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Effects of autumn and spring primary tillage on soybean yield and 1000-grain weight in the agro-ecological conditions of Serbia

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Abstract

Soybean yield depends on the selection of cultivars, soil fertility, applied cultivation practices, and agroclimatic conditions over the years. High-quality and timely primary tillage is essential for stable development and high yields of soybean plants. The effect of autumn and spring primary tillage on soybean yield and 1000-grain weight was examined in a three-year study (2013-2015). The trial included cultivars with different maturity periods, developed at the Institute of Field and Vegetable Crops Novi Sad: Valjevka and Galina 0 maturity group, Sava and NS Maximus I maturity group, Rubin and Venera II maturity group. Trial subplots were prepared using different periods of primary tillage, which was conducted in autumn (November, 01–05) and spring (March, 25–31). The highest yields and 1000-grain weight were obtained after autumn primary tillage in all the three study years. Yield decrease by 2.72% to 38.91% and 1000-grain weight decrease of 1.33%-11.93% were recorded after spring primary tillage.

Key words: soybean yield, 1000-grain weight, primary tillage.

Introduction

Soybean (*Glicine max.* L. Merr.) is considered as an important plant species, both for human and animal consumption. A wide range of products obtained from soybean seed originates from the presence of protein (approx. 40%) and oil (approx. 20%) in seed (Jegadeesan and Yu., 2020). In addition, biological nitrogen fixation in the soybean-bradyrhizobia symbiosis improves soil fertility. The U.S.A., Argentina, Brazil, China, and India are the world's largest soybean producers and represent more than 90% of global soybean production. High yields of soybean plants require the choice of cultivars suitable for certain growing regions, the use of high-quality certified seed, as well as proper and timely application of all cultivation practices. None of the subsequent cultivation practices can correct errors arising from the inadequate application of the previous cropping practices. Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid et al., 2006) and affects the sustainable use of soil resources through its influence on soil properties (Lal & Stewart, 2013). Tillage is mechanical manipulation of soil and plant residues to prepare an appropriate seedbed for crop planting, which has several advantages such as loosening soil, regulating the circulation of water and air within the soil, increasing the release of nutrient elements from the soil for crop growth, and controlling weeds by burying weed seeds and emerged seedlings (Obour et al., 2021). The decision to till in the autumn or spring will be dictated by many factors that are not easy to control. The two main factors for tillage in the autumn or spring are soil moisture conditions and soil temperature. These two factors can have significant impact on soil structure, tillage depth, clod size, and level of soil compaction. Therefore, soil moisture and soil temperature can influence tillage practice, and, ultimately, yield and soil quality performance (Liu et al., 2021).

The aim of this study was to examine the effect of autumn and spring primary tillage on the yield and 1000-grain weight of six soybean varieties, with different maturity periods.

Material and Methods

The trial was set on a plot near agricultural high school in Bačka Topola (45° 48′ 32″ N; 19° 38′ 06″ E), during three growing seasons (2013, 2014, 2015). Research was done on chernozem soil. Groundwater is at 10-40 m and has no influence on the development of typical chernozem.

The trial included cultivars with different maturity periods, developed at the Institute of Field and Vegetable Crops Novi Sad: Valjevka and Galina – 0 maturity group, Sava and NS Maximus – I maturity group, Rubin and Venera – II maturity group. The trial was conducted with four replications. The size of the basic plot was 15 m2 (six rows of soybean were 5 meters long with inter-row spacing of 50 cm).

Trial subplots were prepared using different periods of primary tillage, which was conducted in autumn (01–05 November) and spring (25–31 March). Both spring and autumn primary tillage were carried out up to the 25 cm depth.

Maize was used as the preceding crop in all three study years, whereas primary tillage did not include soil fertilization. Nitrogen was incorporated into the soil as a pre-sowing practice (130 kg ha-1 ammonium nitrate containing 33.5% N), and before sowing, the seed was inoculated with microbial preparation NS Nitragin, containing nitrogen fixing bacteria from the genus Bradyrhizobium japonicum. Pre-sowing practice was performed to a depth of 10 cm. Sowing in 2013 was on 8 April, in 2014 on 10 April, and in 2015 on 11 April.

The pre-sowing cultivation was performed in two passes: furrow closing in mid-March and pre-sowing cultivation in early April. Pre-sowing cultivation was carried out in several passes during spring primary tillage, in order to obtain fine structure of the soil surface, suitable for soybean sowing (3-4 passes of seedbed conditioner).

Standard cultivation practices used in soybean production were applied in all the three study years, including sowing up to the depth of 4-5 cm, application of herbicides against narrowleaf and broadleaf weeds, two intercroppings and prevention of mites (2015). Harvesting was carried out in the stage of technological maturity, along with grain weight measurements and calculation of yield per surface unit (kg ha-1) with 14% moisture, as well as 1000-grain weight measurement.

Weather conditions in the 2013-2015 period. Vegetation seasons across the three study years were warmer (18.65 °C, 18.33 °C, and 19.80 °C) compared to the multiannual average (18.03 °C), and the highest temperatures were recorded in 2015, higher by 1.8 °C compared to the multiannual average (Table 1). Average annual precipitation in the chernozem zone in Serbia is 600-650 mm, and the average temperature is 10.9 ºC (Miljković, 1996).

Tab. 1. Average temperature (° C) and precipitation amount (mm) in the 2013-2015 period

Month	Mean monthly temperature (°C)				Precipitation (mm)			
	2013	2014	2015	Average 1964-2012	2013	2014	2015	Average 1964-2012
IV	13.4	13.2	12.0	11.6	35.8	51.2	15.9	47.7
V	17.4	16.3	18.0	17.0	118.1	202.1	191.7	60.7
VI	20.2	20.5	20.7	20.0	125.7	38.2	26.7	87.9
VII	22.3	21.9	24.9	21.6	34.1	141.1	2.6	67.9
VIII	22.9	20.9	24.5	21.1	26.7	78.7	99.7	58.7
IX	15.7	17.2	18.7	16.9	107.8	84.3	52.6	45.7
Average/total	18.65	18.33	19.80	18.03	448.2	595.6	389.2	368.6

Evapotranspiration was calculated according to the phytothermal index for soybeans (Bošnjak, 1999).

The obtained results were processed by the analysis of variance for three-factorial trials in all years of study. Means were compared using the Tuckey's multiple range test. All analyses were performed in *STATISTICA 10*.

Results and Discussion

In July and August 2015, temperatures were higher by 3.3 °C (24.9 °C) and 3.4 °C (24.5 °C), compared to the multi-year average of 1964-2012 (July 21.6 °C, August 21.1 °C), which are accompanied by insufficient quantities of precipitation during this period, leading to forced maturing and low yields of soybean. Precipitation amounts were higher during soybean vegetation period with avourable distribution in all the three study years, mostly in 2014 while unfavourable distribution of precipitation was typical in 2013 and 2015 with higher precipitation amounts in the first stages of soybean development and distinctive lack during flowering, pod formation, and grain filling (July and August 2013, June, July and early August 2015). Such weather conditions promote vigorous growth of above ground plant parts and development of root system in the surface soil, while the plants have an unfavourable response to the lack of moisture in the second stage of the vegetation period. Weather conditions during vegetation period greatly affect soybean yield (Đukić et al., 2009; Dozet et al., 2013). Agroclimatic conditions during soybean growth have a greater effect on grain yield and its quality than the genotype (Silva et al., 2017).

Potential evapotranspiration (PE) shows the required amount of moisture for soybean crop growth, while actual evapotranspiration (AE) indicates the amount of plant-available moisture. The difference between potential and actual evapotranspiration shows the deficit or surplus of water in soils. Lack of precipitation was recorded in 2013 and 2015 (45 and 106 mm for 0 maturity cultivars, 63 and 132 mm for I maturity cultivars, and 66 and 108 mm for II maturity cultivar, respectively). Higher levels of precipitation were recorded in 2014 (117 mm for 0 and II maturity group, and 119 mm for I maturity group) compared to 2013 and 2015, indicating that soybean crops were not subjected to drought in the given year. Higher PE than AE indicates lack of soil moisture, i.e., the beginning of drought. In 2013 lack of moisture occurred on 5 August, while lack of soil moisture was observed after 18 July 2015 (Table 2).

Tab. 2. Soybean soil water balance based on the phytothermal index for certain maturity groups

Year	2013			2014			2015		
Maturity group	0	I	II	0	I	II	0	I	II
SM	47.05	47.05	47.05	35.32	35.32	35.32	42.17	42.17	42.17
PV	278.3	278.3	297.8	550.6	569.4	577.8	237.1	237.1	326.7
PE	370	388	410	418	435	445	379	405	471
AE	325	325	344	535	554	562	273	273	363
PD	-45	-63	-66	+117	+119	+117	-106	-132	-108
DS	05.08.	05.08.	05.08.	-	-	-	18.07.	18.07.	18.07.

Note. SM – soil moisture reserves during sowing time (mm), PV – precipitation during vegetation period (mm), PE – potential evapotranspiration (mm), ET – actual evapotranspiration (mm), PD – precipitation deficit (mm), DS – drought start (day).

Effect of primary tillage time on soybean yield. The highest average yield of the examined soybean cultivars was obtained in 2014 (3817.79 kg ha^{-1}), and the lowest in 2015 (1429.08 kg ha^{-1}). Differences in yield between the study years were statistically significant (Table 3).

Tab. 3. The effect of year, cultivar, and tillage on yield (kg ha^{-1})

Year (A)	Cultivar (B)	Tillage (C)		Average AxB	Average A
		Autumn	Spring		
2013	Valjevka	2686.25^{b}	2317.00^{a}	2501.63^{a}	2469.31^{b}
	Galina	2572.75^{b}	2261.25^{a}	2417.00^{a}	
	Sava	2894.50^{b}	2283.50^{a}	2589.00^{a}	
	NS Maximus	2829.00^{b}	2259.75^{a}	2544.38^{a}	
	Rubin	2733.50^{b}	2046.25^{a}	2389.88^{a}	
	Venera	2694.00^{b}	2054.00^{a}	2374.00^{a}	
	Average A×C	2735.00^{b}	2203.63^{a}		
2014	Valjevka	3512.00^{a}	3470.25^{a}	3491.13^{a}	3817.79^{c}
	Galina	3669.75^{a}	3453.25^{a}	3561.50^{a}	
	Sava	3947.75^{a}	3931.50^{a}	3939.63^{bc}	
	NS Maximus	3914.00^{a}	3797.25^{a}	3855.63^{b}	
	Rubin	4213.75^{a}	4038.50^{a}	4126.13^{c}	
	Venera	3965.25^{a}	3900.25^{a}	3932.75^{bc}	
	Average A×C	3870.42^{a}	3765.17^{a}		
2015	Valjevka	1806.75^{b}	1264.50^{a}	1535.63^{b}	1429.08^{a}
	Galina	1953.75^{b}	1256.00^{a}	1604.88^{b}	
	Sava	1943.25^{b}	1232.25^{a}	1587.75^{b}	
	NS Maximus	1869.75^{b}	1097.75^{a}	1483.75^{b}	
	Rubin	1632.00^{b}	847.00^{a}	1239.50^{ab}	
	Venera	1440.25^{b}	805.75^{a}	1123.00^{a}	
	Average A×C	1774.29^{b}	1083.88^{a}		

Factory	Year (A)	Cultivar (B)	Tillage (C)	A×B	A×C	B×C
	**	*	**	**	**	**

** – significance at 0.01 probability level, * – significance at 0.05 probability

In cotton cultivation, the primary tillage in the autumn yield achieved 2940 kg ha^{-1}, and in the spring 2660 kg ha^{-1}, i.e., autumn yield was 9.52% higher compared to spring yield, on the silty loam soil type (clayey, kaolinitic, thermic Rhodic Paleudult) (Raper et al. 2000). Primary tillage in the autumn (October) by using different machines: moldboard plough, chisel plough and subsoiler, increased corn yield by 5.56-11.64% relative to primary tillage in the spring (April) (Wells et al.

1990). The amount of tobacco yield does not only depend on the time of primary tillage but also on the machinery used. Medium late maturity soybean cultivars during the three-year study achieved the highest yield, both after the autumn and spring primary tillage (Figure 1).

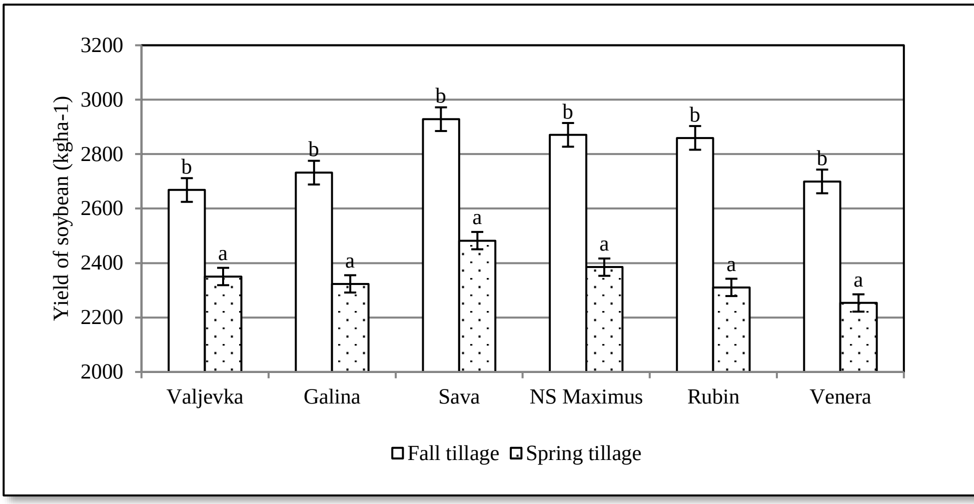

Fig. 1**.** Average yield of soybean grain over the three study years (kg ha^{-1})
Values followed by different small letters within columns are significantly different (p<0.05) according to the Tuckey's test

The lowest yield was recorded in medium-early maturity soybean cultivars after autumn primary tillage, whereas after spring primary tillage, the lowest yield was recorded in medium-late maturity soybean cultivars. The observed results confirmed that soybean cultivars with shorter vegetation period are easily adaptable to unfavourable conditions compared to the medium-late maturity soybean cultivars, having reacted with lower yield decrease after spring primary tillage. Autumn tillage is a better option because soil moisture is generally below field capacity, there is less potential for soil compaction, and soil temperature is suitable (Al-Kaisi and Hanna, 2010).

In all studied soybean cultivars, yield decrease after spring primary tillage during the three study years was 15.84%. Tilling soil during spring may not be very effective for soil structure due to high soil moisture content, and may potentially lead to soil compaction, soil leaching, and creation of large sized soil clods. These effects of spring tillage would be very counter-productive by reducing yield and soil quality (Al-Kaisi and Hanna, 2010). The highest yield decrease was recorded in 2015 (38.91%). Under favourable conditions and high soybean yields, no significant differences were detected among tillage treatments (Adee, 2018).

In the interaction (AxC) of year/ time of tillage, it was noticed that in the autumn of primary tillage, significantly higher yield was obtained compared to spring primary tillage at statistic level p <0.01. In the best year, with a sufficient amount of precipitation and a good distribution of precipitation (2014), the increase in autumn yield on primary cultivation amounted to 3870.42 kg ha^{-1}, which is 2.79% more than the spring yield (3765.17 kg ha^{-1}). In 2015, which was extremely unfavourable for soybean production, the increase in autumn yield on primary cultivation was 1774.29 kg ha^{-1}, which is 63.70% more compared to the spring primary tillage (1083.88 kg ha^{-1}).

Effect of primary tillage time on 1000-grain weight. The highest 1000-grain weight was obtained in 2014 (170.74 g), while the lowest in 2015 (147.01 g) (Table 4). Just like the yield, the differences in 1000-grain weight across study years were statistically significant. The highest value of 1000-grain weight was obtained for the Rubin cultivar (170.05 g), which was higher compared to the other examined soybean cultivars. Among other cultivars included in the study, statistically significant differences were observed for 1000-grain weight values, and the lowest was recorded for the Galina cultivar (148.61 g). Regarding the time of primary tillage, significantly higher 1000-grain weight was recorded after autumn primary tillage (163.41 g) compared to spring primary tillage (153.02 g) (Table 4).

Tab. 4. The effect of year, cultivar, and tillage on 1000-grain weight (g)

Year (A)	Cultivar (B)	Tillage (C)		Average A x B	Average A
		Autumn	Spring		
2013	Valjevka	147.93^{b}	138.55^{a}	143.24^{a}	156.90^{a}
	Galina	152.05^{b}	141.83^{a}	146.94^{a}	
	Sava	172.83^{a}	167.35^{a}	170.09^{b}	
	NS Maximus	165.48^{a}	157.30^{a}	161.39^{b}	
	Rubin	179.15^{a}	164.03^{a}	171.59^{b}	
	Venera	154.60^{b}	141.68^{a}	148.14^{a}	
	Average A × C	162.00^{b}	151.79^{a}		
2014	Valjevka	176.43^{a}	172.48^{a}	174.45^{bc}	170.74^{b}
	Galina	168.83^{a}	164.20^{a}	166.51^{ab}	
	Sava	183.18^{a}	179.53^{a}	181.35^{c}	
	NS Maximus	169.00^{a}	169.40^{a}	169.20^{ab}	
	Rubin	175.40^{a}	172.20^{a}	173.80^{bc}	
	Venera	158.48^{a}	159.73^{a}	159.10^{a}	
	Average A × C	171.88^{a}	169.59^{a}		
2015	Valjevka	140.25^{b}	125.18^{a}	132.71^{a}	147.01^{a}
	Galina	142.03^{b}	122.73^{a}	132.38^{a}	
	Sava	166.45^{b}	142.83^{a}	154.64^{bc}	
	NS Maximus	162.70^{b}	145.33^{a}	154.01^{bc}	
	Rubin	175.43^{b}	154.10^{a}	164.76^{c}	
	Venera	151.18^{b}	135.98^{a}	143.58^{ab}	
	Average A × C	156.34^{b}	137.69^{a}		

Factory	Year (A)	Cultivar (B)	Tillage (C)	A×B	A×C	B×C
	**	*	*	**	*	**

** – significance at 0.01 probability level, * – significance at 0.05 probability

A significant yield component is 1000-grain weight, which besides yield, serves as the best indicator of suitability for soybean production across years or regions (Dozet et al., 2009). The results obtained by Toleikiene et al., (2021) indicated that unfavourable growing conditions during seed reproductive growth stage significantly affected 1000-grain weight. Soybean cultivars Rubin and Sava had the highest 1000-grain weight, whereas Galina had the lowest value for the trait, both after autumn and spring primary tillage (Table 5).

Tab. 5. Decrease in 1000-grain weight of soybeans after spring tillage (%)

Soybean cultivar	2013	2014	2015	2013-2015
Valjevka	6.34^{*}	2.24^{ns}	10.75^{**}	6.11
Galina	6.72^{*}	2.74^{ns}	13.59^{**}	7.38
Sava	3.17^{ns}	1.99^{ns}	14.19^{**}	6.27
NS Maximus	4.94^{ns}	-0.24^{ns}	10.68^{**}	5.06
Rubin	8.44^{**}	1.82^{ns}	12.16^{**}	7.48
Venera	8.36^{**}	-0.79^{ns}	10.05^{**}	5.79
Average:	6.30	1.33	11.93	6.36

** – significance at 0.01 probability level, * – significance at 0.05 probability, ^{ns} no significance

The decrease in 1000-grain weight after spring tillage was 6.36%, considering all the study years and all the cultivars. The highest decrease in 1000-grain weight was recorded in 2015 (11.93%), which was very unfavourable, while the decrease of only 1.33% was observed in 2014 under favourable conditions for soybean production. Considering the cultivars individually, Rubin had the highest decrease in 1000-grain weight in the three-year trial (7.48%), while the lowest decrease in 1000-grain weight was observed in NS Maximus after spring tillage (5.06%). The highest decrease in 1000-grain weight across the study years was exhibited by Galina (2.74%) in 2014, whereas Venera and NS Maximus exhibited the decrease in 1000-grain weight of 0.79% and 0.24%, respectively. Under unfavourable conditions during 2015, the highest decrease in 1000-grain weight was observed for Sava (14.19%), while in 2013 the highest decrease was observed in cultivars Rubin (8.44%) and Venera (8.36%).

Conclusion

Based on the obtained results the following conclusions are drawn: Spring primary tillage caused the decrease in soybean yield, more prominent in the years with unfavourable conditions with a distinctive drought period. 1000-grain weight is the indicator of agroclimatic and production conditions of specific years. Spring primary tillage leads to decrease in 1000-grain weight, with the lower percentage of decrease compared to soybean yield, indicating that, besides 1000-grain weight, spring primary tillage also decreases the number of pods, i.e., the number of soybean grains per plant. Autumn primary tillage is required for high and stable soybean yields.

Confirmation

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Утицај јесење и прољећне основне обраде земљишта на принос и масу 1000 зрна соје у агроеколошким условима Србије

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Сажетак

Принос соје зависи од избора сорте, плодности земљишта, примијењених агротехничких мјера и агроклиматских услова у појединим годинама. Квалитетна и правовремена основна обрада земљишта је услов за нормалан развој биљака соје и остварење високох приноса. У трогодишњим истраживањима (2013-2015) проучаван је утицај јесење и прољећне основне обраде на принос и масу 1000 зрна соје. У огледу су биле заступљене сорте соје Института за ратарство и повртарство Нови Сад, различите дужине вегетационог периода: Ваљевка и Галина–0 групе зрења, Сава и НС Махимус–I групе зрења) и Рубин и Венера, II–групе зрења. Подпарцеле у огледу биле су са различитим временом основне обраде земљишта. Основна обрада је вршена у јесењем периоду (01-05. новембра) и у прољећном периоду (25–31. март). Јесењом основном обрадом земљишта за производњу соје остварени су највиши приноси и највиша вриједност за масу 1000 зрна соје, у све три истраживане године. Код прољећне основне обраде смањење приноса кретало од 2,72 % до 38,91 % и смањење масе 1000 зрна у појединим годинама од 1,33 % до 11,93 %.

Кључне ријечи: принос соје, маса 1000 зрна, основна обрада.

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