Pregledni rad
Review article

Introduction of novel legume crops in Serbia - White lupin (*Lupinus albus*)

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Summary: The renewed interest in introducing white lupin in Serbia is its high crude protein content in grain dry matter of nearly 400 g kg^{-1}, which makes it a potential supplement for soybean meal in animal feeding. The only collection of white and other lupins in Serbia is maintained at Institute of Field and Vegetable Crops in Novi Sad, with about 200 accessions of 10 species, containing about 70 accessions of white lupin. The accessions with high tolerance to alkaline soil reaction of about pH=8 in a carbonated chernozem in Novi Sad regularly formed two orders of pods and grains and produced grain yields of more than 5 t ha^{-1}, 45 t ha^{-1} of green forage and 8 t ha^{-1} of forage dry matter. The first Serbian white lupin breeding programme carried out at Institute of Field and Vegetable Crops in Novi Sad has resulted in developing cultivars Vesna and Panorama, registered in 2008.

Key words: biomass, breeding, forage, grain, *Lupinus albus*, nitrogen, protein, quality, white lupin, yield

Origins and distribution

Lupin or lupine (*Lupinus* L.) is a rich legume genus which comprises few hundred species originating from both Old and New World. It is cultivated on about 1,000,000 ha on a world scale (Mihailović et al. 2007a). The most important crops of this genus are white (*L. albus* L.), yellow (*L. luteus* L.), narrow-leafed (*L. angustifolius* L.) and Andean (*L. mutabilis* Sweet) lupins, which are multi-functional crops like many other annual legumes and are utilized in human consumption and animal feeding in the form of green forage, forage dry matter, forage meal, mature grain, as well as green manure (Mikić et al. 2006). Species such as large-leafed (*L. polyphyllus* Lindl.) and sky lupin (*L. nanus* Douglas ex Benth.) are used as ornamental plants.

Although the primary center of both cultivated white lupin (*L. albus* L. var. *albus* Gladst.) and its wild progenitor (*L. albus* L. var. *graecus* (Boiss. and Sprunn) Gladst.) is most likely the southern Balkans (Cowling et al. 1998), this crop has mostly been unknown in the central and northern parts of the Balkan Peninsula, such as Serbia (Mihailović et

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al. 2005). The first attempts of introducing white lupin as a forage and grain legume into Serbian agriculture have occurred only relatively recently (Popović-Pecija 1950) lacking success. The principal reason for a renewed interest in introducing this crop in the agriculture of Serbia remains its high crude protein content in grain dry matter, ranging between 380 g kg^{-1} and 400 g kg^{-1} (Viveros et al. 2007), making it an excellent potential supplement for soybean meal in animal feeding.

Genetic resources

Today, the only collection of white and other lupins in Serbia exists as a part of the Annual Forage Legumes Collection (AFLCNS) at Institute of Field and Vegetable Crops in Novi Sad (Ćupina et al. 2006b). The Novi Sad collection of lupins contains about 200 accessions of 10 species, white lupin being the most numerous one, with about 70 accessions of different geographic origin and status (Mihailović et al. 2006b).

Among the first white lupin accessions that have entered the collections were advanced cultivars from Poland (Ćupina et al. 2009), one of the greatest lupin producers in Europe. The Novi Sad collection of white and other lupins has its passport database and a complete characterization of morphological and other significant traits of its accessions (Mihailović et al. 2007c) and is maintained in the Forage Crops Department in field conditions (Ćupina et al. 2006a).

Cultivation potential

The preliminary trials with white lupin accessions, comprising advanced cultivars from Poland and wild populations and local landraces from Spain and Portugal, were rather promising (Mihailović et al. 2006a), although some accessions of white lupin, together with majority of the accessions of yellow, narrow-leafed and Spanish (*L. hispanicus* L.) lupins that were also tested, were extremely susceptible to the cultivation on chernozem soils.

The accessions with high tolerance to alkaline soil reaction, such as pH of about 8 in a carbonated chernozem in Novi Sad, have achieved good results, with regularly formed two orders of pods and grains and grain yields of more than 5 t ha^{-1} on average (Table 1).

Tab. 1. Average values of thousand grains mass and grain yield as distributed by orders in white lupin accessions at Rimski Šančevi 2005 and 2006 (Ćupina et al. 2007)

Tab. 1. Prosečne vrednosti mase hiljadu zrna i prinosa zrna po redovima akcesija bele lupine na Rimskim Šančevima 2005. i 2006.

Accession / *Akcesija*	Thousand first-order grains mass / *Masa hiljadu zrna prvog reda* (g)	Thousand second-order grains mass / *Masa hiljadu zrna drugog reda* (g)	Portion of first-order grain yield / *Udeo prinosa zrna prvog reda*	Portion of second-order grain yield / *Udeo prinosa zrna drugog reda*	Grain yield / *Prinos zrna* (kg ha^{-1})	Harvest index / *Žetveni indeks*
BG-001780	339	277	0.71	0.29	6336	0.44
BG-002553	344	309	0.53	0.47	5168	0.39
BG-005555	335	364	0.68	0.32	5088	0.50
LUP 261/89	309	290	0.61	0.39	4992	0.39
Bac	294	288	0.29	0.55	7010	0.44
Petkuser Bittere Weisse Lupine	324	262	0.50	0.50	3692	0.31
Kievskij 409	249	235	0.41	0.49	3517	0.52
LUP 148	336	313	0.76	0.24	6420	0.43
LUP 149	310	307	0.53	0.47	3880	0.37
K-490	336	274	0.55	0.45	3517	0.44
K-509	301	359	0.51	0.43	5280	0.42
K-305	305	343	0.36	0.55	5040	0.45
$LSD_{0.05}$	42	56	0.25	0.14	801	0.14
$LSD_{0.01}$	67	75	0.38	0.19	1075	0.19

Apart from testing the potential of white lupin for grain production in the conditions of Serbia, an evaluation of its potential for forage has been carried out, where the genotypes with high content of alkaloids may find their primary use (Mikić et al. 2009b). The results of this evaluation have revealed a great potential of white lupin for forage production, with average yields surpassing 45 t ha^{-1} of green forage and 8 t ha^{-1} of forage dry matter (Table 2).

Tab. 2. Average values of forage yields in twelve white lupin accessions at Rimski Šančevi for 2006 and 2007 (Mihailović et al. 2008b)
Tab. 2. Prosečne vrednosti prinosa krme dvanaest akcesija bele lupine na Rimskim Šančevima 2006. i 2007.

Accession / *Akcesija*	Green forage yield / *Prinos zelene krme* (g plant^{-1})	Green forage yield / *Prinos zelene krme* (t ha^{-1})	Forage dry matter yield / *Prinos suve materije krme* (g plant^{-1})	Forage dry matter yield / *Prinos suve materije krme* (t ha^{-1})	Forage dry matter proportion / *Udeo suve materije krme*
BG-001743	63.36	48.8	10.00	7.7	0.16
BG-002171	53.58	43.4	8.50	6.9	0.16
BG-002173	32.09	26.6	4.86	4.0	0.15
BG-002553	63.35	48.1	9.38	7.1	0.15
BG-002603	56.45	44.0	7.80	6.1	0.14
BG-005542	73.06	53.3	11.75	8.6	0.16
BG-005555	42.62	35.0	6.99	5.7	0.16
BG-005573	25.35	21.3	4.27	3.6	0.17
Siebacher Red	53.84	43.1	10.05	8.0	0.19
LUP 261/89	71.48	52.9	11.64	8.6	0.16
Termis	57.51	45.4	10.97	8.7	0.19
LUP 149	67.00	50.3	11.48	8.6	0.17
$LSD_{0.05}$	6.52	5.7	1.82	1.4	0.01
$LSD_{0.01}$	8.11	8.0	2.33	1.9	0.02

Regarding the quality, evaluation of forage crude protein yield of several white lupin genotypes has confirmed the potential for yields of more than 2 t ha^{-1}, while the evaluation of above-ground biomass nitrogen yield confirmed the importance of its use as green manure, with yields being able to reach 400 kg ha^{-1} (Table 3).

Tab. 3. Average forage crude protein yield (kg ha^{-1}) and above-ground biomass nitrogen yield (kg ha^{-1}) in white lupin genotypes at Rimski Šančevi in 2005 and 2006 (Mihailović et al. 2007b)
Tab. 3. Prosečni prinosi sirovih proteina krme i azota nadzemne biomase genotipova bele lupine na Rimskim Šančevima 2005. i 2006.

Genotype / *Genotip*	Forage crude protein yield / *Prinos sirovih proteina krme* (kg ha^{-1})	Above-ground biomass nitrogen yield / *Prinos azota nadzemne biomase* (kg ha^{-1})
BG-005573	1,383	221
Siebacher Red	2,500	400
LUP 261/89	2,500	400
Termis	2,261	362
BL-164	2,527	404
Average *Prosek*	2,161	346

Breeding and utilization

The main obstacle to successful growing of white lupin in Serbia may be the dominant chernozem soil in its fertile northern parts. White lupin may be tolerant to slightly calcareous soils with pH values between about 5 and 8, while a high soil pH together with presence of lime can cause chlorosis in white lupin, mainly due to a lack of iron (Duthion 1992). However, wide genetic variation of white lupin present in accessions of different origin has been found useful as a basis for establishing the first Serbian white lupin breeding programme and the development of the cultivars tolerant of calcareous soils and with a potential for high and quality forage, grain and biomass yields. In this way, white lupin was proven to be advantageous for the conditions of Serbia in comparison to other lupin species, such as narrow-leafed lupin that has achieved good results only when cultivated on acid soils such as pseudogley (Eickmeyer et al. 2007, Mihailović et al. 2008a).

The primary goal of the white lupin breeding programme at Institute of Field and Vegetable Crops in Novi Sad was high grain yield by improving each grain yield component. Among the most important ones were grain number per plant, positively correlated with yield only slightly affected by sowing date or plant density (Ney et al, 1993, Putnam et al., 1993) and a thousand grains mass, as a yield component with a high heritability (Julier et al. 1995). At the same time, lines with high harvest index have been selected, since this was of major importance in selection for increased grain yield (Noffsinger & Van Santen 1995).

Two spring lines BL-164 and BL-163 were among numerous lines selected from hybrid populations with desirable agronomic characteristics related to yields of grain, forage and biomass. These two lines were included in the Serbian national list and renamed as Vesna and Panorama in December 2008 (Mihailović et al. 2009). Both Vesna and Panorama feature average yields of more than 5,000 kg ha^{-1} of grain and more than 350 g kg^{-1} of crude protein content in grain dry matter (Mikić et al. 2009a). In a 2009 preliminary trial in Helsinki, Finland, Vesna produced more than 82 t ha^{-1} of green forage and 18 t ha^{-1} of forage dry matter in a single cut at the stage of flowering of the first order (Stoddard, pers. comm.).

In the future, white lupin breeding programme in Novi Sad will be enriched by including more genotypes of diverse origin and status, especially wild populations such as five white lupin landraces from Near East donated from the collection of VIR in St. Petersburg collected in 1926 and 1927 by N. I. Vavilov, with a high content of both protein and oil in grain dry matter, high tolerance to fusarium and grain yields of more than 6 t ha^{-1} (Vishnyakova & Mikić 2008).

Apart from its place in animal feeding, white lupin may be used as a food additive in bread industry, where it has shown a great potential as a bread additive, with loaf height and structure maintained when wheat flour was substituted for lupin flour at levels up to 5% (Pollard et al. 2005). Along with other lupin species, white lupin cultivars may be commercialised as an additive in aquaculture, especially due to high digestibility of phosphorus (Glencross & Hawkins 2004).

Conclusion

White lupin is a crop with a great potential for high, quality and stable yields of forage, grain and biomass and the results of its evaluation suggest its introduction in the agriculture of Serbia as a multi-purpose crop suitable to fit into different cropping systems including organic farming and sustainable agriculture. The high crude protein content in its grain should make this crop another rich and quality supplement for soybean meal in animal feeding. Selecting genotypes tolerant to a wider range of soil reaction, up to pH of 8, offers a possibility for its cultivation on diverse soil types, including both acid, prevailing in central Serbia and preferred by lupins, and alkaline ones, such as chernozem, dominant in the northern parts of the country.

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Uvođenje novih gajenih mahunarki u Srbiji - bela lupina (*Lupinus albus*)

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Izvod: Razlog za obnovu zanimanja za uvođenjem bele lupine u Srbiju jeste visok sadržaj sirovih proteina u suvoj materiji zrna od skoro 400 g kg^{-1}, čineći je mogućim dodatkom sojinom brašnu u ishrani domaćih životinja. Jedina zbirka bele i ostalih lupina u Srbiji održava se u Institutu za ratarstvo i povrtarstvo u Novom Sadu, sa oko 200 akcesija 10 vrsta, od čega je 70 akcesija bele lupine. Akcesije sa velikom tolerantnošću na alkalnu reakciju zemljišnog rastvora, poput one od oko 8 na černozemu u Novom Sadu, uobičajeno obrazuju dva reda mahuna i zrna, te ostvaruju prinose od više od 5 t ha^{-1} zrna, 45 t ha^{-1} zelene krme i 8 t ha^{-1} suve materije krme. Prvi srpski program oplemenjivanja bele lupine, koji se odvija u Institutu za ratarstvo i povrtarstvo u Novom Sadu, iznedrio je sorte Vesna i Panorama priznate 2008.
Ključne reči: azot, bela lupina, biomasa, krma, kvalitet, *Lupinus albus*, oplemenjivanje, prinos, protein, zrno

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