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Genetic Variability of Nitrogen Uptake Efficiency on Grain Yield and Quality traits of Iranian bread wheat (Triticum aestivum L.) landraces

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ABSTRACT: The objective of this study was to gain a better understanding of agronomic nitrogen (N) use efficiency and its effects on grain yield and quality of bread wheat landraces. This experiment was conducted in agricultural research center of Moghan, Iran, with 42 landraces at 3 replications and two N levels (0 and 200 kg ha^{-1}), based on RCB-design. Analysis of variance for N levels was significant at P<0.01 for grain yield and at p<0.05 for Thousands Kernel Weight (TKW), grain N content, grain protein yield and seed hardness index. Genotypes showed high significant differences for all traits at (p≤0.01). Genotype×Nitrogen use efficiency (GN) interactions showed significant differences for all characters except grain yield and grain N content at p≤0.01. Reduction of N causes to diminishing in grain yield, grain N content, bread volume, but it caused increasing of TKW. The highest N Uptake has been shown in G19 and G29. Genotypes showed high genetic diversity in bread making quality characters. Evaluations of GN interactions, based on Wricke equivalent showed 40% of variance belongs to four G4, G5, G9 and G25 genotypes. Protein percent observed a positive and significant correlation with Zeleny Sedimentation, bread volume and grain N content. Cluster analysis classified genotypes in two main groups. Cluster one characterizes with high grain yield, TKW and bread volume and high Zeleny sedimentation, protein percent and grain N content were the second cluster`s characters.

***Keywords*: Genetic diversity, Grain quality, Nitrogen Uptake Efficiency, Triticum aestivum.

INTRODUCTION

Nitrogen (N) is the main component of protein. This is an influence effect on grain protein and grain yield. Because of high consume rate of bread wheat, grain protein of wheat is an important nutrition necessity in human nutrition (Lemon, 2007). Due to economical and ecological factors, agricultural practices attempt to go towards sustainable systems with low inputs of N fertilizers. Global utilization rate of N was increased from 1962 (13.5 million tons) to 2004 (84.4 million tons), which half of this, was applied in developing countries (FAO, 2004). Nowadays N is responsible for an important part of agricultural related pollution through leaching (Mariotti, 1997). Pollution the water quality to an unacceptable level up to 1987, the EU successfully implemented nutrient reduction programs by developing of the best nutrient management practices. Unfortunately, N fertilizer do not use effectively, for instance NUE on cereal is about 33% in the world (Byerlee and Siddiq, 1994). Genetic variation has been reported on wheat for N uptake and use efficiency (Van Sanford and Mackown, 1986; Dhugga and Waines, 1989; Ortiz-Monasterio et al., 1997). Thus, expanding cultivars with high N absorption with low fertilizer would be necessary.

Recently improvement in N utilization in wheat during field experiments in some European Union (EU) countries (Table1) has been accompanied with good results. There are a number of studies demonstrate the new wheat varieties which have improved for NUE (Good et al., 2011).

Table 1. Improvement in NUE in wheat during field trials (Good et al., 2011)

Location	N fertilizer rate (kg N/ha)		% Increasing in yield	NUE (kg grain/kg N applied)	
	High	low		From high rate	From low rate
America	250	180	21	20	34
Europe	200	174	1	27	30
Asia	325	128	5	18	47
Mean	258	161	7	22	37

Modern UK wheat varieties have shown a 14% to 18% increase in NUE, depend on the N conditions (Sylvester-Bradley et al., 2009), while new Spanish wheat varieties had a 24% to 29% increase in NUE (Acreche, 2009). These differences in NUE were primarily determined by greater yield, not increased concentrations of N in the plant material (Good et al., 2011). There has been a 56% decrease in total fertilizer use between 1987 and 2007, including a significant decrease in N application per hectare. We need cultivars that absorb N more effective and use it more efficiently for grain production (Le Gouis et al., 2000).

The aim of this study was to gain a better understanding of agronomic nitrogen (N) uptake efficiency and its effects on grain quality characters on bread wheat landraces.

MATERIALS AND METHODS

The experiment was conducted in 2008-2009 planting season with 42 bread wheat (*Triticum aestivum* L.) landraces from Iran gene bank collection (Table2) was planted in agricultural research center of Moghan (North West of Iran), based on RCB-design with 3 replications and two splits for N levels, N0 and N+ (0 and 200 kg N/ha) on 19 November 2008. The soil, classified as a clay loam (Orthic Luvisol, FAO classification) (Table3).

Time and consumption rate of Urea were 50kg N/ha before sowing, one-fourth at tillering, one-fourth at beginning of stem elongation and the rest at grain filling stage. Source of genotypes, were presented in Table 3. Each planted plots, consist of six rows of 3m long and 20cm apart with the seed density of 350 grains/m^2. Calculated of grain N content we used kjeldal method (Walinga, et al., 1989) and Timsina et al., (2001), equation model for N uptake efficiency; which N uptake ($kg.kg^{-1}$)=[GY*(GNC)+SY*(SNC)]/Nx supply, that GY is grain yieald; GNC, grain N content, SY, stable yield; SNC, stable N content and Nx, amount of N (May et al., 1991). When the G×N interaction was significant for a character, we could calculate Wricke (1962), equivalence (W^2g):

$W^2g=\sum_{n}^{N=1}(Xgn - Xg.. - X.n + X..)^2$, that N is the nitrogen level, Xg.., mean of genotype in all N levels, X.n, mean of N level in all levels and X.., is general mean.

Table 2. Source, abbreviations, date of heading, date of maturity and plant height of 42 bread wheat landraces

Genotype	Source	Days to Heading	Days to Maturity	Plant height (cm)
G1	Kc-219	164	205	120
G2	kc-206	167	209	115
G3	kc-212	176	211	125
G4	kc-216	166	212	118
G5	kc-256	174	210	125
G6	kc-257	175	210	123
G7	kc-259	177	211	120
G8	kc-264	174	211	120
G9	kc-354	173	206	122
G10	kc-677	174	209	125
G11	kc-1196	169	209	120
G12	kc-1200	167	209	117
G13	kc-3719	168	211	125
G14	kc-129	172	210	127
G15	kc-4708	166	212	110
G16	kc-5514	174	209	137
G17	kc-6461	176	210	128
G18	kc-6514	168	212	120
G19	kc-868	168	205	122
G20	kc-435	181	212	115
G21	kc-857	164	205	120

G22	kc-987	168	205	125
G23	kc-1656	170	210	130
G24	kc-1691	168	209	118
G25	kc-1750	166	204	120
G26	kc-2474	169	210	118
G27	kc-2682	176	213	140
G28	kc-2919	167	210	123
G29	kc-3155	173	208	147
G30	kc-3167	170	209	125
G31	kc-4617	161	202	100
G32	kc-4680	173	210	135
G33	kc-4713	167	206	125
G34	kc-5032	178	212	110
G35	kc-5596	177	215	135
G36	kc-5801	175	211	135
G37	kc-6127	168	209	127
G38	kc-6360	177	211	130
G39	kc-388	169	209	135
G40	kc-1652	167	209	128
G41	kc-3366	168	207	132
G42	kc-6143	170	208	140

* Karaj gene bank Collection (KC), Iran

Table 3. Soil characteristics of experimental location from depth o 0-60cm

pH	EC* (ds/m)	P (mg/kg)	K (mg/kg)	SP (%)	OC (%)	TN (%)	CaCO3 (mg/kg)
7.46	0.42	20	350	52	1.20	0.15	28

In order to evaluation of Grain Yield (GY) and Protein percent (% Prot.), Protein Yield (PY), Zeleny Sedimentation Index (Zel.), Grain Hardness Index (HI), Bread Volume (BV), Water Absorption (WA) and Wet Gluten (Wet Glut.) after omitting of borders, each plot was completely harvested. Quality analysis for sedimentation volume, to determine of protein quality was conducted by Carter *et al*., (1999) method. We used Inframatic machine for %Prot., HI and Zel, sedimentation. Measurement of Gluten amount was conducted based on International Association for Cereal Science and Technology (ICC), (Anonymous, 1998). In order to classify genotypes, un-weighted pair-group method using arithmetic average (UPGMA) with squared Euclidean distance method used by SPSS (Ver. 13) soft ware.

RESULTS AND DISCUSSION

Analysis of variance showed significant differences for traits of TKW, PY, HI and GY between two N levels (Table 4). There were not significant differences ffor % Prot, grain N content, WA %, Wet Glut, B.V, Zel, Sedimentation, and N uptake efficiency. We found significant differences ($P \le 0.01$) among genotypes that was representative of high genetic diversity. Except of GY and grain N content, other traits showed significant differences for G×N interactions.

Grain yield and N uptake

Enhancement of N were caused increases of GY, PY and HI but it decreased the TKW at N0 to N+ (200 kg N/ha). Grain yield increased significantly from N0 (3.107 t/ha) to N+ (5.360 t/ha). Approximate reduction of GY at two N levels was about 42%. This was agreement with Ehdaie and Waines (2001) experiments. They showed a 31% grain yield reduction with N reducing rate at 170 to 105 kg N/ha in durum and bread wheat genotypes. Mean comparison of GY showed G19, G26, G29, G37, G38 and G41 as the highest GY genotypes (Table 5). Advancement of high N utilization must be practical both high yielding and high N absorption in plant. Development of root system and growth length stage have important role in N absorption amount and reduction of nitrogen loosing (Good et al,, 2011). Evaluation of grain N content indicated high genetic diversity between genotypes. In our study the genotypes of G9 and G29 not only had both high grain N content and grain yield but also showed the highest N uptake efficiency between genotypes. Nitrogen uptake efficiency increased significantly from N0 (48 gr gr^{-1}) to N+ (105 gr gr^{-1}). The highest N uptake efficiency was belonged to G15, G19, G29, G31, G37 and G42. Genotypes of 19, 29, 37 and 42 showed the highest GY potential and grain N content. TKW was significantly ($p \le 0.05$) decreased from N0 (43.9 gr) to N+ (39.7 gr). It seems the genotypes with low TKW have been main role in variation of GN interaction. Relation of TKW and Zel, Sedimentation (r=-0.413**), % Protein (r=-0.636**) and grain N content (r=-0.554**) were reverse. It means genotypes with high TKW have low amounts of these characters.

Bread making quality traits

Genotypes showed high diversity on bread making quality for all traits. Based on Najafian et al., (2011) bread making quality studies on commercial bread wheat cultivars in the west and northern west of Iran, 16% of samples with 11% grain protein pertained to good quality ones, but in our experiment it was 12.4%. PY showed significant difference for all amounts of N, G and G×N interaction. The PY increases significantly from N0 (355) to N+ (630) kg/ha. The highest PY belonged to genotypes of G19, G26, G37, G38 and G41 with more than of 620 kg/ha. Because of significances of G×N interaction, Wricke equivalence (Fig 2b) showed effects of each genotype on variance of interaction (table 6). Based on wricek's equivalent the main portion of G×N interaction of % protein (Fig 2a) was 41% in G1, G9, G37 and G42**.**

Means of flour water absorption and wet gluten were 63.7% and 33.5%, respectively. The low stable cultivars to N reduction in wet gluten (Fig 2c) were G4, G6, G15 and G25 with 45.5% of G×N interaction. Mean of Zeleny sedimentation index was 33.6% which could be considered as a good type score. Najafian and et al. (2011), in their experiment showed it 28% (which could be considered as a medium type score). Sensitive cultivars for Zel, Sedimentation index (Fig 2d) appertained to six genotypes of G5, G9, G25, G29, G37 and G38 with 51% of the G×N interaction variance. Genotypes of G1 and G31 had the highest Zel, Sedimentation index. The highest B.V. was belonged to G4, G5, G6, G10 and G20. The genotypes of G5, G7, G9 and G17 with high and low B.V were responsible up to 56.6% of G×N interaction variance (Fig 2e). Mean of grain HI score was 51.5 which is normal grains status. Grain HI in G11 and G20 showed the highest. Four genotypes of G4, G9, G37, G38 and G40 were responsible 50% G×N interaction.

Genetic variation

In order to describe response of genotypes at N levels, we used principal component (Grausgruber et al., 2000) two first and second principal companent (Biplot) and those dendrogram of cluster (Fig 3 and 4). The statistics parameters of Wricke equivalence W^2g (1962), have been used for calculating the variance of W^2g parameters for bread making quality traits (Fig 4). Principal component analysis (PCA) showed 69.2% variance by two PCs (PC1 and PC2). The most important characters of PC1 was B.V, %Protein and Zel. Sedimentation and TKW, yield and PY were detected by PC2. The dendrogram created by using UPGMA clustering algorithm revealed two main groups with 24 and 18 odds. Cluster one included genotypes with high TKW, high grain yield, protein yield and BV. High %protein, Zel. Sedimentation and seed N content were characters of genotypes in second cluster. Many of sensible genotypes were placed on cluster 2.

PCA1= 0.500 (Bread Vol.) + 0.498 (Protein %) + 0.296 (Zel.) - 0.213 (Pro Yield) – 0.261 (Yield) – 0.377 (TKW)
PCA2= 0.027 (Bread Vol.) + 0.211 (Protein %) + 0.350 (Zel.) + 0.639 (Pro Yield) + 0.614 (Yield) – 0.216 (TKW)

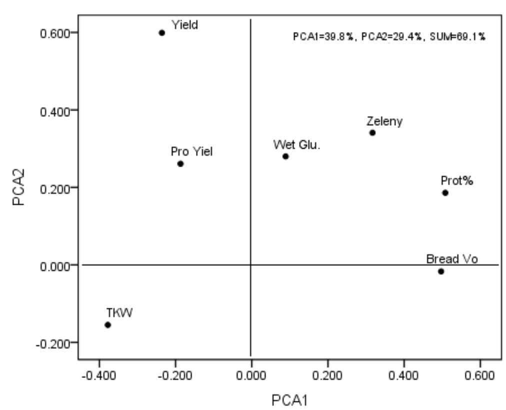


Figure 3. Biplot of two principal components for characters in 42 bread wheat landraces

Table 4. Analysis of variance of grain yield, protein yield, NUE, grain N content and quality characters in 42 bread wheat genotypes

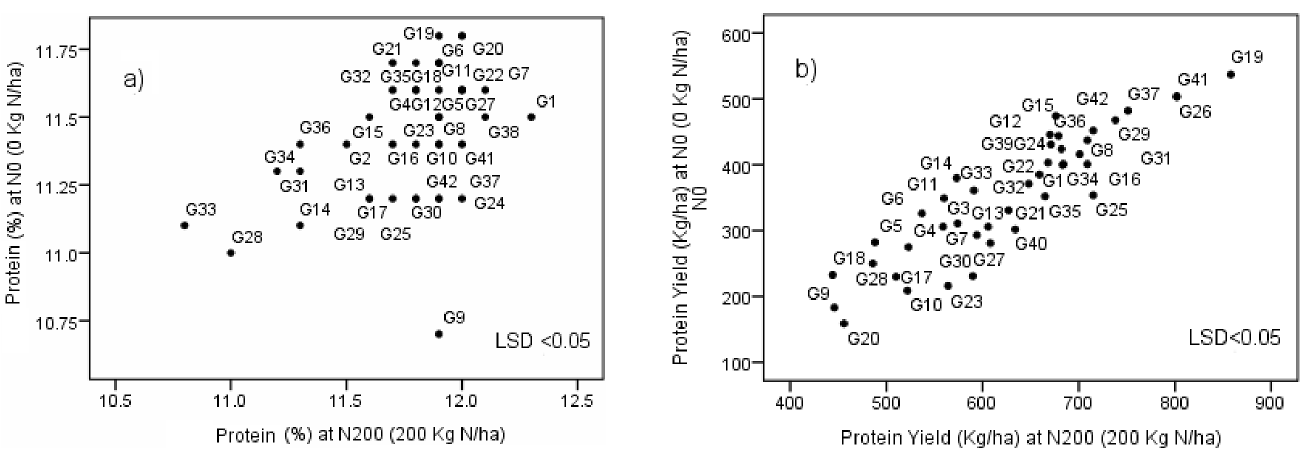
S. O. V	df	TKW	Yield	% Protein	Protein yield	Grain N content	W. Glut	WA%	HI	ZEL.	B.V	N uptake efficiency
Rep.	2	22.09 ns	0.645 ns	2.425 ns	65111.4 ns	0.79 ns	17.361 ns	7.742 *	41.298 *	0.429 *	21522.48 ns	173.54 ns
N	1	1114.68 *	329.58**	7.44 ns	786103.5 *	17.29 ns	4.861 ns	0.713 ns	51.57 *	26.036 ns	39175.3 ns	205.33 ns
E1	2	15.29	8.091	0.801	24583.5	2.022	11.694	0.105 ns	1.083	19.00	8355.35	260.35
G	41	61.24 **	4.009 **	0.309 **	34867.6 **	0.238 **	6.292 **	0.137 ns	3.346 **	4.622 **	2721.36 **	566.68 **
G×N	41	5.04 **	0.211 ns	0.121 **	23048.6 **	0.023 ns	5.398 **	0.112 ns	3.628 **	1.637 **	1114.86 **	362.25**
E2	164	2.304	0.279	0.062	7304.9	0.031	1.613	0.102	1.674	0.812	287.376	107.41
%CV.		3.7	12.5	2.1	17.4	6.7	3.8	0.5	2.5	2.7	3.5	13.8

*P≤0.05; **P≤0.01; ns., not significant

Table 5. Mean of yield, protein yield, TKW, %protein, bread volume, wet gluten, % water absorption, grain hardness index, Zeleny sedimentation and seed nitrogen content. at two nitrogen levels

Interaction	Genotype	TKW (gr)	Protein (%)	Yield (Kg/ha)	Prot. Yield (Kg/ha)	B.V (m^3)	W.GLUT (%)	WA (%)	HI	ZEL.	Grain N Content (%)	N uptake efficiency (gr/gr)
N0	G1	40.0	11.5	3480	400	481	34.0	63.6	51.7	35.0	2.03	49
	G2	41.7	11.4	2900	331	468	33.0	63.2	50.7	33.0	2.10	41
	G3	44.0	11.5	2660	306	492	35.7	63.3	51.7	33.0	2.00	38
	G4	40.7	11.6	2370	275	499	36.3	63.6	48.7	32.0	2.10	31
	G5	41.7	11.6	2430	282	461	34.3	63.7	53.0	34.3	2.13	37
	G6	42.7	11.8	2760	326	488	33.0	64.0	52.7	33.3	2.33	41
	G7	44.0	11.6	2680	311	451	34.3	63.5	52.0	33.3	2.10	35
	G8	43.3	11.4	3830	437	481	32.3	63.7	50.0	33.3	2.17	49
	G9	41.7	10.7	1710	183	432	31.0	63.5	49.0	31.3	2.06	28
	G10	43.0	11.4	1830	209	520	34.0	63.5	51.7	33.7	2.07	24
	G11	43.3	11.7	2980	349	497	34.7	63.7	53.0	35.3	2.57	46
	G12	43.0	11.5	3880	446	482	33.0	63.6	52.7	32.7	2.40	64
	G13	50.3	11.2	2730	306	482	34.7	63.5	52.3	31.7	2.27	42
	G14	45.7	11.1	3420	380	474	33.0	63.6	51.3	31.7	2.23	50
	G15	46.7	11.5	3860	444	482	34.3	63.8	52.3	33.3	2.53	67
	G16	46.3	11.4	3520	401	482	33.7	63.7	51.3	35.0	2.40	58
	G17	41.0	11.2	2050	230	428	34.7	63.5	50.0	33.7	2.27	30
	G18	46.0	11.7	1990	233	479	32.7	63.7	50.0	31.7	2.47	38
	G19	38.7	11.7	4590	537	469	35.7	63.9	50.7	34.3	2.63	71
	G20	41.3	11.8	1350	159	527	34.0	64.0	53.0	34.7	2.33	22
	G21	41.7	11.7	2580	302	496	34.0	63.8	51.3	32.7	2.70	48
	G22	43.3	11.6	3320	385	492	33.3	63.5	52.7	33.3	2.30	50
	G23	39.7	11.5	1880	216	501	33.0	63.9	51.0	33.7	2.50	29
	G24	43.0	11.2	3790	424	447	33.7	63.9	51.7	33.0	2.23	53
	G25	42.0	11.2	3160	354	451	30.7	63.5	52.3	31.7	2.40	53
	G26	45.0	11.4	4420	504	477	32.7	63.7	51.3	32.7	2.23	62
	G27	44.7	11.6	1990	231	466	33.3	63.9	51.3	34.0	2.63	39
	G28	49.7	11.0	2270	250	435	32.7	63.7	51.0	32.7	2.27	41
	G29	41.7	11.2	4180	468	479	31.7	63.7	51.0	32.3	2.70	71
	G30	45.3	11.2	2620	293	483	32.3	63.8	51.0	32.7	2.37	43
	G31	44.7	11.3	3680	416	398	32.7	63.5	50.0	32.3	2.23	60
	G32	46.0	11.6	3200	371	470	32.0	63.8	50.7	35.0	2.57	53
	G33	49.7	11.1	3250	361	454	33.0	63.7	52.7	33.3	2.50	52
	G34	46.0	11.3	3550	401	475	32.7	63.7	51.3	32.3	2.40	52
	G35	45.7	11.7	3010	352	475	34.0	63.4	48.7	34.7	2.27	49
	G36	45.7	11.4	3780	431	484	32.0	63.8	50.0	33.3	2.37	57
	G37	41.0	11.2	4300	482	472	33.0	63.4	49.7	33.0	2.43	66
	G38	45.0	11.5	4120	474	472	34.0	63.4	49.7	32.7	2.40	61
	G39	48.0	11.5	3500	403	449	32.0	63.9	50.7	33.7	2.30	60
	G40	43.3	11.6	2420	281	475	34.7	63.5	49.3	35.0	2.70	43
	G41	42.3	11.4	4410	503	502	33.0	63.1	49.7	34.7	2.30	64
	G42	44.3	11.2	4040	452	471	31.3	63.9	50.3	33.3	2.67	69
	G1	35.0	12.3	5550	683	519	34.0	63.5	53.7	35.3	2.77	105
	G2	38.7	11.5	5450	627	478	30.3	63.7	51.3	33.7	2.53	99
	G3	38.3	11.9	4700	559	491	33.7	64.0	53.3	34.7	2.70	88

	G4	37.0	11.8	4430	523	524	30.7	64.0	53.3	32.7	2.63	85
	G5	37.0	11.9	4100	488	567	31.3	64.0	52.0	32.3	2.47	71
	G6	38.3	11.9	4510	537	536	29.7	63.6	53.3	32.7	2.80	90
	G7	37.3	12.1	4740	574	536	31.7	64.0	52.7	34.3	2.73	82
	G8	38.3	11.9	5960	709	497	32.0	63.7	51.3	34.3	2.70	105
	G9	36.7	11.9	3750	446	522	34.0	63.7	52.3	34.0	2.70	78
	G10	39.7	11.8	4420	522	517	32.7	64.1	52.3	34.7	2.43	73
	G11	40.7	11.9	4710	560	497	34.7	63.7	52.7	34.0	3.03	89
	G12	39.7	11.9	5630	670	490	34.0	63.7	52.3	34.0	2.900	121
	G13	47.0	11.6	5220	606	491	35.0	63.8	50.7	31.7	2.933	111
	G14	42.7	11.3	5070	573	480	34.7	63.8	50.7	33.0	2.567	87
	G15	43	11.6	5850	679	478	37.7	63.5	50.0	33.3	3.167	129
	G16	43.7	11.7	6060	709	463	35.0	63.7	51.7	34.0	3.167	121
	G17	35.7	11.7	4360	510	502	34.3	63.7	52.0	35.0	2.867	76
N200	G18	43.7	11.9	3730	444	500	33.0	63.9	52.3	33.3	2.900	68
	G19	32.7	11.9	7210	858	493	36.0	63.7	52.0	35.0	3.267	146
	G20	39.7	12.0	3800	456	533	33.7	64.0	53.3	35.0	2.900	69
	G21	33.3	11.8	5370	634	507	33.3	63.9	52.0	33.3	3.300	124
	G22	36.3	12.0	5490	659	507	33.3	63.7	51.3	33.3	2.767	99
	G23	34.0	11.9	4740	564	509	32.3	63.5	52.7	34.3	3.000	108
	G24	40.3	11.9	5730	682	488	33.7	64.0	51.7	34.3	2.867	119
	G25	34.7	11.8	6060	715	511	34.3	63.5	52.3	34.7	3.167	133
	G26	41.7	11.9	6740	802	486	34.3	63.8	52.0	34.0	2.800	120
	G27	37.3	12.0	4920	590	495	34.7	64.1	51.0	34.0	3.067	110
	G28	47.0	11.0	4420	486	447	32.7	63.5	49.7	31.7	2.567	88
	G29	35.7	11.6	6360	738	502	33.7	63.8	51.0	34.3	3.100	133
	G30	41.7	11.8	5030	594	520	34.7	63.5	51.3	34.3	2.733	99
	G31	44.7	11.2	6260	701	407	33.3	63.9	51.3	32.0	2.667	130
	G32	45.3	11.7	5540	648	497	35.0	63.5	53.0	35.3	3.067	112
	G33	47.0	10.8	5470	591	451	32.3	63.7	51.3	34.0	3.033	108
	G34	42.0	11.3	6050	684	488	33.7	63.6	52.3	32.3	3.100	125
	G35	40.7	11.7	5680	665	502	34.7	63.6	51.3	34.3	2.733	119
	G36	43.3	11.3	5940	671	489	32.7	63.6	51.3	34.0	2.833	119
	G37	36.7	12.0	6260	751	509	34.3	64.0	52.7	35.0	3.100	124
	G38	41.7	12.1	6340	767	499	35.3	63.7	52.7	34.7	2.733	116
	G39	45	11.9	5610	668	515	34.7	63.9	51.3	35.0	2.800	103
	G40	36.7	11.8	5150	608	495	34.7	63.8	53.3	34.7	3.133	98
	G41	37.0	12.0	6680	802	509	34.0	63.3	52.0	34.7	2.833	119
	G42	39.3	11.9	6010	715	499	32.0	63.9	52.0	34.7	3.100	120
LSD 5%	N	1.88	0.22	405.9	39.0	22.74	0.85	0.08	0.26	1.08	0.36	13.43
	G	2.34	0.30	771.2	97.6	19.32	1.45	0.36	1.47	1.03	0.20	2.26
	G×N	3.30	0.43	1090.7	137.9	27.32	2.05	0.51	2.09	1.45	0.28	3.57



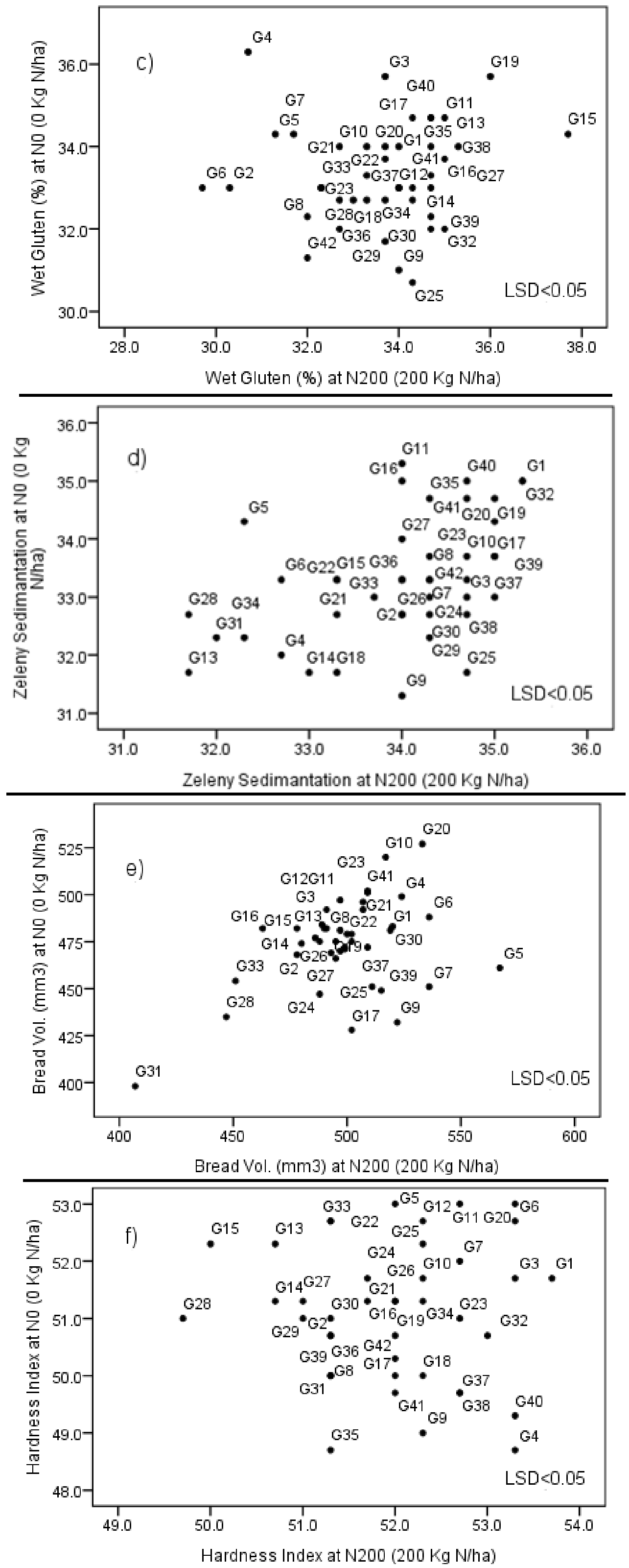


Figure 2. Bread making quality traits, %protein (a),protein yield(b),wet gluten (c), Zel. Sedimentation (d),bread vol (e) and hardness index (f) of 42 bread wheat genotypes at two N levels. The contribution of each genotype at G×N interaction (equivalence) calculated

Table 6. Wrick equivalent coefficient for significant G×N interactions in protein%, protein yield, wet gluten, zeleny sedimentation, bread volume and grain hardness index in 42 landraces

Genotype	Percentage of Wrick equivalent coefficient					
	Protein (%)	Prot. Yield (Kg/ha)	W. Glut (%)	ZEL. Sedimentation	Bread Vol.	HI
G1	8.1	2.5	0	0.1	2.63	3.0
G2	0.2	2.7	4.9	0.8	0.19	0.3
G3	2.2	2.0	2.7	4.6	0.00	2.0
G4	0.5	1.9	20.9	0.8	1.13	16.1
G5	1.3	1.3	6.0	6.3	19.74	0.8
G6	0.2	1.4	7.3	0.6	3.97	0.3
G7	2.3	2.2	4.5	1.6	12.86	0.4
G8	2.6	2.3	0.1	1.6	0.44	1.3
G9	17.8	2.2	6.0	11.5	14.31	8.3
G10	2.2	3.0	1.1	1.6	0.02	0.3
G11	0.6	1.4	0.0	2.7	0.00	0.1
G12	1.9	1.6	0.7	2.7	0.10	0.1
G13	1.6	2.8	0.1	0.0	0.14	2.0
G14	0.3	1.2	1.9	2.7	0.07	0.3
G15	0.1	1.7	7.7	0.0	0.02	4.0
G16	0.9	3.0	1.1	1.6	0.62	0.1
G17	3.3	2.4	0.1	2.7	9.68	3.0
G18	0.3	1.4	0.1	4.0	0.78	4.0
G19	0.8	3.2	0.1	0.8	0.99	1.3
G20	0.5	2.7	0.1	0.1	0.08	0.1
G21	0.3	3.4	0.3	0.6	0.19	0.4
G22	1.6	2.3	0.0	0.0	0.41	1.5
G23	1.4	3.8	0.3	0.6	0.10	2.2
G24	5.3	2.1	0.0	2.7	3.01	0.0
G25	5.1	4.1	8.6	14.2	6.42	0.0
G26	2.9	2.8	1.7	2.7	0.12	0.4
G27	1.9	4.0	1.3	0.0	1.46	0.1
G28	0.0	1.7	0.0	1.6	0.25	1.3
G29	1.9	2.3	2.7	6.3	0.93	0.0
G30	4.2	2.8	3.8	4.0	2.42	0.1
G31	0.1	2.5	0.2	0.1	0.13	1.3
G32	0.1	2.4	6.0	0.1	1.35	4.0
G33	0.9	1.6	0.3	0.8	0.01	1.5
G34	0.0	2.5	0.7	0.0	0.28	0.8
G35	0.0	3.0	0.3	0.3	1.26	5.2
G36	0.1	1.8	0.3	0.8	0.04	1.3
G37	8.1	2.3	1.1	6.3	2.46	6.9
G38	4.2	1.3	1.1	6.3	1.35	6.9
G39	2.5	2.2	4.9	2.7	7.84	0.3
G40	0.6	3.3	0.0	0.1	0.75	12.2
G41	4.7	2.8	0.7	0.0	0.08	4.0
G42	6.8	2.2	0.3	3.1	1.36	2.2

Table 7. Correlation coefficient of TKW, %protein, Zeleny sedimentation, grain hardness index, %water absorption, wet gluten, bread volume and grain N content in 42 bread wheat genotypes

Trait	TKW	Yield	%Prot.	Prot. Yield	Wet Glu.	Zel.	Bread Vol.	grain N cont.
TKW	1.000	0.292 ns	-0.636 **	0.223 ns	0.194 ns	-0.413 **	-0.255 ns	-0.554 **
Yield		1.000	-0.104 ns	0.993 **	0.142 ns	-0.229 ns	0.131 ns	-0.278 ns
%Prot.			1.000	-0.014 ns	0.251 ns	0.445 **	0.487 **	0.674 **
Prot. Yield				1.000	0.158 ns	-0.187 ns	0.184 ns	-0.213 ns
Wet Glu.					1.000	0.013 ns	0.287 ns	0.017 ns
Zel.						1.000	0.234 ns	0.464 **
BV							1.000	0.303 ns

Table 8. Total mean and cluster mean of used characters in 42 bread wheat genotypes

Genotypes in cluster	Character TKW	Yield	%Prot.	Prot. Yield	Wet Glu.	Zel.	Bread Vol.	Seed cont.	N
1, 2, 8, 12, 14, 15, 16, 19, 22, 24, 25, 26, 29, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42	36.9	4837.3	11.5	559.3	33.5	51.4	33.8	480.1	
3, 4, 5, 6, 7, 9, 10, 11, 13, 17, 18, 20, 21, 23, 27, 28, 30, 40	34.4	3427.8	11.7	401.5	33.5	51.8	33.5	494.6	
Mean	35.7	4133	11.6	480	33.5	51.6	33.7	487	

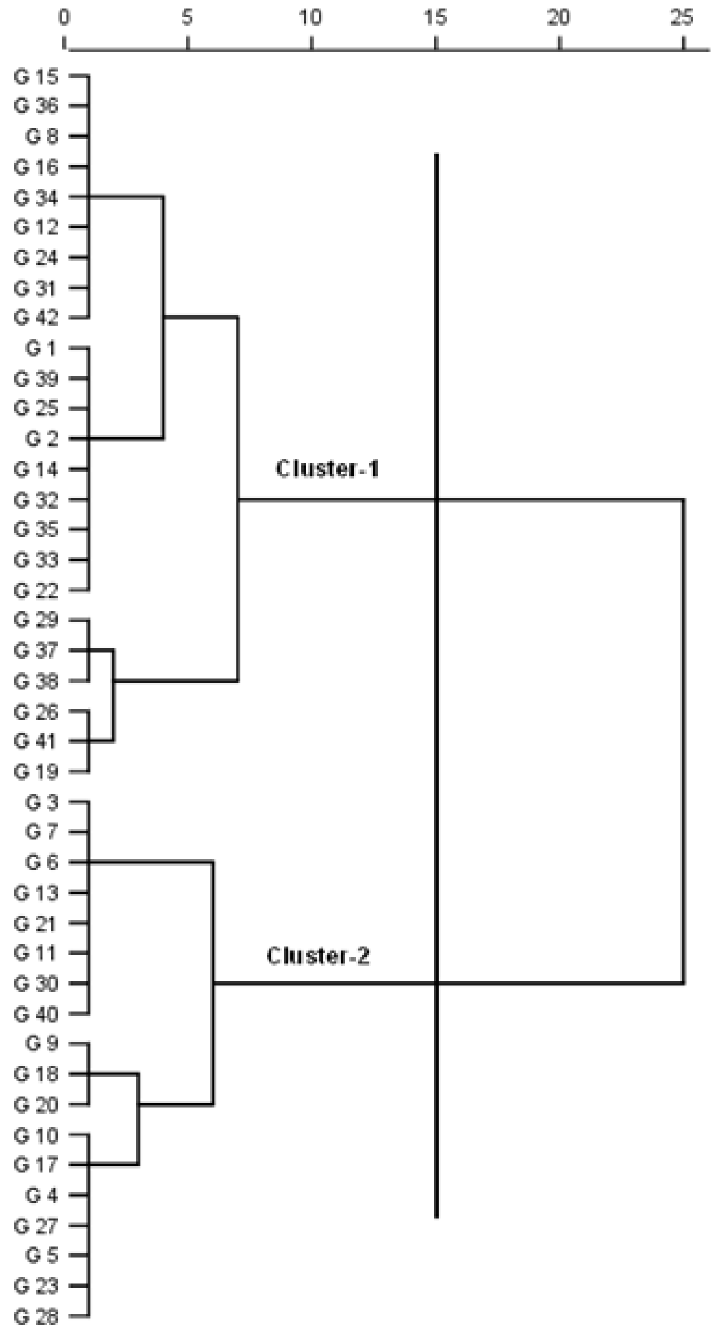


Figure 4. Dendrogram of two first and second interaction principal components with minimum ward method for 42 bread wheat genotypes

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