**RESEARCH ARTICLE**

**Natalia Georgieva [1]**
**Valentin Kosev [2]**

# Estimation of the environment as background for selection on adaptivity in white lupine breeding

***Authors' addresses:***
[1] Department of Technology and Ecology of Forage Crops, Institute of Forage Crops, Pleven, Bulgaria
[2] Department of Breeding of Forage Crops, Institute of Forage Crops, Pleven, Bulgaria

***Correspondence:***
*Natalia Georgieva*
Department of Technology and Ecology of Forage Crops, Institute of Forage Crops, Pleven, Bulgaria
e-mail imnatalia@abv.bg

***Article info:***
*Received:* 6 August 2017
*Accepted:* 7 November 2017

**ABSTRACT**
A representative evaluation of the breeding value of genotypes in the development of varieties with general and specific adaptability is possible using special features of nature background, which often do not coincide in informativity regarding the different parameters and indicators. The study was conducted in 2014 – 2016 to determine the reaction of white lupine varieties under different environmental conditions for the needs of adaptability selection. It was made an estimation of the adaptive properties of ten varieties (Astra, Nahrquell, Ascar, BGR 6305, Shienfield Gard, WAT, Kijewskij Mutant, Hetman, Start, Amiga) on basic quantitative traits was conducted. Genotypes with high general and specific adaptive ability, relative stability and selective value in grain productivity direction were determined. For all the investigated traits, the interaction genotype-environment was significant. With high selective value and level of the trait was variety Shienfield Gard regarding the number of pods, mass of 1000 seeds and seed weight per plant. Kijewskij Mutant and Shienfield Gard, followed by Ascar, had a high index of homeostasis and stability of the studied traits. Varieties Kijewskij Mutant, Ascar and Shienfield Gard represented a breeding interest in terms of the studied traits and may be included in future hybridization schemes for the development of stable and high-yielding white lupine varieties.

**Key words:** adaptivity, breeding, white lupine, background of selection

## Introduction

Lupin, an annual or perennial legume plant belonging to family Fabaceae, is one of the oldest cultures. It is a major food legume in the Old World (Europe) and has a long history of cultivation in the countries of Mediterranean region (Kurlovich, 2002; El-Harty et al., 2016). The lupines can grow under environmental and edaphic conditions that are not tolerated by other crops. There is a large genetic diversity in morphological and agronomic characteristics in *Lupinus albus* as a result of both natural and human selection (Jansen, 2006).

Increasing the productive potential of cultivars has always been and remains an important foundation in selection programs. Modern varieties should not only be high-productive and providing quality production but also to be stable to unfavorable environmental factors. Varieties are required to be broadly adaptive and highly homeostatic (Sterbakov, 1981; Caliskan et al., 2013; Dyckova et al., 2015).

Seed productiveness is an important trait for legume crops because it is an important protein source. In Europe, it is considered that the protein-riched forages and having considerable meaning in animal feeding could replace the soybean because Europe has long been deficient in protein-rich feedstuff and has relied heavily on soybean meal and other oil seed plants (Tan et al., 2012).

Only high adaptability of the variety (due to the homeostasis of its genotype) can provide yield stability under different environmental conditions. Breeding of increased homeostasis is of particular importance in areas characterized by insufficient atmospheric and soil humidity. The breeding direction of resistance to the unfavourable factors of the environment implies a comprehensive assessment of the breeding source material (Zikin et al., 2011).

A representative evaluation of the breeding estimation of genotypes in development of varieties with general and specific adaptability is possible using special features of nature background, which often do not coincide in informativity regarding the different features and indicators (potential productivity, environmental sustainability, etc.) (Zharkova et al., 2009).

In order to assess a cultivar in terms of its compliance with the growing conditions and the immediate response and reply to specific environmental conditions, it is proposed to use parameters and characteristics such as plasticity and stability of varieties, which are a measure of ontogenetic adaptability and homeostatistics of plants (Potanin et al., 2014). Collection, study and use of an appropriate, genetically diverse and with different ecologically-geographic origin source material is a defining precondition for the breeding success. (Valcheva & Vulchev, 2008; Khaidizar et al., 2012).

The purpose of this study was to determine the reaction of white lupine varieties under different environmental conditions for the needs of adaptability selection.

## Materials and Methods

The field experiment was conducted at the Institute of Forage Crops (Pleven) during the period 2014 – 2016. Objects of the study were 10 varieties of white lupine (*Lupine albus* L.): Astra, Nahrquell, Ascar, BGR 6305, Shienfield Gard, WAT, Kijewskij Mutant, Hetman, Start, Amiga. The sowing was carried out in the third decade of March, with a rate of 50 seeds per m2. The varieties were grown in a field for organic production (without the use of fertilizers and pesticides) after a two-year conversion period. A randomized block method was used, with three replications. Each unit plot (5.50 m width × 2 m length) included 12 rows, at a distance of 50 cm apart. At the maturity phase, the following traits were reported: plant height (cm), number of pods per plant, number of seeds per plant, 1000 seeds mass (g), seed weight per plant (g). The data obtained for each trait was processed by two-factor dispersion analysis (ANOVA) to determine the effect of factors – environment, genotype, genotype-environment interaction. The estimation of the ecological stability of the varieties was done by regression analysis, according to Finlay and Wilkinson (1963). The study years were used as environmental conditions.

General adaptive ability (GAA), specific adaptive ability (SAA), relative stability of the trait (Sg, %), criterion for assessing the ability of the genotype to react to the environment (G×E)gi and selective value of genotype (SVG) were calculated according the method of Kilchevskii & Khotilova (1985a; 1985b); stress resistance (SR) – according to the method of Rossielle & Hamblin (1981); homeostatistics (Hom) – according to Hangildin (1984); and indicator for the stability level of variety (SV) (Nettevich et al., 1985; Nettevich, 2001).

Various aspects of the interaction genotype-environment were analyzed by calculating several of the most common parameters and indices for estimation and analysis on that interaction grouped and designated as follows: heterogeneity variance (HV) (non-crossover interaction), variance of incomplete correlation (IC) (crossover interaction), interaction of the genotype with the environment (GE) according to Muir et al. (1992).

In the processing of experimental data was used the software product MS Excel (2003) and the program Genes 2009.7.0 (Cruz, 2009).

## Results

Growth conditions had a significant impact on the phenotypic manifestation of the studied traits (Table 1). This influence was more pronounced than that of genotypes for all indicators. A significant genotype-environment interaction was established, requiring a more detailed analysis of the observed interaction.

The analysis genotype × environment interaction (Table 2) showed the lowest values of variety × year interactions in Hetman, Kijewskij Mutant, BGR 6305, Ascar and Start, where the productivity performances were affected in a lesser extent by the climate condition variability. The high values of genotype × environment interaction were associated with a higher instability of this trait.

When analyzing the seed weight per plant, 99.91% of the genotype × environment interaction was due to variances in heterogeneity, and 0.09% - of the imperfect correlations. Therefore, in assessing the stability of this trait in the studied varieties, non-crossover interactions can be effectively used.

According to sum squares of heterogeneous variances (HV) of Muir et al. (1992) procedure, genotypes Shienfield Gard and WAT were the most stable genotypes based on the sum square of heterogeneous variances. The high percentage of HV indicated that the selection on a given trait in a growing environment will accurately predict the performance of

**Table 1**. *Dispersion analysis of the quantitative traits in white lupine varieties.*

| Source of variation | DF | Mean squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant height | % from total | Pods per plant | % from total | Seeds per plant | % from total | Mass of 1000 seeds | % from total | Seed weight per plant | % from total |
| Year | 2 | 17292.2536** | 96.18 | 1413.1914** | 95.96 | 25596.4865** | 95.58 | 42374.5061** | 79.35 | 958.7312** | 89.87 |
| Replication×Year | 6 | 0.6978 | | 0.9066 | | 4.2464 | | 9.6240 | | 0.1508 | 9.32 |
| Cultivars | 9 | 647.1118** | 3.60 | 52.4328** | 3.56 | 1 012.4811** | 3.78 | 9,914.3162** | 18.56 | 99.4364** | |
| Cultivars×Year | 18 | 39.5985** | 0.22 | 7.1382** | 0.48 | 172.5046** | 0.64 | 1116.3164** | 2.09 | 8.6670** | 0.81 |
| Error | 54 | 2.8866 | | 0.5463 | | 8.7656 | | 91.1809 | | 0.3995 | |
| Corrected Total | 89 | | | | | | | | | | |

**, * significance at level 0.05, 0.01

**Table 2**. *Heterogeneous variance (by Muir, 1992) regarding the trait seed weight per plant.*

| Variety | SS (HV, %) | (%) | SS(IC) | (%) | SS(GE) | (%) |
|---|---|---|---|---|---|---|
| Astra | 4.736 | 8.11 | 0.003 | 6.71 | 4.739 | 8.11 |
| Nahrquell | 4.251 | 7.28 | 0.002 | 4.31 | 4.253 | 7.28 |
| Ascar | 3.279 | 5.62 | 0.002 | 4.77 | 3.282 | 5.62 |
| BGR 6305 | 3.240 | 5.55 | 0.003 | 5.96 | 3.243 | 5.55 |
| Shienfield Gard | 18.621 | 31.90 | 0.008 | 16.50 | 18.630 | 31.89 |
| WAT | 10.390 | 17.80 | 0.001 | 2.73 | 10.391 | 17.79 |
| Kijewskij Mutant | 3.053 | 5.23 | 0.003 | 5.75 | 3.056 | 5.23 |
| Hetman | 2.967 | 5.08 | 0.003 | 5.73 | 2.970 | 5.08 |
| Start | 3.648 | 6.25 | 0.016 | 17.05 | 3.657 | 6.26 |
| Amiga | 4.180 | 7.16 | 0.051 | 30.49 | 4.196 | 7.18 |
| Total | 58.366 | 99.91 | 0.051 | 0.09 | 58.418 | 100 |

HV – heterogeneity variance (non-crossover interaction); IC – variance of incomplete correlation (crossover interaction); GE– interaction of the genotype with the environment.

efficiency in other environments and that the assessment of stability in these genotypes can be effectively used.

Considering the imperfect correlations (IC), it should be noted that varieties WAT, Nahrquell and Ascar were determined to be the most stable, indicating the greater constancy of seed weight per plant during the experimental period. For this trait, variance heterogeneity has major contributions (99.91%) to achieving the variability due to genotype × environment interaction, so it can be used effectively in assessing the stability in this indicator.

The low value of the heterogeneous variance (HV) in Ascar, BGR 6305, Kijewskij Mutant, Hetman and Start was associated with a lower deviation of the average value of the trait in these varieties for each year of the survey. The lesser numerical basis of the percentage of HV in them was an indication that the rearrange of varieties was the main cause of the genotype-environment interaction on the given trait.

The strong variation of a given trait and a low level of interaction with conditions (low level of "GE") in the varieties implied a nonlinear interaction that was valid for varieties showing disagreements of parameter values from one group to another.

Selected varieties reacted differently to the changing environmental conditions and this response was specific to each trait. The data presented in Table 3 demonstrated a well-expressed polymorphism between the white lupine varieties in regard to the studied parameters. This allowed prospective genotypes to be selected on the base of certain traits for inclusion in the breeding process. According to the obtained values for plant height and regression coefficient (bi-FW), varieties Kijewskij Mutant and Ascar can be determined as the closest to the ideal genotype followed BGR 6305. Varieties Astra, Start and Amiga were stable (bi <1), but their plants were lower and did not exceed 88 cm. The highest general adaptive ability was found in Ascar, Shienfield Gard and Nahrquell, and the specific adaptive ability varied from 0.01 (WAT and Start) to 5.14 (Astra). The indicator Sgi (%) for the relative stability of the variety was very high only at Astra, which showed the greatest variability on this trait. The complex parameter SVG determined as breeding valuable varieties Kijewskij Mutant and Ascar. With respect to the number of pods per plant, the coefficient of regression was statistically significant only at Nahrquell, BGR 6305 and Start. Therefore, the assessment of ecological stability and adaptability was done on the basis of the numerical expressions of the other parameters.

To evaluate the ability of the genotype to interact with different environments was used G×Egi criterion. This parameter was considerably higher at Start (132.92) and Amiga (174.01) compared to other varieties. The relative stability of this trait was within the range of 0.19 (Hetman) to 104.28 (Amiga). Among the white lupine varieties tested, Shienfield Gard and Kijewskij Mutant can be distinguished as such combining high general adaptive ability (5.288; 4.799) with relative stability (1.98; 0.36). On the basis of the indicator selective value, varieties BGR 6305, Shienfield Gard and Kijewskij Mutant were of breeding interest.

By the number of seeds per plant, the bi-FW criterion indicated varieties Astra, Shienfield Gard, Kijewskij Mutant and Amiga as ecologically unstable (bi> 1) but responsive to improving cultivation conditions. Nahrquell, WAT and Start were stable but forming a smaller number of seeds per plant. Plants of Hetman provided a relatively large number of seeds per plant as the coefficient of regression being close to 1 but it was statistically insignificant. Among the group of tested varieties, Kijewskij Mutant and Shienfield Gard were characterized by a very good general adaptive capacity and an average level of relative stability of the genotype (Sgi,%). On this indicator, Hetman, BGR 6305 and Kijewskij Mutant can be considered as breeding valuable.

**Table 3**. *Parameters of stability and adaptability of the studied traits in white lupine varieties.*

| Variety | bi-FW | G×Egi | GAA | SAA | Sgi, % | SVG |
|---|---|---|---|---|---|---|
| **Plant height** | | | | | | |
| Astra | 0.77** | 43.22 | 0.053 | 5.14 | 5.82 | -162.53 |
| Nahrquell | 1.12** | 21.16 | 8.652 | 0.26 | 0.27 | 84.37 |
| Ascar | 1.10** | 20.02 | 10.309 | 0.06 | 0.06 | 95.87 |
| BGR 6305 | 1.09* | 8.41 | 3.523 | 0.35 | 0.38 | 74.67 |
| Shienfield Gard | 1.14** | 29.63 | 9.951 | 0.40 | 0.41 | 78.75 |
| WAT | 1.03 | 0.46 | 2.012 | 0.01 | 0.01 | 89.90 |
| Kijewskij Mutant | 1.07* | 7.51 | 5.562 | 0.07 | 0.08 | 90.28 |
| Hetman | 1.09* | 5.07 | -2.147 | 1.11 | 1.29 | 31.77 |
| Start | 0.85** | 55.85 | -20.162 | 0.00 | 0.00 | 68.08 |
| Amiga | 0.74** | 97.67 | -17.754 | 1.36 | 1.93 | 4.13 |
| **Pods per plant** | | | | | | |
| Astra | 1.12 | 11.73 | 0.379 | 3.82 | 8.63 | 36.47 |
| Nahrquell | 0.62** | 68.29 | 1.271 | 25.59 | 56.69 | -6.94 |
| Ascar | 0.89 | 63.54 | 2.564 | 14.43 | 31.08 | 17.06 |
| BGR 6305 | 1.14* | 9.08 | 1.484 | 0.25 | 0.55 | 44.84 |
| Shienfield Gard | 1.28 | 36.95 | 5.288 | 0.97 | 1.98 | 47.17 |
| WAT | 0.82 | 8.58 | -0.722 | 3.88 | 8.99 | 35.25 |
| Kijewskij Mutant | 1.21 | 4.36 | 4.799 | 0.18 | 0.36 | 48.31 |
| Hetman | 1.00 | 0.47 | 0.153 | 0.08 | 0.19 | 43.85 |
| Start | 0.74* | 132.92 | -8.998 | 11.47 | 32.90 | 11.52 |
| Amiga | 1.19 | 174.01 | -6.218 | 39.26 | 104.28 | -42.25 |
| **Seeds per plant** | | | | | | |
| Astra | 1.33** | 184.31 | 8.408 | 115.86 | 153.43 | 7.25 |
| Nahrquell | 0.64** | 221.66 | -4.341 | 137.85 | 219.63 | -18.46 |
| Ascar | 0.93* | 71.02 | -0.395 | 23.97 | 35.94 | 52.58 |
| BGR 6305 | 1.03 | 28.23 | -2.487 | 2.38 | 3.69 | 63.21 |
| Shienfield Gard | 1.27** | 61.51 | 9.470 | 32.28 | 42.15 | 57.56 |
| WAT | 0.74** | 106.80 | -6.269 | 69.04 | 113.48 | 20.16 |
| Kijewskij Mutant | 1.21** | 64.87 | 11.483 | 42.30 | 53.82 | 53.67 |
| Hetman | 0.98 | 5.96 | 2.539 | 0.35 | 0.51 | 69.44 |
| Start | 0.65** | 107.04 | -15.301 | 43.42 | 83.82 | 26.22 |
| Amiga | 1.23** | 180.89 | -3.106 | 90.94 | 142.10 | 10.41 |
| **Mass of 1000 seeds** | | | | | | |
| Astra | 1.17** | 71.96 | -31.798 | 54.31 | 23.10 | 210.30 |
| Nahrquell | 0.43** | 579.06 | 8.812 | 397.97 | 144.34 | 93.96 |
| Ascar | 1.17** | 29.73 | 7.948 | 30.82 | 11.21 | 260.78 |
| BGR 6305 | 1.39** | 209.31 | 31.041 | 138.94 | 46.63 | 234.49 |
| Shienfield Gard | 0.83** | 92.97 | 42.108 | 63.18 | 20.44 | 280.16 |
| WAT | 1.42** | 263.65 | 19.092 | 181.19 | 63.35 | 203.25 |
| Kijewskij Mutant | 1.39** | 214.35 | 22.991 | 146.86 | 50.66 | 222.83 |
| Hetman | 0.95* | -14.68 | -3.582 | 2.19 | 0.83 | 262.32 |
| Start | -0.15** | 2069.83 | -51.027 | 1343.32 | 622.26 | -397.62 |
| Amiga | 1.39** | 368.16 | -45.584 | 247.83 | 111.98 | 108.14 |
| **Seed weight per plant** | | | | | | |
| Astra | 1.23 | 3.01 | -0.384 | 0.93 | 2.80 | 28.57 |
| Nahrquell | 0.79 | 23.96 | 1.495 | 7.11 | 20.28 | -0.41 |
| Ascar | 0.89 | 28.02 | 1.906 | 6.43 | 18.11 | 3.42 |
| BGR 6305 | 1.09 | 4.67 | 0.865 | 0.17 | 0.49 | 33.62 |
| Shienfield Gard | 1.71 | 18.45 | 6.682 | 5.72 | 14.20 | 11.74 |
| WAT | 0.51** | 8.70 | -0.808 | 5.46 | 16.65 | 5.54 |
| Kijewskij Mutant | 1.06* | 0.65 | 4.763 | 0.46 | 1.21 | 36.04 |
| Hetman | 1.03 | 0.77 | 0.543 | 0.04 | 0.13 | 33.92 |
| Start | 0.87 | 37.33 | -8.129 | 3.11 | 12.20 | 9.97 |
| Amiga | 0.76 | 44.84 | -6.933 | 3.77 | 14.15 | 7.84 |

$b_i$-FW - regression coefficient Finlay and Wilkinson's regression model; (G×E)gi - criterion for estimation of the genotype ability to enter into interaction with environment; GAA - general adaptive ability; SAA - specific adaptive ability; Sgi - relative stability of the genotypes; SVG - selective value of genotype; *,**, Significance at 0.05 and 0.01 probability level.

From the studied genotypes with regard to the stability of 1000 seeds mass, the coefficient of regression was significant, indicating a possible statistical analysis of the stability through the method of Finlay and Wilkinson (1963). Of particular interest were Shienfield Gard (bi = 0.83), Ascar (bi = 1.17) and Hetman (bi = 0.95), whose seed mass was over 279 g.

These varieties were suitable for growing in a wide range of environmental conditions. With the heaviest seed was distinguished Nahrquell, which was not responsive to better growing conditions. BGR 6305 also had high values of the trait, it was ecologically unstable but had a high general adaptive ability and can provide high yields under proper growing. Among the group of studied varieties cannot be identified such that combine high general adaptive ability and low variability of the trait. Probably this was the result of the different direction of the selection in the breeding of these varieties. A breeding compromise in this respect was Shienfield Gard (42.108; 20.44), which was also with a high level of selective value indicator (280.16). Plant productivity was a complex trait most clear expression of which was the seed weight per plant. On this trait among the studied varieties were also found statistically significant differences.

The existence of significance of the regression coefficient (bi) with respect to the seed weight per plant only for a small part of the varieties indicated a presence of a nonlinear type of interaction which excluded the correct use of the regression coefficient (bi). With a dashed line in the middle of Figure 1, the average reaction of the investigated population was represented. With the highest regression coefficient (bi=1.71) was the variety Shienfield Gard, which regression curve had the highest inclination to the abscissa but also had a high productivity (19.52 g).

With the lowest regression coefficient (bi = 0.51) and the smallest slope of the regression line, and low-productive was variety WAT. Varieties with regression lines located closest to the population average (the dashed line) were characterized by the highest degree of plasticity. The geometric interpretation of the coefficient of regression bi was that it represented the angular coefficient of the regression line. It was clear that with the growth of bi, the variety will be more responsive to the environmental conditions. In most cases, the bi coefficient was positive, but it can also get a negative value, such as lowering productivity as a result of disease attack, plant lodging and so on. The analysis of the obtained values of the general adaptive ability and the relative stability of the genotype gave reason to suggest that Kijewskij Mutant exhibited better relative stability of the trait and in a specific way responded to changes in the external environment (Figure 2). The selective value of genotype indicator characterized varieties Kijewskij Mutant (36.04), Hetman (33.92) and BGR 6305 (33.62) as the most

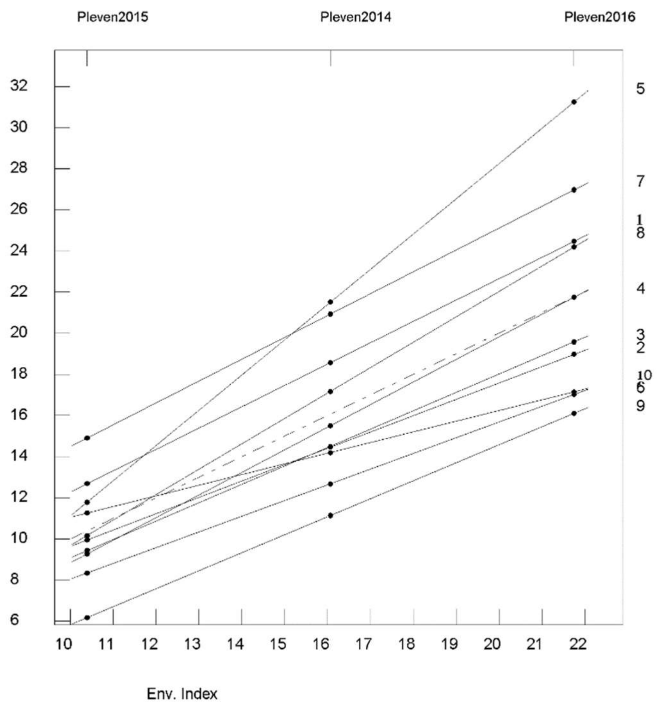


**Figure 1.** *Regression lines showing the interaction between varieties' productivity and the environmental index, based on Finlay & Wilkinson (1963): 1. Astra, 2.Nahrquell, 3.Ascar, 4. BGR 6305, 5. Shienfield Gard, 6.WAT, 7.Kijewskij Mutant, 8. Hetman, 9. Start, 10. Amiga.*

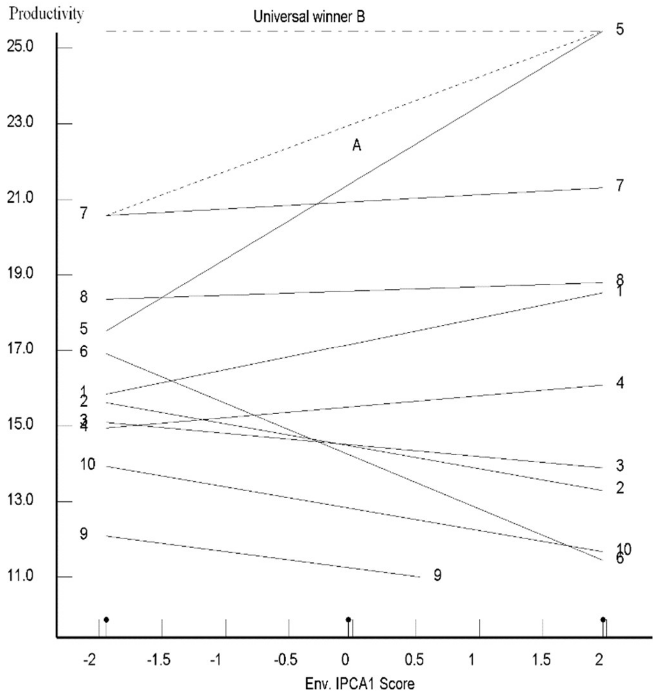


**Figure 2.** *Environmental IPCA1 (first principal component of the interaction) score for productivity in white lupine varieties: 1. Astra, 2.Nahrquell, 3.Ascar, 4. BGR 6305, 5. Shienfield Gard, 6.WAT, 7.Kijewskij Mutant, 8. Hetman, 9. Start, 10. Amiga.*

valuable in terms of the seed weight per plant. The conducted analysis showed that the studied varieties reacted differently to changes in the growing environment and realized a different productive potential expressed by the indicator of the selective value of genotype (SVG). Therefore, in order to obtain highly-productive and stable genotypes, it is necessary to recombine the genetic systems on these traits and on this basis to lead a targeted selection in the breeding process. The results obtained for the parameters of stress resistance, homeostatistics and level of stability of the variety (Table 4) showed Astra, Ascar and Shienfield Gard in terms of plant height exhibited better resistance to the impact of stress factors than other varieties. The varieties had close values regarding their resistance against stress for the number of pods per plant, but with higher homeostasis at Astra and Kijewskij Mutant. Varieties Nahrquell and Start tolerated a minimal adverse impact of the environment regarding the number of pods per plant, and were with relatively low variability (high homeostatistics) on these traits. Differences in homeostasis between varieties by the number of seeds per plant determined the varieties Nahrquell, WAT, Start and Ascar as the most stable. According to the index for stability level, varieties Astra, Shienfield Gard and Kijewskij Mutant were able to minimize the consequences of the adverse impact of environment, as evidenced by the higher stability index.

Regarding the trait of the mass of 1000 seeds, Shienfield Gard and Start were of interest because of the combination of high plant productivity and high stability index.

The manifestations of homeostasis of the varieties in relation to the weight of the seeds per plant showed that Kijewskij Mutant, Shienfield Gard, Astra and Hetman were best adapted to the specific environmental conditions. These varieties were characterized by high productivity and good levels of stability.

The analysis of the values of the particular parameters from the different tables through the approaches applied to the study revealed that the data for the relevant varieties were diverging, making it difficult to formulate the correct conclusions about their behavior.

## Discussion

An important principle in the strategy of adaptive breeding was the orientation not to the potential productivity, but to the real productivity (Kadermas, 2014). In a number of breeding programs, a task is being set to obtain genotypes with high potential productivity. Its manifestation required the creation of an increased agro background, which would be atypical for many areas.

Zolotareva (2012) considered that relative adaptive ability was determined by the degree of stability and effectiveness of genotype in different environments. Genes, controlling the plant productivity were distinguished from genes, controlling the stability. In this way, varieties with high general adaptive capacity can be chosen in the path of a favorable combination of the two parameters - high stability and productivity.

According to many researchers, the weight of 1000 seeds is a key parameter of the seed fullness, and it is one of the most stable structural elements of yield (Garis, 2008). Aliu et al. (2016) reported an average level of grain yield and weight of 1000 seeds and high variation for biological yield and shoot biomass in chickpeas. El-Harty et al. (2016) and Annicchiarico et al. (2010) considered that genotypes that were superior in one of the yield components could be involved in a breeding program to create high-yielding varieties.

In their studies, Tsenov et al. (2016) indicated that low values of one parameter for the same varieties were associated with very high values of other parameters and indicators. This fact showed that these varieties demonstrated very complex interaction with the environment and their response to changes in it can not be predicted.

According to Fan et al. (2007), varieties with high adaptability interacted linearly with environmental conditions. Varieties with very high stability were generally not high-productive and therefore special methods and approaches need to be used in the breeding process to combine high productivity with high stability.

## Conclusions

An estimation of the adaptive properties of white lupine varieties on basic quantitative traits was conducted.

Genotypes with high general and specific adaptive ability, relative stability and selective value in grain productivity direction were determined. For all the investigated traits, the interaction genotype-environment was significant.

With high selective value and level of the trait were the following varieties: Kijewskij Mutant in regard to plant height, number of pods and seeds per plant, seed weight of plant; Askar in plant height and mass of 1000 seeds; Shienfield Gard in number of pods, mass of 1000 seeds and seed weight per plant. With a high index of homeostasis and stability of the studied traits were varieties Kijewskij Mutant and Shienfield Gard, followed by Ascar.

Varieties Kijewskij Mutant, Ascar and Shienfield Gard represented a breeding interest in terms of the studied traits and therefore may be included in future hybridization schemes for the development of stable and high-yielding white lupine varieties.

**Table 4**. *Parameters of homeostatistics in white lupine cultivars.*

| Variety | Parameters | | | | | |
|---|---|---|---|---|---|---|
| | $X_{aver}$ (2014-2016) | $X_{opt}$ | $X_{lim}$ | SR | $H_{om}$ | SV |
| | | | **Plant height** | | | |
| Astra | 88.37bc | 123.32 | 52.30 | -71.02 | 6.58 | 331 |
| Nahrquell | 96.97cd | 140.58 | 48.31 | -92.27 | 4.23 | 295 |
| Ascar | 98.63d | 142.34 | 50.25 | -92.09 | 4.63 | 328 |
| BGR 6305 | 91.84bcd | 133.68 | 44.83 | -88.85 | 3.98 | 253 |
| Shienfield Gard | 98.27d | 142.62 | 48.70 | -93.92 | 4.39 | 314 |
| WAT | 90.33bcd | 130.63 | 45.57 | -85.06 | 4.31 | 258 |
| Kijewskij Mutant | 93.88bcd | 135.86 | 47.18 | -88.68 | 4.11 | 265 |
| Hetman | 86.17b | 126.77 | 39.75 | -87.02 | 3.32 | 193 |
| Start | 68.16a | 99.97 | 31.96 | -68.01 | 3.62 | 129 |
| Amiga | 70.57a | 100.93 | 37.52 | -63.41 | 5.09 | 178 |
| | | | **Pods per plant** | | | |
| Astra | 15.26cd | 24.75 | 9.35 | -15.40 | 1.93 | 5 |
| Nahrquell | 10.68a | 15.73 | 7.25 | -8.48 | 2.69 | 3 |
| Ascar | 11.25ab | 18.80 | 6.65 | -12.15 | 1.78 | 3 |
| BGR 6305 | 12.52abc | 22.38 | 6.75 | -15.63 | 1.23 | 3 |
| Shienfield Gard | 14.43cd | 25.50 | 7.90 | -17.60 | 1.14 | 3 |
| WAT | 11.18ab | 18.10 | 6.86 | -11.24 | 1.81 | 3 |
| Kijewskij Mutant | 16.75d | 27.00 | 10.33 | -16.67 | 1.61 | 5 |
| Hetman | 13.76bcd | 22.17 | 8.50 | -13.67 | 1.44 | 3 |
| Start | 11.24ab | 17.40 | 7.25 | -10.15 | 2.57 | 3 |
| Amiga | 14.06bcd | 24.25 | 7.97 | -16.28 | 1.54 | 4 |
| | | | **Seeds per plant** | | | |
| Astra | 75.51b | 113.75 | 36.00 | -77.75 | 1.86 | 106 |
| Nahrquell | 62.77ab | 69.18 | 31.58 | -37.60 | 4.07 | 84 |
| Ascar | 66.71ab | 82.80 | 28.70 | -54.10 | 3.12 | 94 |
| BGR 6305 | 64.62ab | 85.45 | 25.17 | -60.28 | 2.00 | 68 |
| Shienfield Gard | 76.58b | 107.63 | 33.30 | -74.33 | 1.77 | 92 |
| WAT | 60.84ab | 72.10 | 29.07 | -43.03 | 3.50 | 79 |
| Kijewskij Mutant | 78.59b | 110.80 | 40.37 | -70.43 | 2.04 | 106 |
| Hetman | 69.65ab | 93.50 | 36.50 | -57.00 | 1.81 | 70 |
| Start | 51.80a | 65.50 | 27.67 | -37.83 | 3.31 | 57 |
| Amiga | 64.00ab | 100.50 | 28.65 | -71.85 | 1.58 | 72 |
| | | | **Mass of 1000 seeds** | | | |
| Astra | 241.00ab | 244.29 | 195.43 | -48.86 | 73.74 | 10484 |
| Nahrquell | 308.32de | 343.34 | 274.67 | -68.67 | 49.16 | 8867 |
| Ascar | 286.98cd | 326.01 | 237.75 | -88.26 | 21.14 | 5262 |
| BGR 6305 | 307.87de | 356.57 | 252.02 | -104.55 | 17.35 | 5520 |
| Shienfield Gard | 336.03e | 363.75 | 291.00 | -72.75 | 49.80 | 11677 |
| WAT | 293.15cd | 344.60 | 237.70 | -106.90 | 15.04 | 4683 |
| Kijewskij Mutant | 298.59de | 347.88 | 243.50 | -104.38 | 16.37 | 5051 |
| Hetman | 279.68bcd | 307.67 | 236.16 | -71.51 | 30.60 | 5953 |
| Start | 254.61abc | 298.07 | 238.45 | -59.62 | 195.59 | 27125 |
| Amiga | 218.86a | 274.5339 | 169.80 | -104.73 | 8.73 | 2032 |
| | | | **Seed weight per plant** | | | |
| Astra | 15.05c | 22.23 | 10.18 | -12.05 | 2.96 | 6 |
| Nahrquell | 13.58bc | 18.97 | 9.67 | -9.30 | 3.10 | 4 |
| Ascar | 13.53bc | 19.57 | 9.35 | -10.22 | 3.30 | 5 |
| BGR 6305 | 13.91bc | 21.54 | 8.98 | -12.56 | 1.79 | 3 |
| Shienfield Gard | 19.27d | 31.32 | 11.78 | -19.54 | 1.48 | 6 |
| WAT | 13.23bc | 17.14 | 10.02 | -7.12 | 4.36 | 4 |
| Kijewskij Mutant | 19.52d | 26.98 | 14.04 | -12.94 | 3.17 | 8 |
| Hetman | 15.78c | 22.09 | 11.23 | -10.86 | 2.24 | 4 |
| Start | 9.92a | 15.61 | 6.29 | -9.32 | 1.93 | 2 |
| Amiga | 11.62ab | 17.07 | 7.905 | -9.17 | 2.69 | 3 |

## References

Aliu S, Kaul HP, Rusinovci I, Shala-Mayrhofer V, Fetahu S, Zeka D. 2016. Genetic diversity for some nutritive traits of chickpea (*Cicer arietinum* L.) from different regions in Kosova. Turk J Field Crops, 21(1):156-161.

Caliskan S, Erdogan C, Arslan M, Caliskan ME. 2013. Comparison of organic and traditional production systems in chickpea (*Cicer arietinium* L.). Turk J Field Crops 18(1):34-29.

Cruz CD. 2009. Programa Genes: Biometria. Federal University of Viçosa, Brazil.

Dyckova TA, Rekashus ES, Prudnikov AD, Konova AM, Kurdakova OV. 2015. Ecological plasticity and stability of the red clover samples in the Smolensk region. International Research Journal, 11(6):56-60.

El-Harty E, Ashrie A, Ammar M, Alghamdi S. 2016. Genetic variation among egyptian white lupin (*Lupinus albus* L.) genotypes. Turk J Field Crops, 21(1):148-155.

Fan XM, Kang MS, Chen H, Zhang Y, Tan J, Xu C. 2007. Yield stability of maize hybrids evaluated in multi - environment traits in Yunnan, China. Agron J, 99(1):220-228.

Finlay KW, Wilkinson GN. 1963. The analysis of adaptation in plant breeding programme. Austral J Agric Res 14(6):747-760.

Garis DV. 2008. Selection and genetic evaluation of varieties and hybrids of barley in the environment of Pritish. Dissertation, Omsk, p. 16.

Hangildin BB. 1984. The homeostasis problem in the genetic-breeding researches. Genetic-Cytological Aspects in the Selection of Agricultural Crops, 1, 67-76.

Jansen PC. M. 2006. *Lupinus albus* (L.) Record from Protabase. In: Brink M. & Belay G. (eds.), Plant Resources of Tropical Africa, PROTA, Wageningen, Netherlands.

Kadermas IG. 2014. Formation of photosynthetic and symbiotic apparatus of plants and their contribution to the increase in pea productivity (*Pisum sativum* L.). Dissertation, Omsk, 2014.

Khaidizar MI, Haliloglu K, Elkoca E, Aydin M, Kantar F. 2012. Genetic diversity of common bean (Phaseolus vulgaris L.) landraces grown in northeast Anatolia of Turkey assessed with simple sequence repeat markers. Turk J Field Crops 17(2):145-150.

Kilchevskii AV, Khotilova LV. 1985a. A method for assessing adaptive capacity and stability of genotypes differentiating the ability of the environment. Genetika, 19(9):1491-1498.

Kilchevskii AV, Khotilova LV. 1985b. A method for assessing genotype adaptive capacity and stability, the environment differentiating ability. Report 1. Validation of the method. Genetika. 21(9):1481-1490.

Kurlovich BS. 2002. Lupins: Geography, Classification, Genetic Resources and Breeding., Publishing house Intan, Saint Petersburg, Russia.

Muir W, Nyquist WE, Xu S. 1992. Alternative partitioning of the genotype-by-environment interaction. Theor Appl Genet 84(1-2):193-200.

Nettevich ED, Morgunov AI, Maksimenko MI. 1985. Improvement of efficient selection of spring wheat for stability of harvest yield and grain quality. Agric Scie, 1:66-73.

Nettevich ED. 2001. Potential productivity recommended for spring wheat and barley cultivation in the Central district of the Russian Federation and its realization in conditions of production. Reports of Russian Academy of Agrarian Sciences, 3:50-55.

Potanin WG, Aleinikov AF, Stepochkin PI. 2014. New approach to estimation of the ecological plasticity of plant varieties. Russian Journal of Genetics: Applied Research, 18(3):548-552.

Sterbakov VK. 1981. Evolutional-genetic theory of biological systems: homeostasis, meaning for the development of breeding theory. Agric Sci, 3:56-67.

Tan M, Koc A, Dumlu Gul Z. 2012. Morphological characteristics and seed yield of East Anatolian local forage pea *(Pisum sativum ssp. arvense* L.) ecotypes. Turk J Field Crops, 17(1):24-30.

Tsenov N, Atanasova D, Gubatov T. 2016. Influence of environments on the amount and stability of grain yield in the modern winter wheat cultivars II. Evaluation of each variety. EKIN, 2(1):57-73.

Valcheva D, Vulchev D. 2008. Studying on fenotypic diversity of introduced winter malting barley lines. Conference of Union of Scientists, 5-6 June, 2008, Stara Zagora.

Zharkova SV, Dobrutskaya EG, Sirota SM, Bakulina VA. 2009. Wide environmental and geographic testing as a means of determining the informativeness of the environment for assessing the adaptability of onions. Journal of Altainian Agrarian University, 11(61):28-32.

Zikin VA, Belan IA, Usov VS, Kiraev RS, Chanishev IO. 2011. Ecological plasticity of agricultural plants. Ufa, 2011, p. 97.

Zolotareva SV. 2012. Evaluation and creation of starting material for pea selection in the central part of non-chernozem regions of Russia. Dissertation, Moskow.