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MORPHOLOGICAL AND BIOLOGICAL CHARACTERISTICS OF WHITE LUPINE CULTIVARS (*LUPINUS ALBUS* L.)

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ABSTRACT

White lupine is a species with a great perspective among annual grain legumes. A biological and breeding evaluation of a collection of 23 white lupine cultivars regarding basic traits and indicators was conducted, with an aim to select suitable parental forms. The study was carried out at the Institute of Forage Crops Pleven, Bulgaria during the period 2014-2016. The cultivars differed in their habitus, duration of the growing season, productivity, biochemical seed composition and susceptibility to *Fusarium oxysporum* f. sp. *lupini*. The vegetation period in the Central Northern Bulgaria conditions varied from 129 days in Barde to 148 days in Nahrquell and Shienfield Gard. Dega, Desnyanskii and Barde can be characterized as early-ripening cultivars, and late-ripening ones were Nahrquell, Shienfield Gard and Bezimenii 1. The highest protein content showed Horizont, Bezimenii 2 and Solnechnii (32.7-33.3%), and a reaction of resistance to *Fusarium oxysporum* f. sp. *lupini* was demonstrated by nine cultivars (Nahrquell, BGR 6305, WAT, Kijewskij Mutant, Pflugs Ultra, Termis Mestnii, Solnechnii, Pink Mutant, Dega). Particular interest from a breeding viewpoint represents Tel Keram, Termis Mestnii, Solnechnii and Pink Mutant which are distinguished by high values of seed weight per plant and a favourable combination of the other traits, recommending them to be included in breeding programs for development of high-yielding white lupine cultivars.

Key words: cultivars, early-ripeness, Fusarium wilt, productivity, white lupine.

INTRODUCTION

An important problem in modern agriculture is the provisioning the intensively developing animal husbandry with high energy and protein plant foods that retain soil fertility (Naumkin et al., 2012; Chekmarev et al., 2012). Successful resolution of this problem in many regions of the world is related to the cultivation of high-protein legumes. Among the annual grain legume species, the white lupine (*Lupinus albus* L.) has a great perspective (Turk and Albayrak, 2012; Gataulina et al., 2013; Tan et al., 2014; Naumkin et al., 2015). At the global level, three species of lupine are mainly used - narrow-leafed, yellow and white. Each is characterized by its biological characteristics, occupies a particular ecological niche and they are not mutually exclusive. White lupine has great productive potential, but is more demanding on the soil conditions and temperature regime compared to narrow-leafed and yellow lupine (Sizenko et al., 2004; Takunov and Slesareva, 2007).

Under favourable soil and climatic conditions, white lupine is able to form seed yield of about 4000 kg ha^{-1}, the content of protein in seeds varies in the range 38-43%. White lupine contains the full set of essential amino acids, which are assimilated well and can be used for feeding all animal species. Its cultivation is characterized by relatively low energy intensity, unpretentiousness to soil fertility and high nitrogen-fixing ability (Shtele, 2013; Muraveev et al., 2012).

The main directions in the white lupine breeding are associated with increased potential of seed productivity, optimal length of the growing period (110-120 days), combined with resistance to major diseases, resistance to lodging, drought tolerance,

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improved grain quality - reduced content of alkaloids and high content of protein and fat (Lukashewich and Sviridenko, 2012).

The aim of the research was to study a starting material of white lupine on basic traits with a view to selecting appropriate parental forms for future breeding programs.

MATERIAL AND METHODS

During the period 2014-2016 at the Institute of Forage Crops (Pleven) a field trial was conducted with 23 white lupine cultivars: Astra, Nahrquell, Ascar, BGR 6305, Shienfield Gard, WAT, Kijewskij Mutant, Hetman, Start, Amiga (originating from Poland), Garant (originating from Ukraine), Tel Keram, Bezimenii 1, Bezimenii 2, Pflugs Ultra, Termis Mestnii, Horizont, Solnechnii, Pink Mutant, Manovitskii, Barde, Dega, Desnyanskii (originating from Russia). Sowing was made by hand, in optimum sowing time, according to the technology of cultivation. The field experiment was laid out using randomised block design. The 23 genotypes were grown in an adjusted density of 50 plants m^{-2}. Each plot unit included twelve rows spaced 50 cm apart (5.50 m broad × 2 m length).

The meteorological conditions during the studied period were different (Table 1).

In 2015, the plants suffered from a lack of moisture at the phenological stages of budding and flowering. The distribution of rainfall over next phenological stages was more proper and this created more even conditions for plant growth.

During 2016, after sowing, the subsequent dry weather delayed seed germination. In June-July the rainfall fell regularly, which resulted in better productivity but the higher temperatures accelerated the plant development. The meteorological conditions during 2014 were relatively favourable for the normal course of plant vegetation.

Table 1. Meteorological characteristic of the period 2014-2016

Specification	Years	Months				
		III	IV	V	VI	VII
Average daily temperature (^{o}C)	2014	9.70	12.30	16.70	20.60	23.10
	2015	6.70	12.20	18.80	20.70	25.80
	2016	8.50	15.30	16.40	23.00	24.60
Rainfall (mm)	2014	76.90	139.80	83.00	54.30	71.80
	2015	68.40	43.60	30.60	95.70	21.50
	2016	76.60	73.10	76.50	45.80	7.80
Humidity (%)	2014	68.00	76.00	70.00	67.00	67.00
	2015	71.42	53.83	66.00	64.00	54.00
	2016	73.00	66.00	71.00	67.00	57.00

During the vegetation period the following traits were reported: plant height (cm), height to first pod (cm), pods per plant, number of seeds per plant, seed weight per plant (g), 1000 seeds weight, pod length (cm), pod width (cm).

Analysis of variance (Dimova and Marinkov, 1999) and hierarchical cluster analysis (Georgiev, 2004) were conducted. The coefficient of inheritance in a broad sense (Hbs) was calculated using the method proposed by Mahmud and Kramer (1951). The period from germination to early flowering was determined and for quantitative assessment we used the coefficient of early-ripeness (Kuzmova, 2002):

$$Cr = 1 + [\{Nc-Nmin\}/\{Nmax-Nmin\}]$$

where: Nc is duration of the period sowing - beginning of flowering for the particular cultivar; Nmax and Nmin are the maximum and minimum duration (in days) of the period sowing-beginning of flowering for all tested cultivars.

The values of the coefficient were as followed: for ultra-early ripening cultivars – from 1.00 to 1.17; for early-ripening cultivars – 1.17 to 1.33; for medium-early ripening cultivars – 1.34 to 1.66 and for late-ripening ones > 1.66.

The biochemical composition of lupine seeds was determined as crude protein (CP) by Kjeldal method and crude fiber (CF) by Weende system (AOAC, 2010).

The reaction of the twenty-three lupine cultivars to *Fusarium oxysporum* f. sp. *lupini* was estimated under conditions of natural field infestation. Percentages of Fusarium wilt were recorded 30 and 90 days after sowing, and the number of survived plants (infected and healthy plants) – 120 days after sowing. Healthy survived plants were those with no visual symptoms of the disease. The infected survived plants were estimated by longitudinal sections of stem and root. Disease severity was determined according to the scale of Ishikawa et al., with some modifications (Ishikawa et al., 2005), based on 0-4 grades according to the percentage of inside browning through the stem and root: 0 = healthy, 1 = 0-25% browning, 2 = >25-50% browning, 3 = >50-75% browning and 4 = >75-100% browning.

The data were processed statistically by analysis of variance (multi-factor ANOVA). Least Significant Difference (LSD) was computed to compare means with using software STATGRAPHICS Plus for Windows Version 2.1.

RESULTS

The differences in the plant architectonics determined not only the magnitude of productivity, its stability and sustainability in the years but also the length of growing period (Table 2).

Differences among the cultivars were observed after the budding stage. Astra, Termis Mestnii and Barde were characterized with the lowest average duration of the period germination-beginning of flowering (37 days), but for most cultivars this period was 38 days. Cultivars Ascar and Hetman had the latest flowering.

The observed differences in the occurrence of phenological stages for the studied cultivars were preserved until the end of the growing season. The length of growing season for Barde, Dega, Desnyanskii, Manovitskii and Amiga was significantly lower compared to Nahrquell, Shienfield Gard, Bezimenii 1 and Termis Mestnii. The early cultivars reached technical maturity on average after about 129-134 days and the late ones – for 140-148 days. Cultivars Ascar, Termis Mestnii and Barde could be included to the group of ultra-early ripening cultivars (with coefficient of early-ripeness of 1.00) as well as Amiga, Bezimenii 2, Horizont, Solnechnii, Pink Mutant, Manovitskii, Dega and Desnyanskii (coefficient of early-ripeness of 1.14), followed by medium-early ripening cultivars Astra, Kijewskij Mutant, Start, BGR 6305, WAT, Garant, Tel Keram, Bezimenii 1, Pflugs Ultra (coefficient of early-ripeness >1.34) and the late-ripening ones Hetman, Shienfield Gard, Nahrquell (coefficient > 1.66).

The study of available genetic resources always precedes the execution of a serious breeding program. For its success, an important point was the collection, analysis and efficient utilization of the source material in the breeding process. The tested biological characteristics and important traits in 23 lupine genotypes (Table 3) showed significant diversity in terms of the main components of productivity.

The studied genotypes were characterized by significant differences among them in regard to the plant height (Table 4). In regard of this trait, cultivars Shienfield Gard (79.92 cm), Bezimenii 2 (76.78 cm), Termis Mestnii (76.10 cm) and Nahrquell (76.07 cm) were the highest and they significantly outperformed the others, whose height was between 38.7 cm (Hetman) and 75.17 cm (Bezimenii 1).

The high placement of the first pod is an important requirement, which contributes to harvesting without losses. Most of the cultivars which had long stems (except Ascar and BGR 6305) formed their first pod at a greater height. In regard of that trait, cultivars Bezimenii 1, Bezimenii 2, Pflugs Ultra, Termis Mestnii and Horizont showed higher values than the others, which formed the first pod of a height of about 38-39 cm.

Table 2. Phenological characteristic of the studied cultivars of white lupine

Cultivar	Germination - beginning of flowering (days)	Beginning of flowering - full maturity (days)	Growing period (days)	Coefficient of early-ripeness
Astra	39	101	140bcde	1.57
Nahrquell	41	107	148e	2.00
Ascar	37	99	136abcde	1.00
BGR 6305	39	101	140bcde	1.43
Shienfield Gard	41	107	148e	2.00
WAT	39	95	134abc	1.43
Kijewskij Mutant	39	95	134abc	1.57
Hetman	41	95	136abc	2.00
Start	39	95	134abc	1.57
Amiga	38	95	133ab	1.14
Garant	39	95	134abc	1.43
Tel Keram	39	101	140bcde	1.43
Bezimenii 1	39	107	146de	1.43
Bezimenii 2	38	101	139bcde	1.14
Pflugs Ultra	39	101	140bcde	1.43
Termis Mestnii	37	106	143cde	1.00
Horizont	38	101	139bcde	1.14
Solnechnii	38	98	135abc	1.14
Pink Mutant	38	98	135abc	1.14
Manovitskii	38	95	133ab	1.14
Barde	37	92	129a	1.00
Dega	38	93	131ab	1.14
Desnyanskii	38	93	131ab	1.14
$LSD_{0.05}$			2.85	
$LSD_{0.01}$			3.88	
$LSD_{0.001}$			5.22	

The number of pods and seeds per plant and the seed weight per plant determines the plant productivity. Increasing the productive potential of the genotypes depends on the number of pods and seeds per plant. Comparing the cultivars, essential differences in regard to pod number were observed in Solnechnii, Tel Keram, Termis Mestnii, Barde and Pink Mutant (16-18 pods per plant) as compared with Hetman (6 pods). The mentioned cultivars were the most promising on number of seeds per plant, and they gave 65-75 seeds per plant. Therefore, to improve the plant productivity, they could be used as parent components for the development of genotypes possessing valuable traits.

Larger number of seeds per plant determines a higher seed weight per plant. Of practical interest are the cultivars that combine the other quantitative traits with maximum value of the 1000 seeds weight.

Table 3. Analysis of variance of the studied traits

Source of variation	DF	Plant height (cm)	Height to 1st pod (cm)	Number of pods/ plant	Number of seeds/ plant	Seed weight/ plant (g)	Mass of 1000 seeds (g)	Pod length (cm)	Pod width (cm)
Years	2	4013.99	1191.33	439.33	9198.69	448.14	3121.72	0.45	0.04
Cultivars	22	516.45ns	106.93*	25.15ns	588.59ns	48.60**	3956.09**	0.83**	0.06**
Residuo	44	410.78	53.45	25.25	405.60	18.07	1512.13	0.20	0.02
Average		62.26	31.63	12.56	49.02	12.51	264.62	7.23	1.22
CV (%)		32.55	23.12	40.02	41.08	33.97	14.7	6.12	11.85
Hbs (%)		20.46	50.02	0.01	31.09	62.83	61.78	76.45	66.78

Significance at p = 0.05(*; p = 0.01(**).

The tendency to considerably exceeding the average mass of seeds in cultivars Tel Keram, Termis Mestnii, Solnechnii and Pink Mutant over a largest part of the cultivars was noticed. Cultivars Hetman (174.5 g) and WAT (221.49 g) can be characterized as relatively small-seeded cultivars and Barde, Amiga, Start, Manovitskii, Tel Keram, Kijewskij Mutant and Desnyanskii – as mid-seeded cultivars (with mass of 1000 seeds over 250 g). Cultivars Pflugs Ultra, Astra, Ascar and Termis Mestnii had the largest seeds (mass of 1000 seeds over 300 g).

With regard to the traits length and width of pods, only Hetman was significantly different from the others and characterized by the lowest values of these parameters (5.97 cm; 1.07 cm).

The genotypes were examined with respect to the variability of the investigated parameters through the variation coefficient (VC, %), which determines the phenotypic diversity (Table 3). It was found that VC varied in different limits for each trait.

The variability was expressed to the weakest extent for length (6.12%) and width of the pods (11.85%), and mass of 1000 seeds (14.7%). In the other traits, the variation was more pronounced – in the ranges from 23.12 % for height of the first pod to 41.08 % for number of seeds per plant. The part of the total variability, justified by genetic differences, was determined by using the coefficient of inheritance in broad sense (Hbs). Heritability is a characteristic of the relative share of genetic differences in the total phenotypic variability. Almost all traits had a high coefficient of inheritance (Table 3) with exception of pod numbers per plant and plant height, where the heritability was low. The low coefficient suggests a great influence of the climatic conditions. This means that in future breeding programs involving some of these genotypes, an effective selection in the obtained hybrids will be efficient in the later hybrid generations (F4-F5), where the homozygosity is increased.

Table 4. Morphological characteristics of white lupine cultivars (2014-2016)

Cultivars	Plant height (cm)	Height to 1st pod (cm)	Pods/ plant	Seeds/ plant	Seed weight/ plant (g)	Mass of 1000 deeds (g)	Pod length (cm)	Pod width (cm)
Astra	68.43	26.81	11.41	45.59	13.63	308.00	7.13	1.08
Nahrquell	76.07	26.50	11.48	35.52	9.69	276.64	6.64	1.16
Ascar	71.79	22.97	12.78	41.90	12.39	308.17	7.29	1.25
BGR 6305	72.16	23.11	12.87	48.88	13.48	290.24	7.51	1.21
Shienfield Gard	79.92	29.15	10.23	39.33	10.52	266.10	7.03	1.14
WAT	49.07	19.19	10.67	37.02	8.59	221.49	6.47	1.13
KijewskijMutant	54.37	23.03	8.49	32.04	7.89	240.98	7.19	1.09
Hetman	38.70	14.98	6.33	20.53	3.69	174.50	5.97	1.07
Start	46.90	18.21	11.76	44.38	9.93	230.92	7.12	1.23
Amiga	49.07	19.62	8.53	32.91	7.84	230.09	7.26	1.28
Garant	51.22	19.00	12.44	44.22	11.64	277.92	6.82	1.14
Tel Keram	70.90	33.18	17.05	74.88	16.21	239.35	7.11	1.52
Bezimenii 1	75.17	38.09	11.49	50.38	14.32	290.80	7.93	1.29
Bezimenii 2	76.78	39.63	12.73	55.75	14.46	281.88	7.68	1.60
Pflugs Ultra	70.93	39.35	14.57	55.31	15.26	304.29	7.66	1.11
Termis Mestnii	76.10	38.08	16.70	70.46	21.55	322.18	8.14	1.18
Horizont	70.19	38.64	12.48	50.59	13.58	291.15	7.43	1.50
Solnechnii	72.89	37.33	18.67	75.58	20.51	295.69	7.93	1.27
Pink Mutant	65.88	32.46	15.33	65.00	16.66	271.92	7.96	1.27
Manovitskii	52.25	25.95	12.33	46.58	10.95	232.89	7.08	1.07
Barde	55.38	29.86	16.11	64.58	12.49	222.17	6.73	1.16
Dega	45.30	27.33	12.08	48.83	11.89	262.60	7.38	1.21
Desnyanskii	42.46	24.08	12.33	47.29	10.64	246.19	6.81	1.12
$LSD_{0.05}$	9.12	3.69	3.43	14.47	3.22	45.91	0.78	0.37
$LSD_{0.01}$	12.11	4.91	4.56	19.22	4.28	60.98	1.04	0.50
$LSD_{0.001}$	15.38	6.37	5.92	24.95	5.56	79.16	1.35	0.64

The cultivar productivity depends both on the characteristics of the variety and on the meteorological conditions. For the studied years, the most productive were Termis Mestnii, Solnechnii, Pink Mutant and Tel Keram. The differences among genotypes were negligible in the years with drought, when the plants formed lower stems.

Correlation analysis

The dependencies obtained for the study period (Table 5) showed highly significant positive correlations of the plant height with height of the first bean (r = 0.916), number of pods (r = 0.795) with seeds per plant (r = 0.77); height of the first pod with number of pods (r = 0.764) and seeds per plant (r = 0.777); number of seeds with number of pods per plant (r = 0.98); seed weight per plant with number of pods (r = 0.926) and seeds per plant (r = 0.947).

To a lesser extent, there were positive correlations between the pod length and all other traits. Negative and statistically insignificant were the dependencies between mass of 1000 seeds and plant height, number of pods/seeds per plant.

Table 5. Correlation coefficients among productivity components in white lupine cultivars

Specification	Plant height	Height to 1st pod	Pods/ plant	Seeds/ plant	Seed weight/ plant	Mass of 1000 seeds	Pod length
Height to 1st pod	0.916**						
Pods per plant	0.795**	0.764**					
Seeds per plant	0.770**	0.777**	0.980**				
Seed weight per plant	0.803**	0.829**	0.926**	0.947**			
Mass of 1000seeds	-0.030	0.053	-0.210	-0.201	0.071		
Pod length	0.289*	0.393**	0.316**	0.389**	0.539**	0.445**	
Pod width	-0.019	0.027	-0.096	-0.053	0.006	0.234	0.342**

Significance at p≤0.05(*), p≤0.01(**).

Cluster analysis

Based on the values of studied traits hierarchical cluster analysis of the investigated lupine genotypes was conducted. As a measure of distance, the Euclidean distance was used. The results, presented in Figure 1 as a dendrogram, showed a different grouping of cultivars regarding similarity and difference. The cultivars were divided into three main clusters (A, B and C). The groups "A" and "B" included only one cultivar each, respectively Hetman in the cluster “A” and Ascar in the second cluster “B”. Hetman was characterized by very low values of all traits and was inferior to the other varieties. Only cultivar Ascar, which in some indicators performed very well, found a place in cluster "B". The plants of this cultivar were relatively high, had large seeds with weight above 12 g per plant, with long petals, but unlike the other cultivars with similar characteristics, they formed very low first pods and a smaller number of seeds per plant. The other main group "C", covering most cultivars, was divided into two subgroups "C1" and "C2". The first subgroup included only cultivar Garant, whose plants were low, with not high first formed pods, but well inseminated with moderately large seeds. The second subgroup "C2" was of greater interest. It included cultivars with medium-high and high stem, more pods per plant and a greater number of medium-large to large seeds. The data showed that within this subgroup significant genetic distance between the genotypes was observed. This indicated that the genotypes had differing genetic constructs that determined the expression of each trait. The phenomenon was known as redefinition of the genetic formula of trait upon a change of the environmental conditions. To obtain more prominent transgressive forms in hybrid combinations genotypes from different groups and subgroups should be included, in order to expect better combinations of favourable genes into one genotype. The hierarchical cluster analysis can be used in the planning of starting parental combinations.

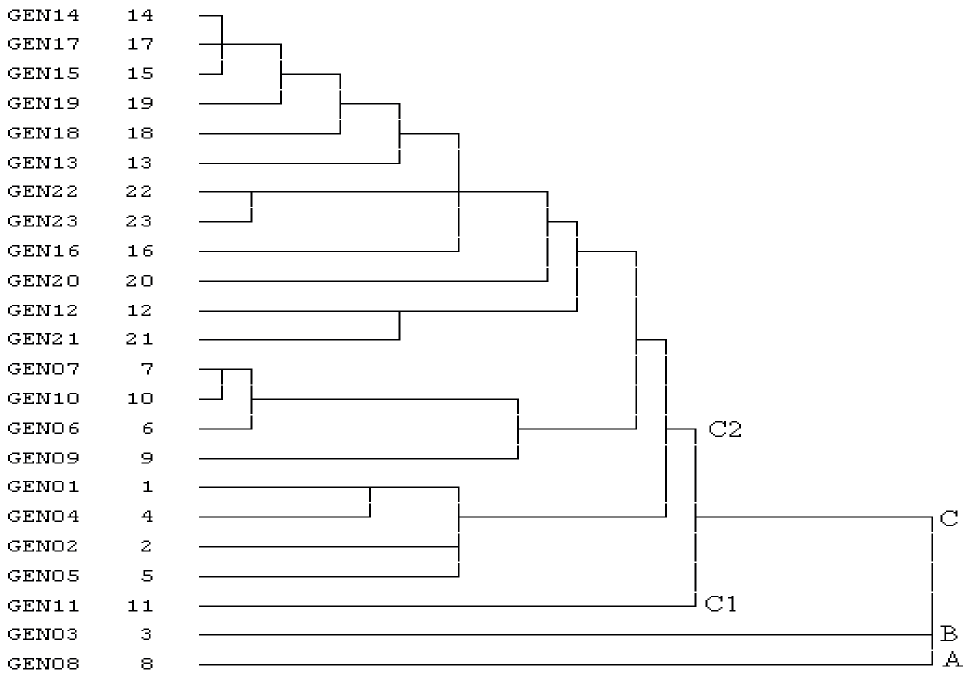

Figure 1. Dendrogram of white lupine cultivars (2014-2016)

One of the important tasks of modern agro production is the development of high-quality products. In white lupine cultivation, main indicators for assessing the seed quality are content of crude protein, crude fibres and fats, and their combination with the yield. Table 6 presents the results of biochemical analysis of the white lupine grain in regard to content of crude protein and crude fiber. The crude protein content varied from 24.9% to 33.3%. The highest crude protein content was observed in cultivars Horizont, Bezimenii 2 and Solnechnii (between 32.7-33.3%), while cultivars Astra, Kijewskij Mutant and Ascar were characterized by very low protein content in the range between 24.9-26.0%. The values obtained for content of crude fiber showed considerable variation between the cultivars. Hetman, Kijewskij Mutant and WAT demonstrated the highest fiber content, which was in the range from 19.6% to 14.8%. Cultivars BGR 6305, Horizont and Solnechnii were characterized by the lowest crude fiber content - between 10.9% and 11.3%.

Table 6. Biochemical seed composition of white lupine cultivars

Cultivars	Crude protein (%)	Crude fibre (%)
Astra	24.90	14.27
Nahrquell	28.35	12.55
Ascar	25.95	14.63
BGR 6305	30.62	10.89
Shienfield Gard	26.47	14.40
WAT	27.35	14.76
Kijewskij Mutant	25.36	15.96
Hetman	27.68	19.59
Start	29.66	11.99
Amiga	31.25	12.07
Garant	31.34	12.88
Tel Keram	31.95	11.69
Bezimenii 1	30.76	12.83
Bezimenii 2	33.02	12.66
Pflugs Ultra	31.56	12.28
Termis Mestnii	31.57	13.42

Horizont	33.30	10.96
Solnechnii	32.67	11.28
Pink Mutant	28.83	13.50
Manovitskii	30.90	13.25
Barde	30.49	12.00
Dega	30.16	12.17
Desnyanskii	28.62	11.75
$LSD_{0.05}$	0.47	0.66
$LSD_{0.01}$	0.65	0.89
$LSD_{0.001}$	0.87	1.20

The studied cultivars differed in their susceptibility to *Fusarium oxysporum* f. sp. *lupini*. The highest percentage of infected plants and disease severity score had Hetman (53% and 3.3, respectively) and Ascar (40% and 3.8, respectively) (Table 7). Nine cultivars (Nahrquell, BGR 6305, WAT, Kijewskij Mutant, Pflugs Ultra, Termis Mestnii, Solnechnii, Pink Mutant, Dega) had no symptoms of the disease during the vegetation period and they were characterised as resistant. Low susceptibility to *Fusarium oxysporum* showed Astra, Horizont, Tel Karam, Barde and Desnyanskii, in which the disease severity score was 1.9-2 and percentages of healthy plants were in limits 85 to 96%.

Table 7. Reaction of white lupine cultivars to *Fusarium oxysporum* f. sp. *lupine*

Cultivars	Wilted plants (%)				Survived plants (%)					
	30 days after seeding		90 days after seeding		Infected plants (%)		Healthy plants (%)		*Disease severity score	
Astra	0	a	4	b	4	ab	96	h	2.0	b
Nahrquell	0	a	0	a	0	a	100	h	0.0	a
Ascar	6	b	13	e	40	h	60	b	3.8	c
BGR 6305	0	a	0	a	0	a	100	h	0.0	a
Shienfield Gard	9	b	9	d	28	fg	72	d	3.8	c
WAT	0	a	0	a	0	a	100	h	0.0	a
Kijewskij Mutant	0	a	0	a	0	a	100	h	0.0	a
Hetman	17	c	17	f	53	i	47	a	3.3	c
Start	0	a	6	bc	25	ef	75	de	3.3	c
Amiga	5	b	14	e	34	gh	66	c	2.0	b
Garant	6	b	6	bc	20	de	80	e	3.3	c
Tel Keram	0	a	14	e	14	cd	86	f	1.9	b
Bezimenii 1	0	a	7	cd	11	bc	89	fg	3.3	c
Bezimenii 2	0	a	5	b	22	ef	78	e	3.3	c
Pflugs Ultra	0	a	0	a	0	a	100	h	0.0	a
Termis Mestnii	0	a	0	a	0	a	100	h	0.0	a
Horizont	0	a	8	cd	8	bc	92	gh	2.0	b
Solnechnii	0	a	0	a	0	a	100	h	0.0	a
Pink Mutant	0	a	0	a	0	a	100	h	0.0	a
Manovitskii	5	a	5	b	24	ef	76	de	3.3	c
Barde	6	b	6	bc	13	c	88	fg	2.0	b
Dega	0	a	0	a	0	a	100	h	0.0	a
Desnyanskii	0	a	13	e	15	cd	85	f	2.0	b
$LSD_{0.05\%}$		4.49		2.59		6.96		5.14		0.94

*0 = healthy, 1 = 0-25% browning, 2 = >25-50% browning, 3 = >50-75% browning and 4 = >75-100% browning.

DISCUSSION

In determining the best genotypes regarding the analysed indicators we took into account the main trends in breeding of the relevant crop, and then appropriate genotypes with a short growing season, which is also an important criterion.

Structural elements of productivity that determine the yield level are always of particular interest to the researchers. Their variability depending on the genotype and growing conditions of the plants is related to the potential of the cultivar and the degree of its adaptation (Gataulina, 2014).

Dyakov et al. (2009) found that as in soybeans and other crops, the yield is always a compromise between productivity and resistance to unfavourable environmental factors. It is known that the potential productivity of the crop plants and their ecological stability is controlled by various relatively independent gene systems.

The correlations between plant productivity and structural elements have an essential meaning in determining the most effective method of breeding and evaluation of breeding material. The values of the correlation coefficients obtained in studies of different researchers often do not correspond, which is due both to the particular tested genotypes and the cultivation conditions (Ashiev, 2014).

In considering the relationships between the main traits in soybeans, Vyshnyakova et al. (2002) reported that the strongest positive dependencies were established between seed productivity and the number of seeds/pods per plant (r = 0.7-0.9). The last trait was admittedly linked with the number of fertile nodes per plant and the number of fertile pods per node. Weak and medium correlations were stated between productivity and mass of 1000 seeds.

Karadavut (2009), Canci and Toker (2006) found a positive and significant correlation of the yield with biological yield and harvest index in lentil. The authors also reported a positive correlation between the number of branches and number of pods, as well as a negative correlation between the mass of 1000 seeds and plant height. In soybeans Turkec (2005) stated a positive correlation between yield and number of pods per plant, which had the highest direct effect on grain yield through the mass of 1000 seeds.

Our research was in line with the results obtained by Canci et al. (2007) in chickpeas cultivars regarding the high coefficient of heredity in the traits mass of 1000 seeds and seed yield.

White lupine suffers from many diseases caused by viruses, fungi and bacteria. According to many authors (Abou-Zeid et al., 2002; Jensen et al., 2004), fungal diseases, especially wilt caused by *Fusarium oxysporum* f. sp. *lupini* is considered the most serious disease of white lupine, causing a considerable damage and loss in seed yield. An alternative and environmental-friendly method of controlling this disease is finding of cultivars with expressed resistance to the pathogen.

According to Kurlovich (1990), lupine cultivars resistant to *Fusarium oxysporum* in some areas, are often sensitive to others. Therefore, the evaluation of the cultivars should be carried out in specific soil and climatic conditions. In conditions of the present the study, nine cultivars showed resistance to *Fusarium oxysporum*. Other researchers also reported genotypes which expressed resistance to Fusarium wilt and others which are susceptible (Rybus-Zajac and Morkunas, 2005; Ali Abeer et al., 2009). The variation in reaction of different lupine cultivars to *Fusarium oxysporum* fungus may be due to their physiological resistance to the infection and mechanical resistance or environmental conditions or fungal strains (Zian et al., 2013).

According to Zakharova et al. (2014) and Muraveev et al. (2015) the most important criteria in developing new white lupine varieties are high yield, high content of protein and low alkaloids content.

CONCLUSIONS

In the conducted study a collection of 23 white lupine cultivars was evaluated on basic traits. The cultivars differed in their habitus, duration of the growing season, productivity, biochemical seed composition and susceptibility to *Fusarium oxysporum* f. sp. *lupini*.

The vegetation period in the Central Northern Bulgaria conditions varied from 129 days in Barde to 148 days in Nahrquelland Shienfield Gard. Ascar, Termis Mestnii and Barde can be characterized as early-ripening cultivars, and late-ripening ones were Nahrquell, Shienfield Gard and Hetman.

The highest protein content showed Horizont, Bezimenii 2 and Solnechnii (32.7-33.3%), and a reaction of resistance to

Fusarium oxysporum f. sp. *lupine* was demonstrated by nine cultivars (Nahrquell, BGR 6305, WAT, Kijewskij Mutant, Pflugs Ultra, Termis Mestnii, Solnechnii, Pink Mutant and Dega).

Particular interest from a breeding viewpoint represent Tel Keram, Termis Mestnii, Solnechnii and Pink Mutant which are distinguished by high values of seed weight per plant and a favourable combination of the other traits, which recommend them to be included in breeding programs for development of high-yielding white lupine cultivars.

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