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INTERRELATIONSHIPS AMONG SOME MORPHOLOGICAL TRAITS OF WHEAT (*TRITICUM AESTIVUM* L.) CULTIVARS USING *BIPLOT*

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Abstract

Sabaghnia N., Janmohammadi M., 2014: Interrelationships among some morphological traits of wheat (*Triticum aestivum* L.) cultivars using *biplot* [Kviečių (*Triticum aestivum* L.) veislių morfologinių požymių sąveika naudojant *biplot* metodą]. – Bot. Lith., 20(1): 19–26.

Wheat (*Triticum aestivum* L.) is one of the major food crops worldwide and Iran produces about 14 million tons of wheat annually. Effective interpretation of the data on breeding programmes is important at all stages of plant improvement. The cultivar by trait (CT) *biplot* was used for two-way wheat dataset as cultivars with multiple traits. For this propose, 13 wheat cultivars with specific characteristics were tested and the CT *biplot* for wheat dataset explained 65% of the total variation of the standardized data. The polygon view of CT presented for 18 different traits of wheat cultivars showed six vertex cultivars as G3, G4, G5, G9, G11 and G12. The cultivar G4 had the highest values for most of the measured traits. Generally based on vector view, ideal cultivar and ideal tester *biplots*, it was demonstrated that the selection of high grain yield will be performed via thousand seed weight, spike length and grain diameter. These traits should be considered simultaneously as effective selection criteria evolving high yielding wheat cultivars because of their large contribution to grain yield. The cultivars G3 and G4 could be considered for the developing of desirable progenies in the selection strategy of wheat improvement programmes.

Keywords: bread wheat, cultivar-by-trait, GGE *biplot*, trait associations.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the major food crops worldwide, which is used to produce different food products and is the most widely consumed cereal of Iran. Iran produces about 14 million tons of wheat annually; with mean yield two tons per hectares, and 90% being bread wheat (FAO, 2012). The area under wheat cultivation in the world in 2012 was 216 million hectares; production 675 million tones and average yield 3100 kg ha^{-1} (USDA, 2012), whereas Iran's area under this crop was 7 million hectares and grain yield 2000 kg ha^{-1} (FAO, 2012). There is a need to improve higher yielding cultivars to fulfill the large gap between world average yield and Iran's average yield for vertically increasing population.

Wheat grain yield is a complex trait and is the product of several contributing components. The restively high wheat production is a historical phenomenon and is based on large genetic diversity of the wheat (Dagustu, 2008). Wheat grain yield is the result of some important physiological traits occurring in the growth and mostly is determined by the number of spikes, the number of grains and grain weight. The importance of these yield traits to wheat grain yield depends on the growth stage and management type (Okuyama et al., 2004). Also, the traits have a direct or indirect influence on its quantity as well as quality. Apart from the direct selection, the objective of yield improvement may in most breeding programmes be effectively reached on the basis of some yield components and selection of associated traits.

The correlation coefficients are important issues in determining the degree of association of different yield contributing traits with grain yield with the knowledge of their effects on different properties of various cultivars. This analysis is a reliable statistical method, which provides tool to quantify the associations among different traits and indicate whether the influence is reflected in the yield. Bhutta (2006) has concluded that the number of grains per spike, the number of tillers and spike length correlate with grain yield per plant. According to Koutis et al. (2012) grain yield correlates with plant height, the number of tillers per plant and thousand-grain weight. According to Del-Blanco et al. (2001) some yield components such as the number of tillers per plant, the number of grains per spike and thousand-grain weight have significant contribution to grain yield. It has been reported that the number of tillers per plant, plant height, thousand-grain weight and spike length have significant correlation with grain yield (Okuyama et al., 2004). Effective interpretation of the data on breeding programmes is important at all stages of plant improvement, particularly when it is only possible to select yield components. Several methods have been used in exploration for an understanding of the data structure. These methods may differ in overall appropriateness; different methods usually lead to the similar conclusions for a given dataset. Yan et al. (2000) have developed a cultivar main effect plus cultivar by environment (GGE) *biplot* methodology for the graphical analysis of multi-environment trial data. A *biplot* is a plot that simultaneously displays the effects of cultivars and the environment (Gabriel, 1971) and the GGE refers to cultivar main effect (G) plus cultivar by environment interaction (GE). The GGE *biplot* can also be used for all types of two-way dataset such as cultivars with multiple traits. Yan & Rajcan (2002) have used a cultivar by trait (CT) *biplot*, which is an application of the GGE *biplot* to study the cultivar by trait data.

The present investigation was performed to study the interrelationship of wheat yield components and their contribution to grain yield using CT *biplot* technique. The information so derived could be employed in reaching further breeding strategies and selection of methods to develop new high yielding wheat cultivars.

MATERIALS AND METHODS

Field experiment was conducted at the experimental field of the Faculty of Agriculture of the University of Maragheh (latitude 37° 23′ N, longitude 46° 16′ E, altitude 1478 m). The region occurs in a semi-arid climate zone characterized by relatively long winters. Average annual precipitation is 375 mm, consisting of 73% of rain and 27% of snow. Relevant properties of soil were: pH 6.85, EC 1.96 dS/m, available K 342 mg kg^{-1}, available P 5.67 mg kg^{-1}, total N, organic carbon and TNV: 0.058, 0.41 and 34%, respectively. Soil texture was sandy loam. The experiment was sown in usual autumn planting dates in 2012. The experimental field design was a RCBD (randomized complete block design) arrangement with three replications. The experiment included 13 bread wheat cultivars, which represent a range of phenotypic variation in maturity, adaptation zone, yield potential and date of release (Table 1). Tillage of all plots was performed prior to sowing date and fertility was constrained by low organic matter and phosphorus contents. Plant density was 250–300 plants m^{-2}. The fertilizer application was performed before sowing, 60 kg $ha^{-1}$of N, 30 kg ha^{-1} of P and 20 kg ha^{-1} of K were spread on the surface and tilled into the soil and the weeds were controlled chemically by MCPA (2-methyl-4-chlorophenoxyacetic acid). The number of days to anthesis or flowering (DF) were recorded in each plot. Stem diameter (SD), plant height (PH), leaf number (LN), leaf length (LL), leaf width (LW), tiller number (TN), internode length (NL), peduncle length (PL), spike length (SL), floret number (FN), spikelet number (SN), grain number (GN), length of awn (AL), grain diameter (GD), number of spikes per unit area (NS) and grain length (GL) were measured based on ten guarded plants, which were randomly selected from each plot. Also, thousand seed weight (TS) and grain yield (GY) of each plot traits were measured.

Because the traits were measured in different units, the *biplots* were generated using the standardized values of the trait means using GGE *biplot* software (yan, 2001). The *biplot* analysis was performed

Table 1. The bread wheat cultivars and their characteristics

Code	Name	Type	Maturity	Adaptation zone	Date of release	Characteristics
G1	Sistani	Variety	Medium-early maturity	Southeastern Iran	2000	Salt tolerant, low grain *falling*, semi-dwarf
G2	C-84D-5502	Line	Medium-early maturity	Temperate regions	2007	Terminal drought tolerant, NVd/Gaspard
G3	MS-81-14	Variety	Early maturity	Yazd, Esfahan, Kerman	1992	Salt tolerant, 1-66-22/Inia
G4	Pishtaz	Variety	Early maturity	Temperate regions	2002	Resistant to yellow rust, resistant to lodging, Adlan/Ias58//Alvand
G5	Sabalan	Variety	Late maturity	North West of Iran	1981	Cold and terminal drought tolerant
G6	Shiroodi-1	Line	Early maturity	Gorgan, Mazandaran, Moghan	1997	Resistant to lodging, low grain falling
G7	C-85-D08	Line	Medium-early maturity	Temperate regions	2006	Cold and terminal drought tolerant
G8	Falat-1	Variety	Early maturity	Tropical southern region	1990	Drought tolerant, low grain falling
G9	Sorkhtokhm	Variety	Medium maturity	Central warm and dry areas	1983	Drought tolerant
G10	Hirmand	Variety	Early maturity	Sistan, Bushehr, Hormozgan, southern Khuzestan and Khorassan	1991	Salt tolerant, resistant to all kinds of rusts and powdery mildew and tolerant to Fusarium head blight
G11	CDC-Ospray	Variety	Late maturity	Cold region with long winter	1995	Semidwarf, cold tolerant
G12	Golestan	Variety	Late maturity	Golestan and Mazandaran provinces and regions with adequate rainfall, moderate to good fertility	1986	Resistant to lodging, low grain falling
G13	Niknezhad	Variety	Medium maturity	Temperate areas and areas with limited irrigation	1981	Resistant to yellow rust

according to Model 2 (Transform = 0) within-trait standard deviation standardized (Scale = 1), and trait-centered (Centering = 2). The polygon views were based on cultivar-focused singular value partitioning (SVP = 2), while the vector views were based on the trait-focused singular value partitioning and is, therefore, appropriate for visualizing the relationships between traits and cultivars. The cultivar by trait (GT) *biplot* model for cultivar by trait interaction *biplot* analysis was used after Yan & Rajcan (2002).

RESULTS AND DISCUSSION

Some of the descriptive statistics of the measured traits are given in Table 2. The range of variation and coefficient of variation (CV) for some traits such as tiller number and grain yield were high, while for some other traits such as internode length and grain diameter and grain length were relatively low. The CT *biplot* for wheat dataset based on the method described by Yan & Rajcan (2002), explained 65% of the total variation of the standardized data. This relatively moderate percentage reflects the complexity of the relationships among the measured traits. The first two principal components (PC1 and PC2) explained 40% and 25%, respectively. In the CT *biplot*, a vector is drawn from the *biplot* origin to each marker of the cultivar to facilitate visualization of the relationships between and among the traits as well as cultivars. According to Kroonenberg (1995), Yan & Rajcan (2002) and Rubio et al. (2004), the basic structure among the traits should be captured by the *biplots*.

The *biplot* in Fig. 1A presents the data of 13 wheat cultivars in 18 different traits and the following information can be obtained: the vertex cultivars in this investigation are G3, G4, G5, G9, G11 and G12. These cultivars are the best or the unsuitable cultivars in some or all of the traits since they had the

Table 2. Some descriptive statistics of the measured traits

Statistics	DF	SD	PH	LN	LL	LW	TN	NL	PL
Mean	85.27	3.27	80.75	5.67	14.64	8.93	2.50	14.90	27.64
Minimum	87.06	3.80	96.73	6.67	17.60	11.50	6.00	16.31	32.96
Maximum	83.24	2.96	63.72	5.17	8.82	7.49	1.33	13.33	21.45
CV	1.32	8.10	11.51	7.41	15.23	13.56	50.10	5.97	12.33

Statistics	SL	FN	SN	GN	AL	GD	GL	TS	GY
Mean	6.99	13.12	35.24	2.80	4.04	3.00	6.58	37.91	5019.05
Mean	8.36	15.00	41.33	3.33	4.76	3.32	7.45	42.21	6936.30
Minimum	4.74	11.50	30.42	2.50	3.26	2.79	6.14	31.27	2954.70
CV	12.64	8.66	10.09	8.35	13.90	5.57	4.95	8.06	35.31

DF – the number of days to anthesis or flowering; SD – stem diameter; PH – plant height; LN – leaf number; LL – leaf length; LW – leaf width; TN – tiller number; NL – internode length; PL – peduncle length; SL – spike length; FN – floret number; SN – spikelet number, GN – grain number; AL – length of awn; GD – grain diameter; NS – the number of spikes per unit area; GL – grain length; TS – thousand seed weight; GY – grain yield

longest distance from the origin of *biplot*. Therefore, it seems that G4 had the highest values for all of the measured traits except PL, LL, PH, NL and LN. The G3 and the other cultivars of this sector had suitable amounts of PL and LL. The vertex cultivar G5 and its related cultivars, which fall in its sector, were suitable for PH and NL. The vertex cultivar G9 and its related cultivars, which fall in its sector, were suitable for LN. The other vertex cultivars (G11 and G12) and related sectors were not suitable performance for the measured traits (Fig. 1A). The vertex cultivars and their related cultivars located in different seven sections of *biplot* are suitable candidates for the examination of heterosis (YAN et al., 2007) for hybrid production in wheat using these cultivars.

The most prominent relations by this figure are: a strong positive correlation between PL and LL; PH and NL; TN and GL; SD, LW and AL; GY, SD, SL and TS as indicated by the small obtuse angles between their vectors (r = cos 0 = +1). The correlation between PH and GY; PL and FN; FN and LN; GY, LW and SD was near zero (Fig. 1B) as indicated by the near perpendicular vectors (r = cos90 = 0). There was a negative correlation between PH and SD, and PL and LN (Fig. 1B) as indicated by the near angle of approximately 180 degrees (r = cos180 = -1). Some discrepancies of the *biplot* predictions and original data were expected, because the *biplot* accounted for <100% of the total variation (65%). The statistical properties of this method have been described in detail by YAN et al. (2000) and YAN & RAJCAN (2002).

As shown in Fig. 1B, the vector view of *biplot* was used to estimate the correlation coefficient among traits, the angle between the vectors of wheat cultivars was used to understand the relationships among cultivars (Fig. 2A) and the most prominent relationships were: a near zero correlation between G5 and G9; G5 and G3; G11 and G12 (Fig. 2A) as indicated by the near perpendicular vectors (r = cos90 = 0). There was a negative correlation between G4 and G13; G2 and G9; G5 and G12 (Fig. 2B) as indicated by the near angle of approximately 180 degrees (r = cos180 = -1). Most of the mentioned results can be verified using original correlation coefficients, but some of these can not be verified using original correlation coefficients, because the *biplot* accounted for <100% of the total variation. It is clear that the studied cultivars were completely different from each other and showed remarkable variation, and, thus, are suitable genetic source for genetic improvement of wheat in semi-arid areas.

In the context of CT *biplot* analysis, an ideal tester of trait has been defined as the tester that combines several suitable cultivars in its genetic composition (DEHGHANI et al., 2008). Based on Fig. 2B, the ideal trait is strongly related to as GY, SL, TS, GD and TN traits following to DF, GL, FN SN and GN traits. It is interesting that the grain yield exists in these traits. Therefore, these important traits must be regarded in the wheat breeding programmes and determination of selection indices. In the ideal entry view of *biplot*, an ideal cultivar has been determined as the cultivar that combines several suitable traits

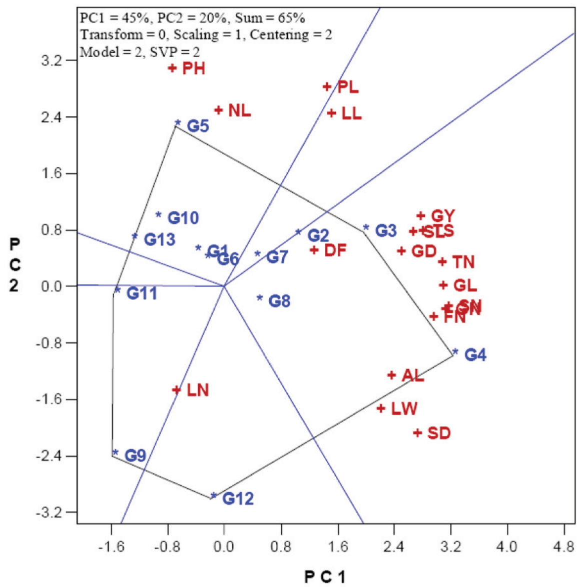

Fig. 1A. Polygon view cultivar by trait *biplot*, showing which cultivar had the highest values for which traits for 13 different wheat cultivars

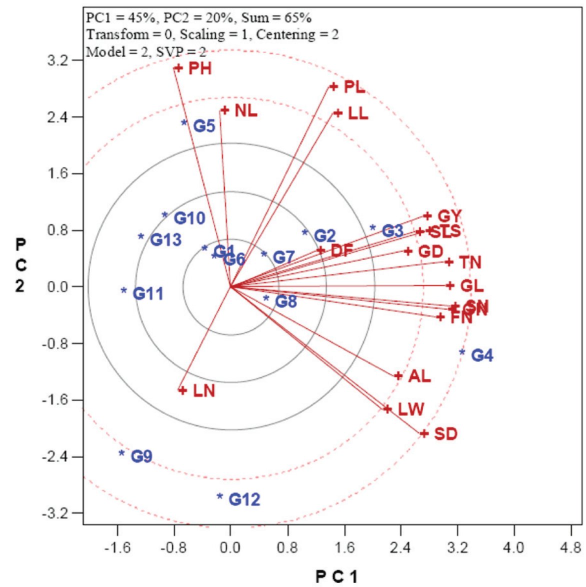

Fig. 1B. Vector view cultivar by trait *biplot*, showing the interrelationship among all measured traits for 13 different wheat cultivars

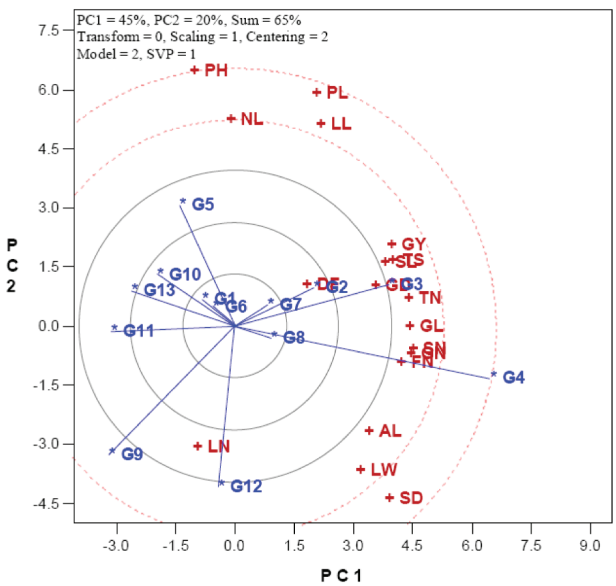

Fig. 2A. Vector view cultivar by trait *biplot*, showing the interrelationship among all cultivar traits for 18 measured traits

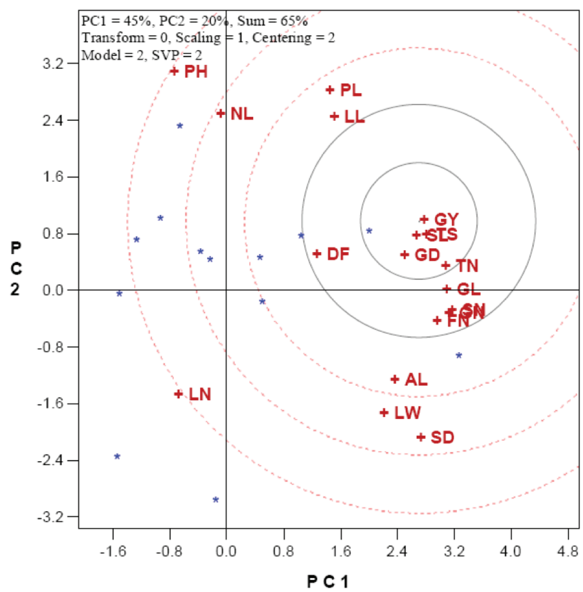

Fig. 2B. Ideal tester view of cultivar by trait *biplot*, showing the relationships of traits of 18 measured traits

in its genetic composition (Badu-Apraku & Akinwale, 2011). Based on Fig. 3A, the similar cultivars to ideal cultivar are G3 following to G2, G7 and G8. After these cultivars, G1, G4 and G6 could be regarded as the most favourable cultivars based on the ideal cultivar (Fig. 3A).

Due to great importance of grain yield in wheat improvement programmes, this trait was compared in the studied cultivars and the relation of grain yield with cultivars was visually displayed (Fig. 3B). In the context of CT *biplot*, the GY was determined and the single-arrow line that passes through the *biplot* origin

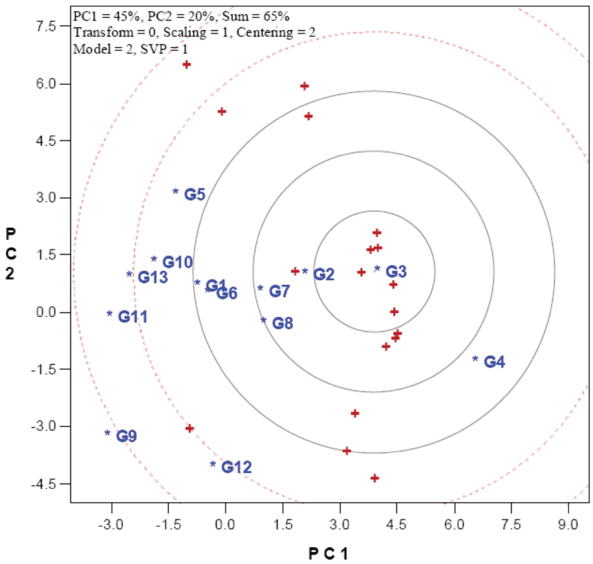

Fig. 3A. Ideal entry view of cultivar by trait *biplot*, showing the relationships of wheat cultivars with ideal entry

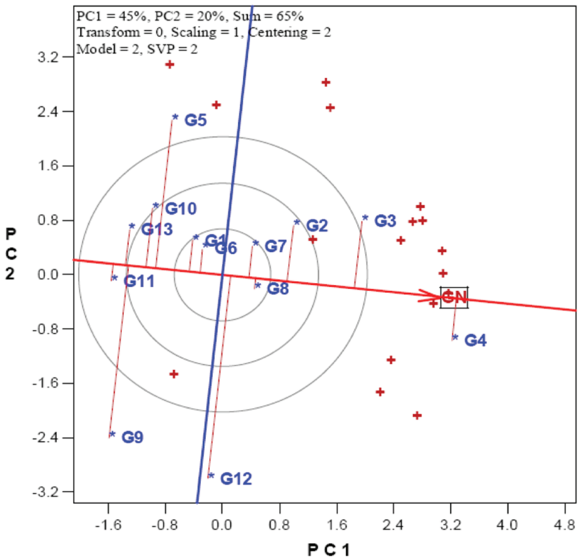

Fig. 3B. Tester comparison view of cultivar by trait *biplot*, showing the relationships of traits with grain (GY) yield

was referred to as the average-tester axis (ATC) abscissa, and on this line genotypes were ranked according to their GY performance. The ATC ordinate divides the ATC abscissa into two at the middle (YAN et al., 2007) and the portion of the ATC towards the right displays the above average cultivar and towards the left indicates the cultivar below average. The best cultivar, which showed the above average performance was G4 following to G3> G2> G8> G7> G12. The other remaining cultivars including G6, G1, G5, G10, G13, G11 and G9 indicated below average performance (Fig. 3B).

The effects of the number of spikes per unit area and the number of grains per spike were large on grain yield. These results were similar to those obtained by SIMANE et al. (1998), DEL-BLANCO et al. (2001) and OKUYAMA et al. (2004). Also, thousand seed weight (TS) had high effect on grain yield and the similar investigations indicated a tendency of TS to decrease with increasing of the number of spikes per unit area and the number of grains per spike. When the target is to establish associations among the traits that affect grain yield, CT *biplot* analysis is a more efficient method than the correlation analysis (RUBIO et al., 2004). For a possible increase in productivity of bread wheat production in the semi-arid areas of Iran, intercrosses between high yielding cultivars, G3 and G4 or G5 and G4 can be suggested. Furthermore, the significant differences were observed among the 13 wheat cultivars and this can be an appropriate substrate for further breeding. Selection of the cultivars must be performed carefully keeping in view higher grain yield along with the identified important traits. The above cultivars may be used in further breeding programmes and these crosses may yield more transgressive segregates for these traits for grain yield improvement.

Previous investigations on bread wheat have also demonstrated significant differences among cultivars for grain yield and related traits of wheat (MENON & SHARMA, 1997; JOSHI et al., 2004; DAGUSTU, 2008). In general, some environmental factors such as rainfall, drought and biotic stresses influence wheat grain yield (AUSTIN & ARNOLD, 1989), as well as temperature and rainfall at flowering time (DAGUSTU, 2008). It may be concluded from this investigation that spike length, spike number, thousand seed weight and the number of grains per spike appeared to contribute on the grain yield. Therefore, indirect selection for higher grain yield may be effective for improving above traits, as it has been shown by KHALIQ et al. (2004) and ANWAR et al. (2009) in various studies on bread wheat crop. Such type of breeding programme may lead to the improvement of the economic traits in general and farmers living in the semi-arid areas in particular.

CONCLUSIONS

This investigation demonstrated that the programme for the selection of high grain yield will be suitable for TS, SL, TS and GD. Two cultivars (G3 and G4) were selected with proven high yield potential. These cultivars could be used as commercial cultivars or after further improvement and selection as pure lines or as parental lines for the development of new wheat cultivars proper for semi-arid areas.

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KVIEČIŲ (*TRITICUM AESTIVUM* L.) VEISLIŲ MORFOLOGINIŲ POŽYMIŲ SĄVEIKA NAUDOJANT *BIPLOT* METODĄ

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Santrauka

Kviečiai (*Triticum aestivum* L.) yra viena iš pagrindinių maistinių kultūrų visame pasaulyje. Irane jų kasmet išauginama apie 14 milijonų tonų. Efektyvus selekcinių programų duomenų interpretavimas yra svarbus visuose augalo tobulinimo etapuose. Veislių požymių *biplot* analizė buvo taikyta įvairiomis savybėmis pasižyminčių kviečių veislių dvipusiam duomenų rinkiniui. Buvo tirta 13 specifinėmis savybėmis pasižyminčių kviečių veislių, o jų duomenų *biplot* analizė paaiškino 65 % visos standartizuotų duomenų variacijos. Daugiakampis veislių pagal 18 skirtingų požymių vaizdas išskyrė šešias geriausias veisles: G3, G4, G5, G9, G11 ir G12. Veislė G4 turėjo didžiausias daugumos vertintų požymių vertes. Remiantis vektoriaus vaizdu buvo nustatyta, kad derlingiausias veisles galima atrinkti pagal tūkstančio sėklų svorį, akuoto ilgį ir grūdų skersmenį. Šie požymiai gali būti traktuojami kaip veiksmingi atrankos kriterijai kviečių veislių selekcijoje.