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Original scientific article

NEW VARIETY OF WHITE LUPINE MONICA (*Lupinus albus* L.)

Valentin KOSEV[1], Viliana VASILEVA[2], Vera POPOVIĆ[3]

[1]Institute of Forage Crops, 5800 Pleven, Agricultural Academy, Bulgaria
[2]Maize Research Institute, 5835 Knezha, Agricultural Academy, Bulgaria
[3]Institute of Field and Vegetable Crops, 21000 Novi Sad, R. of Serbia

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Characterization of promising white lupine hybrid lines (LN5 and LN1-1) and their parental forms (Lucky801 and PI533704) was done. Biometric analysis of each variety and line was performed according to main quantitative traits and phenological stages and periods. A new variety of white lupine Monica (from line LN5) was created with a direction of use for seeds. It was obtained through repeated individual selection from the cross Lucky801 × PI533704. The variety belongs to the medium-ripening group with a duration of the vegetation period of 129 days. It has genetically completed growth. The height of the plant was 87 cm. The variety has high lodging resistance and good adaptability to abiotic conditions. The first pods were formed at 40 cm. The pods of the plant are formed on the main stem and on shortened lateral branches of the first and second order. About 28 uncrackable pods formed on one plant. The inflorescence is medium-sized, blue-white, the seeds are white, medium-sized. The number of seeds in one plant is on average 114. The protein content of the grain is 33%. The variety is distinguished by high potential seed productivity (the mass of seeds per plant 37 g). The mass of 1000 seeds is 339 g. The average yield of grain (3150 kg/ha) in the competition variety trials exceeds the average yield of the parental forms (2940 kg/ha). By decision of the Expert Commission at the Executive Agency for Variety Testing, Field Inspection and Seed Control, Bulgaria (appointed by order RD-10-1/14.01.2022) and by order No. RD-12-1 of the Minister of Agriculture of the Republic of Bulgaria dated 02.03.2022, the Monica variety was recognized as a new and original.

Keywords: white lupine, productivity, yield, variety

Corresponding author: Viliana Vasileva, Maize Research Institute, 5835 Knezha, Agricultural Academy, Bulgaria, e mail: viliana.vasileva@gmail.com, ORCID: 0000-0001-5602-7892, V. Kosev ORCID: 0000-0003-3292-4200, V. Popović ORCID: 0000-0002-7701-9928

INTRODUCTION

Lupinus is a large genus in the *Fabaceae* family. Lupine is a common name used in Europe and Australia for both wild native species and cultivated species, while in North America it usually refers to native populations. Taxonomically, lupins are classified in the family *Fabaceae*, in the genus *Lupinus* (CLEMENTS *et al.*, 2008; EASTWOOD *et al.*, 2008).

In terms of breeding, white lupine is a relatively young crop. The first varieties began to be created in the 1930s. The modern selection of white lupine goes in several directions. Breeding is directed to increasing of the economic use of lupine and creating universal varieties – for grain and forage. Special models with the parameters of the selected traits have been developed for each direction of lupine use (LIKHACHEV and NOVIK, 2012).

Currently, the main selection method for white lupine is intraspecific hybridization. Most often, the "step" crossing is used, which allows to combine valuable traits and properties inherent in the parental forms in one genotype. In hybrid lupine breeding, backcrossing, recurrent and diallelic selection are used (ŚWIĘCICKI *et al.*, 2015; LUKIN *et al.*, 2017).

In order to transfer individual valuable traits to new hybrid forms without the negative characteristics of the donor, recurrent crossing schemes and individual selection are jointly used. In recent years, the method related to the selection of individual seeds in the offspring has been used (TIURIN, 2014).

Multiple selection plays an essential role in lupine breeding when working in hybrid populations. It allows for a shorter time to stratify the population into separate more homogeneous and uniform groups, and also gives the opportunity to carry out additional crosses between the best promising forms (RUKSHAN *et al*., 2011, TEFERA *et al*., 2015).

The challenges in the breeding of the white lupine are the creation of early and medium-early ripening varieties with a high and stable yield of grain and green mass; increased content of protein and fat in seeds; tolerant to viral and fungal diseases and extreme environmental factors (ARTYUKHOV and PODOBEDOV, 2012; TAYLOR *et al.*, 2020). Years and genotypes had an influence on the morphological and productive properties of the investigated genotypes (TERZIC *et al.*, 2019; LAKIĆ *et al.*, 2019; 2022; KOSTIĆ *et al.*, 2021; KOSEV *et al.*, 2022; 2023; STEVANOVIĆ *et al.*, 2023; RAKIĆ *et al.*, 2023). The aim of the research was to characterize the main distinguishing traits of promising hybrid lines of white lupine.

MATERIALS AND METHODS

The studies were carried out from 2019 to 2021 at the Institute of Forage Crops - Pleven, Bulgaria. A competitive varietal experiment was established using the method of long plots with a harvest plot size of 10 m^2 in four repetitions. Distance between rows was 50 cm and the depth of planting 5 cm. The productive potential of the white lupine hybrid lines - LN5 (Lucky801 × PI533704) and LN1-1 (Lucky801 × PI533704) was studied. The parental white lupine cultivars were used as controls (PI533704 (Spain), Lucky801 (France).

Phenological stages and periods are reported as follows: date of emergence, beginning of flowering, full flowering, technical maturity, duration of the growing season (days). In the technical maturity stage, a biometric analysis was done according to the following characteristics: plant height (cm); height of the first pod (cm); number of pods per plant; number

of seeds per pod; number of seeds per plant; weight of the seed per plant (g) and 1000 seeds weigth (g). Finally, grain yield (kg/ha) was determined.

The variety Monica was obtained by multiple individual selection in the cross (Lucky801 × PI533704) (line LN5). In 2020, it was presented in the Expert Commission at the Executive Agency for Variety Testing, Field Inspection and Seed Control system for testing for distinguishable homogeneity and stability. By the decision of Expert Commision (appointed by order RD-10-1/14.01.2022) and by order No. RD-12-1 of the Minister of Agriculture of the Republic of Bulgaria dated 02.03.2022, the Monica variety was registered as a new and original. The variance analysis according to DIMOVA and MARINKOV (1999) was used to find the reliable differences between individual genotypes (varieties and lines) in terms of yield and the studied elements of productivity. Data from the studied indicators were processed statistically using the Statgraphics Plus 2.1 program.

RESULTS AND DISCUSSION

The duration of the vegetation period, calculated as the number of days from the date of sowing to the date of technical maturity in the studied genotypes - promising lines and parental varieties, varied from 114 days (PI533704 and LN1-1 in 2020) to 142 days (Lucky801 in 2021). The shortest growing season was line LN1-1 (114 to 135 days) (Table 1).

Table 1. Phenological developments of lines and varieties white lupine, 2019-2021

Stages/Variety (line)	Year	Sowing data	Data of germination	Beginning of flowering	Full maturity	Technical maturity	Vegetation period, days
Lucky801	2019	05.03	08.04	20.05	27.05	15.07	132
	2020	20.03	04.04	22.05	29.05	18. 07	119
	2021	04.03	26.04	21. 05	26. 05	24. 07	142
PI533704	2019	05.03	08.04	13.05	21.05	11. 07	128
	2020	20.03	04.04	15.05	20.05	13. 07	114
	2021	04.03	26.04	18. 05	22. 05	20. 07	138
LN5	2019	05.03	08.04	16.05	24.05	10. 07	127
	2020	20.03	04.04	17.05	26.05	16. 07	117
	2021	04.03	26.04	21. 05	25. 05	22. 07	140
LN1-1	2019	05.03	08.04	11.05	20.05	14. 07	131
	2020	20.03	04.04	14.05	19.05	13. 07	114
	2021	04.03	26.04	16. 05	21. 05	17. 07	135

The lines and cultivars of white lupine with regard to the occurrence of the individual phenological stages and the duration of the vegetation period (in accordance with the climatic conditions and their genetic background) can be characterized as follows: PI533704 and LN1-1 as early, and Lucky801 and LN5 as later maturing.

Significant differences were found in most of the analyzed quantitative characteristics. The values of the plant height trait as one of the structural elements of productivity showed that there is a significant variation between the investigated cultivars and lines (Table 2).

Table 2. Biometric analysis of quantitative traits of cultivars and lines white lupine, 2019-2021

Variety, line	Plant height, cm	Height of the first pod, cm	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	Weight of the seeds per plant, g	1000 seeds weigth, g
Lucky801	108c	44b	33a	4a	130a	45b	349b
PI533704	80ab	36ab	23a	5a	103a	30a	298a
LN5 (*Lucky801* x PI533704)	87b	40ab	28a	4a	114a	37ab	339b
LN1-1(*Lucky801* x PI533704)	68a	33a	24a	4a	92a	26a	305a

means followed by the same letter are not statistically different at the p < 5% probability level

Plant height largely determines lodging resistance and suitability for mechanized harvesting. In terms of plant height, variety Lucky801 emerged as the genotype forming plants with the tallest stems (108 cm). Taking into account the climatic conditions during the years of cultivation, the greater responsiveness of the Lucky801 variety to their improvement is evident. Line LN5 (Lucky801 × PI533704) and variety PI533704 occupy an intermediate position with plant height (80 - 87 cm), and for plants of line LN1-1 the value of this trait is 68 cm (Figure 1).

The data for the height of formation of the first pod were similar. Variety Lucky801 sets the first pod on the lowest node, at 44 cm. The value of this parameter for variety PI533704 was 36 cm, respectively. The higher line LN5 set first pod at a higher height, about 40 cm, and line LN1-1 at 33 cm.

Figure 1. Representative plants of white lupine Lucky801, PI533704, LN5 and LN1-1 in the technical maturity

The observed differences in the number of pods per plant were not statistically significant. It was found that the parental variety Lucky801 formed the highest number of pods per plant (33), followed by line LN5 (28). Line LN1-1 and variety PI533704 yielded up to 23-24 pods per plant.

Results for number of seeds per plant were similar to the previous trait and showed superiority of Lucky801 (130) and line LN5 (114) over PI533704 (103). The last position was occupied by line LN1-1, whose plants managed to feed 92 seeds.

Biometric analysis did not show compensatory mechanisms for the trait number of seeds in pods, therefore no change in the arrangement of white lupine genotypes was observed.
Seed weight per plant, as a trait representing seed productivity, is the result of the ratio of many characters, of which the number of seeds per plant and the 1000 seeds weight are decisive. In the present study, on average for the period, cultivar Lucky801 showed the highest seed productivity (45 g), but the seed weight per plant in line LN5 (37 g) was intermediate to the two parental components.

Variety PI533704 and line LN1-1 showed a certain similarity in the number of pods, number of seeds per plant and number of seeds per pod, therefore the seed productivity is also close and statistically significant (30 g; 26 g).

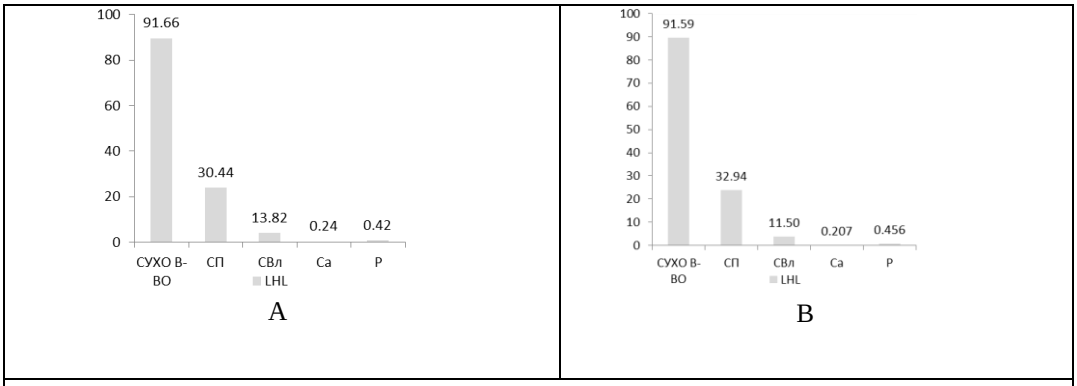
The 1000 seeds weight depends on the features of the genotype and on the environment. Data analysis showed that the productivity of Lucky801 was very well matched with the seed size (349 g). The PI533704 characterized by the lowest 1000 seeds weight (298 g), but line LN1-1 the 1000 seeds weight was 305 g (Figures 2 and 3).

Of interest is line LN5, distinguished by the 1000 seeds weight of 339 g, statistically not significant different from the better parent Lucky801.

As a complex quantitative trait, the formation of grain yield is directly dependent on changing climatic conditions. In the conducted field experiment, the yield of white lupine cultivars and lines varied significantly by year (Table 3).

Figure 2. Line white lupine LN1-1 (*Lucky801* x PI533704)

Figure 3. White lupine line LN5 (*Lucky801* x PI533704)



Dry matter (%), CP – crude protein (%), CF – crude fiber (%), **Ca**–calcium (%), P – phosphorus (%)

Figure 4. Basic chemical composition of lines white lupine (*Lupinus albus* L.)
A - LN1-1; B - LN5

Table 3. Grain yield (kg/ha) in varieties - parental components and hybrid line white lupin, 2019-2021

Parameter	Year			
Variety/line	2019	2020	2021	Average
Lucky801(P1)	4460	1780	3920	3390c
PI533704 (P2)	3760	1120	2600	2490a
LN5	4190	1580	3680	3150bc
LN1-1	3700	1110	3080	2630a
Average (P1+P2)	4110	1450	3260	2940b

means followed by the same letter are not statistically different at the p < 5% probability level

Unfavorable for growth and development was 2020, when the grain yield of all varieties studied and lines was significantly lower. In 2021, the grain yield variation was from 2600 kg/ha to 3920 kg/ha, and in the most favorable year 2019, the grain yield variation was from 3700 kg/ha to 4460 kg/ha. Variety Lucky801 and line LN5 were the most productive genotypes, and line LN1-1 showed biological qualities close to the second parental component PI533704.

Line LN5, even in the unfavorable environment, succeed to fully express its productive capabilities and formed a significant quantity of seeds (3150 kg/ha), which exceeded the average value of the parents. On average for the study period, line LN1-1 was characterized by a higher grain yield (2630 kg/ha) compared to variety PI533704 (2600 kg/ha), although it was not significantly different from it. The lowest yield was due to the shorter growing season, during which it fails to form a significant quantity of seeds, as well as to the lower plants.

Differences in grain yields between line LN5 (3150 kg/ha) and variety Lucky801 (3390 kg/ha) were not statistically significant, therefore these genotypes are into the same statistical group. The values of the grain yield of line LN1-1 in the individual years of the study (3700 kg/ha, 1110 kg/ha, 3080 kg/ha) give reason to believe that it is significantly affected by changes in climatic conditions. The yield obtained was found lower than the average of the two parent

components (2940 kg/ha). Variety PI533704 showed lower grain yield (2490 kg/ha), and the difference compared to line LN1-1 was statistically unsignificant.

Plants of the candidate white lupine cultivars LN1-1 and LN5 had high content of dry matter in the grain (91.66%; 91.51%) (Figure 4).

In line LN5, the higher crude protein content (32.94%) was combined with the lower crude fiber content (11.50%). For line LN1-1, a crude protein content of 30.44% and a crude fiber content of 13.82% were found. In terms of calcium content, the white lupine lines do not differ significantly (0.240%; 0.207%). The values for phosphorus content were also very close, as for LN1-1 it was 0.420% and for LN5 it was 0.456%, respectively.

Successful breeding significantly depends on the extent of the available genetic resources (BEYENE, 2020). Legumes are pivotal for the sustainability of farming and food systems, by promoting soil fertility and environmental protection, in addition to food security. Modern white lupin breeding aims to exploit genetic resources for the development of "sweet" elite cultivars, resilient to biotic adversities and well adapted for cultivation on a global level. The rich lupin local germplasm genetic diversity and the distinct genotypic composition compared to elite cultivars, highlights its potential use as a source of important agronomic traits to support current breeding efforts and assist its integration to modern sustainable agriculture (ZAFEIRIOU *ET AL.*, 2021).

The breeding lines showed improved performance of resistance towards *c. lupini* compared to the reference varieties. Improved resistance had a favorable effect on grain yield, particularly in environments with high disease pressure, and yield stability. Average grain yields were 2.6 t ha^{-1} for the breeding lines and 1.5 t ha^{-1} for the reference cultivars. The alkaloid content varied among environments and breeding lines (JACOB *et al.,* 2017). Expansion of white lupin cultivation to various hardiness zones, would promote legume reintroduction to the European farming systems, endorsing agriculture and environment sustainability in support of green farming (ZAFEIRIOU *et al.,* 2021).

CONCLUSION

Characterization of promising white lupine hybrid lines (LN5 and LN1-1) and their parental forms (Lucky801 and PI533704) was done. Lucky801 had higher number of seeds per plant (130), higher number of pods (33), seed weight per plant (45 g) and grain yield (3390 kg/ha). Line LN5 also had a high grain yield (3150 kg/ha) and a good combination of the traits plant height (87 cm), number of seeds per plant (114) and seed weight per plant (37 g). Line LN1-1 can be defined as early ripening with a fast growth rate, with a shorter growing season and with a grain yield (2630 kg/ha) higher than that of variety PI533704 (2490 kg/ha).

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NOVA SORTA BELE LUPINE MONIKE (*Lupinus albus* L.)

Valentin KOSEV[1], Viliana VASILEVA[2], Vera POPOVIĆ[3]

[1] Institut za krmne kulture, 5800 Pleven, Poljoprivredna akademija, Bugarska
[2] Institut za kukuruz, 5835 Kneža, Poljoprivredna akademija, Bugarska
[3]Institut za ratarstvo i povrtarstvo, Nacionalni institut za Republiku Srbiju, 21000 Novi Sad, Republika Srbija

Izvod

Urađena je karakterizacija perspektivnih hibridnih linija bele lupine (LN5 i LN1-1) i njihovih roditeljskih oblika (Lucki801 i PI533704). Urađena je biometrijska analiza svake sorte i linije prema glavnim kvantitativnim osobinama i fenološkim fazama i periodima. Stvorena je nova sorta bele lupine Monika (iz linije LN5) sa smerom upotrebe za seme. Dobijen je ponovljenom individualnom selekcijom iz ukrštanja Lucki801 × PI533704. Sorta pripada grupi srednjeg sazrevanja sa trajanjem vegetacionog perioda od 129 dana. Ima genetski završen rast. Visina biljke bila je 87 cm. Sorta ima visoku otpornost na leganje i dobru prilagodljivost abiotičkim uslovima. Prve mahune su formirane na 40 cm. Mahune biljke formiraju se na glavnom stablu i na skraćenim bočnim grančicama prvog i drugog reda. Na jednoj biljci formirano je oko 28 mahuna koje ne pucaju. Cvast je srednje veličine, plavo-bela, seme je belo, srednje veličine. Broj semena u jednoj biljci je u proseku 114. Sadržaj proteina zrna je 33%. Sorta se odlikuje visokom potencijalnomza produktivnost semena (masa semena po biljci 37 g). Masa 1000 semena je 339 g. Prosečan prinos zrna (3150 kg/ha) u ogledima takmičarske sorte je veći od prosečnog prinosa roditeljskih formi (2940 kg/ha). Odlukom Stručne komisije pri Izvršnoj agenciji za ispitivanje sorti, terenske inspekcije i kontrole semena u Bugarskoj (imenovana naredbom RD-10-1/14.01.2022.) i naredbom br. RD-12-1 ministra poljoprivrede Republike Bugarske od 02.03.2022., sorta Monika je prepoznata kao nova i originalna.

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