Bulgarian Journal of Agricultural Science, 17 (No 5) 2011, 615-622
Agricultural Academy

ANALYSIS AMONG MAIN AGRONOMIC TRAITS OF SPRING WHEAT (*TRITICUM AESTIVUM*) IN QINGHAI TIBET PLATEAU

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Abstract

DEYONG, Zhao, 2011. Analysis among main agronomic traits of spring wheat (*Triticum aestivum*) in Qinghai Tibet Plateau. *Bulg. J. Agric. Sci.,* 17: 615-622

In order to reveal the underlying association between agronomic traits of spring wheat in the eastern arable region of Qinghai Tibet Plateau, partial correlation analysis, principal components analysis and cluster analysis were applied to study the relationship between grain yield and agronomic traits. The result of partial correlation analysis revealed that GW (r = 0.242) and UW (r = 0.234) correlated positively with yield, while NVE (r = 0.084) and NSNME (r = 0.040) correlated less positively with yield. GNME (r = -0.186), SNME (r = -0.174), FLA (r = -0.114), PH (r = -0.071), LME (r = -0.043) were negatively correlated with yield. SNME (r = 0.541) and NSNME (r = 0.500) were positively correlated with PH, while NVE (r = -0.332) was negatively correlated with PH. SNME (r = 0.449) was positively correlated with GNME, while it was negatively correlated with NVE (r = -0.370). LME and FLA were positively correlated (r = 0.378). Principal components analysis indicated that spring wheat with higher GNME, GW, FLA, UW seem to possess high-yield potential. The experimental varieties were grouped into 14 groups through cluster analysis, the result of which could be informative in high-yield spring wheat breeding program in the future.

Key words: cluster analysis; high-yield; partial correlation; principal components analysis
Abbreviations: flag leaf area (FLA), grain number of main ear (GNME), 1000-grain weight (GW), length of main ear (LME), non-pregnancy spike number of main ear (NSNME), number of valide ear (NVE), plant height (PH), spike number of main ear (SNME), Unit weight(UW), yield (YD)

Introduction

Spring wheat which is a main crop in the eastern arable region of Qinghai Tibet Plateau provides the essential food for the local residents. Therefore, keeping sustainable food production is of great importance because it will not only facilitate the life of local residents, but will also sustain the development of this region. Consequently, breeding high-yield spring wheat varieties which are an important approach to sustain grain production draw the breeders' attention in this area. As wheat yield depends mainly on three factors: kernels per spike, 1000-grain weight, spikes per hectare,

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many scientists focus on modifying the kernels per spike and 1000-grain weight of spring wheat so as to realize high yield, nevertheless, grain yield of wheat is the integration of many variables that affect plant growth throughout the growing period (Leilah and Al-Khateeb, 2005). In order to breed high-yield spring wheat, the genetic association between grain yield and its components should be taken into consideration. As yield is controlled by multigenes, progressive accumulation of genes conferring higher yield and/or the elimination of unfavorable genes through the breeding process may be a useful method (Evans and Fischer, 1999). Statistical analysis of agronomic traits could be informative in high-yield spring wheat breeding program, because agronomic traits are reflection of genes in a macroscopically level.

Correlation coefficient is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contribution of the yield variables. Many scientists have used the combination of correlation analysis and path analysis to get valuable information on soybean (Nag et al., 2007), wheat (Anwar et al., 2009; Dogan, 2009), maize (Abirarni et al., 2007), rice (Girolkar et al., 2008). However, correlation analysis couldn't indicate the real linkage relationship between complicated agronomic traits as the mutual-interference among agronomic traits was not taken into consideration in this method. Partial correlation coefficient seems to be more effective in revealing the association between agronomic traits and yield, because it indicates the degree of association between two random variables, with the effect of a set of controlling random variables removed, consequently, partial correlation analysis was applied to reveal the relationship between either two agronomic traits in this study.

As a multivariate statistical technique, the principal components analysis could transform a number of possibly correlated variables into a smaller number of variables called principal components (Ziegel, 2002), the principal components are linear transformations of the original variables and could be respective of a particular meaning (Jobson, 1991). This approach seems to be effective in deciding which agronomic traits of crop contributing most to yield, subsequently, these agronomic traits should be emphasized in the breeding program. Parental selection plays an important role in plant breeding program, as the genotypes of hybridization progenies depends on the genotypes of parents. Cluster analysis approach which based on the principle of similarity and dissimilarity is helpful for parental selection in the breeding programme (Souza and Sorrells, 1991) and crop modeling (Jaynes et al., 2003).

Crop with desirable agronomic traits are able to produce higher grain yield. However, attempts to create ideal plant architecture of spring wheat in the eastern arable region of Qinghai Tibet Plateau have rarely been made. One objective of this study was to clarify the association between each investigated agronomic trait of spring wheat and the yield. Principal component analysis (PCA) and cluster analysis were also conducted to provide valuable information for breeders who are interested in researching the agronomic traits of spring wheat and/or breeding new high-yield spring wheat varieties in future.

Materials and Methods

Spring wheat varieties involved in this study are shown in Table 1. Randomly block design with three repeats was conducted for the experiment in five sites during two consecutive seasons (2008-2009). Each variety was sowed in a 6 m^2 plot (width: 2 meters, length: 3 meters), 30 plants of each plot were randomly sampled to measure the agronomic traits. The agronomic traits included Flag leaf area, Grain number of main ear, 1000-grain weight, Length of main ear, Non-pregnancy spike number of main ear, Number of valid ears per plant, Plant height, Spike number of main ear, Unit weight. Yield was measured after harvest.

Partial correlation analysis and Principal components analysis was performed using the software

Table 1
Spring wheat varieties with their pedigree and released year

Genotype	Pedigree	Released year
Abodanza	Fransineto Ao 5 / Mentana // Autgmia / 3 / Fontatarroneo	1964
Caoxuan No 5	Unknown	1980
Chaichun 018	Selected from line 75-55	1988
Chaichun 044	Gaoyuan 55 / 111 D 74-765	1988
Chaichun 236	TB 902 / 76-335	1988
Chaichun 901	Selected from the mutant offspring of Fanxuan No 2	1994
Dongchun No 1	Gaoyuan 384 / Huzhuhong	1994
Gaoyuan 158	Unknown	1994
Gaoyuan 175	Unknown	1994
Gaoyuan 205	80642 / Gaoyuan 338 // 81-143 / Gaoyuan 472 /// Gaoyuan 472 / Duonian No1	1998
Gaoyuan 314	Gaoyuan 602 //// ST142 /// (82 Ning 182 / 82 Yuan 11)/47-2 // (78-17-3 / 83-228-3) / (Chanal / 338)	2001
Gaoyuan 356	Lanli / 83-228-3	1994
Gaoyuan 363	Selected from mutant offspring of Gaoyuan 2 D and B 3-1-1	1999
Gaoyuan 448	QingChun 533 / Gaoyuan 602	1999
Gaoyuan 465	Unknown	2004
Gaoyuan 506	Neixiang No 5 ///// Fengshou // Nanda 2419 /Eguan 186 //// Nanda2419 /// Misui Chang sui / Eguan599	1978
Gaoyuan 584	80642 / Gaoyuan 338 // 80-143 / Gaoyuan 472/ // Duonian No 1	1999
Gaoyuan 602	Gaoyuan182 / 3987-88 (3)	1987
Gaoyuan 913	Selected from mutant offspring of Gaoyuan 2 D and B 3-1-1	1998
Gaoyuan $V_0$28	HER / SAP "S" // VEE	1998
Hanhai 304	Selected from mutant offspring of Xinzhe bingcao wheat	1986
Humai 11	Qingchun No 17 / Qingchun No 5	1988
Humai 12	Jin 2148 / Huzhuhong	1988
Humai 13	Huzhuhong / Huadong No 10 / /Acoadras	2000
Huzhuhong	Selected from an anonymous immigrated wheat	1979
Lantian No 3	Lantian No 1 / Tiannong No 1	2001
Minhe 588	ALondraS-76 // Opal / Orofen	1999
Minhe 665	ALondraS-76 // Opal / Orofen	2001
Minhe 853	ALondraS-76 // Opal / Orofen	1998
Moyin No 1	K 134 (60) / VEE // BOW / PVN	2004
Moyin No 2	ALTAR 84 / AEGILOPSSOUARROSA (TAUS) // OPATA	2004
Ningchun 26	Yong 3263	2003
Potam	Unknown	1973
Qingchun 144	QingChun 533 // 93-1680 / 93-29	2003
Qingchun 254	Unknown	1996

(continued)

Table 1 (continued)

Qingchun 37	Unknown	2005
Qingchun 415	Selected from mutant of abodanza	1993
Qingchun 533	367 B / ALondras-76	1988
Qingchun 570	73γ42-20-2 /// A108 Autume 3-5-1-2 / YeKaoLa // Obel / Orou F	1996
Qingchun 587	Selected from mutant of line 108	2000
Qingchun 891	Poland wheat / 367B ///// 79533-1 //// Poland wheat / 367B // 79533-1 /// 567	1994
Qingchun 952	Qingchun 891 // Poland wheat / TB 115	2001
Qingnong 469	Unknown	1984
Qingnong 524	FengChan No 3 / 72B-1377 // CajemeF 71	1984
Shanhan 901	Selected from mutant of Minhe 853	2005
Tongmai No 1	Huzhuhong / Qingchun 533	2005
Xiangnong	Nanda 2419 / A Fu	1970
Xinzhe No 9	Immigrated from Hainan states in 1979	1988
Zhangchun 811	Immigrated from Zhangye Gansu Province in 1990	1994

SPSS 16.0. Pearson correlation (2-tailed) was conducted among agronomic traits and yield, Principal components analysis was conducted using the data reduction method. Cluster analysis was conducted by NTSYSpc (Numerical Taxonomy and Multivariate Analysis System), version 2.10.

Results

The result of Partial correlation analysis (Table 2) showed that GW (r = 0.242) and UW (r = 0.234) were positively correlated with yield, while NVE (r = 0.084) and NSNME (r = 0.040) were less positively correlated with yield. GNME (r = -0.186), SNME(r = -0.174), FLA(r = -0.114), PH(r = -0.071), LME(r = -0.043) were negatively correlated with yield. However, all the correlations between each agronomic trait and yield were not significant; such a result indicates that the yield of spring wheat is affected by the combination of agronomic traits.

The correlations among all the measured agronomic traits were also listed in Table 2. SNME (r = 0.541) and NSNME (r = 0.500) were positively correlated with PH, while NVE (r = -0.332) was negatively correlated with PH. SNME (r = 0.449) was positively correlated with GNME, while it was negatively correlated with NVE (r = -0.370). LME and FLA were positively correlated (r = 0.378). The above correlations were significant at 0.05 or 0.01 level. Such information indicates that many agronomic traits are highly correlated, probably resulting from that many of the agronomic traits are controlled by linked genes, such phenomenon is even more significant in a species with a narrow genetic background.

In order to know with which combination type of agronomic traits, the spring wheat would attain high yield, principal component analysis (PCA) was performed (Table 3). Four main factors are extracted from the complicated factors, the total cumulative variance of these four factors amounted to 76.356%. GNME contributes most to F1 factor (eigenvector, 0.859), while GW contributes most to F2 factor (eigenvector, 0.845), and FLA contributes most to F3 factor (eigenvector, 0.530), UW contributes most to F4 factor (eigenvector, 0.519), this information indicates that the ideal agronomic traits combination type of spring wheat should be more grain numbers of main ear, larger flag area, heavier 1000-grain weight, heavier unit weight.

At genetic coefficient 0.10, the varieties were grouped into 14 groups with their own distinguished character through cluster analysis approach (Table 4). Among these 14 groups, there were 5 groups containing only one variety respectively,

Table 2
Correlation matrix among all the measured agronomic traits and yield

	NVE	YD	PH	LME	NSNME	SNME	GNME	GW	UW
YD	0.084								
PH	-0.332*	-0.071							
LME	-0.226	-0.043	0.234						
NSNME	-0.328*	0.04	0.379**	0.500**					
SNME	-0.370**	-0.174	0.520**	0.541**	0.506**				
GNME	-0.073	-0.186	0.127	0.264	-0.259	0.449**			
GW	0.121	0.242	-0.347*	0.203	0.022	-0.278	-0.360*		
UW	0.02	0.234	-0.114	-0.066	0.015	-0.214	-0.122	0.084	
FLA	-0.263	-0.114	0.19	0.378**	0.136	0.117	0.053	0.307*	-0.334*

* means correlation is significant at 0.05 level ($P < 0.05$), ** means correlation is significant at 0.01 level ($P < 0.01$).

they were Moyin No 2, Gaoyuan 448, Xinzhe No 9, Ningchun 26, Zhangchun 811. However, group 6, group11 and group 3 included 11, 8, 6 varieties respectively. This apparent uneven distribution indicates that the genetic background of spring wheat in the eastern arable region of Qinghai Tibet Plateau is at a narrow level. Agronomic traits of spring wheat are the reflection of interaction of gene and environment. Varieties with similar agronomic traits were clustered into the identical type. As a case, Shanhan 901 was selected from a mutant of Minhe853, these two varieties share most morphological traits, and consequently, they were clustered into an identical type. Minhe 588

Table 3
Principal component analysis

	F 1	F 2	F 3	F 4
NVE	-0.58	-0.063	0.187	0.233
PH	0.685	-0.207	-0.218	-0.323
LME	0.697	0.356	0.114	0.488
NSNME	0.637	0.368	-0.516	-0.034
SNME	0.859	-0.217	-0.031	0.177
GNME	0.359	-0.586	0.488	0.462
GW	-0.223	0.845	0.165	0.225
UW	-0.274	0.03	-0.639	0.519
FLA	0.416	0.519	0.53	-0.212
Total initial eigen values	2.863	1.684	1.317	1.008
Of variance, %	31.812	18.711	14.631	11.202
Cumulative, %	31.812	50.523	65.154	76.356

Table 4
Characters of different spring wheat type

Group	Varieties	Characters
1	Abodanza; Gaoyuan 363; Gaoyuan $V_0$28; Humai13; Moyin No1	PH higher; NVE less; NSNME more; GW heavier
2	Chaichun 018; Dongchun No 1; Qingchun 37	PH lower; NVE more; LME shorter; FLA smaller
3	Chaichun 901; Gaoyuan 465; Gaoyuan 913; Humai 11; Huzhuhong; Qingchun 415	PH higher; LME longer
4	Potam; Qingnong 524	PH lower; NVE more; GW heavier
5	Caoxuan No 5; Minhe 665	PH higher; LME shorter
6	Chaichun 236; Gaoyuan 175; Gaoyuan 584; Gaoyuan 356; Gaoyuan 602; Qingchun 144; Qingchun 533; Qingchun 570; Qingchun 587; Qingchun 952; Xiangnong No 3	NVE less; FLA smaller
7	Chaichun 044; Gaoyuan 314; Gaoyuan 506; Lantian No 3; Tongmai No 1	LME longer; SNME more; GNME more
8	Moyin No 2	PH lower; NVE more; GNME more; GW heavier; FLA smaller
9	Gaoyuan 205; Hanhai 304	PH lower; NVE more; GW heavier; FLA bigger
10	Gaoyuan 448	NVE more; FLA bigger
11	Gaoyuan 158; Humai 12; Qingchun 891; Minhe 588; Minhe 853; Qingchun 254; Qingnong 469; Shanhan 901	PH higher; NVE less; FLA bigger
12	Xinzhe No 9	PH higher; NVE more; FLA smaller
13	Ningchun 26	PH lower; NVE more
14	Zhangchun 811	PH lower; NVE more; FLA smaller

and Minhe 853 share the same pedigree (ALondraS-76 // Opal / Orofen), and they were clustered into the same type, this may be an explanation for above analysis. However, Minhe 665, a variety which shares the same pedigree with Minhe 588 and Minhe 853, was clustered into another type, this phenomenon may be explained as follows: many combinations of gene would have occurred during the process of hybridization, as common wheat are hexaploid, breeders would select the ideal offspring according to their own experience and local agricultural practice, resulted in the morphological difference between Minhe 665 and Minhe 588, Minhe 853.

Discussion

Many variables, such as the agronomic traits investigated in this study contribute to crop yield. The relationship among these agronomic traits is often complicated attributing to the complicated molecular pathways underlying the formation of these agronomic traits. A clear relationship between these agronomic traits will not only address the fundamental principle of plant breeding, but will also facilitate the plant breeding practice. Partial correlation analysis which is an useful statistical approach could reflect the relationship between either two agronomic traits by excluding the interference of other factors, consequently, the result of this analysis method could be effective in unveiling a real problem. In present study, GW(r = 0.242), UW(r = 0.234), NVE(r = 0.084), NSNME (r = 0.040) were positively correlated to yield, implicating that a variety with higher GW, UW, NVE, NSNME possess high-yield potential. GNME (r = -0.186), SNME (r = -0.174), FLA (r = -0.114), PH (r = -0.071), LME (r = -0.043) were negatively correlated to yield, which indicates that a variety with higher GNME, SNME, FLA, PH, LME is apt to achieve low grain yield. Such information should be taken into consideration in the spring wheat breeding program in future.

Crop with desirable architecture are able to produce higher grain yields, for example, grain yields have been significantly increased by growing lodging-resistant semi-dwarf varieties of wheat and rice in 1960s, famous for the 'green revolution' (Peng et al., 1999). Therefore, designing ideal crop architecture fosters many scientists' searching for the underlying molecular mechanisms of plant architecture. For example, many genes conferring the architecture have been isolated and/or characterized in the model plants Arabidopsis, Antirrhinum and petunia and in the crop plants pea, tomato, maize and rice (McSteen and Leyser, 2005; Schmitz and Theres, 2005). However, which agronomic trait contributing most to the yield complicates the designing of ideal crop architecture. Finding out several typical agronomic traits of a crop seems to be helpful in architecture designing and/or high-yield crop designing.

Fortunately, this conception could be realized through statistical analysis method. Principal component analysis could change the complicated variables into several clear variables through dimension-reduction method. In present study, four main factors with total cumulative variance 76.356% were extracted from the complicated factors through the principal component analysis, with GNME, GW, FLA, UW contributing most to F1, F2, F3, F4 factor respectively. The result indicates that spring wheat with higher GNME, GW, FLA, and UW seems to achieve high yield easily. Therefore, these four agronomic traits should be emphasized in the spring wheat breeding program.

Parental selection is a crucial step in traditional plant breeding program, different combination of parental materials would produce different F1 hybridized progeny. Breeders would select excellent hybrids from F1 populations to regenerate F2, and then F2 to F3……, until a stable line is obtained. Cluster analysis of the germplasm resources is helpful for parental selection in the plant breeding program. In this study, all the materials were clustered into 14 types with their own characters; such information would be effective in selecting parental materials to breed new expected spring wheat varieties.

In conclusion, excellent exotic parental materials should be integrated into the local spring wheat varieties or landraces so as to enlarge the genetic background of spring wheat in the eastern arable region of Qinghai Tibet Plateau. Further more, GNME, GW, FLA, UW should be emphasized and the correlation among agronomic traits should also be taken into consideration in screening progeny. Subsequently, excellent progeny materials with high-yield potential could be screened in the spring wheat breeding program.

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Received February, 12, 2011; accepted for printing September, 2, 2011.