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Analysis of Character Association of Quantitative Traits in Lupinus Species

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Abstract

An evaluation of the agronomic performance of two lupin species (*Lupinus albus* and *Lupinus luteus*) was conducted at the Institute of Forage Crops (Bulgaria) during 2012-2014. The hightest positive correlations among the agronomic traits in white lupin were between number of pods per plant and seed weight per plant (r = 0.956); plant height with pod stem length (r = 0.935) and pod length (r = 0.934); seed weight per plant and number of pods per plant (r = 0.956). In yellow lupin relatively high phenotypic correlations were detected between number of pods per plant and seed weight per plant (r = 0.956); seed weight per plant and number of pods (r = 0.875) and number of seeds per plant (r = 0.927). Collecting data on the mutual relationships among individual yield components and their effect on the yield remains crucial for their optimisation and development of improved lupin genotypes with high quality and stable yields. 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.

Keywords: lupin, quantitative traits, correlation, inheritance

1. Introduction

Lupins have a long history of being used both as ornamental plants in gardens and as an agricultural crop. Four lupin species, *Lupinus angustifolius* L., *Lupinus albus* L., *Lupinus luteus* L. and *Lupinus mutabilis* L., have gained agricultural importance. Focused breeding efforts began in Germany during World War I due to a need for high-protein pulse crops adapted to temperate conditions. Subsequent breeding has concentrated on the introduction of key traits such as early flowering, reduced pod shattering, soft seed and anthracnose disease resistance (Phan et al., 2007). The species are geographically separated in two big groups: 12 species in the Old World and the majority of the genus components in the Americas. Some of them have been cultivated by mankind since a long time, especially *L. albus*, *L. angustifolius* and *L. luteus*, in the Old world, and in the Americas, *L. mutabilis* (Camillo et al., 2006).

The white lupin (*L. albus*) is an annual grain legume of the family Fabaceae. Its large seeds have a high protein (between 35-45%, according to the genotype) and high oil content (between 8-15%), dietary fibre (30%) and contain minimal starch (Lindbeck et al., 1998; Noffsinger et al., 2005). White lupin itself is used as feed for livestock and has established a growing market for human consumption due to the development of low alkaloid varieties with a lack of protease inhibitors (Hamama & Bhardwaj, 2004). In addition, white lupin has become an illuminating model for the study of plant adaptation to extreme phosphorus (P) deficiency (Massonneau et al., 2001; Neumann & Artinoia, 2002; Schulze et al., 2006).

L. luteus is widely distributed across the Mediterranean region, has shallow soil requirements, and cultivated accessions have variable seed yields in Mediterranean environments. In addition, yellow lupin seeds have the highest protein content and twice the cysteine and methionine content of most lupins (Gladstones, 1974; Parra-González et al., 2012). However, despite its highly nutritional qualities, there is a lack of genetic and molecular tools to aid the genetic breeding of this species (Berville et al., 2003; Glencross et al., 2004).

Nowadays, in Europe exists the tendency to avoid some of the negative effects caused by the hyperintesivity of agriculture such as the genetical erosion. The white lupin due to its characteristics (content and quality of proteins very good, nitrogen fixing attributes, allowing phosphate mobilisation, capacity to be used in integrated farming systems and environmentally sustainable agriculture) could become a very interesting specie for the farmers (Simioniuc et al., 2011). Lupins can be improved through conventional breeding based on natural germplasm stocks and also genetic engineering may play an important role in future lupin crop improvement (Clements et al., 2012).

The objective of the present study was to describe character association and contribution of various yield influencing traits aiming establish appropriate plant attributes for selection to improve the grain yield .

2. Method

2.1 Plant Materials

The field experiment was conducted during 2012-2014 at the Institute of Forage Crops, Pleven (43.41ºN, 24.61ºE), situated in the central part of the Danube hilly plain. The trial included two cultivars of different lupin species (*Lupinus albus* L.) and (*Lupinus luteus* L.), namely Garant and Chernilovec, with Ukrainian origin. The cultivars were sown by hand, in March, with a sowing rate of 50 germinating seeds m^{-2}. It was used a long-plot design method, with three replications and a plot size of 4 m^{-2}. The experiment was carried out in conditions of organic farming (without using fertilizers and pesticides). Among the targeted traits related to seed yield were plant height (cm); number of pods per plant; pod length (cm); pod stem length (cm); number of seeds per plant; 1000-seed weight (g); seed weight per plant (g); grain yield (kg da^{-1}). Twenty plants per cultivar were harvested at full maturity for the analysis of seed components.

2.2 Data Analysis

The next statistical methods were used to process the experimental data: two-factor analysis of variance (ANOVA); correlations and path analysis calculated by Williams et al. (1990); coefficients of variations at phenotypic (CVe%) and genotypic (CVg%) levels and genetic advance (GA) were estimated using the formula adopted by Johnson et al. (1995). Broad sense heritability (H2) was calculated using the formula proposed by Mahmud and Kramer (1951). All the experimental data were statistically processed using the computer software GENES 2009.7.0 for Windows XP (Cruz, 2009).

3. Results and Discussion

For half of the observed traits, differences between the lupin species were not significant at the level of 0.05 (Table 1). Significant differences were established in regard to the traits pod length, seed weight per plant, 1000 seeds mass and grain yield. The analysis of yield components in both species showed a substantial variability by years in the values of pod numbers, seed numbers, seed weight per plant и 1000 seeds mass. On average for the experimental period the white lupine Garant formed 3.5 times higher grain yield than the yellow lupine Chernilovec, which was determined mainly by traits weight of seeds per plant and weight of 1000 seeds.

Table 1. Distinctive features of the investigated varieties

Variety/Traits	Garant				Chernilovec			
	2012	2013	2014	Average	2012	2013	2014	Average
Ph	40.00	56.60	46.10	47.56^a	46.60	44.30	42.30	44.40^a
Npp	8.00	7.80	5.35	7.05^a	5.70	9.30	8.20	7.73^a
Lps	0.52	0.66	0.55	0.58^a	0.40	0.38	0.38	0.38^a
Pl	6.30	7.04	6.74	6.69^a	4.08	4.62	4.03	4.24^b
Nsp	25.00	26.70	15.50	22.40^a	14.00	31.20	26.20	23.80^a
Swp	5.50	6.47	4.51	5.49^a	1.16	2.69	1.91	1.92^b
Tsm	233.00	267.33	67.90	189.41^a	80.50	84.00	27.90	64.13^b
Gy	161.00	177.00	132.00	156.67^a	25.00	46.00	63.00	44.67^b

Note. Ph: Plant height; Npp: Number of pods per plant; Lps: Length of pod stem; Pl: Pod length; Nsp: Number of seeds per plant; Swp: Seed weight per plant; Tsm: 1000 seeds mass; Gy: Grain yield.

a, b: statistically proven differences at P = 0.05.

3.1 Correlation Analysis

The phenotypic correlation is conditioned by the relationship between individual characters and the influence of environmental factors. All significant correlations between characters were positive. The highest correlation among the agronomic characteristics in white lupin (Table 2) was between number of pods per plant and seed weight per plant (r = 0.956). Strong positive phenotypic correlations were found between plant height with pod stem length (r = 0.935) and pod length (r = 0.934); between seed weight per plant and plant height (r = 0.807), number of pods per plant (r = 0.956) and pod length (r = 0.719); between number of seeds per plant with 1000 seeds mass (r = 0.763) and seed weight per plant (r = 0.674). The highest correlation among the agronomic characteristics in white lupin was between number of pods per plant and seed weight per plant.

In yellow lupin number of pods per plant and number of seeds per plant were also highly correlated (r = 0.976). Relatively high phenotypic correlations were detected between seed weight per plant and number of pods per plant (r = 0.875), pod length (r = 0.818) and number of seeds per plant (r = 0.927).

Table 2. Simple correlation coefficients (r) among the seed yield components in white lupin variety Garant (below diagonal) and yellow lupin variety Chernilovec (above diagonal)

Traits	Ph	Npp	Lps	Pl	Nsp	Swp	Tsm	Gy
Ph		-0.176	0.745*	0.501	-0.216	-0.062	0.538	-0.568
Npp	0.610		-0.038	0.666	0.976**	0.875**	-0.127	0.732*
Lps	0.935**	0.291		0.285	-0.041	-0.040	0.116	-0.075
Pl	0.934**	0.491	0.908**		0.669*	0.818**	0.474	0.052
Nsp	0.185	0.852**	-0.152	0.030		0.927**	-0.158	0.744*
Swp	0.807**	0.956**	0.548	0.719*	0.674*		0.175	0.476
Tsm	0.202	0.519	0.026	0.002	0.763*	0.397		-0.67*
Gy	-0.233	-0.356	-0.119	-0.413	-0.064	-0.413	0.442	

Note. Ph: Plant height; Npp: Number of pods per plant; Lps: Length of pod stem; Pl: Pod length; Nsp: Number of seeds per plant; Swp: Seed weight per plant; Tsm: 1000 seeds mass; Gy: Grain yield.

*: significant at 0.05; **: significant at 0.01.

3.2 Path Coefficient Analysis

The path coefficient analysis (Table 3) revealed that the pod stem length (14.38; 0.06), seed weight per plant (1.71; 0.16) and number of seeds per plant (0.87; 1.01) were the productivity components possessing the highest positive direct effects on seed yield for both cultivars. They can be an important criterion for selecting desirable traits for the genetic improvement of the lupin crops. The strongest indirect effects were by pod stem length via 1000 seeds mass (129.47) and plant height (100.7), also pod length via number of seeds per plant (102.95) and number of pods per plant (95.59) for Garant. For Chernilovec the positive indirect effects were by number of seeds per plant via plant height (51.80) and pod length (38.59). The highest total effect was found in pod length (96; 29), number of seeds per plant (82; 6) and 1000 seeds mass (42; 76) for both varieties.

Table 3. Path coefficient analysis showing direct and indirect effects of component traits on grain yield in Chernilovec (bold) and Garant

Trait	Direct effect	Indirect effect							Total
		Ph	Npp	Lps	Pl	Nsp	Swp	Tsm	
Ph	**-2.88**		**-17.83**	**100.7**	**29.41**	**0.1**	**71.9**	**10.75**	**32**
	0.30		-0.12	0.73	0.1	51.80	0.96	-6.86	63
Npp	**-0.29**	**-51.95**		**14.38**	**95.59**	**71.45**	**0.1**	**45.71**	**60**
	-0.03	2.74		14.36	-18.82	5.07	4.03	-0.31	7
Lps	**14.38**	**-124.12**	**-17.83**		**29.41**	**0.1**	**65.05**	**-8.06**	**2**
	0.06	7.63	-0.15		-4.39	1.01	15.82	-18.3	2
Pl	**1.47**	**-25.97**	**-5.94**	**0.1**		**69.71**	**0.1**	**-40.3**	**96**
	-0.17	11.90	-0.21	0.48		38.59	0.96	-22.7	29
Nsp	**0.87**	**-132.77**	**-17.83**	**71.93**	**102.95**		**68.48**	**-10.7**	**82**
	1.01	1.52	-15.76	14.42	-28.32		9.20	-0.46	6
Swp	**1.71**	**-40.41**	**0.1**	**14.38**	**23.53**	**69.71**		**-67.2**	**0**
	0.16	0.1	-2.15	0.36	-15.48	23.36		-0.38	7
Tsm	**-2.68**	**-129.89**	**-11.88**	**129.47**	**0.1**	**0.1**	**65.05**		**42**
	-0.07	82.41	-7.67	4.01	-9.67	6.09	1.29		76

Note. Ph: Plant height; Npp: Number of pods per plant; Lps: Length of pod stem; Pl: Pod length; Nsp: Number of seeds per plant; Swp: Seed weight per plant; Tsm: 1000 seeds mass; Gy: Grain yield.

3.3 Coefficients of Variation

The comparison of characters as regards to the extent of genetic variation could be better judged by the estimation of the genotypic coefficient of variation (CVg) in relation to their respective phenotypic coefficient of variation (CVe). Amongst the investigated characters small difference between CVg and CVe was observed for pod length (Table 4). It indicates that the observed variations for the trait were mostly due to genetic factors. However, the environment played a little role in the expression of this trait. On the other hand, large difference between CVg and CVe was observed for the all other characters: plant height; number of pods; pod stem length; number of seeds per plant; seed weight per plant and 1000 seeds mass. This indicated the role of environmental influence over these characters. In this experiment high CVg was observed in characters like length pod stem, number of seeds per plant, seed weight per plant and 1000 seeds mass. The high CVg for these traits indicated that further selection could improve the genotypes.

Table 4. Genetic parameters for different quantitative characters

Variety/Trait	Garant				Chernilovec			
	CVg (%)	CVe (%)	H2	GA	CVg (%)	CVe (%)	H2	GA
Ph	15.44	15.92	73.82	14.64	1.63	7.76	11.38	0.31
Npp	5.62	35.13	7.22	0.13	22.69	12.75	90.47	6.43
Lps	25.83	11.18	94.14	0.65	-	-		-0.05
Pl	4.28	6.29	58.31	0.40	6.38	7.60	67.88	0.47
Nsp	33.04	21.88	87.32	25.85	36.52	12.05	96.50	54.26
Swp	-	-	-	-0.56	31.89	9.60	31.89	9.61
Tsm	55.93	5.66	99.66	2172.06	49.47	4.73	99.70	687.95
Gy	-	-	-	-19.08	50.96	12.52	98.03	186.68

Note. Ph: Plant height; Npp: Number of pods per plant; Lps: Length of pod stem; Pl: Pod length; Nsp: Number of seeds per plant; Swp: Seed weight per plant; Tsm: 1000 seeds mass; Gy: Grain yield; CVg: genotypic coefficient of variation; CVe: phenotypic coefficient of variation; GA: genetic advance; H2: Heritability.

3.4 Heritability

The part from common variability conditioned from genetic differences was determined through using coefficient of heritability (H2). The inheritance is characterization of the relative part of the genetic differences and these which are result of the action of the environment in the phenotypic diversity. At change of genotype or the environment follow and variation of the assessment of inheritability. In our study in both varieties Garant and Chernilovec was established a high coefficient of heritability (H2) in the traits 1000 seeds mass (99.66%; 99.70%), number of seeds per plant and pod length (87.32%; 96.50%; 58.31%; 67.88%) (Table 4). There were considerable differences between varieties in the inheritance of plant height. In this trait the exceedance in Garant compared to Chernilovec was over 60%. For pod numbers were obtained higher values of the coefficient of heritability in Chernilovec (90.47%), while in Garant the inheritance had a very low value (7.22%).

The presented data demonstrate that the seed yield in lupin is a complex trait and is the result of the combined effect of all seed yield components (Sultana et al., 2002). The lower seed yield in cultivar yellow lupin Chernilovec than the one of the white lupin Garant in this study was in line with the reports of Spencer (2002) and Yeheyis et al. (2012). Similarly, Lopez-Bellido et al. (2000) stated strong correlation and direct effect of number of pods on the lupin yield and a negative effect of plant height. Rubio et al. (2004) and Hefny (2013) reported a positive and strong association among plant height, 1000-seed weight and yield. Mikic et al. (2010) also found that grain numbers per plant correlated positively with grain yield.

Lesech and Huyghe (1991) established a high coefficient of heritability in the lupin in regard to the main stem height, seed weight and seed yield. Mohammadi and Pourdad (2009), and Hefny (2013) have reported high values of heritability, which are similar to those in the present study for plant height, seed yield per plant and 1000 seed weight.

Julier et al. (1995) also reported for high heritability in respect to thousand grains mass as the yield component. 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).

The results of the present study represent a contribution to a better knowledge on yield components in lupin species. Collecting data on the mutual relationships among individual yield components and their effect on forage yield remains crucial for their optimisation and development of improved lupin genotypes with high quality and stable yields. Based on the trait association it can be concluded that the 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.

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