Uluslararası Tarım Araştırmalarında Yenilikçi Yaklaşımlar Dergisi
International Journal of Innovative Approaches in Agricultural Research 2019, Vol. 3 (1), 67-80
https://doi.org/10.29329/ijiaar.2019.188.7

Original article

Ecological Stability of Quantitative Signs in White Lupin Varieties [1]

Valentin Kosev [a, *], Viliana Vasileva [a] & Yalçın Kaya [b]

[a] Institute of Forage Crops, 89 "General Vladimir Vazov" Str., 5800 Pleven, Bulgaria
[b] Trakya University, Department of Genetic and Bioengineering, Edirne, Turkey

Abstract

Ecological stability of quantitative signs in white lupine varieties was studied in field trial in the Institute of Forage Crops, Pleven, Bulgaria. Seven varieties of white lupine were used. Analysis of variance showed a well-proven influence of genotype and environment factors and the interaction between them in terms of plant height, number of pods, number of seeds and seeds weight. For plant height, number of seeds and seeds weight, the influence of the environment was stronger than that of the other two factors. The seeds weight strongly correlated with the Anicchiarico Wi indices (r = 0.87), bi (r = 0.634), ai (r = 0.633) and T (r = 0.559) and negative correlated with the Lin and Binns (r = -0.977) parameter. Ecological stability parameters for plant height showed the most stable and high-growing PI533704 variety; for the number of pods, number of seeds and seeds weight Zuter variety, respectively. Zuter variety was found close to the ideal type combining high productivity with ecological stability. Lucky801, for most signs, was environmentally unstable but highly productive and is therefore suitable as a parent component in breeding programs for obtaining high yield varieties.

Keywords: Adaptation, *Lupinus albus*, Genotype, Environment.

Received: 14 August 2018 * **Accepted:** 19 January 2019 * **DOI:** https://doi.org/10.29329/ijiaar.2019.188.7

*** Corresponding author:**

Valentin Kosev, Institute of Forage Crops, 89 "General Vladimir Vazov" Str., 5800 Pleven, Bulgaria.
Email: valkosev@hotmail.com

[1] A part of this study was presented at the International Agricultural, Biological and Life Science Conference, Edirne, Turkey, September 2-5, 2018.

INTRODUCTION

Leguminous crops as nitrogen-fixing are an essential component of modern agriculture. They are an important source of food both for animals and for human consumption. White lupine is a legume crops with valuable qualities - high protein content in the seeds and green mass, possibility to grow without nitrogen fertilization, ability to absorb poorly soluble nutrients from the soil. The new varieties created, even under optimum growing conditions, can not realize their maximum biological capabilities due to their poor adaptability when changing the environment. An important role in determining the biological productivity of genotypes plays the environmental sustainability of plants and their ability to counteract the effects of abiotic and biotic stressors on the environment (Nettevich, 2001; Ionova et al., 2014). Unsatisfactory grain yields in some regions of the world are largely due to the lack of a variety that meets modern production requirements, which is a significant difficulty in expanding the range of this crop (Berger et al., 2012).

The purpose of this study was to assess the phenotypic stability of white lupine varieties by basic quantitative signs and to determine the possibility of using them as an initial material for future breeding programs.

Materials and methods

The study was conducted in 2014-2016 on the experimental field of the Institute of Forage crops, Pleven, Bulgaria. Sowing was carried out manually in optimal time, according to the technology of cultivation of white lupin. Plant material from above ground biomass of 7 white lupin (*Lupinus albus*) varieties, PI457923, PI368911, PI533704, PI457938, KALI, Zuter and Lucky801 was analyzed.

The following characteristics have been assessed: i) in the beginning of flowering stage - plant height (cm); ii) in the technical maturity of seeds stage - pods number per plant, seeds number per plant, seeds weight per plant (g). Biometric measurements were made to 10 plants of each variety.

The obtained data were processed by two-way analysis of variance (two-way ANOVA) for each trait to determine of effects of genotypes (G), (E) environments and genotype environment interaction (G x E). The estimation of the ecological stability of the tested varieties was done through the application of next methods: regression analysis - according to Eberhart and Russell's (Eberhart and Russell, 1966) in which the regression coefficient (bi), the variance of the deviations from regression (Si^2); Tai (1979), (ai; λi); Theil (1950), (T); analysis of variance - mean variance component (PP) according to Plaisted and Peterson (1959); ecovalence (W^2), Wricke (1965) and index (W_i) Annicchiarico (1992); non parametrical analysis through using rank (R) on the model of Huehn (1990) and P_i parameter on the model of Lin and Binns (1988). Plaisted and Peterson's (1959) mean variance component (PP) was a measure of a variety's contribution to the GE interaction and was computed from a total of pair-wise analysis. Annicchiarico's method proposed a reliability index (W_i) which estimates the probability of a particular genotype (variety) to present a performance below the environmental average or below any standard used. According to superiority measure of Lin and Binns (1988) the distance mean square between the cultivar's response and the maximum response over locations were the major parameters in identifying more superior cultivars. The smaller the mean square the more superior the new cultivar is. GGE biplot model was done, which uses singular value decomposition of first two principal components (Yan, 2002).

All experimental data were processed statistically with using the computer software GENES 2009.7.0 for Windows XP (Cruz, 2009) and GEST (Ukai, 1996).

Results

The assessment of the patterns (varieties, lines) on the parameters of stability and plasticity can be done when they are grown in contrast environmental conditions over several years (Murugova, 2015).

Phenotypic stability has been intensively studied by biometrics who have developed a variety of statistical methods for analysis. Typical statistical analyzes in the trials for productivity are limited to the following groups: Analysis of variance (ANOVA), Principal Component Analysis (PCA), and Linear Regression. ANOVA mainly reflects the additive effects of the trait and the regression gives information about both the additive effects and some of its interaction with the environment. Nonparametric analyzes are used as methods for parallel selection in yield and yield stability (Zobel et al., 1988).

In the study for quantitative assessment of the ecological stability and adaptability of the varieties tested, ANOVA (Table 1), regression analyzes (Table 2) and nonparametric analyzes were used (Table 3).

Analysis of variance

According to the data from the ANOVA (Table 1) the studied varieties differ reliably in their genetic nature, except for the seeds weight, where the influence of any of the sources of variation has not been statistically proven. The averages of squares of plant height, seeds number and seeds weight indicate that the influence of the environment is many times stronger than the influence of the other two genotype (variety) factors and the genotype-environment interaction. The significant variation of these signs by years showed that their formation depends largely on changing environmental conditions. The factor variety has a greater part of the influence of the total variation of the plant height and the seeds weight relative to the genotype-environment interaction.

With the traits number of seeds and number of pods from the plant, the number of pods per plant has a larger share. The results obtained justify the need to assess the ecological stability of the plant height, number of pods, number of seeds and seed weight per plant.

Ecological stability assessment

The calculated parameters of the phenotypic stability of each variety are presented in Table 2. The Lucky801 variety is characterized by a limit value of the plant height, but also with the maximum value of the parameter "bi" (bi = 1.21). It can be referred to genotypes with well-defined ecological plasticity. Zuter (bi = 1.18) and PI457923 (bi = 1.18) also belong to the same group, the plants of which were also high.

The plants of the varieties PI368911, PI457938, KALI were lower and the coefficient of "bi" <1, indicating their stability under deterioration of the environment. PI533704 showed statistically insignificant regression coefficient of 1.00, which determines it as close as possible to the "ideal" genotype for this trait. The values of the other stability parameters also define it as the most preferred.

The number of pods per plant is a major trait and an integral part of the yield composition. This trait, along with the number of seeds per plant, allows to assess the potential productivity of genotype as well as its adaptive capacity through stability parameters (Ieronova, 2007).

Plaisted and Peterson (1959) criteria (PP) and ecovalence (W^2) of Wricke (1965) define the PI368911 and Zuter as the most stable in regard to the number of pods per plant (Figure 1). These two varieties managed to form about 9-10 pods per plant on average for the years of study and retreat only on PI533704, which formed 10-11 beans. PI457923 and PI457938 are characterized by high variability and an average biological potential in terms of the number of pods. Stability parameter values showed that PI533704 under certain favorable environmental conditions, can develop its potential and form an even greater number of pods per plant.

The high regression coefficient (bi) of 1.23 to 1.67 determines the varieties PI457938, Lucky801, PI457923 and PI533704 as ecologically unstable in the number of seeds but with a certain degree of responsiveness. The varieties PI533704 and Lucky801 under favorable conditions of development can provide a relatively high number of seeds per plant. PI368911 is low productive in this respect. By the bi (bi 0.13) values, as well as the other parameters, it is clear that this variety is environmentally stable and poorly adaptable. Its low biological potential prevents it from taking precedence over other varieties.

According to the information obtained from all parameters of stability, Zuter is found close to the ideal type, combining high productivity (large number of seeds in one plant) with ecological stability. This variety is suitable for growing in a wide range of environmental conditions.

The seeds weight is one of the parameters determining the value of the variety and depends on other quantitative characteristics of the genotype. Studying of the varieties under this trait indicates that it depends both on the environment and on the genotype. Zuter showed the highest seeds weight, followed by Lucky801, PI533704 and PI457923.

Following the assessment of the varieties of ecological stability, PI368911 has the lowest regression coefficient (bi = 0.11), indicating its stability and low adaptive capacity. Lucky801, PI533704 and PI457923 are highly productive but ecologically unstable (bi> 1). They are suitable for cultivation at a high level of agro technology.

Zuter variety showed high seeds weight and good ecological stability according to the criteria used for assessing stability and is of interest for selection. The KALI variety is also low variable, but with an unsatisfactory level of seeds weight trait relative to almost all other varieties.

GGE biplot analysis

The GGEbiplot used allows the varieties to be ranged of their productivity (expressed by the respective quantitative trait) and stability in different growing environments. In Figure 2, the average tester coordinate or the productivity line starts from the beginning of the bout with an arrow indicating the positive end of the axis. The axis of stability also originates from the co-ordinate of the brute. It has arrows at both ends and is perpendicular to the line of productivity.

The average productivity of the genotype is assessed by the projection of each variety marked "Gn" relative to the axis „X” (average tester coordinate).

At the height of the plant, the Lucky801 and Zuter varieties were distinguished by the highest plants, and the PI368911 variety, occupying the extreme left position of the coordinate system was characterized by the lowest plants. By this indicator, PI457923 was most highly variable. The high-yielding varieties Lucky801 and Zuter exhibit less stability than the less-growing varieties PI533704 and PI457938.

The "ideal" genotype is one that possesses both a high average expression of the studied traits and high stability in different environments. In fact, such a genotype may not exist, but it can be used as a reference in assessing genotypes. By the number of pods per plant, the length of the vectors determines the varieties PI457923 and PI457938 as highly variable. The short vector at PI368911 characterized the variety as stable, but it formed a small number of pods per plant. PI533704 was in a more favorable position due to the higher value of the trait. The KALI variety, which exhibits an average level of trait stability, has been found to be most desirable and has been able to form a relatively large number of pods per plant.

The number of seeds per plant was first of the variety PI533704, followed by Lucky801, which is highly unstable. The Zuter variety was less productive than PI533704, but formed a very short vector with the axis that characterizes the stability of genotypes, which gives it a definite advantage in growing in different cultivation environments. The PI368911, KALI and PI457938 varieties were low productive and highly variable.

Regarding the seed weight, the distribution of varieties on the coordinate system indicates that the environment have a different influence on the appearance of the trait in the individual genotypes. The PI368911 and KALI varieties can be defined as stable and low productive (with the lowest seed weight). PI457923 was found relatively high-performance and highly variable. Breeding interest represents Zuter which is stable and high productive. Lucky801 is environmentally unstable but also highly productive and can be included in future breeding programs to obtain new forms with higher seed weight per plant.

Correlation analysis

The correlation analysis of ecological stability parameters (Table 4) showed that the seed weight is closely related to the Anicchiarico Wi index ($r = 0.87$). High but statistically unproven are the correlations with the bi ($r = 0.634$), ai ($r = 0.633$) and T ($r = 0.559$) parameters. This result showed the close similarity and effectiveness of these parameters in assessing stable white lupine genotypes in different environments.

The correlation with the Pi parameter of Lin and Binns ($r = -0.977$) was strongly negative. Thus, if the seed weight is the primary target of the selection, then selection based on this stability parameter would be less useful.

Eberhart and Russell's Si2 parameter was in strong positive correlation with λi ($r = 1.00$), with PP and W2 ($r = 0.821$), Tai with PP of Plaisted and Peterson and W2 Wricke ($r = 0.819$). Positive correlations between the Huehn parameter R and Plaisted and Peterson and Wricke ($r = 0.885$) are also positive. These results indicate that the joint application of Plaisted and Peterson and Wricke parameters, those of Eberhart and Russell and Huehn can be used as a means of assessing white lupine varieties in future breeding programs in selecting both stable and high yield genotypes.

A positive statistically significant correlation was also found between the T and Wi parameters, while a strictly negative ($r = -0.898$) between Wi and Pi ($r = 0.788$).

Discussion

As a result of studies on the testing of patterns of productivity and ecological stability, Temesgena et al. (2015) consider that the parameters P59, σ2, Wi, CVi, EV, and ASV are appropriate and favor the right choice of high yield genotypes. For similar results regarding the reliability of the parameters σi2 and Wi reported Mulusew et al. (2008) for bean varieties

In lens studies, Karimizadeh et al. (2012), using the same stability assessment parameters, reported that low yielding varieties in the worsening of the chenotic environment showed greater stability than high yield genotypes. According to Charlson et al. (2009), Valentine et al. (2011) and Murugova (2015), yield is always the result of a compromise between genotype productivity and resistance to adverse environmental conditions. In the same crops, applying the principle of component analysis, Sabaghnia et al. (2012) and Mohebodini et al. (2006) found that it is desirable for the researcher to group the priority-indicating stability indexes with the studied traits and thus to get a clearer picture of the behavior of the genotype in a dynamic environment.

According to Temesgena et al. (2015) the statistically significant positive correlation between stability parameters suggests that the same parameters will show similar results in the assessment of genotypes by stability and variability.

Kilic (2012) reported high correlation coefficients between P59, σ2, and Wi, as well as between P59, σ2, Wi and Tai's λ and ASV.

Therefore, these stability statistics can be used as parallel methods to select genotypes with high stability and moderate yield (Ahmadi et al., 2015).

Tsegaye et al. (2012) and Ahmadi et al. (2015), commenting on the importance of determining the phenotypic stability of varieties, recommend the use of different statistical models and parameters in assessing the stability of genotypes in different environments to determine the most suitable high yield variety for specific climatic conditions.

Conclusions

The influence of genotype factors, environment and interaction between them on the plant height, number of pods, number of seeds, weight of seeds per plant in white lupin genotypes was very well documented. For plant height, seeds number and seeds weight, the influence of the environment was found stronger than that of the other two factors.

The seeds weight was in strongly correlation with the Anicchiarico Wi parameters (r = 0.87), bi (r = 0.634), ai (r = 0.633) and T (r = 0.559), and in negative correlation with the Pi of Lin and Binns (r = -0.977) parameter.

Ecological stability parameters showed the PI533704 variety as the most stable on plant height; the Zuter variety as the most stable on number of pods, number of seeds and seeds weight. Zuter variety was found close to the ideal type combining high productivity with ecological stability and the most preferred.

Lucky801, for most traits, was environmentally unstable but highly productive and is therefore suitable as a parent component in breeding programs for obtaining high yield varieties.

REFERENCES

Ahmadi, J., B. Vaezi, A. Shaabani, K. Khademi, S. Fabriki Ourang and A. Pour-Aboughadareh (2015). Non-parametric Measures for Yield Stability in Grass Pea (*Lathyrus sativus* L.) Advanced Lines in Semi Warm Regions. J. Agric. Sci. Technol., 17, 1825-1838.

Annicchiarico, P. (1992). Cultivar adaptation and recomendation from alfalfa trialsin Northern Italy. J. Genet. Plant Breed., 4, 269-278.

Berger, J. D., B. J. Buirchell, D. J. Luckett and M. N. Nelson (2012). Domestication bottlenecks limit genetic diversity and constrain adaptation in narrow-leafed lupin (*Lupinus angustifolius* L.). Theor. Appl. Genet., 124, 637-652.

Charlson, D.V., S. Bhatnagar, C.A. King, J.D. Ray, C.H. Sneller, T.E. Carter and L.C. Purcell (2009). Polygenic inheritance of canopy wilting in soybean [*Glycine max* (L.) Merr.]. Theor. Appl. Genet., 119, 587-594.

Cruz, C.D. (2009). Programa Genes: Biometria. version 7.0. University of Federal Viçosa, Viçosa, Brazil.

Eberhart, S. A. and W. A. Russel (1966). Stability parameters for comparing varieties. Crop Sci., 6, 36-40.

Huehn, M. (1990). Nonparametric measures of phenotypic stability. Pan 2: Applications. Euphytica, 47, 195-201.

Ieronova, V.V. (2007). Complex evaluation and selection of ecologically plastic forms of barley (*Hordeum* L.) for the Tyumen region. Author's abstract. PhD thesis, Tyumen, p. 25.

Ionova, E.V., V.A. Gase and E.I. Nekrasov (2014). Prospects for the use of adapted zoning and adaptive crop selection (overview). Grain Economy, 1 (31), 19-22.

Karimizadeh, R., M. Mohammadi, N. Sabaghnia and M.K. Shefazadeh (2012). Using different aspects of stability concepts for interpreting genotype by environment interaction of some lentil genotypes. Aust. J. Crop Sci., 6, 1017-1023.

Kilic, H. (2012). Assessment of parametric and nonparametric methods for selecting stable and adapted spring bread wheat genotypes in multi-environment. J. Anim. Plant Sci., 22, 390-398.

Lin, C.S. and M. R. Binns (1988). A superiority measure of cultivar performance for cultivar x location data. Can. J. Plant Sci., 68, 193-198.

Mohebodini, M., H. Dehghani and S. H. Sabaghpour (2006). Stability of performance in lentil (*Lens culinaris* Medik.) genotypes in Iran. Euphytica, 149, 343-352.

Mulusew, F., T. Tadele and L. Tesfaye (2008). Genotype-environment interaction and stability parameters for grain yield of faba bean (Vicia faba L.) genotypes grown in southeastern Ethiopia. Int. J. Sust. Crop Prod., 3, 80-87.

Murugova, G.A. (2015). An estimation of a starting material of a summer barley with the purpose of creation of breeds with high efficiency and ecological plasticity in the conditions of Primorye Territory. DSc thesis, Federal State Educational Establishment "Primorsky NIISH", Timiryazevsky settlement - 2015.

Nettevich, E.D. (2001). Potential of the yields of spring wheat and barley varieties recommended for cultivation in the Central region of the Russian Federation and its reproduction under production conditions. Reports of the Russian Academy of Agricultural Sciences, 3, 50-55.

Plaisted, R.L. and L. C. Peterson (1959). A technique for evaluating the ability of selection to yield consistently in different location and seasons. Am. Potato J., 36, 381-385.

Sabaghnia, N., R. Karimizadeh and M. Mohammad (2012). Genotype by environment interaction and stability analysis for grain yield of lentil genotypes. Agriculture, 99 (3), 305-312.

Tai, G.C.C. (1979). Analysis of genotype - environment interactions of potato yield. Crop Sci., 19, 434.

Temesgena, T., G. Kenenib, T. Seferaa and M. Jarsob (2015). Yield stability and relationships among stability parameters in faba bean (*Vicia faba* L.) genotypes. Crop J., 3 (3): 258-268.

Theil, H. (1950). A rank-invariant method of linear and polynomial regression analysis. Indagationes Mathematicae, 12, 85-91.

Tsegaye, D., W. Tadesse and M. Bayab (2012). Genotype X environment interactions and grain yield stability of haricot bean varieties in Northwest Ethiopia. Scientific Research and Essays, 7 (41), 3487-3493.

Ukai, N. Y. (1996). A packet of computer programs for the statistical analysis of genotype x environment interaction and stability GEST. Breeding Science, 46, 73-79.

Valentine, A.J., V.A. Benedito and Y. Kang (2011). Legume nitrogen fixation and soil abiotic stress: From physiology to genomic and beyond. Annual Plant Rev., 42, 207-248.

Wricke, G. (1965). Zur berechnung der ökovalenz bei sommerweizen und hafer. Pflanzenzuchtung, 52, 127-138.

Yan, W. (2002). Singular-value partitioning in biplot analysis of multienvironment trial data. Agron. J., 94, 990-996.

Zobel, R. W., M. J. Wright and H. G. Gauch Jr. (1988). Statistical analysis of a yield trial. Agron. J., 80, 388-393.

Table 1. Analysis of variance for stability for seed yield and yield components in *Lupinus* varieties for the period 2014-2016

Source of variation	**Df**	**Mean sum of squares for the traits studied**				
		plant height, cm	**pods number per plant**	**seeds number per plant**	**seeds weight per plant**	**seeds weight/pod**
Environments (E)	2	19852.47**	8.95*	2266.74**	163.15**	2.43
Genotypes (G)	6	307.69**	13.81**	118.61**	23.76**	0.41
G x E Interactions	12	141.73**	36.17**	230.05**	17.24**	0.11
Environments/ Genotype	14	2957.55**	32.28**	521.01**	38.08**	0.44
Env/ PI457923	2	4041.60**	67.84**	860.68*	68.70**	0.07
Env/ PI368911	2	1501.07**	5.93*	9.31**	0.50	0.32
Env/ PI533704	2	2844.87**	34.27**	975.77**	56.01**	0.24
Env/ PI457938	2	2071.40**	60.68**	678.90**	42.43**	0.51
Env/ KALI	2	2133.32**	17.15**	160.35**	9.25*	0.21
Env/ Zuter	2	3943.47**	7.39*	137.22**	12.73**	0.99
Env/ Lucky801	2	4167.15**	32.68**	824.82**	76.95**	0.74
Total	20					

Significant at P = 0.05 (*), ** P = 0.01(**)

Table 2. Estimates of the adaptability and stability parameters for the seed yield and yield components in investigated varieties

Cultivar		**Eberhart and Russell (1966)**		**Tai (1979**		**Theil (1950)**	**Plaisted and Peterson (1959)**	**Wricke (1965)**	**Annic-chiarico (1992)**
		bi	**Si^2**	**ai**	**λi**	**T**	**PP**	**W^2**	**W_i**
	Plant height, cm								
PI457923		1.18**	47.569**	1.18	139.282	96.54	38.15	414.53	95.02
PI368911		0.71**	23.167**	0.71	68.267	95.44	48.00	583.33	84.60
PI533704		1.00	1.826**	1.00	5.910	99.79	14.56	10.13	99.92
PI457938		0.85**	0.937*	0.85	3.344	99.84	21.35	126.53	90.46
KALI		0.87**	2.565**	0.87	8.060	99.62	20.73	115.83	90.37
Zuter		1.18**	1.283*	1.18	4.320	99.89	24.96	188.40	105.27
Lucky801		1.21**	1.427**	1.21	4.690	99.89	29.26	262.03	105.83
	Pods number per plant								
PI457923		5.59**	10.988**	6.16	28.687	58.66	9.815	109.69	73.70
PI368911		-2.15*	-0.200	-2.55	-1.867	100.00	4.901	25.44	79.65
PI533704		3.07*	8.690**	3.33	25.127	34.97	6.649	55.40	101.66
PI457938		4.11	15.440**	4.50	43.801	35.39	9.420	102.91	70.59
KALI		-0.58	6.486**	-0.78	19.031	2.26	5.740	39.83	92.15
Zuter		-0.99	2.254**	-1.24	6.412	16.77	4.724	22.41	93.72
Lucky801		-2.04*	10.754**	-2.42	30.222	15.98	7.986	78.33	73.78
	Seeds number per plant								
PI457923		1.36**	105.558**	1.36	308.429	59.92	58.47	611.32	75.18
PI368911		0.13**	1.369*	0.13	4.494	45.01	51.93	499.23	79.93
PI533704		1.67**	27.609**	1.67	81.017	90.70	48.02	432.30	102.06
PI457938		1.23*	76.676**	1.23	224.205	63.07	47.16	417.45	73.26
KALI		0.63**	13.187**	0.63	39.040	72.77	31.99	157.54	82.34
Zuter		0.65**	0.679*	0.65	2.552	97.91	27.80	85.68	99.65
Lucky801		1.34**	95.931**	1.34	280.346	61.98	55.30	557.07	80.12
	Seeds weight per plant								
PI457923		1.43	8.298**	1.43	24.755	59.75	4.498	50.98	79.94
PI368911		0.11**	-0.115	0.11	0.115	45.31	3.693	37.18	69.91
PI533704		1.49	1.371*	1.50	4.540	90.87	2.648	19.27	92.19
PI457938		1.14	4.636**	1.14	14.102	62.91	2.988	25.11	68.95
KALI		0.56	0.566	0.56	2.201	73.06	2.271	12.81	74.41
Zuter		0.73	-0.116	0.73	0.234	97.84	1.742	3.75	114.11
Lucky801		1.53	8.711**	1.53	25.942	62.32	4.891	57.73	92.18

Significant at P = 0.05 (*), ** P = 0.01(**)

Table 3. Classification of genotypes based on nonparametric analysis of Lin and Binns (1988) and Huehn (1990)

Parameter	**Lin and Binns (1988) (Pi)**	**Huehn (1990) Rank (R)**	**Lin and Binns (1988) (Pi)**	**Huehn (1990) Rank (R)**
Variety	Plant height, cm		Pods number per plant	
PI457923	14.91	5	8.47	5
PI368911	115.91	6	9.89	3
PI533704	22.71	1	1.80	4
PI457938	75.49	3	10.09	5
KALI	75.21	3	4.34	3
Zuter	1.90	5	5.22	3
Lucky801	1.31	5	9.86	5
	Seeds number per plant		Seeds weight per plant	
PI457923	50.51	5	4.437	5
PI368911	89.04	5	9.630	5
PI533704	8.40	4	2.360	4
PI457938	59.36	4	6.965	4
KALI	68.46	3	7.874	2
Zuter	32.16	2	0.801	2
Lucky801	37.03	5	1.987	5

(1)- Better performance (7)-Worst performance

Table 4. Estimates of Spearman correlations between seed yield and the methods of stability and adaptability for the analysis of the effectiveness of different algorithms to identify genotypes of white lupin

	bi	**Si^2**	**ai**	**λi**	**T**	**PP**	**W^2**	**W_i**	**Pi**	**R**
Si2	0.741									
ai	1.000**	0.738								
λi	0.743	1.000**	0.739							
T	0.230	-0.376	0.232	-0.373						
PP	0.399	0.821*	0.396	0.819*	-0.715					
W2	0.399	0.821*	0.397	0.819*	-0.715	1.000**				
Wi	0.248	-0.108	0.249	-0.106	0.788*	-0.309	-0.309			
Pi	-0.648	0.592	0.818	-0.266	-0.707	0.043	0.042	-0.898**		
R	0.338	0.616	0.338	0.614	-0.699	0.885**	0.885**	-0.386	0.132	
Seeds weight per plant	0.634	0.382	0.633	0.383	0.559	0.120	0.120	0.870*	-0.977**	-0.004

*, ** Significant at (P < 0.05) and (P < 0.01) respectively

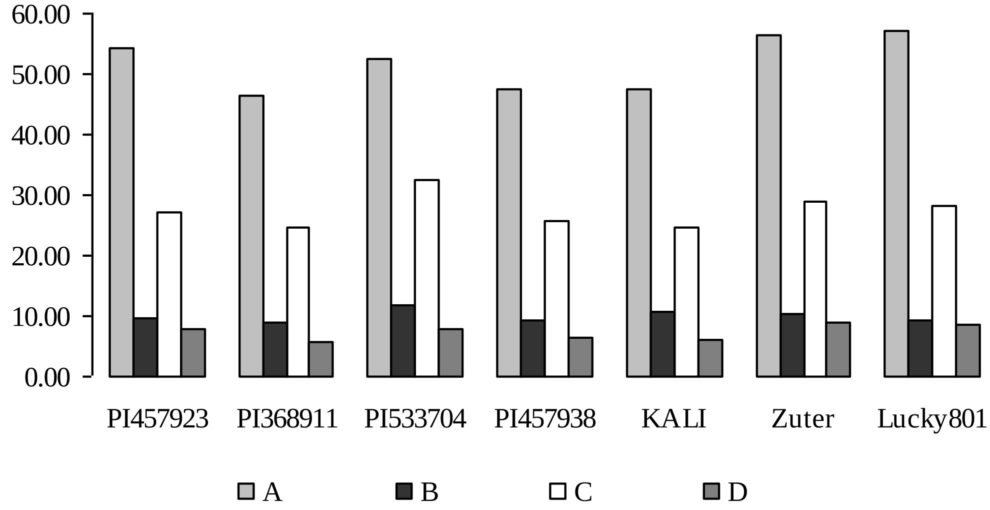
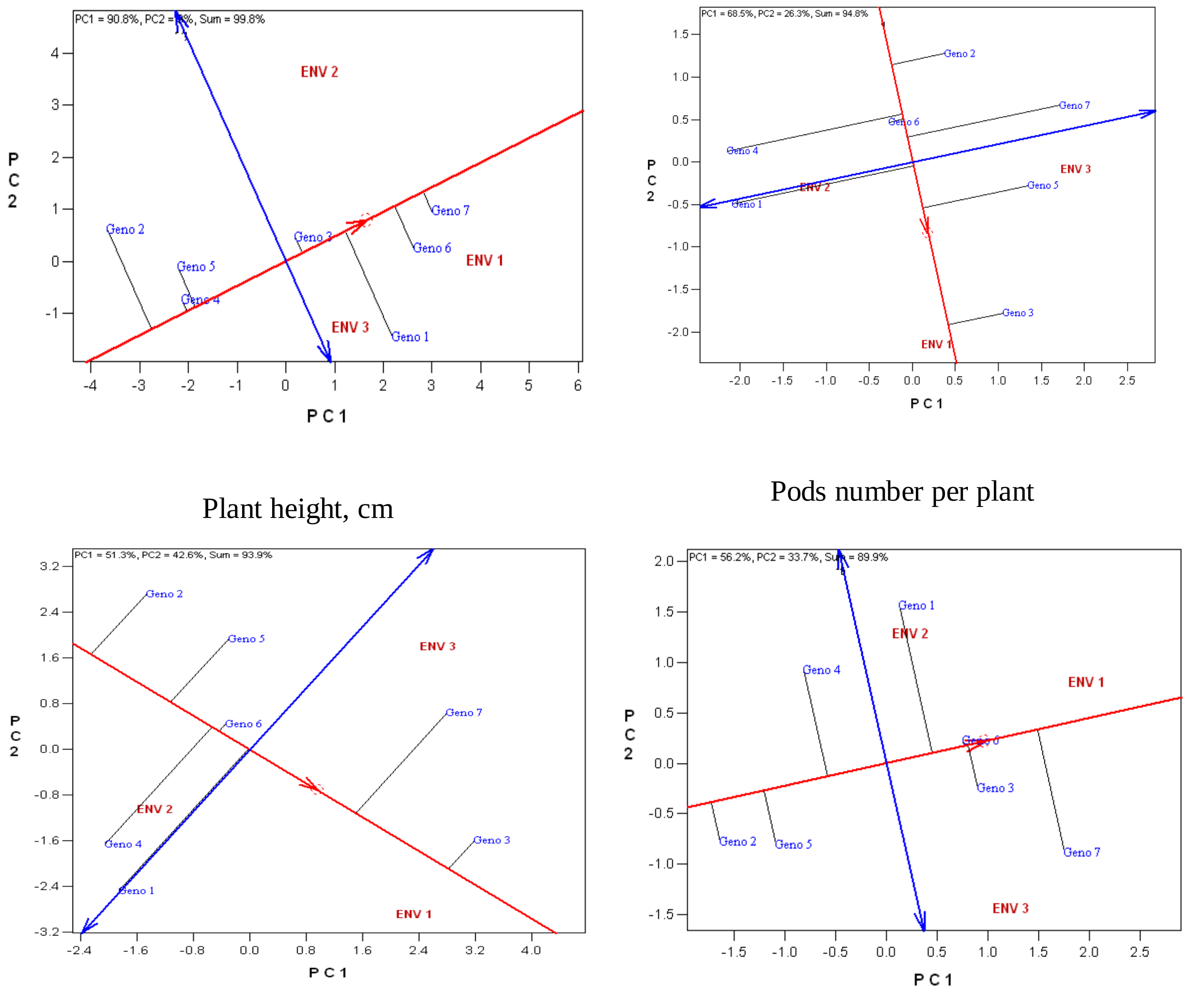


Figure 1. Productivity of the white lupin varieties according to the studied traits

A - plant height (cm), B - pods number per plant, C - seeds number per plant, D - seeds weight per plant



Plant height, cm

Pods number per plant

Seeds number per plant

Seeds weight per plant

Figure 2. GGE biplot analysis of traits: plant height (cm), pods number per plant, seeds number per plant, seeds weight per plant

Geno 1 - PI457923, Geno 2 - PI368911, Geno 3 - PI533704, Geno 4 - PI457938, Geno 5 - KALI, Geno 6 - Zuter, Geno 7 - Lucky801