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Evaluation of Morphological Traits Diversity in Synthetic Hexaploid Wheat

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ABSTRACT

Genetic variation is primary requirment of any breeding program which establishes from the natural evolution and warrants sustainable production of plants under variable environmental conditions. One of the successful methods to introgress desirable agronomic genes from bread wheat ancestors to wheat is producing synthetic hexaploid wheat. The objective of presents study is to assess genetic diversity of synthetic hexaploid wheats using morphological traits. Ninty-nine synthetic hexaploid wheats were evaluated under field conditions. The results indicated a significant variation in the synthetic-hexaploid wheat genotypes. Grain yield per plant had the highest coefficient of variation and days to maturity had the lowest coefficient of variation. Polymorphism was observed for traits such as flag leaf color, glume color, auricle color, hairy auricle, hairy node and hairy glume. There was a positive and significant correlation between plant height and glume length, also between glume length and grain yield per plant. Grain yield per plant and yield components were also correlated significantly. Correlations between phonological traits such as days to heading and days to pollination (r=0.42**(as well as between days to maturity and days to pollination (r=0.28**) were positive and significant. The results of stepwise regression indicated that number of grain per spike, number of spikes per plant and 1000 grains weight could explained 47% of variation of grain yield per plant.
KEYWORDS: wheat, synthetic hexaploid, genetic variation, morphological traits

1. INTRODUCTION

As per archaeologists excavations, human civilization has commenced with using wheat or barely in valleys or slopes overlooking the Tigris and Euphrates. This region is now comprised of such countries as Iran, Turkey, Iraq and Syria whose populations have begun farming wheat over eight thousand years before Christ. The major centers of initial wheat (*Triticum dicoccum* and *Triticum monococcum*) are Syria and Palestine, then it came to Egypt, Mesopotamia and Iran, and was spread through Iran to India, Turkmenistan, China, Russia and finally to Europe and other parts of the world.

Wheat is the most important cereal crops so that it has the highest cultivation in Iran and throughout the world. Today bread wheat (*T. aestivum* L. AABBDD) is an amphidiploid with three genomes A, B, and D that still grows in the Middle East along with three species of ancestral wild grasses. Bread wheat is in fact the newest type of wheat which is in the latest stage of the wheat complicated evolution process [2].

T. monococcum and/ or *T. urartu* is considered as the origin of genome A in the wheat. By banding somatic chromosome of tetraploid wheat and hexaploid wheat, Gill and Kimber depicted that *T. monococcum* chromosomes are very similar to chromosomes of genome A of the bread wheat [5] Many researches started from 1986 confirmed the close relation between *T. urartu* and *T. monococcum* [10].

The precise origin of genome B is still unknown. Scholars' studies reveal that there are two pairs of chromosomes with large satellites in *T. turgidum* and *T. aestivum*. Monosomies analysis has demonstrated that these chromosomes belong to genome B [16]. Comparing satellite-bearing chromosomes existing in T. turgidum with satellite-bearing chromosomes of *Ae. bicorrins*, *Ae. longissima*, and *Ae. speltoides*, Rilli et al. found out that morphology of satellite- bearing chromosomes in *Ae. speltoides* is very similar to satellite- bearing chromosomes in *T. turgidum*, and it is very likely that *Ae. speltoides* is the ancestor of gnome B in *T. turgidum* and *T. aestivum* [5].

Morphologies of chromosomes and plants have revealed that *Ae. squarrosa* diploid genus is the donor parent of genome D to *T. aestivum* [17]. Through union of two gametes generated from confluence of *T. turgidum* and *Ae. squarrosa*, Kihara produced an allohexaploid that is, morphologically speaking, very similar to *T. aestivum* and proved this matter [12].

As a source of genetic compatibility, plant genetic resources not only play a fundamental role in agricultural development, but it also acts as a buffer against environmental changes. Plant genetic resources supply raw materials of genetic resources and, if properly utilized, new and better plant varieties may be produced. Allohexaploid wheat of bread is grown more than other crops; yet it seems that genetic variation is

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less than variation existing in other species. Molecular genetics analyses indicate that allohexaploid bread wheat enjoys less variation compared with many other diploid species. The amount of DNA polymorphismis caused by mutation, recombination, emigration, selection, changes in size of population, population breakdown, and genetic random drift [19]. Considering that today bread wheat with limited number of confluence among a limited number of specific plants has been made from three grasses, obviously other species that have not participated in these initial confluences contain valuable genes for improving the wheat [3]. So wheat improvement plans must be consistent with sustainable utilization of plant genetic resources and they must not be restricted to utilizing a particular species or even one particular sex [19]. In 1980, the first paper as regards synthetic wheat was published [6]. By making confluence between tetraploid wheat and a sample of *Ae. tauschii* and creating hexaploid synthetic wheat, genetic variation of bread wheat was enhanced significantly [7].

In general, the process of creating synthetic hexaploid wheat is comprised of confluence, embryo rescue, haploid seedlings growth, and doubling their chromosomes. In fact, synthetic hexaploid is produced through synthetic confluence between wheat tetraploid forms (durum and emmer: *T. turgidum* 2n = 4x = 28 AABB) that donate genomes A and B to the wheat, and *Ae. tauschii* (2n = 2x = 14 DD) that donate genome D to the wheat. The produced hybrid is haploid and contains genomes A, B, and D (2n =3x =21, ABD). This hybrid is converted into real hexaploid by doubling chromosomes through using colchicines treatment.

To date, over 1000 synthetic wheats have been developed using near 600 *Ae. tauschii* samples in CIMMYT (International Maize and Wheat Improvement Center; Mexico) many of which are applied throughout the world for improving wheat [20].

Use of synthetic wheat in modifying the wheat has been accompanied by such problems as below:

1) Extreme stiffness of cluster and glumes axis which is observed in synthetic wheat and its inheritance is unknown; yet fortunately it is possible to restore easy threshing ability through reversible confluence of synthetic wheat and common wheat [7].
2) Hybrids caused by confluence of common wheat and synthetic wheat may be necrotized and disappeared in the initial stages of germination. It is occurred when in the F1 caused by confluence, necrosis locus alleles are converted into heterozygous (Ne1/Ne2); in this condition seedlings are disappeared in the stage of one or two leaves [21]. Confluence between synthetic wheat and bread wheat results in necrosis of 1-5% hybrids, in average. Thus it is recommended to use different combinations of synthetic wheat and bread wheat in order to eliminate this problem [7].
3) In general, a few number of synthetic wheat are superior to bread wheat in terms of agronomic traits and biomass production; sometimes this advantage can be identified and transmitted to the bread wheat in confluences [7].
4) Grain quality is another problem of synthetic wheat. When *Triticum tauschii* was applied in confluences for the first time, its potential for improving or probably reducing the quality by introgression of undesirable genes was unknown. Nowadays many researchers believe that introgression of genome D improves the wheat quality [14].

Synthetic hexaploids are also produced by hybridization between durum wheat (AABB) and *T. monococcum*, *T. urartu*, and *T. monococcum ssp . aegilopoides*. The genomic formula of the mentioned synthetic hexaploid is as AABBA*A*in which genome A*A* originates from genome A- bearing diploid that has been used in the hybridization.

Another type of synthetic hexaploid is created by confluence between *T. timopheevii ssp. timopheevii* (GGAA) and *Ae. tauschii* (DD) which is a hexaploid with genomic formula of GGAADD [3].

Aegilops germplasm are valuable genetic resources for resisting environmental and non environmental stresses [9]. Hence, synthetic hexaploid wheat resulted from confluence between tetraploid wheat (emmer and durum) and *Ae. tauschii* contains resistance genes of all kinds of environmental and non environmental stresses and can act as an intermediate for transmitting these resistance genes from wheat ancestors to bread wheat [13]. Synthetic hexaploid contain environmental stresses resistance genes including leaf rust, stem rust, septoria leaf spot, powdery mildew, cyst nematode seed, and hessien flies and non environmental stresses resistance genes such as drought-tolerance, cold- tolerance, salt- tolerance, and flooding- tolerance [7].

Due to the importance of synthetic hexaploid wheat as readable genetic resources for bread wheat, this paper aims at assessing synthetic hexaploid wheat for the morphological traits.

MATERIALS AND METHODS

Plant materials and growth conditions

A test has been carried out to assess genetic variation in 99 synthetic hexaploid wheat based on morphological traits in the research field of Isfahan University of technology located in Lurk, Najafabad. This region lies in E longitude 51˚:23" and N latitude 32˚: 32" and at an altitude of 1630 meters. Its climate is semi-dry and cool with dry summers. The average rainfall of this region is 140.5 ml and its annual temperature is 14.5

C. The soil texture is clay loam with apparent specific weight of 1.4 g/cm^3, EC (electrical conductivity) 7/1 dS/m, and pH 7.5.

In this study, 99 synthetic hexaploid wheat along with Roshan wheat cultivar were used. Synthetic wheats were obtained from International Center for Wheat and Maize Improvement (CIMMYT) in Mexico.

Morphological Traits

This paper measures simple morphological traits with Mendelian inheritance and quantitative morphological traits. Seven simple morphological traits and ten quantitative morphological traits were selected and measured based on wheat gene catalog. These traits are namely glume color, auricle color, flag leaf color, hairy glume, hairy auricle, hairy flag leaf, hairy node, hairy peduncle, days to heading, days to pollination, days to maturity, plant height, flag leaf length and width, spike length, awn length, number of spike per plant, number of grain per spike, 1000 grain weight, grain yield per plant

Data were gathered and analyzed to estimate morphological traits diversity. Correlation among traits is also important in breeding programs. So correlation coefficients among phenotypic traits were calculated by SAS software. Stepwise regression was also used to determine valuable effective variables on dependent variable. In so doing, grain yield per plant and yield components were respectively considered as dependent variable and independent variable. Cluster analysis by Ward's method was appliedto group genotypes based on morphological traits.

RESULTS AND DISCUSSION

Descriptive observations of morphological traits

Results of analysis of variance showed significant differences among synthetic wheat genotypes. Table 1 depicts mean, range, variance and coefficients of morphological traits diversity in synthetic hexaploid wheat. Grain yield per plant with average 10.6 had the highest coefficient of variation (59.4) and its range changed from 1 g in synthetic wheat No. 91 to 31 g in synthetic wheat No. 54. Number of spike per plant with average 9.3 has the second rank in terms of coefficient of variation (37.6) and it ranged from 2.3 g in synthetic wheat No. 7 to 20.5 g in synthetic wheat No. 19. Shah et al. reported a significant difference among different genotypes of bread wheat in terms of number of spike per plant (18). Awn length and number of grain per spike means were respectively 7.2 cm and 31.1 cm, and their coefficient of variations were 24.7 and 23.8, respectively. Moghadam et al. (1997) demonstrated that number of grain per spike varies in different genotypes of bread wheat. The plant height mean and coefficient of variation were 89.4 and 16.8 respectively; minimum height was 58 cm (genotype No. 79) and maximum height was 124 cm (genotype No. 97). Flag leaf length, spike length and flag leaf width with means 18.3, 11.3, and 1.5 cm and coefficient of variations 1.3, 14.14, and 12.6 had the next ranks, respectively. Flag leaf length varied from 11.4 cm in synthetic wheat No. 5 to 15 cm in synthetic wheat No. 8. Spike length varied from 5.5 cm in synthetic wheat No. 5 to 15 cm in synthetic wheat No. 17; and flag leaf width ranged from 1 cm in synthetic wheat No. 79 to 1.9 cm in synthetic wheat No. 94.

One-thousand grain weight with mean equaling 48.3 g showed a moderate variation and ranged from 37.5 to 56.4. days to maturity, days to 50% pollination, and days to heading had the last ranks with means 209, 168.9, and 162.9 days and coefficient of variations 0.1, 2.4, and 3.5, respectively. Also comparison of synthetic wheat phonological stages revealed that synthetic wheat No. 54 is a type with early heading which may be an important trait for plant compatibility that warrants plant survival and reproduction under drought and heat stresses. Results of other researches [11] indicate that there is a genetic difference among wheat cultivar in terms of days to heading. Studying 30 bread wheat genotypes, Fuma et al. reported a high significant difference for all agronomic traits including plant height, spike length, grain yield, weight and number of grain per spike [4].

Table 1- Descriptive statistics of quantitative morphological traits studied in 99 synthetic hexaploid wheats

Trait	Mean	Range	Variance	Coefficient of variation
Spike length (cm)	11.3	(5.5-15)	2.5	14.1
Awn length (cm)	7.2	(2.5-10.1)	3.2	24.7
Flag leaf length (cm)	18.3	(11.4-25.7)	7.3	14.3
Flag leaf width (cm)	1.5	(1-1.9)	0.05	12.6
Plant height (cm)	89.4	(58-124)	224.7	16.8
Number of spike per plant	9.3	(2.3-20.5)	12.2	37.6
Number of grain per spike	31.1	(13-63.5)	54.8	23.8
1000 grain weight (g)	48.3	(37.5-56.4)	18.5	8.9
Grain yield per plant	10.6	(1-31)	39.06	59.4
Days to heading	162.9	(149- 181)	31.5	3.5
Days to pollination	168.9	(160- 184)	15.4	2.4
Days to maturity	209	(205-220)	4.4	0.1

A considerable variation was observed for qualitative traits including glume color, auricle color, flag leaf color, hairy glume, hairy auricle, and hairy node (table 2). Most of studied genotypes lack hairy peduncle, and only genotypes No. 86, 72, 71, 48, and 32 have hairy peduncle.

Color is regarded as an important trait to avoid heat. Pale leaf color is important for passive compatibility in high densities of light [1]. It must be noted that most genotypes studied in this paper have light leaf color.

Table 2- Qualitative traits studied in 99 synthetic hexaploid wheat

Genotype entry	PI	Hairy peduncle	Hairy glume	Hairy node	Hairy auricle	Auricle color	Glume color	Leaf color
2	152418	0	1	0	1	White	White	Light green
3	88724	0	0	0	1	Purple	White	Dark green
4	159521	0	0	1	1	White	Bronze	Dark green
5	88725	0	1	1	1	White	White	Light green
6	62052	0	1	0	1	White	Bronze	Dark green
7	159524	0	0	0	1	White	White	Light green
8	152421	0	0	0	1	White	Bronze	Light green
9	88726	0	0	0	1	White	Bronze	Dark green
10	159528	0	0	0	1	White	Bronze	Dark green
11	159531	0	1	0	1	White	Bronze	Dark green
12	159532	0	0	1	1	White	White	Dark green
13	159536	0	0	0	1	White	Bronze	Dark green
14	159537	0	1	0	1	White	White	Dark green
15	159539	0	0	0	0	White	Bronze	Dark green
16	62078	0	0	0	1	Purple	White	Light green
17	159540	0	1	0	1	White	Bronze	Light green
18	159541	0	0	0	1	White	Bronze	Dark green
19	62062	0	1	0	0	White	Bronze	Dark green
20	88720	0	1	0	0	White	Bronze	Dark green
21	159542	0	0	0	1	White	Bronze	Light green
22	159090	0	0	0	1	White	Bronze	Dark green
23	159543	0	0	0	0	White	Bronze	Dark green
24	62059	0	0	0	1	White	Bronze	Dark green
25	159544	0	0	0	1	White	Bronze	Dark green
26	159559	0	0	1	1	Purple	Bronze	Dark green
27	159560	0	0	0	1	White	Bronze	Light green
28	159562	0	0	1	1	White	Bronze	Light green
29	159567	0	0	1	1	Purple	Bronze	Light green
30	159573	0	0	0	1	White	Bronze	Dark green
31	159573	0	1	0	1	White	Bronze	Light green
32	159583	1	1	1	1	White	Bronze	Dark green
33	159586	0	1	0	1	White	Bronze	Dark green
34	160185	0	1	0	1	White	White	Light green
35	160186	0	0	1	1	White	Bronze	Light green
36	154094	0	1	0	1	White	White	Dark green
37	160193	0	1	0	1	White	Bronze	Dark green
38	160197	0	1	0	1	White	Bronze	Dark green
39	160199	0	1	0	1	White	Bronze	Light green
40	160201	0	0	1	1	White	Bronze	Dark green
41	160202	0	0	0	0	White	Bronze	Dark green
42	160204	0	1	0	1	White	White	Dark green
43	160211	0	1	0	1	White	Bronze	Light green
44	160213	0	1	0	0	White	Bronze	Dark green
45	160213	0	1	0	1	White	Bronze	Dark green
46	160214	0	1	0	1	White	Bronze	Dark green
47	160215	0	0	0	1	White	White	Dark green
48	160216	1	1	0	0	White	Bronze	Light green
49	160218	0	1	0	1	White	White	Light green
50	160233	0	0	0	1	White	Bronze	Light green
51	152340	0	0	0	1	White	Bronze	Light green
52	161185	0	1	0	0	White	Bronze	Dark green
53	161077	0	1	0	0	White	Bronze	Light green
54	161079	0	0	1	0	White	Bronze	Light green
55	161005	0	1	0	1	White	White	Light green
56	161577	0	0	0	1	White	White	Light green
57	161189	0	0	0	0	White	Bronze	Light green
58	161578	0	0	1	1	White	Bronze	Light green
59	161006	0	1	1	1	White	White	Light green

60	161191	0	1	0	0	White	Bronze	Light green
61	154095	0	1	0	1	White	Bronze	Light green
62	161588	0	1	1	1	White	Bronze	Light green
63	161589	0	1	0	0	White	Bronze	Light green
64	161089	0	0	1	1	White	White	Dark green
65	161089	0	0	1	1	White	Bronze	Dark green
66	161590	0	1	0	1	White	Bronze	Light green
67	161194	0	1	0	1	White	Bronze	Light green
68	161591	0	0	0	1	White	Bronze	Dark green
69	161591	0	0	0	1	White	Bronze	Dark green
71	161604	1	0	0	0	White	White	Light green
72	161606	1	1	1	1	White	White	Light green
73	161608	0	0	0	0	White	Bronze	Dark green
74	161609	0	1	0	1	White	Bronze	Light green
75	161626	0	1	0	1	White	Bronze	Dark green
76	161638	0	1	0	1	White	White	Light green
77	161639	0	1	0	1	White	Bronze	Light green
78	161642	0	1	0	1	White	White	Light green
79	161651	0	0	1	1	White	White	Dark green
80	161669	0	1	1	1	White	Bronze	Dark green
81	161674	0	1	1	1	White	Bronze	Dark green
82	161675	0	1	1	1	White	Bronze	Light green
83	161677	0	1	0	0	White	Bronze	Dark green
84	161679	0	1	0	1	White	White	Dark green
85	161698	0	0	1	1	White	White	Light green
86	161729	1	1	1	0	White	White	Dark green
87	161734	0	0	1	1	White	Bronze	Dark green
88	161735	0	0	0	1	White	Bronze	Light green
89	161746	0	1	1	1	White	Bronze	Dark green
90	161747	0	0	0	1	White	Bronze	Dark green
91	161750	0	1	0	0	Purple	White	Light green
92	161768	0	1	0	1	White	Bronze	Light green
93	161771	0	1	0	1	White	Bronze	Dark green
94	161773	0	0	0	1	White	Bronze	Light green
95	161775	0	0	1	1	White	Bronze	Dark green
96	161640	0	1	0	1	White	White	Dark green
97	161661	0	1	1	0	White	White	Dark green
98	161709	0	0	0	0	White	White	Dark green
99	161747	0	0	0	0	White	White	Light green

Traits correlation

The results of correlation coefficients among morphological traits revealed that there is a positive and significant correlation (r= 0.66 **) between spike length and plant height (table 3). So synthetic hexaploid wheat that has more height is able to compete with others and produces clusters with more length that finally leads to increase in grain yield per plant. Thus there is a positive and significant correlation (r= 0.35**) between spike length and grain yield per plant. Golabadi (2007) reported a positive and significant correlation between plant height and spike length. The findings indicate that genotypes with more height have played a greater role in supplying photosynthetic materials.

Three main components of grain yield comprising 1000 grain yield, number of spike per plant, and number of grain per spike have positive and significant correlations (respectively, r= 0.20*, r= 0.43**, and r= 0.57**) with grain yield per plant; though number of grain per spike is more important due to higher (strong) correlation.

Number of grain per spike had a negative correlation with days to pollination. The negative correlation reflects that genotypes which begin pollination earlier produce more number of grains per spike as pollination is not encountered with high heat.

The relation among days to heading, days to pollination, and days to physiological maturity is positive and highly significant; as such, days to pollination has a relation with days to heading and days to maturity with correlation coefficients r= 0.42** and r= 0.28**, respectively. The correlation reflects that genotypes that reached earlier to heading completed their course of growth, pollination and maturity in a shorter time span.

Flag leaf length and width have a positive and significant correlation with number of spike per plant, number of grain per spike, and grain yield per plant; because the more the flag leaf area, the more the photosynthesis amount and consequently grain yield per plant. Hence, flag leaf length with correlation coefficient r= 0.41** and flag leaf width with correlation coefficient r= 0.34** had relation with grain yield per plant. Flag leaf length and width had a positive and significant phenotype correlation with each other (r= 0.6**).

Table 3- Phenotype Correlation Coefficient among Morphological Traits

	Traits	1	2	3	4	5	6	7	8	9	10	11	12
1	Spike length	1											
2	Awn length	0.06	1										
3	Plant height	0.66**	-0.16	1									
4	1000 grain yield	0.04	0.02	0.09	1								
5	Number of spike per plant	0.34**	-0.006	0.46**	0.019	1							
6	Number of grain per spike	0.14	-0.21*	0.22*	0.06	0.02*	1						
7	Days to heading	-0.12	0.23*	-0.26**	0.03	-0.19	-0.30*	1					
8	Days to maturity	0.09	0.03	-0.18	0.11	-0.12	-0.14	0.21**	1				
9	Days to pollination	-0.18	0.20*	-0.25*	-0.05	-0.18	-0.27**	0.42**	0.28**	1			
10	Grain yield per plant	0.36**	-0.25*	0.52**	0.20*	0.43**	0.58**	-0.34**	-0.07	-0.36**	1		
11	Flag leaf length	0.16	0.006	0.26**	0.02	0.28**	0.28**	-0.16	0.13	0.13	0.31**	1	
12	Flag leaf width	0.23*	-0.21*	0.42**	-0.05	0.36**	0.29**	-0.28**	-0.03	0.016	0.34**	0.60**	1

* and ** significant at 5% and 1% levels.

Stepwise regression

The results of stepwise regression for grain yield per plant as the dependent variable and number of grain per spike, number of spike per plant, 1000 grain weight as the independent variables have been presented in table 4. Number of grain per spike explained by itself 34 percent of changes in grain yield per plant. Then number of spike per plant was entered into the model and along with number of grain per spike, explained 43 percent of the variation existing in grain yield per plant. In the end 1000 grain weight was added to the model which explained 47 percent of the total variationof the grain yield per plantalong with two above mentioned traits. With regard to moderate correlation coefficient between grain yield per plant with any of the traits namely number of grain per spike (r= 0.58 **), number of spike per plant (r= 0.43**) and 1000 grain weight (r= 0.20 **), the results of stepwise regression is predictable. In the present paper, yield components have not so much contributed to explanation of changes in grain yield per plant; considering that the relation between yield and its components may not be always linear and these relations change under environmental conditions, these results are not unexpected.

Table 4- The results of stepwise regression for determining the relative contribution of the yield components in synthetic hexaploid wheat

Stage	Independent variable	Intercept	Regression coefficients			Cumulative coefficient of determination
			b1	b2	b3	
1	Number of grain per spike	-4.85 **	0.49 **			0.34
2	Number of spike per plant	-8.3 **	0.43 **	0.57 **		0.43
3	1000 grain weight	-20.04 **	0.42 **	0.6 **	0.25 **	0.47

** significant 1% level

Cluster analysis

Synthetic wheat genotypes were grouped by Ward's method and calculating squared Euclidean distance based on 12 morphological traits, and genotypes were placed into three groups based on Hotelling's T2 Test and each of them have 1, 30, and 66 genotypes, respectively (figure 1). Group two was linked to group three in the changed distance 11.5 and genotype 2 of group three and genotype 36 of group two had the maximum distance.

To compare groups' means in terms of measured traits, variance analysis was carried out based on unbalanced completely randomized design; so groups were considered as treatment and their genotypes were regarded as replication. The results suggested that genotypes existing in group one have been placed in a separate group due to possessing the most grain yield per plant (table 5). Following group one, genotypes of group two have the most grain yield per plant. Group one had the maximum number of grain per spike and groups two and three had the minimum number of grain per spike. Genotypes existing in group two had the maximum number of spike per plant and genotypes of group three had the minimum number of spike per plant. Genotypes of group one were between two other groups in terms of number spike per plant. Groups one and two had the maximum spike length and group three had minimum spike length. Groups one and two had the maximum height and group three had the minimum height. In terms of days to 50% heading, genotypes existing in group one (genotype 54) depicted the minimum value; it denotes that the mentioned genotype had earlier reached heading. Genotypes existing in groups two and three had maximum days to 50% heading. In terms of days to pollination, genotypes existing in groups one and two have earlier reached pollination stage while genotypes of group three had maximum days to pollination. So genotypes of group one have reached germination phase earlier than other synthetic wheat. Genotypes existing in group one had maximum flag leaf length and along with group two had the maximum flag leaf width. Genotypes existing in group three had minimum flag leaf width and along with group two had minimum flag leaf length.

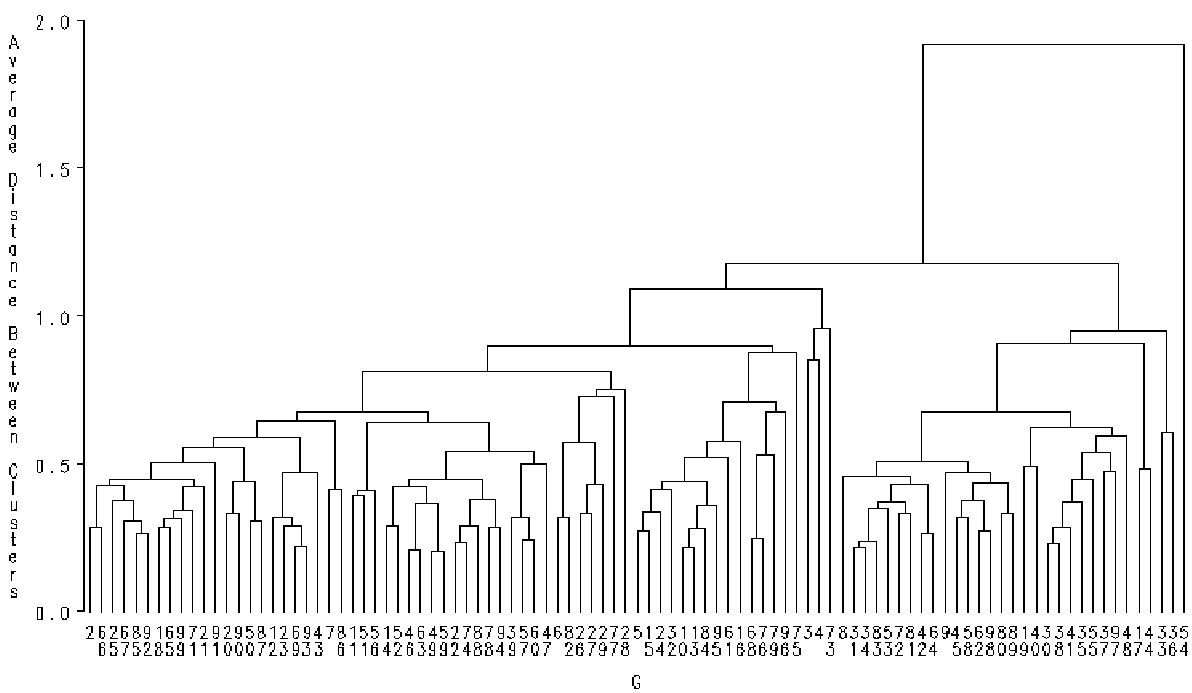
High grain yield per plant of genotypes existing in group one is probably due to increase in number of grain per spike; so if the goal is to increase the yield, selecting this genotype is recommended. It must also be noted that strong correlation between number of grain per spike and grain yield per plant (r= 0.58 **) implies consistency between the results of correlation and cluster analysis.

Table 5- Results of analysis of variance and mean comparison of traits in groups made by cluster analysis

Trait	Between group variance	Within group variance	Mean		
			Group 1	Group 2	Group 3
Spike length (cm)	45.56 **	1.58	14.54 ^{a}	12.57 ^{a}	10.6 ^{b}
Awn length (cm)	2 ^{ns}	3.2	6.87	6.94	7.37
Height (cm)	67.64**	85.6	118 ^{a}	106.1 ^{a}	81.29 ^{b}
1000 grain weight	31.35 ^{ns}	18.10	44.56	49.32	47.78
Number of spike per plant	157**	9.10	9.5 ^{ab}	11.96 ^{a}	8.06 ^{b}
Number of grain per spike	569.4 **	43.81	63.15 ^{a}	32.34 ^{b}	30.10 ^{b}
Days to heading	119.4 **	29.56	149 ^{b}	162 ^{a}	163.5 ^{a}
Days to pollination	81.81 **	13.93	160 ^{b}	167.5 ^{b}	169.5 ^{a}
Days to maturity	10.19 ^{ns}	4.24	208	208.3	209.3
Grain yield per plant (gr)	723.7 **	24.48	30.96 ^{a}	15.19 ^{b}	8.13 ^{c}
Leaf length (cm)	29.87 *	6.79	25 ^{a}	19.57 ^{b}	18.53 ^{b}
Leaf width (cm)	0.17 **	0.03	1.83 ^{a}	1.56 ^{a}	1.46 ^{a}

* and ** significant at 5% and 1% levels, and ns non-significant

Figure 1- Dendrogram of grouping 99 synthetic hexaploid wheats based on morphological traits



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CONCLUSION

Studying morphological traits in synthetic hexaploid wheat revealed that most traits possessed high variation. Grain yield per plant had the maximum coefficient of variation (59.4) and days to maturity had the minimum coefficient of variation (0.1). spike length, awn length, flag leaf length, flag leaf width, plant height and number of spike per plant depicted moderate variation, and 1000 grain weight, days to heading, and days to pollination had low coefficient of variations. Among qualitative traits, polymorphism was seen in flag leaf color, glume color, auricle color, hairy auricle, hairy node, hairy glume, yet no variation was seen for hairy flag leaf and hairy peduncle.

The results of correlation among morphological traits reflected a positive and significant relation between plant height and spike length (r= 0.66 **) and between spike length and grain yield per plant (r= 0.36 **). Also yield main components comprising 1000 grain weight, number of spike per plant, and number of grain per spike showed a positive and significant correlation with grain yield per plant (r= 0.20 **, r= 0.43 **, and r= 0.58 **). Days to maturity had positive and significant correlation with days to heading (r= 0.21 **) and days to pollination (r= 0.28 **). Also there was a positive and significant correlation (r= 0.42 **) between days to pollination and days to heading. Stepwise regression for grain yield per plant as the dependent variable and yield components as the independent variables confirmed the correlation among these traits. Number of grain per spike was entered into the model as the first variable and then number of spike per plant and 1000 grain weight were added to the model. These three mentioned traits explained 47 percent of changes in grain yield per plant.

Cluster analysis of traits classified genotypes into three separate groups. There was a significant difference among these groups in terms of most traits. Incorporation of genotypes 34, 36, 80, and 83 with common tetraploid wheat parent (Doy1) into a similar group approved cluster grouping. Assessment of morphological traits indicated relative superiority of synthetic wheat No. 54 (*Ceta/Ae. squarrosa* (895)) in terms of most morphological traits.

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