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THE INFLUENCE OF COVER CROPS AND MICROBIOLOGICAL FERTILIZER ON YIELD AND YIELD COMPONENTS OF SWEET MAIZE (*Zea Mays* L. *sacharata* Sturt)

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Abstract

Sweet maize, a popular vegetable, occupies an important place in the population's diet, and in recent decades, the area under this crop has been increasing. In this paper, the influence of cover crops (CC), with and without the application of microbiological fertilizer, on the yield and yield components of sweet maize (hyrbid ZPSC 421su, FAO 400) was examined. The experiment was carried out at the "Zemun Polje" Maize Research Institute during 2014/15-2015/16. CC consisted of four types of plants: 2 legumes: T1-common vetch, T2-field pea, 2 non-leguminous species: T3-winter oats and T4-fodder kale. Two variants with mixtures were: T5-common vetch + winter oats and T6-field pea + winter oats and two controls T7 (straw) and T8 (bare soil). CC was sown in autumn, plowed at the end of April or May, after which 1/2 of the plot was treated with microbiological fertilizer. Sweet maize was sown in mid-May at a density of 65,000 plants per ha. For industrial processing, the shape, size and uniformity of the corn cob, grain size, and row configuration are important. CC influenced the increase in the number of grain rows and the number of grains in a row, the most in the variant T4, and the weakest in the variants with mixtures (T5 and T6). The highest cob length values were measured in the T4 variant. The largest cob diameter was measured in 2016 in T4 (4.6 cm), and the smallest value in controls (3.1 cm and 3.3 cm) in 2015. By comparing the examined years, we can see that in the first year the highest yield was achieved in the T4 variant (6261.70 kg ha^{-1}), while the lowest was achieved in the T6 variant (2732.88 kg ha^{-1}) in the second year.

Key words: *cover crops, microbiological fertilizer, sweet maize, yield, grain.*

Introduction

The highest production growth rate among all grains, including wheat and rice, was recorded by maize in the period from 2010-2020. year, due to changed eating habits, as well as increased industrial needs (Das and Singh, 2016). In Serbia, hybrids of maize with specific properties (protein maize), popcorn and sweet maize are grown, which are increasingly popular in the diet. Srdić et al. (2019) states that sweet maize is a tasty and high-quality vegetable whose grain, in addition to sugar, also contains amino acids, minerals and vitamins of the B group, which are in a very good ratio. Unlike standard maize, sweet maize is used fresh, as direct food for humans or for industrial processing in the milky stage of endosperm development, when the grain is tender, juicy and sweet. It contains a lower proportion of starch and a higher proportion of sugar, primarily sucrose. Types of sweet maize with yellow endosperm are the most important for industrial processing and fresh consumption (Pajić et al., 2008). Hybrids for the fresh sweet maize market should produce a large number of attractive cobs per unit area. When it comes to freezing the entire sweet maize cob, the requirements are similar to the consumption of hybrids in a fresh state - a higher number of cobs per unit area and a suitable appearance of the cob. The yield of each plant species represents the most significant quantitative characteristic. When it comes to sweet maize, the meaning of "yield" changes depending on the market (Pajić et al., 2008). Dolijanović et al. (2012) states that by using cover crops and covering the soil during autumn and winter with dead organic mulch - straw, the highest sweet maize grain yield is obtained, while the lowest sweet maize grain yield and the lowest grain yield were achieved in the conventional cultivation system. Of the cover crops, the sweet maize yield was positively influenced by sweet vetch from leguminous plants in winter, and forage kale from non-leguminous plant species in winter. The yield of sweet maize is influenced by the type of cover crop, the amount of biomass and the date of plowing (Brzeski et al., 1993; Tejada et al., 2008; Dolijanović et al., 2012; Dolijanović et al., 2013; Rosa, 2014). The positive impact of cover crops on increasing the yield of the main crops is the result of less infestation and increased competition for the main factors of growth and development and through the secretion of allelopathic compounds. Legumes as cover crops can often provide sufficient nitrogen needed for main crop production. Thiessen-Martens et al. (2005) called this feature of cover crops "fertilizer replacement value". The corn crop better absorbs accumulated nitrogen from the soil after plowing cover crops, than by direct addition of nutrients through mineral fertilizers (Janošević, 2021). Apart from the positive effect on sweet corn yield, Abdul-Baki et al. (1997) states that the cultivation of cover crops makes it possible to reduce the use of herbicides and pesticides. Cover crops with higher biomass production, plant height and root system elongation are usually more competitive. In systems of sustainable production, an important role is played by the application of microbiological fertilizers, that is different types of microorganisms, which can influence the increase of soil biogenicity and overall fertility, which leads to the production of an ecologically valuable product. Glamočlija et al., (2022) states that biopreparations based on bacteria and fungi can be an alternative or supplement to mineral nutrients in the production of cultivated crops. Cover crops in cropping systems could provide economic and environmental benefits and play an important role in adjusting the cropping systems toward sustainable production and climate-smart agriculture (Vojnov et al., 2022). The benefits of cover crops have been recognized for a long time; however, only a few studies have assessed multi-mixes in terms of agronomic, environmental, and economic indicators (Chapagain et al., 2020). Drill-interseeding is becoming a viable method for integrating cover crops in no-till maize (*Zea mays* L.). Development of best management practices for drill-interseeding cover crops into no-till grain crops requires greater understanding of cover crop performance at the species and cultivar level (Caswell et al., 2019). Cover crops can provide ecological services and improve the resilience of annual cropping systems (Noland et.al, 2018). The aim of this work is to examine the influence of cover crops, grown individually or in mixtures, which are important in preserving and improving the chemical properties of the soil, with the application of microbiological fertilizers, on increasing the yield of sweet corn in Serbia. The tested sweet corn hybrid with specific properties is very interesting for producers, because it was selected for special purposes.

Materials and methods

Field experiment was carried out in 2014/15–2015/16 (factor Y) growing seasons, at Maize Research Institute in Zemun Polje, Belgrade (44°52'N; 20°20'E). The experiment was established as a block design with four replications. As winter cover crops (factor T) the following plants were grown: T1–common vetch (*Vicia sativa* L.), T2-field pea (*Pisum* *sativum* L.), T3-winter oats, (*Avena sativa* L.), T4-fodder kale (*Brassica oleracea* (L.) *convar. acephala*), two mixture variants of legume crops with oats: T5 - common vetch + winter oats and T6- field pea + winter oats, and two control treatments: a variant in which the surface was covered with straw (T7) and traditional variant: after ploughing in the fall plot stayed uncovered during the winter (T8). The cover crops were sown in the amount: common vetch – 120 kg, field pea – 150 kg, winter oat – 160 kg, and fodder kale 15 kg per ha, and in mixture relation between legume and oats was 70:30. The plot size was 17.5 m^2. The seeds of sweet maize hybrid ZPSC 421*su* (FAO 400) were sown in mid-May at the arrangement of 70 cm between rows and 22 cm between plants in the row (65,000 plants per ha). Preceding crop in both years was winter wheat. The autumn soil preparation (ploughing and seedbed preparation) was performed immediately before sowing, when also soil samples were taken for available N analysis at a depths of 0-20 cm and 20-40 cm. Further soil sampling from all CC and control treatments was done in the spring, after CC harvest, as well as after sweet maize harvesting. Before the sowing of CC (autumn) and sweet maize (spring) mineral fertilization was applied in order to obtain 120 kg ha^{-1} N, 90 kg ha^{-1} P and 60 kg ha^{-1} K. The total amount of P and K fertilizers was applied in autumn with mono-potassium phosphate fertilizer (a.m. 0:52:34) and the required N amount was incorporated together with sweet maize sowing (Urea 46% a.m). Nitrogen fertilization was conducted as following: for non-legume crops and control treatments it was 120, for sole legume itwas 80 and for mixture it was 90 kg ha^{-1} N. The remaining 40 or 30 kg ha^{-1} N was considered to be provided by nitrogen fixation. Green biomass of the cover crops was incorporated in the soil, immediately after; half of the elementary plot was infested with bio-fertilizer – Uniker (factor BF) mobilizer of nutrients, in an amount of 10 l ha^{-1}. Adding BF to the soil immediately after plowing cover crops is expected to intensify the mineralization of plant residues. The cobs were harvested at the stage of milk maturity of kernels. The obtained data were processed statistically, using the method of analysis of variance (ANOVA), for individual comparisons the least significant difference test LSD test (significance level 0.05) was used.

Table 1. Chronology of field operations and length of vegetation period of sweet maize

Year	2015	2016
Cover crops sowing	November, 13 2014	November, 4 2015
Cover crops sampling	May, 12	April, 19
Cover crops and microbiological fertilizer incorporated	May,21	April, 28
Sweet maize sowing	May, 21	April, 28
Hand weeding 1	June, 22	June, 12
Hand weeding 2	July, 15	July, 9
Sweet maize harvest	August, 21	Avgust, 3
Length of vegetation period of sweet maize (in days)	92	97

Table 2. Average air temperatures and precipitation sums from April to September at Zemun Polje

Months	Temperature (°C)		Precipitation (mm)	
	2015	2016	2015	2016
April	12.9	15.5	19.7	53.9
May	19.1	17.5	97.8	71.3
June	22.1	22.5	31.1	152.2
July	26.4	24.4	7.2	35.0
August	25.7	22.3	56.0	60.8
September	20.2	19.7	73.6	47.8
Average/Sum	21.1	20.3	285.4	70.2

Meteorological conditions during the test period are shown in Table 2. In 2015, the mean monthly air temperatures were higher, and the amount of precipitation was significantly lower, especially there was a significant lack of precipitation for use during the critical period of grain filling, which was not favorable for sweet maize. Precisely in dry years, cover crops showed greater efficiency, while microbiological fertilizers increased the quantity, but not the quality, of the yield of the main crop. The second year of the trial is more favorable from the point of view of the distribution of precipitation for the main crop, with a short dry period in July, which was compensated by a significant amount of precipitation from the previous month.

Results and discussion

For sweet maize producers, especially in sustainable agriculture, where there is less investment, satisfactory results are achieved in terms of yield compared to conventional. Sweet corn is grown on small areas in Serbia (about 5,000 ha), but despite this, it represents a significant financial gain for producers, and in proportion to the growing needs, it is expected that the areas under this crop will increase significantly in the coming years. These results show that the introduction of cover crops in the corn hybrid cultivation technology is justified. In this paper, the number of rows of grains, the number of grains in a row, the length of the cob and the diameter of the cob of sweet maize were analyzed as yield components.

Table 3.Number of crain rows in sweet maize

Year/ Treatmens	2015			2016			Average
	BFØ	BF	Average	BFØ	BF	Average	
T1	16.2	15.9	16.1	17.2	15.8	16.5	16.3
T2	16.3	16.5	16.4	17.4	16.1	16.8	16.6
T3	16.2	16.3	16.3	16.4	14.8	15.6	16.0
T4	17.0	16.7	16.9	17.0	16.7	16.9	16.9
T5	15.3	17.2	16.3	15.4	16.0	15.7	16.0
T6	16.1	16.9	16.5	16.0	17.0	16.5	16.5
T7	16.2	17.2	16.7	17.6	16.2	16.9	16.8
T8	16.3	15.9	16.1	16.7	16.7	16.7	16.4
Average	**16.2**	**16.6**	**16.4**	**16.7**	**16.2**	**16.5**	**16.5**
Factor	Y	BF	T	YBF	YT	BFT	YBFT
LSD 0.05	0.366	0.366	0.732	0.518	1.035	0.518	1.464

$p<0.05$ significant (*); $p>0.05$ no significant (^{ns})

Sweet maize hybrids that have at least 16 regularly distributed rows of grains, deep grains, and grain to the top of the cob are most valued (Pajić et al., 2008). In interaction with the year of the study, Uniker exerted a significant influence on this component of the yield, which indicates that its action depended to a high degree on meteorological conditions, primarily the amount and distribution of precipitation during the vegetation period of the main crop. A greater number of grain rows was determined in the first year of the trial, where more robust cover crops, such as winter fodder kale, as well as the mixture showed the greatest impact (Table 3). Le Vinh Thuc et al. (2022) in the research came to the result that treatment with supplemental lime and microbial organic fertilizer gave a greater kernel length than those with only lime or microbial organic fertilizer.

Table 4. Number of kernels in a row in sweet maize

Year/ Treatmans	2015			2016			Average
	BFØ	BF	Average	BFØ	BF	Average	
T1	32.0	30.0	31.0	33.2	35.2	34.2	32.6
T2	33.5	32.2	32.9	33.3	35.0	34.2	33.6
T3	31.6	34.7	33.2	29.7	29.3	29.5	31.4
T4	34.4	34.9	34.7	36.8	35.3	36.1	35.4
T5	30.5	29.7	30.1	34.1	30.8	32.5	31.3
T6	30.9	30.4	30.7	30.1	26.9	28.5	29.6
T7	33.7	36.2	35.0	35.6	33.3	34.5	34.5
T8	29.8	30.9	30.4	35.6	33.0	34.3	32.4
Average	**32.1**	**32.4**	**32.3**	**33.6**	**32.4**	**33.0**	**32.7**
Factor	Y	BF	T	YBF	YT	BFT	YBFT
LSD 0.05	1.386	1.386	2.773	1.961	3.922	3.922	5.547

$p<0.05$ significant (*); $p>0.05$ no significant (^{ns})

In the first year of testing, the number of grains in a row in sweet maize was significantly influenced by the factors of year and type of cover crops, as well as their mutual interaction, where there was an increase in the value of varieties with the application of Uniker. Dragičević et al. (2015) states that in the absence of precipitation, and especially in conditions of high air temperatures, the effect of applied microbiological fertilizers is more pronounced. The highest values were achieved by winter fodder kale, field pea and common vetch, while the lowest was recorded for varieties with mixtures.

Table 5. Cob length (cm) of sweet maize

Year/ Treatmans	2015			2016			Average
	BFØ	BF	Average	BFØ	BF	Average	
T1	14.8	14.9	14.9	17.3	19.9	18.6	16.8
T2	14.8	14.6	14.7	18.3	18.8	18.6	16.7
T3	15.0	15.3	15.2	16.3	16.0	16.2	15.7
T4	16.7	16.1	16.4	19.5	19.7	19.6	18.0
T5	15.2	14.4	14.8	18.4	18.8	18.6	16.7
T6	15.4	15.3	15.4	18.1	19.7	18.9	17.2
T7	14.5	14.7	14.6	18.4	18.8	18.6	16.6
T8	14.6	14.1	14.4	18.6	18.5	18.6	16.5
Average	**15.1**	**14.9**	**15.0**	**18.1**	**18.8**	**18.4**	**16.7**
Factor	Y	BF	T	YBF	YT	BFT	YBFT
LSD 0.05	0.427	0.427	0.854	0.604	1.208	1.208	1.709

$p<0.05$ significant (*); $p>0.05$ no significant (^{ns})

The year and type of cover crop and their mutual interaction had the greatest influence on the yield component of cob length. Higher values were measured in the second year of the test (Table 5), where the variant with winter fodder kale had statistically significant values. The measured cob lengths ranged from 13.5 to 19.5 cm and had values that are close to the values measured by Srdić (2009) for hybrids in her dissertation at the same location. Depending on the tillage system, Orosz (2017) in his research obtained a significantly smaller cob length, 16-17cm. The variant with winter oats recorded the smallest cob length. Pajić et al. (2008) states in their research that for the majority of the fresh sweet maize market, the most desirable hybrids are those with at least 16 straight rows of grains and with a cob length of 20-23 cm. The choice of varieties or hybrids has an impact on the length of the cob, as the length of the sweet corn cob decreases with the increase in the length of the growing season (Orosz, 2020).

Table 6. Cob diameter (cm) of sweet maize

Year/ Treatmans	2015			2016			Average
	BFØ	BF	Average	BFØ	BF	Average	
T1	3.1	3.9	3.5	5.0	4.1	4.6	4.1
T2	3.3	3.4	3.4	4.8	4.6	4.7	4.1
T3	3.4	3.4	3.4	4.9	3.7	4.3	3.9
T4	3.7	4.0	3.9	6.6	4.7	5.7	4.8
T5	3.8	3.2	3.5	5.4	4.2	4.8	8.3
T6	3.6	3.1	3.4	4.7	4.5	4.6	4.0
T7	3.2	3.4	3.3	4.1	4.3	4.2	3.8
T8	3.1	3.1	3.1	4.3	4.1	4.2	3.7
Average	**3.4**	**3.4**	**3.4**	**5.0**	**4.3**	**4.6**	**4.0**
Factor	Y	BF	T	YBF	YT	BFT	YBFT
LSD 0.05	0.151	0.151	0.304	0.215	0.429	0.429	0.607

$p<0.05$ significant(*); $p>0.05$ no significant (ns)

By measuring the diameter of the cob of sweet maize it was established that there is a statistically significant variation in the recorded values depending on all the investigated factors, except for the interaction of Uniker and the type of cover crop. The highest values for cob diameter were achieved in the second year of the test on varieties of individual cover crops (Table 6), while the lowest values were measured on the control varieties in the first year.

Table 7. Yield of sweet maize kernels (kg ha^{-1})

Year/Treatm	**2015**			**2016**			Average
	BFØ	BF	Average	BFØ	BF	Average	
T1	4410.17	3730.61	4070.39	3722.71	4221.74	3972.23	4021.31
T2	5076.85	6148.06	5612.46	3064.86	4527.91	3796.39	4704.43
T3	4648.85	6529.26	5589.06	4345.00	2047.05	3196.03	4392.60
T4	6602.47	5920.93	6261.70	5308.75	4573.53	4941.14	5601.42
T5	4290.71	4786.33	4538.52	2921.50	3073.33	2977.42	3758.00
T6	5792.68	5074.11	5433.40	3311.87	2153.89	2732.88	4083.14
T7	4180.51	6554.72	5367.62	4023.13	4869.60	4446.37	4907.00
T8	5605.98	4232.43	4919.21	4143.22	3470.79	3807.01	4363.11
Average	**5076.03**	**5372.06**	**5224.04**	**3855.13**	**3617.23**	**3736.18**	**4480.11**
Factor	Y	BF	T	YBF	YT	BFT	YBFT
LSD 0.05	283.70	283.70	567.40	401.21	802.43	802.42	1134.80

$p<0.05$ significant(*); $p>0.05$ no significant (ns)

Yang et al.(2023) states in the research the effectiveness of cover crops. Crop productivity and grain yields varies substantially with weather, length of growing season, soil type, crop species, and cover crop characteristics such as biomass production, C:N ratio and residue decomposition rate. From CC, field pea and fodder kale, as well as leguminous mixtures with winter oats stood out in the first year of testing (Table 7) with the highest yield, while in the second year the lowest yield was recorded for varieties in mixtures (T5 and T6). Observing the meteorological conditions in the years of the study, the effect of cover crops was smaller in the year with lower amounts of precipitation, with increased air temperatures during the vegetation period of the main crop. According to the results of Williams et al. (2008), in the case of sweet corn, the main factors of grain yield reduction are lower competitiveness in relation to weeds and greater sensitivity to drought during the summer months. Antosh et al. (2020) reported the results regarding the yield of sweet corn grains during two years of trials and at two locations after a cover crop of vetch, that it increased by 35.9% to 50.4% compared to conventional cultivation technology, while in the trials of Moore et al. (2020) ranged from 13.2 to 16.4 t ha^{-1}. Of the winter cover crops and their mixtures, as well as in relation to the conventional way of growing sweet corn (Dolijanović et al., 2014), winter hairy vetch had the advantage in terms of the achieved yield grain of sweet maize. Research results Noland et al. (2018) support that interseeding cover crops into maize at the seven-leaf collar stage introduces little to no risk of maize yield reduction, at least in years with above-normal precipitation.

Conclusions

The results of this work indicate that in a dry climate, without irrigation, cover crops that are more robust, with more developed above-ground biomass and greater soil coverage, primarily legumes grown individually or in mixtures, can increase the productivity of sweet maize and serve as an important part of sustainable cultivation systems of corn hybrids for specific purposes in our climatic conditions. The significant variation of yield and yield components in relation to the examined factors and their interactions is an indicator of a significant influence of both growing conditions and applied agrotechnical measures before and during the sweet maize vegetation period. From this research we conclude that the inclusion of some species as cover crops in the simplified cropping systems which actually predominate in the semiarid regions, improves N use efficiency, compared to the alternative long fallow periods between summer crops. Despite the clear benefit of cover crops, additional work must resolve the apparent interactions of fertilizer and cover crops on N mineralization/ immobilization processes.

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