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EFFECTS OF THE SECOND CROP ON MAIZE YIELD AND YIELD COMPONENTS IN ORGANIC AGRICULTURE

UTJECAJ POSTRNIH USJEVA NA PRINOS I KOMPONENTE PRINOSA U EKOLOŠKOM UZGOJU KUKURUZA

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ABSTRACT

The second crop use in organic agriculture is a known method of maintaining the soil tilth, soil protection against environmental deterioration, soil nutrients conservation and even the weed control. The nitrogen conservation from previous leguminose crop is even more important, especially in the organic agriculture where use of N-fertilizers is the strictly forbiden, and second crops can be used as a catch crops for nutrients in rotation prior to the crops with the high N requirement. The choice of the proper second crop has, however, been insufficiently investigated, especially for agri-environmental conditions of the Panonian agricultural area in Croatia. The second crop experiment was established in Valpovo, Croatia, in the eutric brown soil type, during the years 2005 and 2006. The aim of the experiment was to investigate the effects of different second crops and their combinations on maize (*Zea mais L.*) yield and yield components in organic agriculture after soybean (*Glycine max L.*) in crop rotation. The experimental design was set up as a CRBD in four repetitions, with soybean as a previous crop in crop rotation.

The six second crop treatments were: O – Control, without second crop; WW – winter wheat (*Triticum aestivum L.*) second crop; RY – rye (*Secale cereale L.*) second crop; FP – fodder pea (*Pisum arvense L.*) second crop; WP – mixture of the WW and FP; and RP – mixture of RY and FP. The WW treatment had the highest second crop dry mass, whereas FP had the lowest dry

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mass. The highest plant density was recorded for FP, and it was higher than the RP plant density, which also had the lowest plant height. The achieved maize yields were the highest for RY, but they were not significanlty different from the O, RP, and WW treatments. However, the yield achieved by RY treatment was significantly higher than the yields recorded for WP and FP treatments. The absolute mass and hectolitre mass did not show any statistical differences among treatments.

Key words: organic agriculture, maize, second crop, rye, winter wheat, fodder pea

SAŽETAK

Upotreba postrnih usjeva u ekološkoj/organskoj poljoprivredi je priznata metoda za održavanje ugorenosti tla, zaštite tla protiv vremenskih neprilika, konzervacije hraniva u tlu te čak i borbe protiv korova. Konzervacija dušika od prethodnog leguminoznog usjeva je čak važnija funkcija, posebice u ekološkoj poljoprivredi gdje je upotreba mineralnih dušičnih gnojiva izrijekom zabranjena, te postrni usjevi mogu poslužiti za čuvanje dušika od ispiranja iz tla za sljedeći usjev u plodoredu s visokim zahtjevima za dušikom. Nažalost, izbor postrnih usjeva nije dostatno istražen, posebice za agroekološke uvjete u Hrvatskoj. Stoga je postavljen pokus u Valpovu, Republika Hrvatska, na eutričnom smeđem tlu, tijekom 2005. i 2006. godine, s ciljem da se istraže učinci različitih postrnih usjeva i njihovih kombinacija na komponente prinosa i prinos kukuruza (*Zea mais L.*) u ekološkoj (organskoj) poljoprivredi, a u plodoredu iza predusjeva soje (*Glycine max L.*). Pokus je postavljen kao potpuno slučajan blok raspored u četiri repeticije, sa šest tretmana postrnih usjeva: CT – kontrola, bez postrnih usjeva; WW – ozima pšenica (*Triticum aestivum L.*); RY – ozima raž (*Secale cereale L.*); FP – stočni grašak (*Pisum arvense L.*); WP – mješavina WW i FP; te RP – mješavina RY i FP. WW tretman imao je najveću masu postrnih usjeva, dok je FP imao najmanju masu postrnih usjeva. Najgušći sklop zabilježen je na FP tretmanu, značajno viši nego sklop na RP tretmanu, koji je također imao i najnižu visinu stabljika usjeva kukuruza. Ostvareni prinosi kukuruza bili su najviši na RY tretmanu, no nisu bili signifikantno različiti od O, RP i WW tretmana. Ipak, prinos zabilježen na

RY tretmanu bio je signifikantno viši od prinosa na WP i FP tretmanima. Apsolutna i hektolitarska masa nije se statistički razlikovala između tretmana.

Ključne riječi: ekološka poljoprivreda, kukuruz, postrni usjevi, raž, ozima pšenica, stočni grašak

INTRODUCTION

The second crop use is a known method of crop production improvement through the soil quality build-up and maintenance of the soil tilth (De Bruin et al., 2005; Stipešević et al., 2005), soil protection against environmental deterioration, soil nutrients and moisture accumulation and conservation (Karlen and Doran, 1991), soil microbial biomass (Motta et al., 2007) and even the weed control (Williams et al., 1998; Reddy, 2001; Reddy and Koger, 2004). The nitrogen conservation from previous leguminous crop is even more important (Kessavalou and Walters, 1997), especially in the organic agriculture where the use of N-fertilizers is strictly forbidden, and second crops can be used as catch crops for nutrients in rotation prior to crops with the high N requirement (Kessavalou and Walters, 1999; Pietsch et al., 2002). The choice of proper second crop has, however, been insufficiently investigated, especially for the Croatian agri-environmental conditions, and even more for organic agriculture, defined as a complex system (Brumfield et al., 2000) where crop productivity can be improved after more years under organic management (Lockeretz et al., 1981). Since several trials of transition period from conventional to organic farming have reported initially lower yields, followed by yields similar to conventional production (Liebhardt et al., 1989; MacRae et al., 1990), the main object of this research was to determine the most suitable second crops strategy to overcome problems connected with this transition, especially in the light of the potentials for organic crop production growth.

MATERIAL AND METHODS

The second crop experiment was established in Valpovo, Croatia, in the eutric brown soil type, during the years 2005 and 2006. The aim of the experiment was to investigate the effects of different second crops and their combinations on maize (*Zea mais L.*) yield and yield components in organic agriculture after soybean (*Glycine max L.*) in crop rotation. The used maize was the self-pollinated mother line OsSK 1767/99, chosen for its low nitrogen requirements and great financial turnover. In both years the same soybean cultivar "Anica" was used for previous crop in crop rotation. The experimental design was set up as a complete randomized block design in four repetitions, with the basic experimental plot size of 5 x 30 m^2. The six second crop (SC) treatments were used: O – Control, without second crop; WW – winter wheat (*Triticum aestivum L.*) second crop, cultivar "Žitarka", with the aimed population of 700 plants per m^2 and seeding rate of 300 kg ha^{-1}; RY – rye (*Secale cereale L.*) second crop, cultivar "Eho Kurz", with the aimed population of 400 plants per m^2 and seeding rate of 150 kg ha^{-1}; FP – fodder pea (*Pisum arvense L.*) second crop, cultivar "Osječki zeleni", with aimed plant density of 100 plants per m^2 and seeding rate of 125 kg ha^{-1}; WP – mixture of the WW and FP, sown in the 50%:50% ratio of sole winter wheat and fodder pea second crops; and RP – mixture of RY and FP, sown in the 50%:50% ratio of sole winter rye and fodder pea second crops. All second crops were sown by broadcasting seed over the soil surface, discharrowed after the harvest of the previous soybean crop. The second crop material for the second crop mass was collected prior to soil preparation for the maize sowing, by cutting and collecting second crop biomass from four ¼ m^2 wire-frames, after which collected material was dried up at 60ºC for 24 hours and then weighed. Plant density of maize was determined by counting the total plot population and recalculated on the hectare basis. The maize stalk height was measured from the soil level to the top of the highest standing leaf. Measuring was done in the teaselling stage, after stalk elongation had been fineshed. The harvest of the maize crop was made manually, after the grains had been detached from the ear and weighed by the field scale (max. weight 20 kg, d=±50 g). Three subsamples from each plot were taken into plastic bags for the moisture content determination by "Dickey John GAC 2000" grain moisture meter, and average moisture was used to recalculate grain yield at 14% grain moisture. The split-plot ANOVA was performed by SAS statistic package (V 8.02, SAS Institute, Cary, NC, USA, 1999) with the Year as the main level, and SC as the sub-level of treatments. The Fisher protected LSD means comparisons were performed for P=0.05 significance levels.

Weather data are showed in Figure 1, where it is visible that the year 2005 had a marked water surplus in comparison with average climatic conditions, especially during the summer period, where 237 mm poured down in August. Lack of precipitation during October 2005 did not affect crops due to plentiful soil moisture and crop's generative phases (close to the full maturity), and soil moisture condition was in favour of soil tillage and autumn sowing that year. In spite of sufficient precipitation during the spring, the year 2006 had a dry summer below average, especially July and September, the driest months in previous 10 years. Lack of water in that period was not bad for crops, especially for winter crops which entered maturity prior to this dry period.

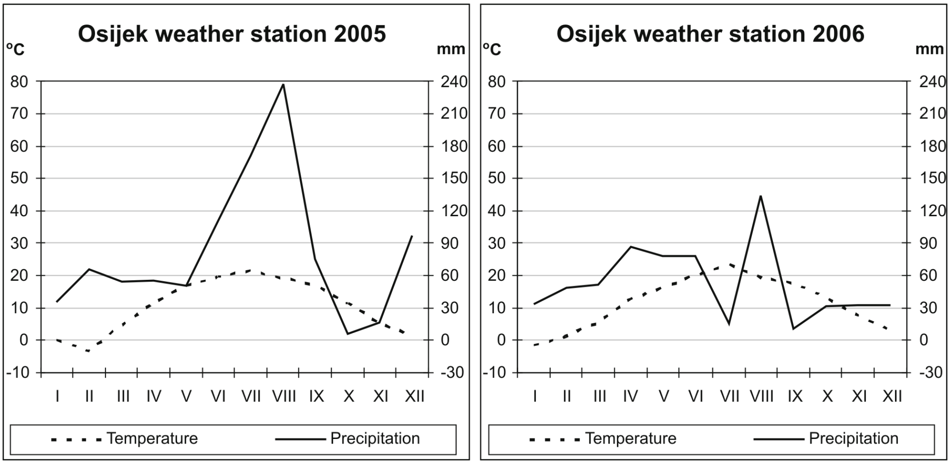

Figure 1: Weather conditions at the Meterological station Osijek, years 2005 and 2006.

RESULTS

The results for the second crop biomass are presented in the Table 1. In both years the most productive second crop statistically was winter wheat, with the average of 66.95 g m^{-2}, significantly higher than other second crops. Next to it was WP, followed by RP, RY and FP, with only 18.42 g m^{-2}.

Table 1: The second crop biomass (g m^{-2}), experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	-	66.14	32.11	17.50	45.00	36.03	32.80
2006	-	67.76	38.09	19.34	49.66	40.23	35.85
SC mean	-	66.95 a†	35.10 bc	18.42 c	47.33 b	38.13 b	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

The maize plant density (Table 2) was established the most successive in the FP (110714 plants m^{-2}), followed by WW, O, WP and RY, which were not statistically different from the FP treatment. Only RP had maize plant density which was statistically lower than the FP treatment plant density (92857 plants m^{-2}).

Table 2: Plant density of the maize (plants ha^{-1}), experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	100782	103634	97435	108083	101231	90947	100352
2006	102790	107794	98993	113345	98769	94767	102743
SC mean	101786 ab	105714 ab	98214 ab	110714 a	100000 ab	92857 b	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

The highest maize stalks (Table 3) were measured in the WP (151 cm), followed by FP, RY, WW and O, whereas the lowest maize stalks were observed in RP (only 120 cm), which was statistically lower than WP and FP.

Table 3: The maize stalk height (cm) in tasseling stage, experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	134.7	132.2	136.6	139.4	148.9	119.7	135.3
2006	136.5	142.2	142.4	147.6	152.5	124.1	140.9
SC mean	135.6 ab	137.2 ab	139.5 ab	143.5 a	150.7 a	121.9 b	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

The maize grain yields are given in Table 4. The highest yield was recorded in RY (879.5 kg ha^{-1}). Next to that treatment were WW, RP and O. Treatments

WP and FP (the lowest yield, only 565.5 kg ha^{-1}) recorded significantly lower yields than RY.

Table 4: The maize grain yield (kg ha^{-1}), recalculated at 14% grain moisture, experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	701.8	733.3	868.2	561.1	610.1	715.4	698.3
2006	727.4	755.9	890.8	569.9	617.3	737.0	716.4
SC mean	714.6 ab	744.6 ab	879.5 a	565.5 b	613.7 b	726.2 ab	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

The grain quality parameters, namely the 1000 grains weight and the hectolitre weight are presented in Tables 5 and 6, respectively, and both parameters were statistically not different at the P<0.05 significance level. The 1000 grains weight ranged from 331 g (FP treatment) to 383 g (WP treatment), and the hectolitre weight was between 68.2 kg hl^{-1} (O and RP treatment) to 69.5 kg hl^{-1} (WP treatment), which can be considered within the normal limits for given maize crop.

Table 5: The 1000 grains weight (g) for the maize crop, experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	333.2	337.9	350.8	328.7	375.3	354.5	346.7
2006	341.6	341.9	359.4	332.9	391.7	360.7	354.7
SC mean	337.4 a	339.9 a	355.1 a	330.8 a	383.5 a	357.6 a	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

Table 6: The hectolitre weight (kg hl^{-1}) for the maize crop, experimental site Valpovo, years 2005 and 2006.

SC trts	O	WW	RY	FP	WP	RP	Year mean
2005	66.9	68.1	68.8	67.9	68.7	67.9	68.1
2006	69.5	70.3	70	70.5	70.3	68.5	69.9
SC mean	68.2 a	69.2 a	69.4 a	69.2 a	69.5 a	68.2 a	

†Means labelled with the same letter are not statistically different at the P<0.05 significance level

DISCUSSION

The most productive second crop, as regards the biomass, proved to be the WW treatment, with almost the double value of the following RY second crop, and more than three times higher than FP (Table 1). Mixtures of cereals with FP, WP and RP, also gave more than FP alone. The main reason for better establishment of the cereals sown by broadcasting is presumably their ability to develop their fibrous root system faster and more successive by than the FP. Also, since FP seed is rather large in comparison with both cereals, the close contact between FP seed and rough surface soil aggregates was not so good, and moisturing of the seed was not successive for starting germination as in the case of smaller cereal seeds. The consequence of poorer germination and crop stand establishment was lower second crop population of the FP, with smaller crop biomass production and, consequently, lesser nitrogen fixation, whereas in the same time both cereal second crops developed dense population, good surface coverage and larger biomass, partially due to the sequestration of the soybean pre-crop nitrogen. Garibay et al. (1997) also observed nitrogen accumulation in second crop residues when cereals were used for that purpose.

Partially better yield explanation for RY, WW and RP should also be considered through the allelopathic properties of decomposing WW and RY residues within the soil. This is found to be inhibitive for the soil microorganisms, pests and weed (Alsaadawi, 2001; Khanh et al., 2005), thus protecting nitrogen and other nutrients incorporated as a part of second crop residues from leaching or consumption by weed, and therefore providing nutrients for higher maize yields in RY treatment. Anyhow, although Denison et al. (2004) reported that organically grown maize had lower yield in comparison with the conventional one, this research results were comparable with the same maize production in a near-by field.

CONCLUSION

The WW treatment had the highest second crop dry mass, whereas FP had the lowest dry mass. The highest crop population was recorded in FP, and it was higher than the RP population, which also had the lowest plant height. The achieved maize yields were the highest for RY, but they were not significantly different from the O, RP and WW treatments. However, the yield achieved by

RY treatment was significantly higher than the yields recorded for WP and FP treatments, which, based on this research, should not be recommended for agricultural practice.

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