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Variability, correlation and path analysis in *Lupinus albus* L. genotypes under South Bulgarian conditions

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Abstract

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Lupine is rich protein crop with many uses – except for fodder, this crop can find place in the food and cosmetics industries, and its beautiful flowers are also identified as an ornamental plant. The aim of the research was to study the heritability, simple correlations and to determine direct and indirect contributions of certain traits to grain yield in white lupin accessions. Determination of the relationship between the grain yield and its indices and some biological traits and its impact of the grain yield of the *Lupinus albus* L. genotypes will be determined by correlation and path coefficient analyses. The genetic and phenotypic coefficient of variation and broad-sense heritability were estimated for all studied traits. The estimated heritability and expected genetic advance were high for the traits – plant height, height to the first pod, number of pods per plant, number of grains per plant, mass of grains per plant, 100 grains mass suggesting that these traits were more useful for varietal improvement program. The genetic variability revealed highly significant difference for all the characters. The grain yield was significantly correlated with followed traits – number of main branches, number of pods per plant, number of grains per plant and number of grains per pod. Path coefficient analysis revealed that number of grains per plant, number of pods per plant and 100 grains mass had the highest positive direct effects on grain yield. Several accessions were selected possessing extreme values of some of the traits. The accession with number 57113 was the earliest maturing genotype with tall plants. The number of pods and grains per plant, number of grains per pod and 100 grains mass can be used as selection criteria for improvement grain yield from *Lupinus albus* in South Bulgarian region.

Keywords: lupinus; genetic variability; heritability; correlation; direct and indirect effects

Introduction

Large genetic diversity exists in morphological and agronomic traits in *Lupinus albus* (Christiansen et al., 2000; Mülayim et al., 2002; Jansen, 2006). Understanding crop genetics and the extent of genetic variation in seed yield components is important for future improvement of white lupin and efficient use of its genetic resources. Under good soil and climatic conditions, white lupine is able to form grain yield of about 4000 kg ha^{-1}, the content of protein in grains varies in the range 38-43%. Its cultivation is characterized by relatively low energy intensity, unpretentiousness to soil fertility and high nitrogen-fixing ability (Muraveev et al., 2012; Mulayim et al., 2002).

The knowledge about association between grain yield and yield components facilitates the choice of suitable breeding method to be applied for improving the crops. Path analysis has been used by plant breeders to assist for identifying useful selectable traits (Dewey & Lu, 1959). According to El-Harty et al. (2016) and Annicchiarico et al. (2010) genotypes that were superior in one of the yield components can be involved in breeding programs for new varieties development. According to Georgieva & Kosev (2018) the hightest positive correlations among the agronomic traits in white lupin were between number of pods per plant and seed weight per plant; plant height with pod stem length and pod length; seed weight per plant and number of pods per plant. Based on the trait associations it can be concluded that lupin breeders should pay attention to the traits such as pod length, number of seeds per plant and 1000 seeds mass when selecting high-yielding genotypes.

Julier et al. (1995) reported for high heritability of white lupin accessions in respect to thousand grains mass as the yield component. Mohammadi & Pourdad (2009) and Hefny (2013) have reported high values of heritability for plant height, seed yield per plant and 1000 seed weight. High heritability alone does not generally guarantee a large enough gain to make sufficient improvement through selection in advance generations unless accompanied by a substantial amount of genetic advance (Bhargava et al., 2003).

Collecting, exploring and using a suitable, genetically diverse source material with different ecological-geographical origin was a determining prerequisite for the breeding success (Khaidizar et al., 2012). The main genetic and breeding problems were related to increasing productivity and improving grain quality, some morphological, biological and physiological traits and properties of culture (Caliskan et al., 2013). The solution of these problems was related to the necessity of applying complicated genetic and mathematical-statistical methods and conducting systematic researches and analysis of the main selective traits of the materials in the work collection (Ayan et al., 2012). The knowledge of genetic diversity is a useful tool in gene-bank management and breeding experiments like tagging of germplasm, identification and/or elimination of duplicates in the gene stock and establishment of core collections (Aliu et al., 2016).

The aim of the paper was to study the heritability, simple correlations and to determine direct and indirect contributions of certain traits to grain yield in white lupin accessions.

Material and Methods

The experiment was carried out on the experimental field in IRGD – Sadovo on cinnamon forest soil, after a precursor of wheat during the period 2019-2020. Twenty local and introduced lupin genotypes were used for this study. Sowing was made by hand, in optimum sowing time, according to the growing technology. The field experiment was laid out using randomised block design with three replications on 10.0 m^2 (Dimova & Marinkov, 1999).

Ten plants per genotype were rooted out by each replication, from the center of the experimental plot and phenotyped for agronomic traits. Yield components and phenological periods were determined as follow: plant height (cm), height to the first pod (cm), number of main branches, number of pods per plant, number of grains per plant, number of grains per pod, mass of grains per plant (g), 100 grains mass (g), vegetation period (in days) and sowing-beginning of flowering (in days) (Petrova, 2021).

Evaluation of variation components, phenotypic and genotypic variance were evaluated according to Burton & Devane (1953). Genetic advance as a percentage of a mean (GAM) were determined by Johnson et al. (1955). The coefficient of inheritance in a broad sense (Hbs) was calculated using the method proposed by Mahmud & Kramer (1951). By correlation and path coefficient analyses the relationship between the grain yield and its indices were determined as well as the impact of some biological traits on the grain yield. Phenotypic correlations were calculated by phenotypic variances and covariance. Correlation coefficients were established according to Lidansky (1988) as well as path coefficient analysis by Dewey & Lu (1959). All experimental data were processed statistically with using the computer software SPSS for Windows Version 19.0 (IBM SPSS Statistics 19 Product Version: 19.0.0) (IBM, 2019).

Results and Discussion

The range, mean, mean error and genetic parameters of white lupin accessions are given on Table 1. Several accessions were selected possessing extreme values of some of the traits. The accession № 57113 had the tallest plants and the shortest vegetation and sowing-beginning of flowering periods. Two other genotypes (№ 72107 and 6278) had the biggest number of grains and pods per plant and number of grains per pod. Two other accessions (№ 5944 and № 5939) differed from the others possessing big mass of 100 grains.

Heritability and genetic variance of the traits of interest are important genetic parameters to select the best parents (Ubi et al., 2001). The carried out analysis of the variance components on the obtained data revealed that the phenotypic variance was relatively higher than the genetic variance for all morphological and biological traits (Table 1). One possible explanation could be a larger environmental influence on genotypes during the growing period. This fact provided a good opportunity to improve the traits through phenotypic selection.

The heritability estimates are important genetic parameters that play a significant role in selection of different cowpea genotypes from a population (Manggoel et al., 2012). Broad sense heritability varied from 0.613% to 36.121%. The genetic advance ranged from 0.020 (number of grains per pod) to 20.219 (vegetation period). The estimated broad sense heritability and expected genetic advance were higher for the traits – number of grains per plant (36.121>14.244), number of pods per plant (8.791> 5.765), mass of grains per plant (10.622>5.878) and 100 grains mass (3.748>1.303) suggesting that these were more useful traits for varietal improvement programme. According to Manggoel et al. (2012) and Rashwan (2010), high broadsense heritability values usually indicate the predominance of additive gene action in the expression of the traits. This implies that the traits can be improved through single plant selection. The high values for broad sense heritability will help in transferring the genetic characteristics from the parents to the generation (Rashwan, 2010).

Pearson correlation analysis of vegetation period, sowing-beginning of flowering, grain yield and yield-related traits showed that there was significant correlations among some of the quantitative traits (Table 2). The simple correlations between each pair of phenotypic traits clearly depicted the close association between some of the traits. Selection of associated traits can be used to improve important traits of interest. The analysis of the interrelationship between the studied characteristics shows a strong positive and statistically significant correlation between grain productivity (grain mass/plant) with number of pods per plant (r = 0.972), number of grains per plant (r = 0.967), number of grains per pod (r = 0.815) and number of main branches (r = 0.811) and also between vegetation period and sowing-beginning of flowering (r = 0.746).

There was average and statistically insignificant correlation among plant height and mass of grains per plant (r = 0.630). This might be due to the functional relationship between vegetative growth and yield traits, though some important traits are positively correlated. The positive association between a pair of

Table 1. Distinctive features and genetic parameters of white lupine

Traits	Range	Mean/ Mean error	$g\sigma^2$	$p\sigma^2$	GCV, %	PCV, %	GCV/PCV, %	GA	GAM, %	H^2, %
Plant height, cm	51.57-68.43	59.96±0.03	4.651	286.653	27.852	218.649	0.127	0.567	0.945	1.623
Height to the first pod, cm	22.57-38.00	29.20±0.05	2.774	158.145	30.820	232.721	0.132	0.455	1.558	1.754
Number of productive branches	2.14-4.43	3.24±0.07	0.020	3.262	7.775	100.302	0.077	0.022	0.690	0.613
Number of pods per plant	6.14-15.14	10.84±0.09	1.045	11.887	31.039	104.706	0.296	0.625	5.765	8.791
Number of grains per plant	22.00-64.43	42.85±0.10	24.227	67.071	75.198	125.119	0.601	6.103	14.244	36.121
Number of grains per pod	3.84-5.03	4.59±0.03	0.021	4.615	6.795	100.231	0.068	0.020	0.443	0.455
Mass of grains per plant, g	7.99-22.20	15.54±0.10	1.847	17.388	34.470	105.774	0.326	0.914	5.878	10.622
100 grains mass, g	32.45-40.80	36.57±0.02	1.424	37.994	19.730	101.928	0.194	0.476	1.303	3.748
Vegetation period, days	90.00-99.00	96.00±0.89	0.050	96.050	2.202	96.025	0.023	20.219	0.284	2.293
Sowing-beginning of flowering, days	49.00-54.00	53.00±0.52	0.283	53.28	3.875	53.141	0.073	15.058	28.411	7.292

$g\sigma^2$ – genotypic variance; $p\sigma^2$ – phenotypic variance; PCV – phenotypic coefficient of variance (%); GCV genotypic coefficient of variance (%), GA -genetic advance; GAM – genetic advance as a percentage of the mean (%) and H^2 – broad sense heritability (%)

Table 2. Phenotypic correlation of different characters in lupine

№	Plant height, cm	Height to the first pod, cm	Number of main branches	Number of pods per plant	Number of grains per plant	Number of grains per pod	Mass of grains per plant, g	100 grains mass, g	Sowing-beginning of flowering, days	Vegetation period, days
	1	2	3	4	5	6	7	8	9	10
1	1.000	0.525	0.660*	0.664*	0.613	0.519	0.630	-0.143	-0.430	-0.485
2		1.000	-0.103	-0.220	-0.293	-0.288	-0.242	-0.148	-0.375	-0.495
3			1.000	0.898**	0.876**	0.717*	0.811**	-0.399	-0.232	-0.096
4				1.000	0.977**	0.855**	0.972**	-0.128	-0.082	0.074
5					1.000	0.850**	0.967**	-0.123	-0.211	0.001
6						1.000	0.815**	-0.229	-0.187	0.087
7							1.000	0.072	-0.061	0.116
8								1.000	0.445	0.227
9									1.000	0.746*
10										1.000

*, ** indicates significant at 5 % and 1% level of probability respectively

Table 3. Direct and indirect effects of different characters on grain yield in lupine

	Direct and indirect effect								Total indirect effect	Total phenotypic correlation with mass of grains per plant
	Plant height, cm	Height to the first pod, cm	Number of main branches	Number of grains per plant	Number of grains per pod	100 -grains mass, g	Sowing-beginning of flowering, days	Vegetation period, days		
Plant height, cm	-0.0560	0.1086	0.0299	0.6137	0.0369	-0.0285	-0.0314	-0.0437	0.6188	0.630
Height to the first pod, cm	-0.0294	0.2070	-0.0046	-0.2935	-0.0205	-0.0295	-0.0274	-0.0446	-0.4494	-0.242
Number of main branches	-0.0370	-0.0212	0.0450	0.8769	0.0509	-0.0794	-0.0169	-0.0087	0.7646	0.811**
Number of grains per plant	-0.0343	-0.0607	0.0394	1.0010	0.0603	-0.0244	-0.0154	0.0067	-0.0284	0.967**
Number of grains per pod	-0.0291	-0.0596	0.0323	0.8506	0.0710	-0.0456	-0.0137	0.0078	0.8471	0.815**
100 grains mass, g	0.0080	-0.0306	-0.0180	-0.1227	-0.0163	0.1990	0.0325	0.0204	-0.1470	0.072
Duration of flowering, days	0.0241	-0.0777	-0.0104	-0.2113	-0.0133	0.0887	0.0730	0.0671	-0.1328	-0.061
Vegetation period, days	0.0272	-0.1025	-0.0043	0.0008	0.0062	0.0452	0.0544	0.0900	0.1923	0.116

*, ** – indicatesgnificant at 5 and 1 % level of probability respectively

phenotypic traits indicate that selection of desirable quantitative trait(s) will have simultaneous positive effects on other traits, which would help breeders to improve both characters at the same time.

Negative and statistically insignificant were the dependencies between mass of 100 grains and plant height, height to the first pod, number of main branches, number of pods per plant, number of grains per plant, number of grains per pod and number of grains per pod. These results were in agreement with the results obtained by Georgieva et al. (2018) and Georgieva & Kosev (2018). Selection of parents or genotypes based on such traits is adopted for improvement in lupin.

The direct and indirect contributions of each character as revealed by path coefficient analysis (Table 3) indicated that number of grains per plant (1.0010) had highest direct effect on grain yield per plant followed by height to the first pod (0.2070) and 100 grains mass (0.1990). These direct effects were mainly responsible for significant positive association of these characters with mass of grain per plant. Mass of grains per plant has been found an important factor for yield by Noffsinger et al. (2000) but yield is independent from mass of grains per plant in the experiment of Julier & Huyghe (1993). The number of main branches (0.8769), number of grains per pod (0.8506) and plant height (0.6137) exerted its effect on grain yield through number of grains per plant. The number of pods per plant has had highest direct effect on grain yield per plant and had no indirect effect on it thus this traits was not involved in table 3 which is similar to finding of González-Andrés et al. (2007). Main yield components of white lupin are plant per square meter, number of pods per plant and number of seeds per pod to obtain a high seed number per square meter and seed weight. The number of pods per plant has been revealed an important component for yield and is responsible for more than 90% of yield variance (Shield et al., 1996; Lopez-Bellido et al., 2000; Noffsinger et al., 2000).

Conclusions

Based on the obtained results several accessions were selected possessing extreme values of some of the traits. The genotypes № 72107 and № 57113 had the biggest number of pod and grain per plant and number of grains per pod. Two other accessions (№ 5944 and № 5939) differed from the remaining possessing big mass of 100 grains. The accession № 57113 was the earliest maturing genotype with tall plants. The estimated broad sense heritability and expected genetic advance were higher for some of the traits (number of pods per plant, number of grains per plant, mass of grains per plant and 100 grains mass) suggesting that they are the most useful traits for a varietal improvement programme. A strong positive and statistically significant correlation was established between grain productivity and: number of pods per plant; number of grains per plant, number of grains per pod and number of main branches. The number of grains per plant had the highest direct effect on grain yield per plant followed by 100 grains mass and height to the first pod. Based on findings of the present investigation it could be concluded that the most desirable plant type in lupin should possess bigger number of pods and grains per plant, number of grains per pod and bigger mass of 100 grains.

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