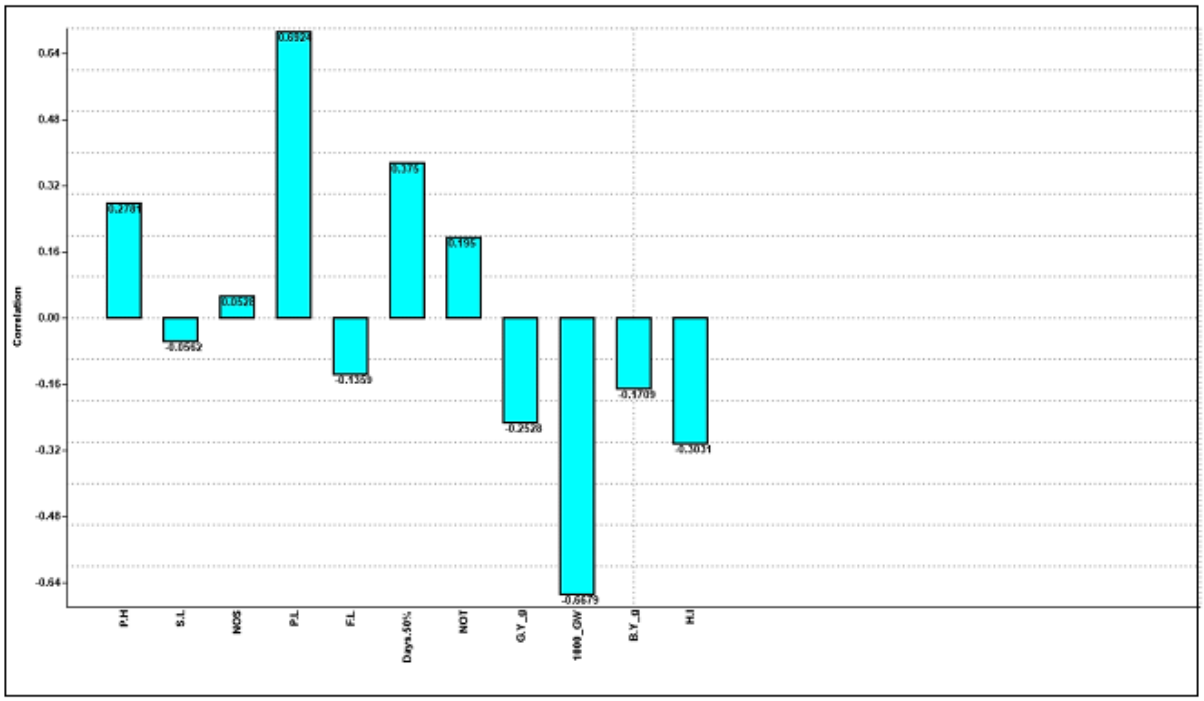

Fig. 3. Factor loading for principal component 3 (PC3).

Loading for Factor 2: Loading for factor 2 was shown in Fig. 2. In factor 2, the maximum positive load of the parameters like days to 50 % heading (0.6593), flag leaf area (0.6094), 1000 grain weight (0.5604), peduncle length (0.2245), biological yield (0.1607) and spike length (0.07505), while maximum and minimum negative load was contributed by harvest index (-0.5733), number of tiller (-0.5123), grain yield (-0.2264), plant height (-0.1519) and number of spikelet (-0.05417).

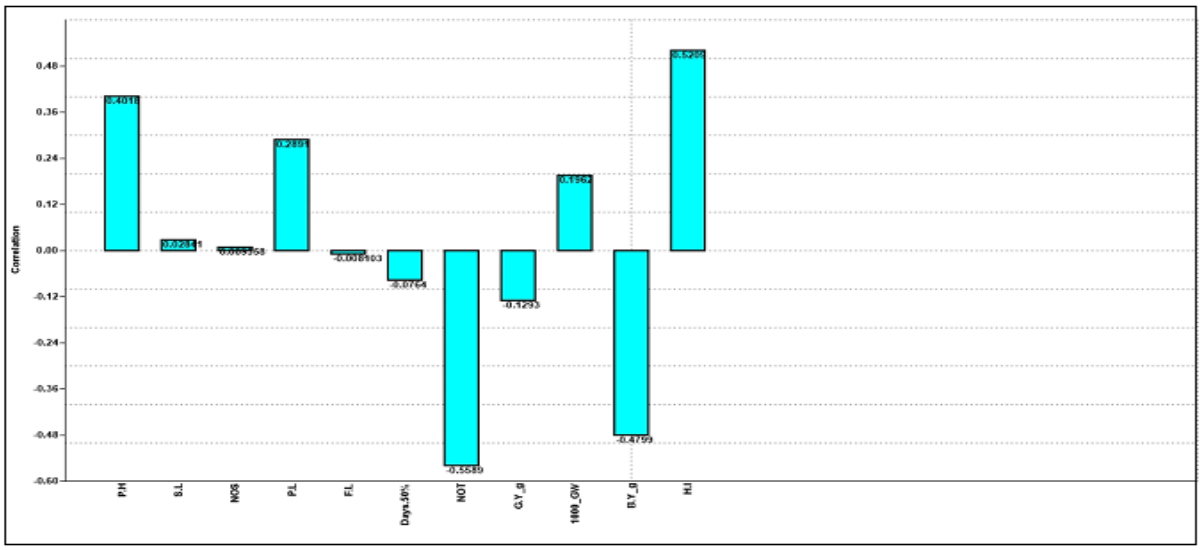

Fig. 4. Factor loading for principal component 4 (PC4).

This PC can be called as effective PC for days to 50 % heading. Correlation studies showed negative correlation between days to 50% heading and plant height and number of spikelet. It satisfied by loading PC also.

Loading for Factor 3: Loading for factor 3 are shown in Figure 3 maximum positive load of the traits like peduncle length (0.6924), days to 50 % heading (0.375), plant height (0.2781), number of tiller (0.195) and number of spikelet (0.0528) while maximum and minimum negative load was contributed by 1000 grain weight (-0.6679), harvest index (-0.3031), grain yield (-0.2528), biological yield (-0.1709), flag leaf area (-0.1359) and spike length (-0.0562).

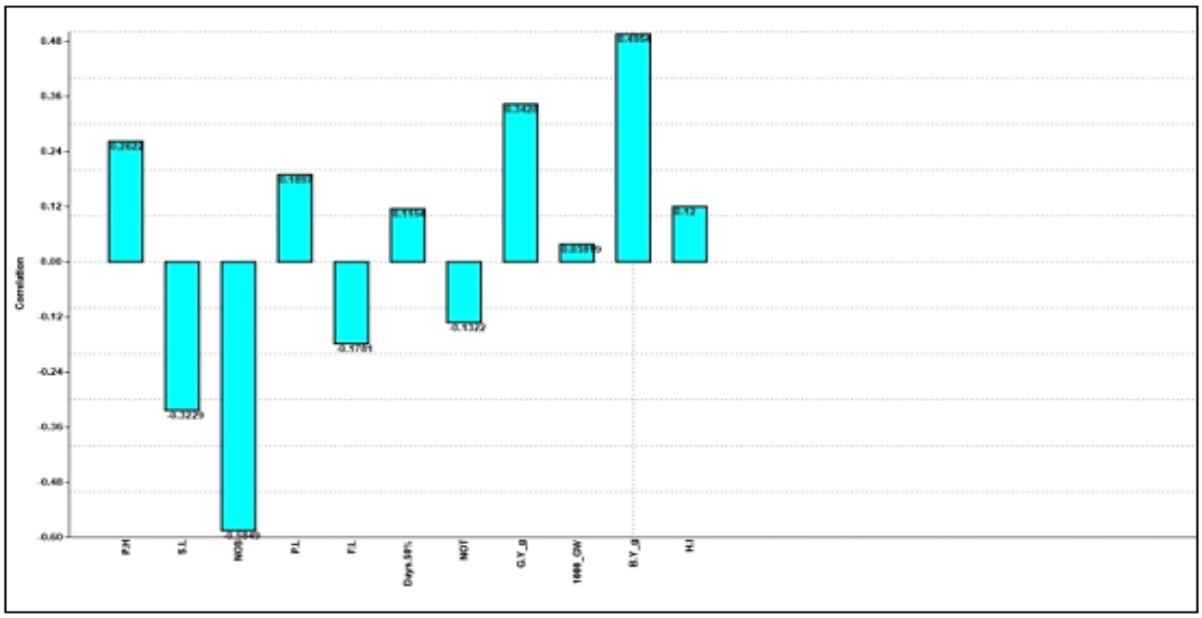

Fig. 5. Factor loading for principal component5 (PC5).

As this PC contained maximum positive load of peduncle length hence it can be called effective PC for "peduncle length". Correlation studies also justified this relationship because peduncle length has highly significant with plant height and positive correlation and significant with spike length, spikelet and days to 50 % heading and number of tiller. Correlation studies also support PC studies.

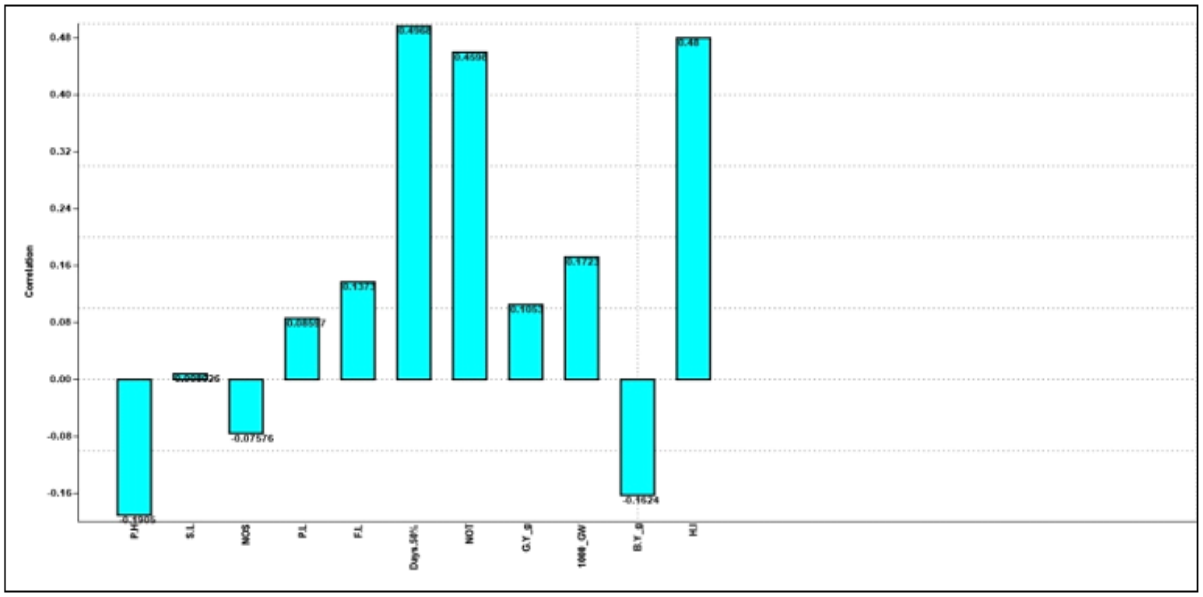

Fig. 6. Factor loading for Principal component 6 (PC6).

Loading for Factor 4:Loadings for factor 4 are shown in Fig. 4.The maximum positive load of factors like harvest index (0.5209), plant height (0.4018), peduncle length (0.2891), 1000 grain weight (0.1962), spike length (0.02841) and number of spikelet (0.00358) whereas highest and lowest negative load was contributed by number of tiller (-0.5589), biological yield (-0.4799), grain yield (-0.1293), days to 50% heading (-0.0764) and flag leaf area (-0.008103).

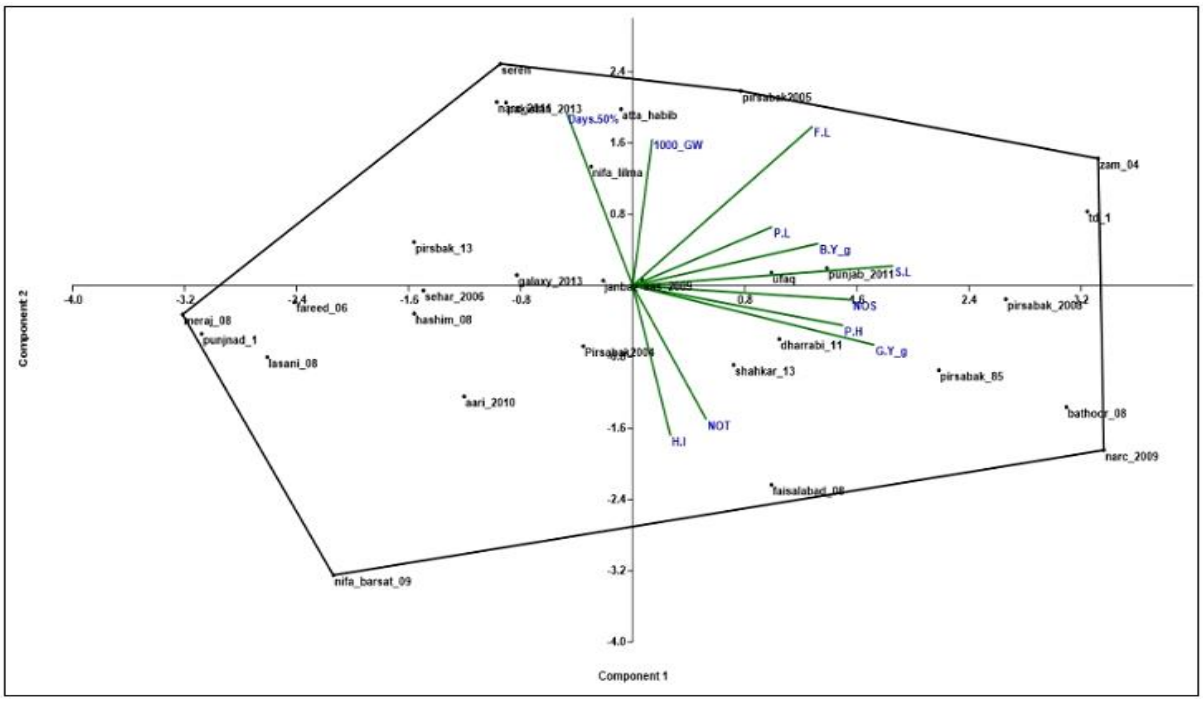

Fig. 7. Biplot diagram.

This PC can also be called as effective PC for "harvest index". Correlation studies showed positive correlation of harvest index with plant height, spikelet, spike length and grain yield also. Correlation studies do not support the PC studies.

Loading for factor 5: Loadings for factor 5 are shown in Fig. 5. Maximum positive load of factors like biological yield (0.4954), grain yield (0.3428), plant height (0.2622), peduncle length (0.1897), harvest index (0.12), days to 50 % heading (0.1154) and 1000 grain weight (0.03819) whereas highest negative load was contributed by number of spikelet (-0.5849), spike length (-0.3229), flag leaf area (-0.1761) and number of tiller (-0.1322).

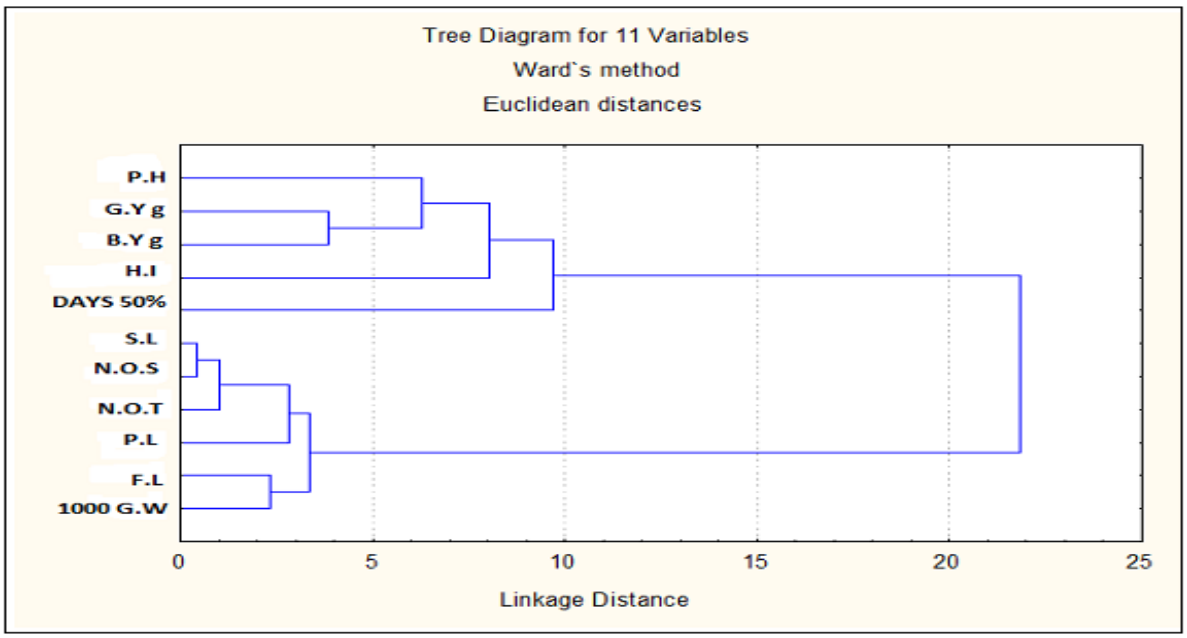

Fig. 8. Tree diagram based on different morphological traits in wheat genotypes.

This PC can be called as effective PC for "biological yield". Correlation studies showed that biological yield has highly significant positive correlation with grain yield which is justified by PC loading.

Loading for factor 6: Loading for factor 6 is shown in Fig.6. The maximum positive load contributed by factors like days to 50 % heading (0.4968), harvest index (0.48), number of tiller (0.4598), 1000 grain weight (0.1723), flag leaf area (0.1373), grain yield (0.1053), peduncle length (0.08597) and spike length (0.008026), whereas maximum and minimum negative loads contributed by plant height (-0.1905), biological yield (-0.1624) and number of spikelet (-0.07576). As this PC contained maximum positive load of days to 50% heading hence it can be called effective PC for "days to 50% heading". Correlation studies showed negative correlation between plant height, number of spikelet and biological yield. It satisfied by loading PC also.

Biplot diagram

First two PCs generating maximum variance were utilized to construct a scatter biplot diagram for metric traits of 30 commercial wheat varieties. Four traits grain yield, flag leaf area, days to 50 % heading and spike length showed more variation as these traits are found far away from the point of origin and lines representing these traits are longer. Peduncle length, biological yield and plant height were less variable as the line showing this trait was very close to the origin and shorter.

The biplot illustrated that days to 50% heading were negatively correlated with 1000 grain weight, flag leaf area, peduncle length, biological yield, number of spikelet, plant height, grain yield, number of tiller, harvest index and spike length. Correlation analysis showed the positive relationship among peduncle length, flag leaf area, biological yield, spike length and

1000 grain weight. Scatter biplot depicted those eight commercial cultivars like Pirsabak-2005, Zam-04, Td-01, Bathoor-08, Narc-2009, NIFA-Barsat-09, Meraj-08 and Seren as highly diverse as they were spotted far away from other genotypes.

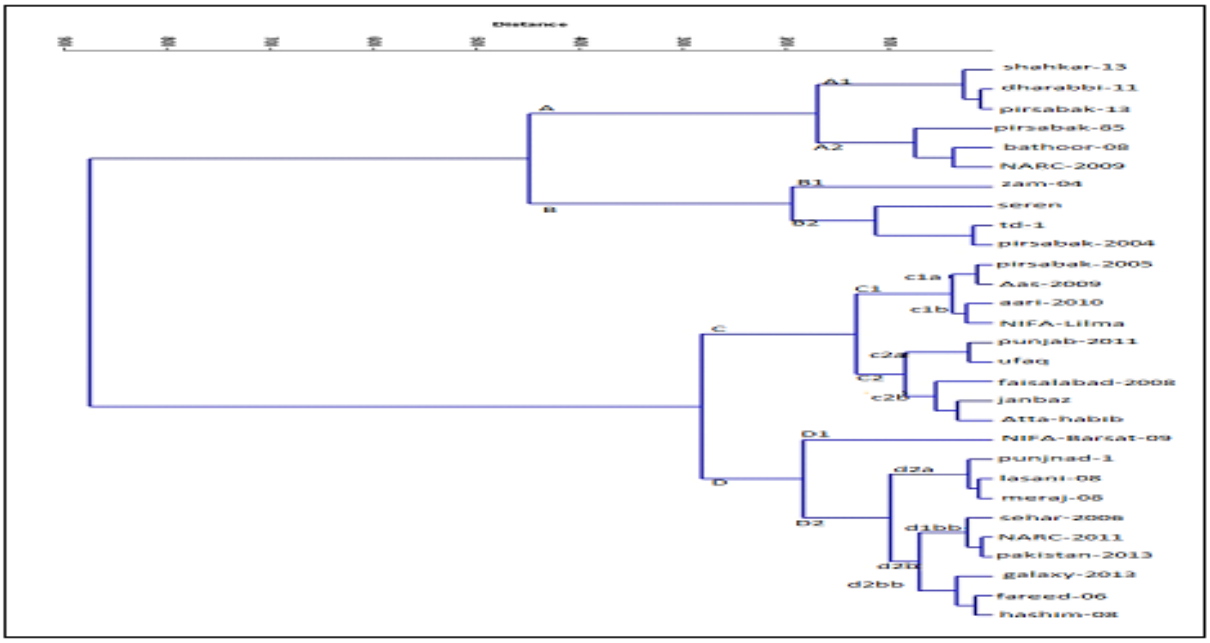

Fig. 9. Average linkage distance among 30 wheat genotypes.

Cluster analysis

Dendrogram based on metric traits

The tree diagram based on different morphological traits in wheat genotypes is displayed in Figure 8. The figure indicated two main clusters at linkage distance 23.

The clusters were named as cluster I and cluster II. In cluster I Plant height, days to 50% heading and harvest index was an outlier while biological yield and grain yield fall in the same cluster. In Cluster II Number of tiller and peduncle length was an outlier to this cluster and show more diversity. Two parameters, flag leaf area and 1000 grain weight present in the same cluster. Similarly, Spike length and number of spike showed a close relationship and found in the same cluster.

Average linkage distance among 30 wheat genotypes (Quantitative trait)

The tree diagram based on 30 wheat genotypes is displayed in Figure 9 which indicated two main clusters at the linkage distance 870.

The clusters were named as cluster 1 and cluster 2. Cluster 1 was further sub divided into A and B. Cluster A was further sub divided into A1 and A2. In sub cluster A1 genotype Shahkar-13 was outliers while genotypes Dharabbi-11 and Pirsabak-13 were closely related to each other and were in same cluster. Sub cluster A2 was grouped of one outlier Pirsabak-85 and two genotypes Bathoor-08 and NARC-2009.

Cluster B was further sub divided into B1 and B2. Sub cluster B1 having genotype Zam-04 is outlier showing more diversity. Sub cluster B2 was grouped of three genotypes seren was outlier and Td-1 and Pirsabak-2004 were in same cluster.

Cluster 2 was further divided into two sub clusters C and D which is further divided into C1 and C2. Cluster C1 was further divided into Sub cluster C1a which was grouped of genotypes Pirsabak-2005 and Aas-2009 and C1b having genotypes Aari-2010 and NIFA-Lilma. Cluster C2 divided into two sub clusters C2a and C2b. C2a consisted of Punjab-2011 and Ufaq whereas C2b consisted of an outlier named as Faisalabad-08 and two genotypes Janbaz and Atta- Habib.

Cluster D divided into two sub clusters D1 and D2. D1 consisted of an outlier named as NIFA-Barsat-09.D2 again divided into two sub clusters D2a and D2b. D2a consisted of an outlier Punjnad-1 and D2b consisted of two genotypes named as Lasani-08 and Meraj-08. D2b further divided into two sub clusters D1bb and D2bb. Sub cluster D1bb comprises of three genotypes Sehar-2006 was an outlier and show more diversity from other genotypes NARC-2011 and Pakistan-2013.Similarly, D2bb comprises of three genotypes an outlier Galaxy-2013 and two genotypes Fareed-2006 and Hashim-08.

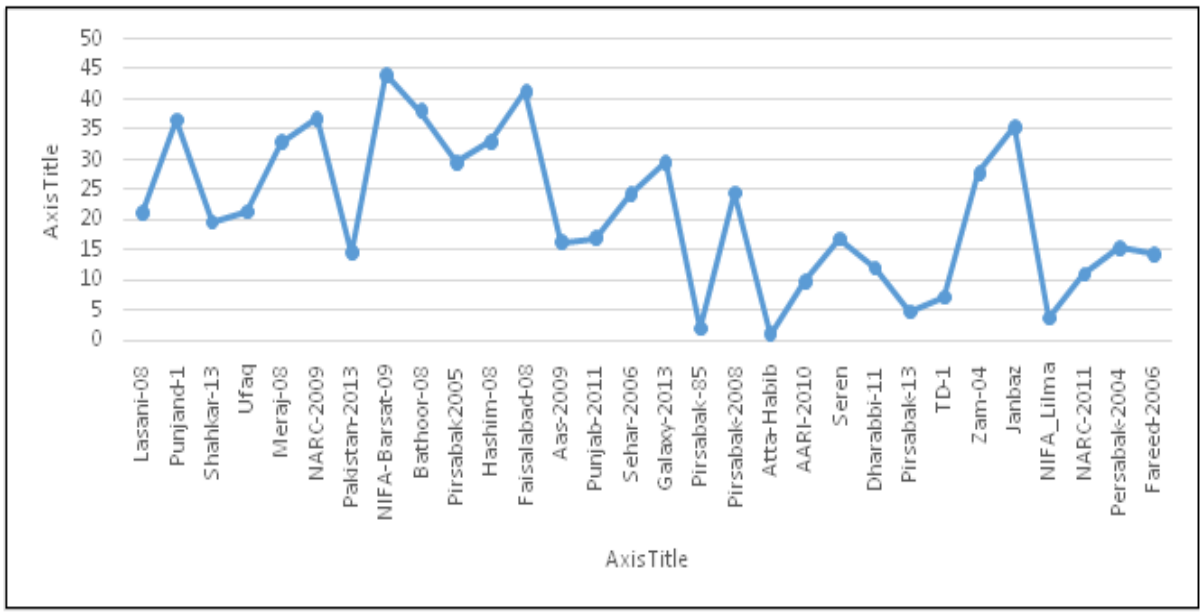

Fig. 10. Antioxidant potential in 30 commercial wheat varieties.

Biochemical analysis

Antioxidant activity in 30 commercial wheat varieties

The DPPH radical has been extensively utilized to examine the capacity of compounds as free-radical scavengers or hydrogen contributors and to evaluate the anti-oxidative activity of plant extracts and diets (Porto *et al*., 2000).

The antioxidant activity of 30 commercial wheat varieties shown in figure 10. The values were ranging between 1.1 to 44.09 percent, which showed that wheat varieties have huge range of antioxidant potential. The antioxidant activity was assessed by using different concentrations of DPPH.

The antioxidant activity was minimum in case of Atta-Habib (1.1) and the antioxidant activity was recorded maximum for NIFA-Barsat 09 (44.09). Similarly wheat varieties like Faisalabad-08 (41.26), Bathoor-08 (38.04), NARC-2009 (36.8), Punjnad-1 (36.59), Janbaz (35.4), Hashim-08 (33.03), Meraj-08 (32.91),

Galaxy-2013 (29.5), Pirsabak 2005 (29.5), Zam-04 (27.8), Pirsabak-2008 (24.5), Sehar 2006 (24.23), Ufaq (21.34), Lasani (21.18), Shahkar 13 (19.6),

Punjab 2011 (17.2), Seren (16.9), Aas 2009 (16.28), Pirsabak 2004 (15.4), Pakistan 2013 (14.6), Fareed 2006 (14.4), Dharabbi (12.3), NARC-2011 (11), AARI 2010 (9.9), Td-1 (7.2), Pirsabak 13 (4.8), NIFA-Lilma (3.8), Pirsabak 85 (2.06) and Atta-Habib (1.1) showed anti-oxidant activity respectively.

The results were in accordance with Lacko-Bartošová *et al.* (2013).

Percentage phenolic contents in 30 commercial wheat varieties

The phenolic content of 30 commercial wheat varieties was shown in Fig. 11. The values were ranging from 3.33 mg/g to 52.9 mg/g of gallic acid equivalent of aqueous wheat grain extract.

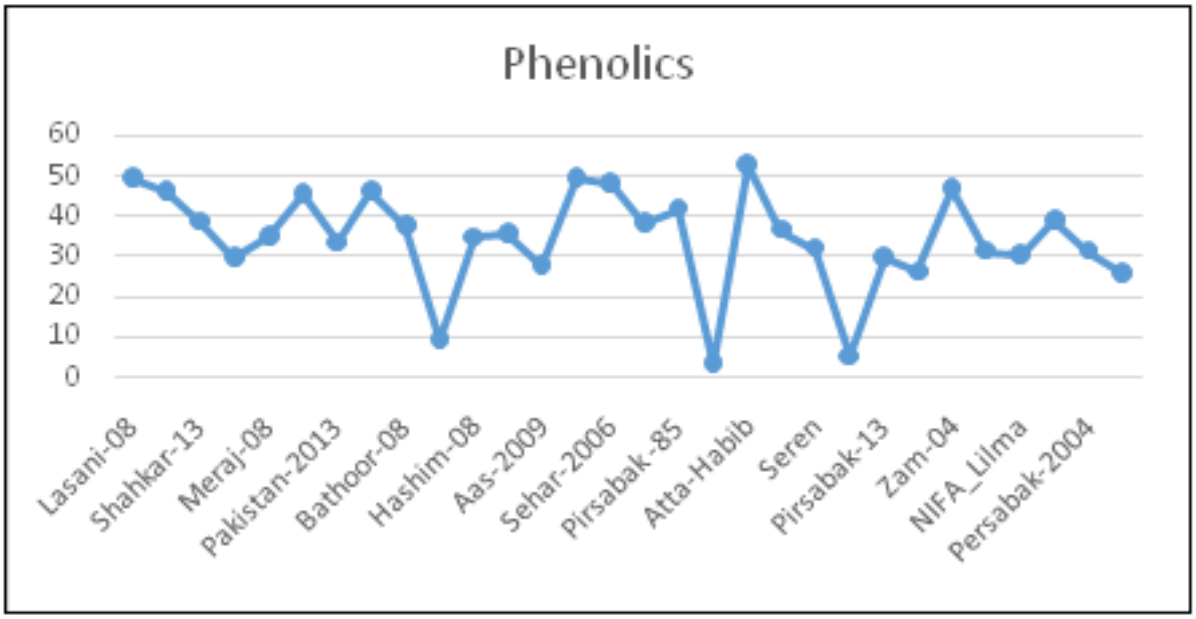

Fig. 11. Percentage phenolic contents in 30 commercial wheat varieties.

The phenolic contents were minimum in case of wheat varieties such as Persabak-2005 (9.2 mg GAE/g) Dharabbi-11 (5.06mg GAE/g) and Persabak-2008 (3.33mgGAE/g) similarly the phenolic contents were recorded maximum for Atta-Habib (52.9 mg GAE/g), Punjab-2011 (49.45 mg GAE/g), Lasani-08 (49.45 mg GAE/g), Sehar-2006 (48.07 mg GAE/g), Zam-04 (46.73 mg GAE/g), Punjand-1 (46 mg GAE/g), NIFA-Barsat (46), NARC-2009 (45.54 mg GAE/g), Persabak-85 (41.975 mg GAE/g).

Some commercial varieties such as NARC-2011 (38.775 mg GAE/g), Shahkar-2013 (38.64 mg GAE/g), Galaxy-2013 (38.18 mg GAE/g), Bathoor-08 (37.72 mg GAE/g), AARI-2010 (36.68 mgGAE/g), Faisalabad-08 (35.88), Meraj-08 (35.19), Hashim-08 (34.75 mg GAE/g), Pakistan-2013 (33.465 mg GAE/g), Seren (31.97 mg GAE/g), Janbaz (31.39 mg GAE/g), Persabak-2004 (31.395 mg GAE/g), NIFA-Lilma (30.36 mg GAE/g), Ufaq (29.9 mg GAE/g), Persabak-2013 (29.67 mg GAE/g), Aas-2009 (27.6 mg GAE/g), Td-1 (26.22 mg GAE/g) and Fareed-2006 (25.99 mg GAE/g) showed average phenolic content. The results of this study were in accordance with Okarter *et al.* (2011).

Conclusion

Commercial cultivars Faisalabad-08, NARC-2009, Td-1, Pirsabak-2008, Janbaz and Dharabbi showed complete resistance, these cultivars are recommended for general cultivation in areas where yellow rust is a severe yield reducing factor. The cultivars Pirsabak 2005, Sehar -2006, Bathoor-08, NARC-2011, Seren, Pakistan-2013, Atta-Habib, Shahkar-13, NIFA-Barsat, Pirsabak-13 and NIFA-Lilma showed moderate resistance ranging from 5MR to 40MR.

These cultivars should be used in hybridization programs to pyramid genes of horizontal resistance. Correlation studies, factor loadings and cluster analysis revealed that four metric traits peduncle length, number of tillers, days to 50 % heading and harvest index were intended for most of variation in commercial cultivars, hence these traits might be fixed with ease in breeding programs. Four commercial cultivars Pirsabak-2004, Pakistan-2013, Aas-2009 and Dharabbi-11 were determined as more diverse; these cultivars can be exploited in transgressive breeding. The cultivars Bathoor-08 and Zam-04 produced more grain yield hence it is recommended that these cultivars can be used for general cultivation as sources of high grain yield.

Mean values for phenolic content of 30 commercial wheat varieties ranged from 3.33 mg/g to 52.9 mg/g of gallic acid equivalent of aqueous wheat grain extract.

The phenolic contents were minimum in case of wheat varieties such as Persabak-2005 (9.2 mg GAE/g) Dharabbi-11 (5.06 mg GAE/g) and Persabak-2008 (3.33mgGAE/g) similarly the phenolic contents were recorded maximum for Atta-Habib (52.9 mg GAE/g), Punjab-2011 (49.45 mg GAE/g), Lasani-08 (49.45 mg GAE/g), Sehar-2006 (48.07 mg GAE/g), Zam-04 (46.73 mg GAE/g), Punjand-1 (46 mg GAE/g), NIFA-Barsat (46), NARC-2009 (45.54 mg GAE/g), Persabak-85 (41.975 mg GAE/g).

All genotypes showed almost average phenolic contents so can be used in biochemical improvement because too high or low phenolic, both are not good characters. Similarly antioxidant activities are also in medium standard so can be utilized in breeding program to improve nutritional value.

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