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RESPONSE OF SPRING GARLIC ECOTYPES TO ENVIRONMENTAL GROWTH CONDITIONS

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SYNOPSIS

Key words:
Garlic,
ecotype,
AMMI.

The objective of this paper was to determine to what extent garlic bulb traits change across growing seasons. Thirty spring garlic ecotypes were used in an experiment, which was carried out over a period of three years at the Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad. Clove number and clove weight as the direct yield components were analyzed.

The AMMI model was used to determine main genotype effects on the two traits via main environmental effects on individual genotypes and their interactions. The largest variability of clove weight (64.42%) was caused by the year, while ecotype and year caused a large variability in clove number (31.14 and 40.61%, respectively). The GE interaction had a high contribution for both traits. A biplot was used for graphic presentation of the GE interactions.

SINOPSIS

Ključne riječi:
Beli luk,
ekotip,
AMMI.

REAKCIJA EKOTIPOVA PROLEĆNOG BELOG LUKA NA EKOLOŠKE USLOVE GAJENJA

Cilj rada je da se ispita u kojoj meri dolazi do promene osobina lukovice tokom vegetacionih sezona, i na taj način ispita reakcija ekotipova prolećnog belog luka. Za ova ispitivanja korišćeno je 30 ekotipova prolećnog belog luka. Ogled je postavljen na oglednom polju Instituta za ratarsvo i povrtarsvo u Novom Sadu, tokom tri godine. Analizirane su broj i masa čenova, osobine koje predstavljaju direktne komponente prinosa.

Primenom AMMI modela ustanovljeni su glavni efekti genotipova za ispitivane osobine preko glavnog efekta sredine za genotipove i njihove interakcije. Najveći izvor varijabilnosti za masu čenova imale su godine (64,42%). Visok stepen variranja broja čenova imali su ispitivani ekotipovi (31,14%) kao i godine (40,61%). Visok udeo interakcije GE je dobijen za obe ispitivane osobine. Korišćen je biplot da bi se grafički predstavila G E interakcija.

INTRODUCTION

In our country, garlic is mostly propagated vegetatively. In the case of plant species which are vegetatively propagated, variability between plants is due to variable environmental factors, which is considered as environmentally induced variability (BOROJEVIĆ, 1992). As we are dealing with complex quantitative and qualitative characteristics and vegetative propagation, genetic stability refers to phenotypic uniformity in different environments (JANICK, 1999). Environmental factors such as temperature and distribution of rainfall are frequently limiting factors in garlic production (KANG, 2002). Our objective was to assess the reaction of spring garlic ecotypes to the environment by evaluating the stability of their production characteristics.

SUBJECT AND METHOD OF RESEARCH

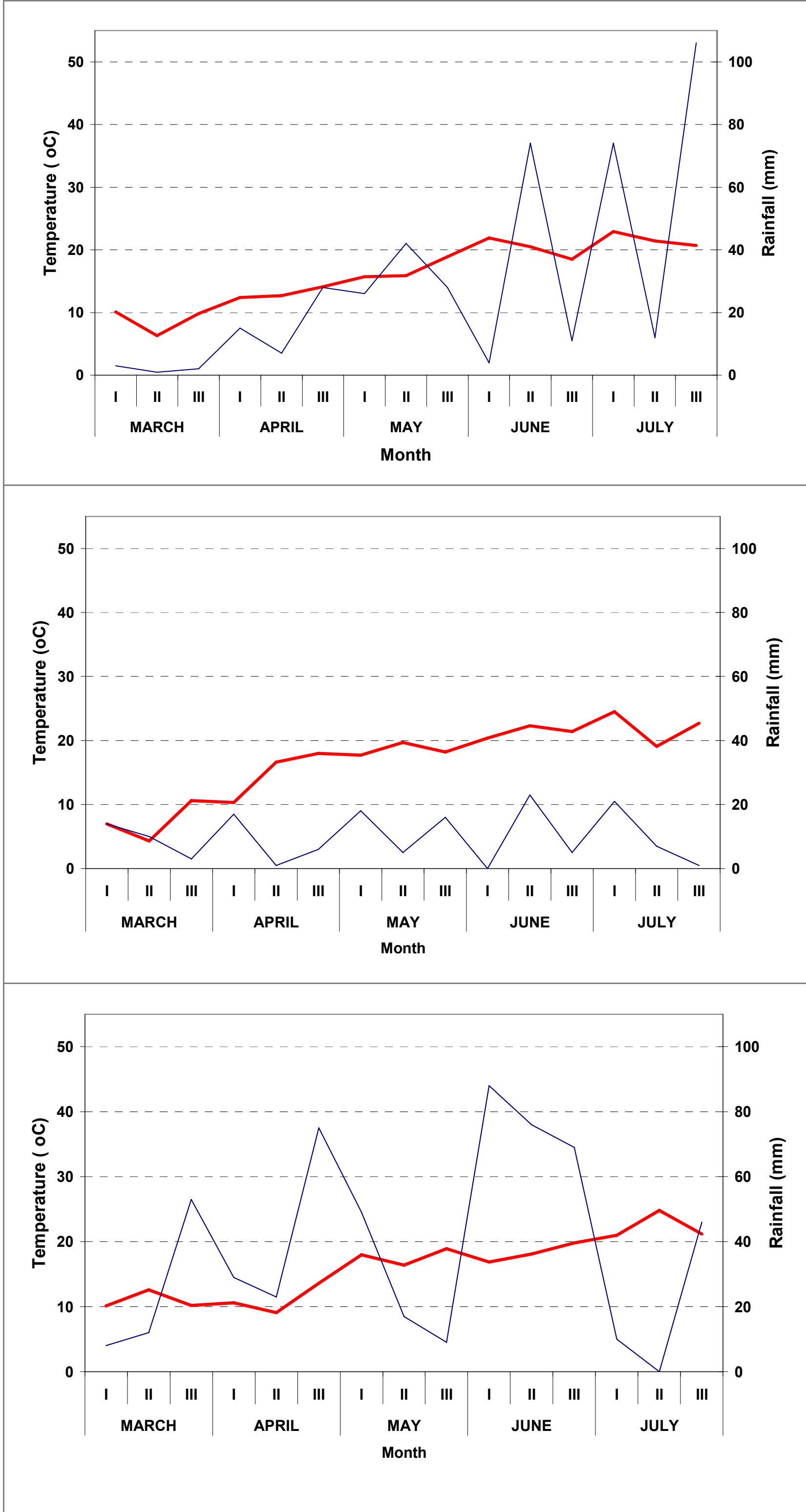
The material studied is a part of the collection of spring garlic of Institute of Field and Vegetable Crops in Novi Sad. It included 30 genotypes, i.e. 8 populations, 2 cultivars and 20 lines selected from the existing collection. All genotypes originated from a local agroecological region. They were selected for study because of the well-known fact that garlic is highly sensitive to a change in production area or changed environmental conditions.

The experiment was established in a random block design in three replicates, at Rimski Šančevi Experiment Field of Institute of Field and Vegetable Crops in Novi Sad. It lasted for three years (1999, 2000 and 2001). The experimental unit consisted of three rows 200 cm long, with the row distance of 40 cm and 10 cm within the row. A basic analytical sample included 30 plants which were measured for the number and weight of cloves.

The soil of the experimental plot was calcareous chernozem on loess and loesslike sediments. It has neutral reaction. According to the humus content, the soil is a low-humus type, but it is optimally provided with phosphorus and potassium. Mean temperatures and rainfall for the three growing seasons are presented in Graph 1.

The AMMI model (additive main effects and multiplicative interaction) was used for stability analysis (genotype/environment interaction) of spring garlic genotypes. The AMMI model is a combination of ANOVA and principal components analysis (PCA). The additive component of variation was calculated by the analysis of variance (ANOVA) and tested by the F-test. Sources of variability in the genotype/environment interaction were differentiated by the principal components analysis and were titled accordingly *Ipca* (interaction PCA). *Ipca* significance was tested by the F-test according to GOLLOB (1968).

The applied analytical procedure and the interpretation of results are based on the procedure of ZOBEL et al. (1988). AMMI analysis and graphic presentation of G x E interactions and genotype stability evaluation were processed in Excel, the procedure of VARGAS et al. (2000), and Biplot and Singular Value Decomposition Macros for Excel, the procedure of LIPKOVICH et SMITH (2002).



Graph 1. Walter climate diagram for garlic growing season

a) Temperature and rainfall in 1999.

b) Temperature and rainfall in 2000.

c) Temperature and rainfall in 2001.

RESULTS WITH DISCUSSION

The mean value of the number of cloves for the genotypes and years was 10.2, with the actual values ranging from 8.5 (K-29/2) to 12.2 (K-3/3). The mean value of clove weight for the tested genotypes and the three growing seasons was 1.9 grams. The highest three-year mean value of clove weight was found in the cultivar Labud (2.9 g), the lowest in the clone K-16/1 (1.4 g) (Table 1). Clove weight and number are negatively correlated characteristics (GVOZDANOVIĆ-VARGA et al., 1994, 1997) and they are main quantitative characteristics which determine the method of garlic use. Regarding the market value of garlic bulbs, smaller number and larger cloves are preferred. These characteristics are in demand for both, fresh use and processing. Regarding seed production, however, genotypes with a large number and uniform size of cloves are preferred (GVOZDANOVIĆ-VARGA et al., 2001; BRAND, 1996) because they improve the utilization of seed material. This requirement is present in breeding programs of all countries with intensive garlic production (France, USA, Spain).

The analysis of variance for the number of cloves in all sources of variability showed that effects of genotype, year and their interaction (GE) were highly significant. Year was responsible for the largest variation in the number of cloves (40.61%), followed by genotype and GE interaction (31.14% and 28.04%, respectively) (Table 2). ANOVA of mean effects for clove weight showed high percentages of variability for the year and GE interaction (64.42% and 28.13%), while the variability for genotypes was low (7.27%). All three sources of variability were highly significant (Table 2). Outstandingly high effects of the year, regarding the ranges of rainfall amount and distribution and temperature, were registered in the second and third years (Graph 1). In the second year, the entire growing season was dry. In the third year, a large part of the growing season was humid. These extreme climatic conditions had decisive effects on clove size. LIN and BINNS (1986) and KANG (2002) maintained that the effect of the year on the genotype is reflected most frequently via two principal factors, soil type and weather conditions in a location. In our case, soil type was stable across the years and it may be considered as a constant. Weather conditions, however, which include air temperature and rainfall amount and distribution, are an unforeseeable component in the assessment of genotype reaction (stability).

By decomposing the GE source of variability, two principal components were separated. The first principal component for the number of cloves was accountable for 68.01% of the variation of GE, i.e., for 19.08% of the total variability for this characteristic. The respective values for clove weight were lower, 60.49% and 17.02%, respectively. The second principal component was responsible for the remaining portion of the variation (Table 2).

The *Ipca* values for the number of cloves obtained by the AMMI analysis ranged around 1 for most of the genotypes under study. Negative *Ipca-1* and *Ipca-2* were found in the cultivar Sedef (-0.918 and -0.762, respectively), the clone K-7/2 (-1.003 and -0.553, respectively) and the clone K-27/1 (-0.577and -0.131, respectively). The

Table 1. Mean values of clove number and weight (g) for spring garlic and *Ipca* from AMMI model

Genotype	No. of cloves			Clove weight		
	Average	*Ipca 1*	*Ipca 2*	Average	*Ipca 1*	*Ipca 2*
P-23	9.8	-0.21	0.12	1.8	0.06	0.11
P-38	9.8	0.32	0.41	2.2	0.04	0.03
P-44	9.9	-0.04	0.18	2.1	0.01	-0.15
P-47	10.2	0.07	-0.26	1.7	-0.35	0.09
P-50	10.8	0.34	-0.04	1.9	-0.54	0.03
P-Dac	10.0	0.67	-0.39	2.8	-0.25	0.01
P-Des	12.0	-0.14	0.78	1.6	0.14	0.40
P-Jan	10.2	0.25	0.16	2.0	0.01	0.10
Sedef	9.8	-0.92	-0.76	1.8	0.41	-0.05
Labud	10.3	0.51	-0.30	2.9	-0.46	0.11
K-3/2	11.1	0.26	-0.61	1.9	0.28	-0.22
K-3/3	12.2	0.25	-0.04	1.5	0.04	-0.02
K-7/1	10.0	-0.34	0.43	2.6	0.32	-0.17
K-7/2	10.0	-1.00	-0.55	1.7	0.48	-0.10
K-10/2	9.8	0.54	0.20	1.9	-0.26	0.10
K-11/1	11.0	-1.22	0.51	1.6	0.25	0.47
K-16/1	12.0	-0.12	-0.49	1.4	0.25	0.05
K-19/1	10.2	-0.48	0.46	1.6	0.19	0.18
K-24/1	10.3	0.03	0.06	1.7	0.05	-0.35
K-27/1	9.3	-0.58	-0.13	1.8	0.29	0.04
K-28/2	10.8	0.06	-0.16	1.6	-0.11	-0.25
K-29/2	8.5	-0.10	0.20	1.9	0.01	0.06
K-31/1	9.8	0.30	-0.20	2.6	-0.30	0.22
K-32/3	10.3	0.12	-0.19	1.9	0.08	0.07
K-32/5	10.5	0.35	-0.50	1.9	0.07	-0.33
K-34/2	9.2	-0.31	0.30	2.4	-0.03	0.17
K-35/1	9.2	0.48	0.74	1.9	-0.26	0.19
K-35/4	9.5	0.58	0.19	2.0	-0.14	-0.05
K-37/3	11.3	0.26	-0.01	1.7	-0.03	-0.03
K-42/2	8.7	0.07	-0.10	2.3	-0.26	-0.71
Godine	**10.2**			**1,9**		
1999	11.5	0.44	-1.68	1.9	-0.28	0.97
2000	9.0	-1.98	0.53	2.1	-0.79	-0.71
2001	10.2	1.54	1.16	1.8	1.08	-0.27

highest negative value of *Ipca-1* was found in the clone K-11/1 (-1.222). Highest values of the second principal component were found in the population P-Des (0,781) and the clone K-35/1 (0,740). The first year of study had a high negative value of *Ipca-2* for the number of cloves (-1.682), as well as the second year (*Ipca-1*; -1,979).

The negative correlation indicated that the effect of the year reduced the number of cloves. The high positive values of both principal components for clove number registered in the third year, however, indicated that the climatic conditions in the third year were favorable for this trait as well as for clove weight (GVOZDANOVIĆ-VARGA, 2005) (Table 1). The high percentages of GE interaction indicated that there existed differences in adaptability, especially for the direct yield components, i.e., bulb and clove weight, number of cloves. KAZAKOVA (1978) claims that, in the process of garlic evolution, selection pressure made the non-flowering form of compound bulb evolve from the flowering form when the former was transferred to conditions more favorable for plant growth and development. This claim has been supported by numerous studies of the change of characteristics in dependence of environmental factors (temperature, day length, soil moisture) and geographic origin of studied material.

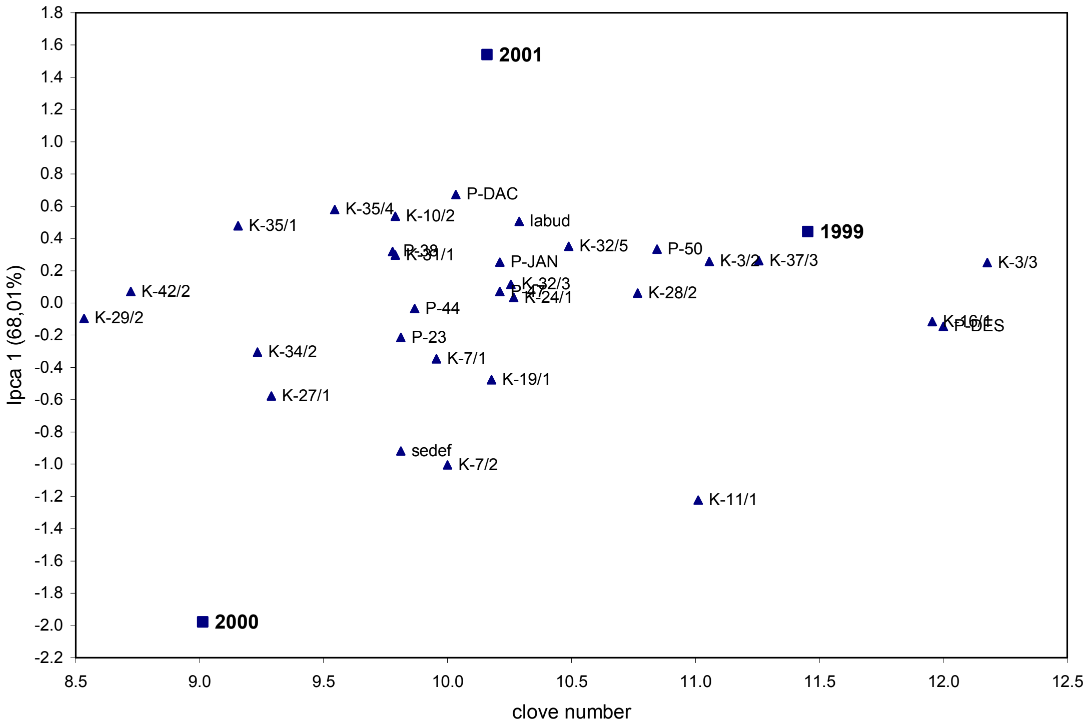
Table 2. ANOVA for principal effects and multiple interactions for clove weight and number in spring garlic genotypes

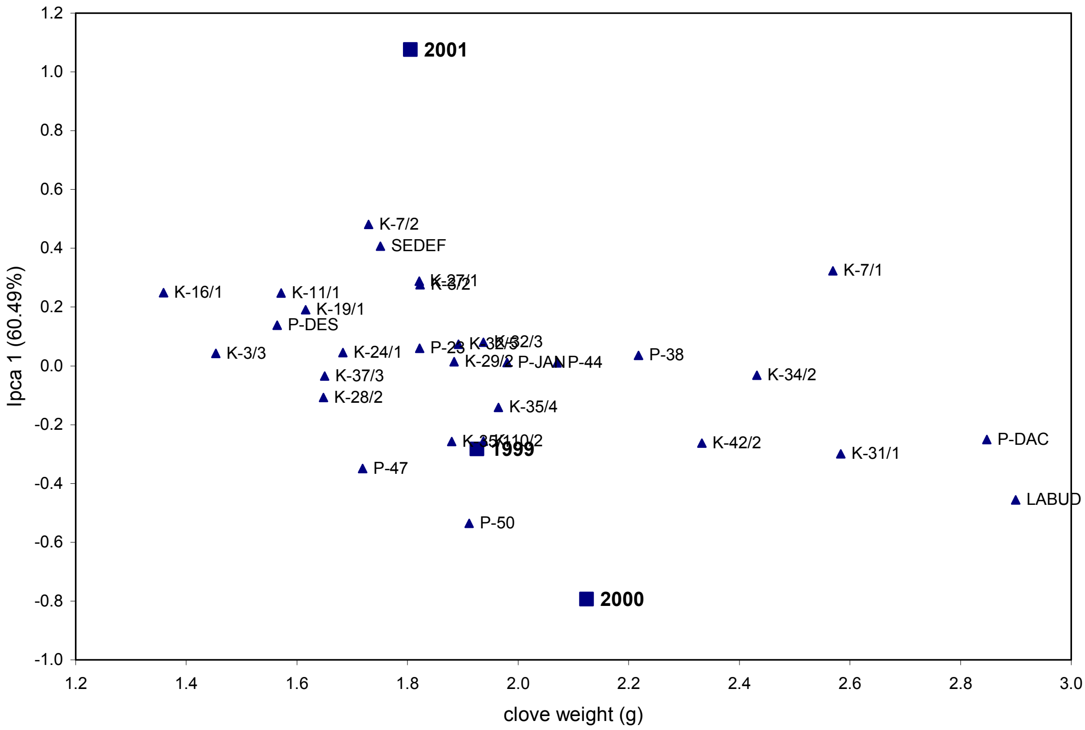
Source	df	No. of cloves			Clove weight		
		Sum of squares	F-ratio	Explained %	Sum of squares	F-ratio	Explained %
R (replication)	2	1.39	1.68	0.21	0.11	1.24	0.18
G (genotype)	29	205.88	17.20**	**31.14**	4.47	48.66**	**7.27**
E (years)	2	268.48	325.30**	**40.61**	39.54	29.72**	**64.42**
G x E (GEI)	58	185.36	7.74	**28.04**	17.28	6.49**	**28.13**
Gollob F-test							
GEI		SSAMMI	F-AMMI	Explained %	SSAMMI	F-AMMI	Explained %
Ipca 1	30	126.06	10.17**	68.01	10.45	7.59**	60.49
Ipca 2	28	59.30	5.13**	31.99	6.82	5.31**	39.51

The stability of ecotype reaction to the changes of environmental conditions was presented graphically in an integrated biplot. The graph contains the mean values for the number of cloves and *Ipca-1* for the ecotypes and years. Genotypes and environments with high values of *Ipca* (positive or negative sign) also have high effects of interaction; however, if the value is around zero, the effect of interaction is low, i.e., these genotypes are stable in the studied environments (CROSSA et al., 1990).

The largest deviation from the mean value for the number of cloves, as well as low values of the first principal component, was found in the clone K-3/3. Large deviations were also found in the clone K-16/1 and the population P-Des. On the opposite side to these genotypes was the clone K-11/1, which had the largest number of cloves as well as the highest negative value of *Ipca-1*. Smaller numbers of cloves were found in the genotypes P-Dac, K-35/4, K-35/1 and K-42/2, as well as in the third year, but with a positive value of *Ipca-1*. On the lower side of the graph, there are genotypes with low mean values for the number of cloves and negative *Ipca-1*, as well

Graph.2. AMMI analysis biplot for clove number





Graph.3. AMMI analysis biplot for clove weight

as the second year of study (Graph 2). YAN (2001) stated that genotypes taking the highest position in a certain sector grow best in the environment also included in that sector. Practically, in the integrated biplot, the positions of the genotypes indicate their reaction in the study period, while the positions of growing seasons indicate the behavior of the genotypes in individual years. Regarding clove weight, for example, most of the genotypes are concentrated around the source point, indicating their stability; however, stable genotypes with the mean value higher than the total mean value are important for further study (Graph 3).

REFERENCES

BOROJEVIĆ, S. 1992: Principi i metode oplemenjivanja bilja. Izd. RU "Radivoj Ćirpanov", Novi Sad.

BRAND, R. 1996: L Ail, une semence a part. Sauve qui peut! Sauve qui veut! Les *Allium,* 9, 11-17.

CROSSA, J.H., GAUCH, G. Jr., and ZOBEL, R.W. 1990: Additive Main Effects and Multiplicative Interaction Analysis of Two International Maize Cultivar Trials. - *Crop Science*, 30: 493-500.

GOLLOB, H.F. 1968: A Statistical Model which Combines Features of Factor Analytic and Analysis of Variance Techniques. - *Psychometrika*, 33, (1), 73-115.

GVOZDANOVIĆ-VARGA, J., TAKAČ, A. and VASIĆ, M. 1994: Novi klonovi jarog belog luka. - *Selekcija i semenarstvo*, I (1): 65-69.

GVOZDANOVIĆ-VARGA, J. and VASIĆ, M, 1997: Divergentnost ekotipova prolećnog belog luka. - *Savremena poljoprivreda*, 46 (3-4): 234-242.

GVOZDANOVIĆ-VARGA, J., VASIĆ M. and ČERVENSKI, J. 2001: Prinos prolećnog belog luka u zavisnosti od krupnoće čenova. - *Savremena poljoprivreda*, 1-2: 141-145.

GVOZDANOVIĆ-VARGA J. 2005: Analiza stabilnosti komponenata prinosa prolećnog belog luka (*Allium sativum* L.). Doktorska disertacija, Poljoprivredni fakultet, Novi Sad, 120 str.

JANICK, J. 1999: Exploitation of Heterosis: Uniformity and Stability. p. 319-333. The Genetics and Exploatation of Heterosis in Crops.

KANG, M. S. 2002: Genotype-environment Interaction: Progress and Prospects. Quantitative Genetics, Genomics and Plant Breeding. - *CAB International.* Ed. M.S. Kang, pp 221-243.

KAZAKOVA, A. A. 1978: Luk. Kulturna flora SSSR. Leningrad

LIN, C.S., BINNS, M.R. and LEFKOVITCH, L.P. 1986: Stability Analysis: Where Do We Sstand? - *Crop Sci.*, 26: 894-900.

LIPKOVICH, I. and E.P. SMITH, 2002: Biplot and Singular Value Decomposition Macros for Excel©. http://filebox.vt.edu/artsci/stats/vining/keying/biplot.doc

VARGAS, M., J. CROSSA, F. A. VAN EEUWIJK, K. D. SAYER, and M. REYNOLDS, 2001: Interpreting Treatment x Environment Interaction in Agronomy Trials. - *Agronomy* J., 93: 949-960.

YAN, W., 2001: GGE Biplot-A Windows Application for Graphical Analysis of Multienvironment Trial Data and Other Types of Two-way Data. - *Agronomy* J. 93: 1111-1118.

ZOBEL, R. W., WRIGHT, M. J. and GAUCH, H. G. Jr. 1988: Statistical Analysis of a Yield Trial. - *Agronomy* J., 80: 388-393.

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