Influence of conservation tillage and fertilization on weed infestation and soybean yield

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Bojana Brozović[1], Irena Jug[1], Boris Đurđević[1], Marija Ravlić[1], Iva Rojnica[2], Marko Aragović[3], Danijel Jug[1]

[1]*Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, Osijek, Croatia (bojana.brozovic@fazos.hr)*
[2]*Križevci University of Applied Sciences, Milislava Demerca 1, Križevci, Croatia*
[3]*Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, Osijek, Croatia - student*

Abstract

The aim of the experiment set up in Čačinci (17° 86' 36" E, 45° 61' 32" N, 111 m a. s. l.) on Stagnosol soil type in 2021 year was to determine the influence of conservation tillage and fertilization on soybean weediness and yield. Tillage treatments included conventional tillage (ST), deep (CTD) and shallow conservation tillage (CTS). Fertilization subtreatment were recommended amount (FR) and (HF) - 50% off. Tillage had a significant effect on soybean weediness. The highest average weed biomass (141.86 g m^{-2}) and weed density (25.17 m^{-2}) were recorded on CTS. Reduced fertilization resulted with the highest weed density (32.00 m^{-2}) on CTD. Average soybean yields were the highest at ST (6.98 t ha^{-1}) without significant differences ($p<0.05$) compared to CTS (6.88 t ha^{-1}). Conservation tillage increased weediness without a significant decrease in soybean yield.

Keywords: soil tillage systems, mineral fertilization, weediness, *Glycine max* (L.) Merr.

Introduction

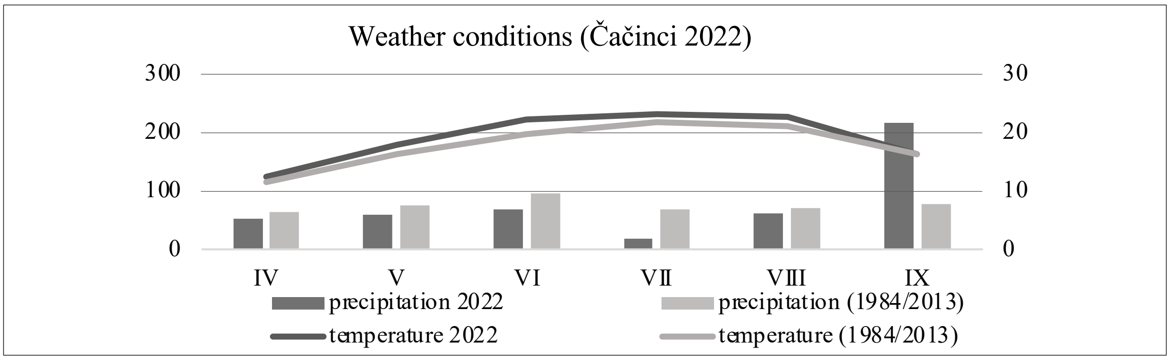
Nowadays, when agriculture is one of the most vulnerable sectors affected by climate change, conservation agriculture is recognized as one of the most effective methods of adaptation and mitigation of the negative consequences of climate change on plant production (Jug et al. 2018; Aune, 2012). It implies proper crop rotation, minimum soil disturbance and permanent soil coverage with at least 30% of crop residues (FAO, 2016). Conservation tillage is a suitable way to prevent soil degradation processes with preservation of soil health and fertility due to the positive effect on soil quality, water and nutrient conservation, yield stability, increased biodiversity while reducing production costs (Palm et al., 2013; Derpsch, 2005). Despite the numerous advantages of conservation tillage, the systematic introduction and acceptance of such production systems is still sometimes limited by certain factors that often relate to expected changes in the level of weediness of agricultural crops (Derksen, 1996; Derrouch et al., 2020). In addition to numerous available measures of sustainable weed management, weeds still represent a dominant limiting biotic factor in plant production, and conservation tillage certainly changes the composition of the weed flora and the intensity of weediness, but not necessarily to the detriment of agricultural crop. Besides tillage, fertilization is also a significant factor that contributes to the sustainability of crop production systems and also has an impact on crop weediness (Wan et al., 2012; Brozović et al., 2021). According to previous research, optimal fertilization can have a two-fold effect on weediness level. Due to the greater weed nutrient use efficiency related to the crops, the occurrence of weeds can be increased with optimal fertilization (Nie et al., 2009; Cheimona et al., 2016). However, it is also possible to reduce the occurrence of weeds through an increased competitive advantage of the crop as a result of optimal fertilization (Travlos et al., 2018; Kaur et al., 2018) and due to lower nutrient requirements of weeds suboptimal fertilization can result in a competitive advantage of weeds over the agricultural crops (Légère et al., 2008). The importance of soybean as an agricultural crop stems from its wide multiple uses as well as its positive agronomic effects (Stritongtae et al., 2021; Sudarić and Vratarić, 2008). Adverse weather conditions have been increasingly present in the soybean vegetation in recent years, which requires adoption of effective measures such as conservation tillage to maintain stability of soybean yield (Moraru and Rusu, 2012). Soybean is susceptible to weeds (Gaweda et al., 2020) and weediness is one of the main causes of yield reduction (Wallace et al., 2018). Because of all the above, the aim of this study was to determine the influence of conservation tillage and fertilization systems on weediness and yield of soybeans.

Material and methods

The research with conservation tillage and fertilization was conducted in the eastern region of Croatia in Čačinci (17° 86' 36" E, 45° 61' 32" N, 111 m a. s. l.) on Stagnosol soil type (IUSS Working Group) in 2021 year with basic soil chemical properties: pH $_{KCl/H2O}$ (4.09/5.65), Hy-hydrolytic acidity (7.90 cmol$^{(+)}$ kg^{-1}), AL $_{P2O5}$ (10.37 mg 100 g^{-1}), AL $_{K2O}$ (15.63 mg 100 g-^{1}), SOM-soil organic matter (2.8 %). This paper presents the results of the second research year (2022) where the impact of different tillage and fertilization systems on weediness and soybean yield was investigated. The basic plot size was 160 m^2 (tillage treatment) and the size of the subtreatment (fertilization) plot was 80 m^2 (8 x 10 m). The soil tillage treatments were: conventional (ST) - plowing up to 30 cm depth, deep conservation tillage (CTD) - loosening up to 30 cm depth with a minimum of 30% soil coverage with crop residues and shallow conservation tillage (CTS) - loosening up to 10 cm depth with a minimum of 50% soil surface coverage with crop residues. Subtreatments included recommended fertilization (F) calculated with the ALRxp computer program for fertlizer recommendations (Vukadinović and Vukadinović, 2011) and suboptimal fertilization (HF) reduced by 50%. Soil tillage (plowing and loosening) was performed in autumn 2021 after the maize harvest. The winter furrow was closed in spring 2022 on ST tillage with a two pass of spike-tooth harrow combine with a hollow roller. Pre-sowing soil preparation was performed with one pass of a spike-tooth harrow combined with hollow roller. Fertilization was carried out in autumn prior to basic soil tillage in recommended amount (530 kg ha^{-1} NPK – 0:20:30) and 50% reduced dose (265 kg ha^{-1} NPK – 0:20:30). Combined with pre-sowing soil preparation recommended (150 kg ha^{-1}) and reduced amount (75 kg ha^{-1}) of KAN (27% N) were applied in spring. No-till seeder was used for soybean sowing (cultivar IKA) on April 12 with seeding rate of 600 000 seeds ha^{-1}. Chemical weed control was carried out uniformly on each investigated treatment and subtreatment twice and included pre-em treatment with application of 960 gl^{-1} S-Metolachlor (1.2 l ha^{-1}) and Metribuzin 70 % (0.6 kg ha^{-1}) and post-em with 22.4 g l^{-1} Imazamox, 480 g l^{-1} Bentazon (1 l ha^{-1}) using sprayer. Soybean harvest was preformed manually on the whole investigated subplots and the rest of the experimental area was harvested using combine harvester. The yields have been recalculated to standard moisture content (9%). Weed assessment was carried out by weeds sampling in V3 (three unfolded trifoliolate leaves) and R7 (beginning maturity - one normal pod on the main stem has reached its mature pod color) soybean growth stages. The weed density, above-ground biomass, the number of weed species and weed coverage were determined at each treatment and sub-treatment. All classified weed species on the area of 0.25 m^2 in four repetitions were counted for weed density determination and cut off on the ground level, separated by different weed types and dried at 60 °C for 48 h to evaluate the aboveground biomass while weed coverage was determined visually. ANOVA design with soil tillage and fertilization as given factors was used to test the influence of different soil tillage systems and different fertilization levels on weed density, weed biomass, weed species number, weed coverage and soybean yield. Mean values that were significant according to the performed F- test were compared using the LSD test at $p < 0.05$ level of significance for the investigated factors. Statistica software package, version 14.0.0. (TIBCO Software Inc., Palo Alto, CA, USA) was used to conduct the ANOVA analysis.

Results and discussion

The lack of precipitation was pronounced during the soybean growing season from April to August in the conducted research (Graph 1). The amount of precipitation was lower compared to the multi-year average (1984/2013), with pronounced dry conditions in July, when only 18 mm of rain fell, which is almost 4 times less than the annual average (Graph 1). The lack of precipitation in the mentioned period was accompanied by above-average air temperatures, looking at the multi-year average (1984/2013). The dry period was interrupted in September, which was extremely wet, and the recorded amount of rain was almost three times higher than the average value (Graph 1).



Graph 1. Weather conditions at experimental site (Čačinci 2022)

During the research, the most numerous broadleaved annual was *Ambrosia artemisiifolia* L. while dominant perennial was *Calystegia sepium* (L.) R. Br. *Setaria viridis* (L.) P. Beauv. was the most present annaul grass. In addition to the above, *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L., *Lythrum salicaria* L., *Mentha spicata* L., *Xanthium strumarium* L., *Setaria glauca* (L) P. Beauv. and *Panicum capilare* L. were also determined weed species. Soil tillage significantly affected weed occurence in V3 soybean growth stage (Table 1). Tillage had a significant effect on biomass, weed density and weed coverage in V3 soybean growth stage, while the average effect of fertilization on all investigated parameters of weediness was absent which is opposite to Tang et al. (2014) but consistent with Légère et al., (2008) who reported stronger effects of tillage on weed community than fertilization in soybean-maize crop rotation. The weed density was almost three times higher on CTS compared to ST in average (Table 1) but on deep conservation tillage systems (CTD) there was no statistically significant difference compared to ST. Higher weed densities, biomass and weed coverage are also confirmed by Légère et al., (2008); Romaneckas et al., (2021); Brozović et al., (2023) who investigated the impact of lower tillage intensity on weed community in agricultural crops. Interactions among tillage and fertilization existed in the case of weed density and coverage, which were the highest on shallow conservation tillage with suboptimal fertlization (CTS/HF) with statistically significant differences ($p<0.05$) compared to conventional tillage and lower fertilization (ST/HF) (Table 1). Soybean weediness increased during the growing season (Table 2). A noticeable increase in all investigated parameters of weediness is a possible consequence of unfavorable weather conditions (lack of precipitation) (Graph 1) and it is known that stressful environmental conditions benefit weeds more than crops (Patterson, 1995) due to their ability to adapt to different adverse conditions (Radicetti and Mancinelli, 2021).

Table 1. Weed infestation of soybean in V3 growth stage

Tillage (T)	ST		CTD		CTS		Average (F)	
Fertilization (F)	FR	FH	FR	FH	FR	FH	FR	FH
WB (g m^{-2})	3.87 $^{n.s.}$	2.97	5.89	8.21	10.84	8.64	6.87 $^{n.s.}$	6.61
Average (T)	3.42 ^{B}		7.05 ^{A}		9.74 ^{A}			
$F_{(T)}=11.753$, $F_{(F)}=0.060$, $F_{(TxF)}=1.578$								
WD (m^{-2})	36.00 ^{b}	25.33 ^{c}	23.67 ^{c}	33.00 ^{bc}	38.00 ^{b}	50.33 ^{a}	32.56 $^{n.s.}$	36.22
Average (T)	30.67 ^{B}		28.34 ^{B}		44.17 ^{A}			
$F_{(T)}=9.670$, $F_{(F)}=1.335$, $F_{(TxF)}=5.173$								
WSN (m^{-2})	2.00 $^{n.s.}$	2.33	1.67	1.67	2.67	1.67	2.11 $^{n.s.}$	1.89
Average (T)	2.17 $^{n.s.}$		1.67		2.17			
$F_{(T)}=1.800$, $F_{(F)}=0.800$, $F_{(TxF)}=2.600$								
WC (%)	19.00 ^{c}	12.00 ^{d}	36.33 ^{ab}	33.00 ^{bc}	34.00 ^{b}	38.67 ^{a}	29.78 $^{n.s.}$	27.89
Average (T)	15.5 ^{B}		34.67 ^{A}		36.34 ^{A}			
$F_{(T)}=131.591$, $F_{(F)}=2.627$, $F_{(TxF)}=8.736$								

T-tillage, F-fertilization, ST-conventional tillage, CTD-deep conservation tillage, CTS-shallow conservation tillage, FR-recommended fertilization, FH-reduced fertilization, WB-weed biomass, WD-weed density, WSN-weed species number, WC-weed coverage, F(T)- F test for tillage, F(F)-F test for fertilization, F(TxF)-F test for tillage and ferilization interaction

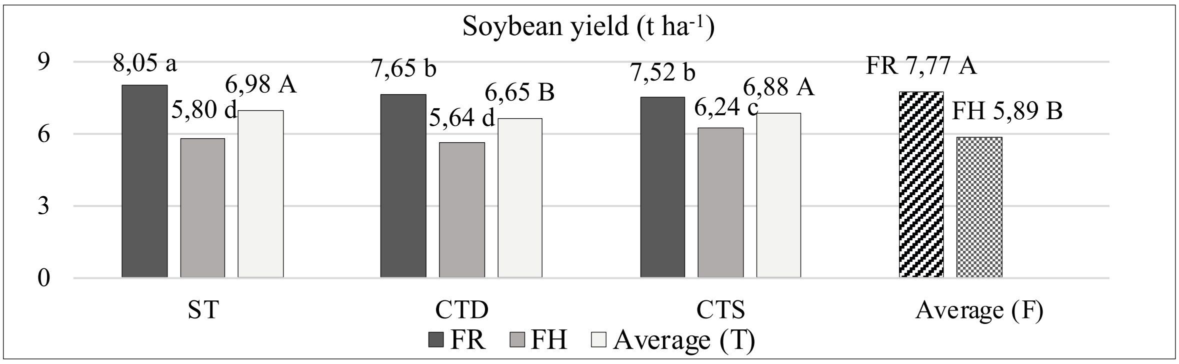
In average, shallow conservation tillage (CTS) resulted in the highest weediness, and all investigated parameters were statistically significantly different ($p<0.05$) compared to conventional tillage (ST) (Table 2).

Table 2. Weed infestation of soybean in R7 growth stage

Tillage (T)	ST		CTD		CTS		Average (F)	
Fertilization (F)	FR	FH	FR	FH	FR	FH	FR	FH
WB (g m^{-2})	20.28 $^{n.s.}$	8.19	45.71	56.28	129.87	153.85	65.29 $^{n.s.}$	72.77
Average (T)	14.24 ^{C}		51.00 ^{B}		141.86 ^{A}			
$F_{(T)=}36.131$, $F_{(F)}=0.352$, $F_{(TxF)}=0.696$								
WD (m^{-2})	18.33 ^{b}	16.00 ^{bc}	11.33 ^{c}	32.00 ^{a}	20.67 ^{b}	29.67 ^{a}	16.78 ^{B}	25.89 ^{A}
Average (T)	17.17 ^{C}		21.67 ^{B}		25.17 ^{A}			
$F_{(T)}=9.926$, $F_{(F)}=38.423$, $F_{(TxF)}=20.406$								
WSN (m^{-2})	3.33 ^{c}	2.33 ^{cd}	2.00 ^{d}	3.67 ^{b}	4.67 ^{b}	6.67 ^{a}	3.33 ^{B}	4.22 ^{A}
Average (T)	2.83 ^{B}		2.84 ^{B}		5.67 ^{A}			
$F_{(T)}=36.125$, $F_{(F)}=8.000$, $F_{(TxF)}=9.125$								
WC (%)	33.00 ^{c}	18.67 ^{d}	38.00 ^{b}	40.33 ^{ab}	37.33 ^{b}	42.33 ^{a}	36.11 ^{A}	33.78 ^{B}
Average (T)	25.84 ^{B}		39.17 ^{A}		39.83 ^{A}			
$F_{(T)}=24.856$, $F_{(F)}=1.627$, $F_{(TxF)}=10.937$								

T-tillage, F-fertilization, ST-conventional tillage, CTD-deep conservation tillage, CTS-shallow conservation tillage, FR-recommended fertilization, FH-reduced fertilization, WB-weed biomass, WD-weed density, WSN-weed species number, WC-weed coverage, F(T)- F test for tillage, F(F)-F test for fertilization, F(TxF)-F test for tillage and ferilization interaction

Increase in weed biomass, weed coverage and weed species number during the growing season on reduced tillage systems is also reported by previous research (Hofmeijer et al., 2019; Armengot et al., 2016; Sans et al., 2011). Optimal fertilization resulted with average decrease of weed density and weed species number but with higher weed biomass and weed coverage in maturity soybean growth stage (R7) (Table 2). Inconsistent influence of fertilization on weed infestation is a possible consequence of greater weed nutrient use efficiency (Nie et al., 2009; Cheimona et al., 2016) or lower nutrient requirements related to crops (Légère et al., 2008) and at the same time increased competitive advantage of the crop as a result of optimal fertilization (Travlos et al., 2018; Kaur et al., 2018). Increase in the average number of weed species on conservation tillage systems compared to conventional (ST) indicate the possitive effects of reduced tillage on species diversity (Légère et al., 2008). The highest weed species number was recorded on shallow conservation tillage with reduced fertilization CTS/FH , almost three times higher compared to ST/FH while CTD/FH resulted with greater weed density compared to ST/FH. Tillage and fertilization had a significant impact on soybean yields. Average soybean yields were not significantly different ($p<0.05$) among shallow conservation tillage (CTS) and conventional tillage (ST). Adequate soybean yields on reduced tillage systems are also reported by Chețan et al., 2022. Reduced fertilization led to an average decrease in soybean yield and obtained yield was lower on FH for almost 2 t ha^{-1}. Significant interactions between tillage and fertilization in terms of yields were found. The highest soybean yield was achieved in ST/FR, while yields on CTD/FR and CTS/FR did not statistically significantly differ among themselves. Looking at soybean yields on reduced fertilization, the best was achieved on CTS/FH, and there were no statistically significant differences ($p<0.05$) between ST/FH and CTD/FH. Soybean production is under the influence of soil fertility and available soil water content in relation to the soil tillage (Acharya et al., 2019). Drought conditions correlated with high temperatures during the research certainly influences the yield formation (Basal and Szabo, 2020; Cotrim et al., 2021) but despite the present drought, soybean yields in this research were satisfactory.



Graph 2. Soybean yield on different tillage and fertilization treatments

Conclusion

Conservation tillage systems had the effect of increasing the level of soybean weediness. The average influence of fertilization on weediness was less expressed compared to soil tillage. Tillage and fertilization significantly affected soybean yield. The highest soybean yields were achieved on the conventional (ST) and shallow conservation tillage systems (CTS) despite the fact that this treatment had the highest weediness. Reduced fertilization led to a decrease in soybean yield on average, but not on the CTS tillage system, which can be recommended as supstitution for plowing with the need for further research.

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