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THE ECONOMIC SUSTAINABILITY OF SECOND CROPS IMPLEMENTATION IN ORGANIC MAIZE PRODUCTION

EKONOMSKA ODRŽIVOST PRIMJENE POSTRNIH USJEVA U EKOLOŠKOM UZGOJU KUKURUZA

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ABSTRACT

Although organic crop production has numerous advantages, concerns about economic sustainability, both environmental and financial, make farmers reluctant to convert their conventional production into the organic production. Certain agricultural methods, such as second crop use, can alleviate some problems regarding soil tilth, erosion prevention, nutrients availability and weed control, thus contributing toward more sustainable crop production. Also, the added value crop growth, such as maize (*Zea mais L.*) hybrid's parental line production, with lower yields but higher prices, can contribute to sustainability of organic production. In order to test the hypothesis that the use of second crops can contribute toward the sustainability of organically grown maize after soybean (*Glycine max L.*) as a previous crop in the crop rotation, the experimental site was established in Valpovo, Croatia, in the eutric brown soil type, during the years 2005 and 2006. The experimental design was set up as a CRBD in four repetitions, with six second crop treatments: CT – 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 WW and FP; and RP – mixture of RY and FP. In order to assess the soil surface protection and evaluate the weed suppression, the second crop coverage had been recorded.

Regarding the economic sustainability, the second crop use depending costs were analysed in relation to the extra produced maize yield. The RY treatment

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had the highest profitability, followed by WW, RP and O. The WP and FP revealed lower relative profitability than O, thus presenting the evidence of sustainability risk of these treatments.

Key words: organic agriculture, economic sustainability, maize, soybean, second crop, soil cover

SAŽETAK

Premda ekološka poljoprivreda ima brojnih prednosti, zabrinutost zbog održivosti, i ekološke i ekonomske, farmere često odvraća od prijelaza s konvencionalne proizvodnje na ekološku. Intenzifikacijom plodoreda uporabom postrnih usjeva, mogu ukloniti neke probleme vezane za ugorenost tla, prevenciju erozije, dostupnost hraniva i suzbijanje korova, doprinoseći na taj način održivosti proizvodnje usjeva. Također, uzgoj usjeva s dodatnom vrijednošću, kao što su roditeljske linije za proizvodnju hibrida kukuruza (*Zea mais L.*), s nižim prinosima ali višom cijenom, može pridonijeti održivosti (profitabilnosti) ekološke proizvodnje. U namjeri da se potvrdi hipoteza da postrni usjevi mogu doprinijeti održivosti ekološkog uzgoja kukuruza u dvopoljnom plodoredu sa sojom (*Glycine max L.*) kao prethodnim usjevom, postavljeno je pokušalište u Valpovu, Hrvatska, na eutričnom smeđem tlu, tijekom 2005. i 2006. godine. Pokus je postavljen kao potpuno slučajan blok raspored u četiri ponavljanja, 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 – smjesa WW i FP; te RP – smjesa RY i FP. U cilju određivanja zaštite površine tla i evaluacije suzbijanja korova, zabilježena je pokrivenost postrnim usjevima. Glede isplativosti, analizirani su relativni troškovi upotrebe postrnih usjeva u odnosu na dodatno proizvedeni urod kukuruza. RY tretman je zabilježio najvišu profitabilnost, a pratili su ga tretmani WW, RP i O. Tretmani WP i FP pokazali su se manje profitabilni od O, time pružajući dokaze o rizičnoj održivosti ovih tretmana.

Ključne riječi: ekološka poljoprivreda, isplativost, kukuruz, soja, postrni usjevi, prekrivanje tla

INTRODUCTION

In spite of the fact that organic crop production has numerous advantages, concerns about profitability, both environmental and financial, make farmers reluctant to convert their conventional to organic farming, due to possibly of lower yields in the transitional period (Liebhardt et al., 1989; MacRae et al., 1990). Certain agricultural methods, such as second crop use, can alleviate some problems regarding soil tilth, erosion prevention (Kemper and Derpsch, 1981), nutrients availability and weed control (Raimbault et all, 1990).

Although well-tilled bare soil presents certain advantages for spring crop establishment, the soil surface is left unprotected from precipitation impact of high-intensity rainstorms in late fall and early spring. In temperate regions worldwide rainstorms can cause soil structure deterioration through crusting, soil compaction, and erosion (surface runoff), which can lead to depletion of organic matter from soil, nutrient leaching, etc. Such processes can irreversibly damage soil productivity and agricultural sustainability and cause environmental degradation through water pollution. Problems for sustainability can be more prevalent in monocultural crop production, since absence of crop rotation provides a more suitable environment for survival of specialized weeds, pests and diseases (Butorac et al., 1999; Berzsenyi et al., 2000; Helmers et al. 2001).

A solution can be found in second crop practices, where living plants cover the soil during the winter period. Due to shoot and root growth of the second crop, soil physical properties can be considerably improved. One of the most emphasized soil structural features is aggregate stability, because soil with larger, more stable aggregates is less susceptible to erosion, surface slaking and waterlogging and provides a better environment for plant growth through more favourable air-water ratio. Different second crops, both cereals and legumes, have been found to improve soil aggregation for a wide range of soil types, as presented by different authors (Stamatov, 1979; McVay et al., 1989; Roberson et al., 1991, 1995; Zebarth et al., 1993; Basso and Reinert, 1998; Kabir and Koide, 2000). Other authors found lower soil bulk density and soil compaction after second crop growth (Jackson et al., 1987; Scott et al., 1990; Arevalo et al., 1998; Calkins and Swanson, 1998; Ess et al., 1998; Raper et al., 1998a, 1998b, 2000), although not always (Wagger and Denton, 1989; Burmester et al., 1995).

Through improved aggregation, reduced compaction and greater porosity, second crops were also found to improve infiltration and saturated hydraulic conductivity (Davidoff and Selim, 1986; Phene et al., 1987; McVay et al., 1989; Scott et al., 1990; Bruce et al., 1992; Stirzaker and White, 1995). Greater water infiltration, water retention (Scott et al., 1990) and soil water content through the second crop mulching effect (Layton et al., 1993; Teasdale and Mohler, 1993; Yoo et al., 1995; Clark et al., 1997) can provide advantageous soil moisture for the following cash crop in cases of serious water stresses during the summer period of growth, whose occurrence is more emphasized during the last decade, as observed by Birkas et al. (2007).

But under certain conditions, second crops can also be detrimental for the cash crop growth through their large biomass growth. In dry springs, some authors (Campbell et al., 1984; Helsel et al., 1991; Unger and Vigil, 1997) found that second crops depleted soil moisture needed for the following cash crop. Furthermore, in wet springs second crops may cause higher soil moisture content that can, in combination with lower soil temperature, cause delays in early cash crop development for temperature-sensitive crops, as was found by Teasdale and Mohler (1993), Johns (1994) and Drury et al. (1999).

Based on the previously reviewed literature and other sources, some of them even hundred years old (NN, 2007), there are certain possibilities for improvement of organic maize production and higher sustainability by second crop management. Cereals such as winter wheat and winter rye can be an attractive choice for the second crop, since they are available and affordable, they can produce substantial soil surface coverage thus protecting bare soil during the summer cash crops non-vegetational period and they have a satisfactory winter survival rate. Legumes, on the other side, provide nitrogen through the symbiosis with the nitrogen fixing bacteria. Also, the added value crop production, such is maize (*Zea mais L.*) hybrid's parental line production, with lower yields but higher prices, can contribute to sustainability of the organic production.

MATERIAL AND METHODS

In order to test the hypothesis that the use of second crops can contribute to the sustainability of organically grown maize after soybean (*Glycine max L.*) as a previous crop in the crop rotation, the experimental site was established in Valpovo, Croatia, in the eutric brown soil type, during the years 2005 and 2006. The used maize was the self-pollinated mother line OsSK 1767/99, due to its substantially higher financial turnover than with regular hybrids. In both years for previous crop in crop rotation the same soybean cultivar "Anica" was used. 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. Six second crop (SC) treatments were used: CT – 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 the aimed population of 100 plants per m^2 and seeding rate of 125 kg ha^{-1}; WP – mixture of 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. The second crop seed was planted by the broadcasting method, and incorporated into the soil by the mouldboard plough within the week prior to the maize planting. In order to assess the soil surface protection against water erosion and potential for weed suppression, the second crop coverage had been recorded by photographing four ¼ m^2 frames on each experimental plot, after which digital photos were processed by Arc View software package in order to determine the exact area covered by second crops. The water erosion and weed risk assessment were classified by the percentage of total soil coverage by second crop, into four categories: low, with coverage of soil surface by second crops above 75%; medium, with soil surface coverage from 50 to 75% of soil surface; high, with soil surface coverage from 25 to 50%; and very high, with soil surface coverage below 25%. Regarding the economic sustainability, the second crop use relative costs were analysed in relation to the extra produced maize yield. The second crop added value was calculated as the difference of yield due to the second crop treatment in relation to the control (O) and the price of 10 HRK kg^{-1}. The relative profit was calculated as the difference between second crop added value and the cost of seed for each applied second crop treatment, where the seed prices were as follows: WW = 800, RY = 450, FP = 750, WP = 775 and RP = 600 HRK ha^{-1}. 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.

RESULTS

The soil coverage by the second crop treatments is shown in Table 1. The most successful coverage was achieved by WW (85%), followed by RY (80%) and WP (78%), thus providing low or medium risk for the occurrence of the soil water erosion or weed proliferation (Table 2). A slightly worse was the performance of RP (60), evaluated with the high risk, whereas FP managed to cover only 38% of the soil surface, thus presenting very high risk for the erosion or eventual weed proliferation.

Table 1: The second crop surface coverage (%), experimental site Valpovo, years 2005 and 2006.

SC trts	CT	WW	RY	FP	WP	RP
2005	-	82 a[†]	76 a	18 c	72 a	55 b
2006	-	88 a	84 a	58 b	83 a	65 b
SC mean	-	85 A	80 A	38 C	78 A	60 B

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

Table 2: The soil water erosion and weed risk assessment based on the crop surface coverage, experimental site Valpovo, years 2005 and 2006.

SC trts	CT	WW	RY	FP	WP	RP
2005	Very high	Low	Low	Very high	Medium	High
2006	Very high	Low	Low	High	Low	High
SC mean	Very high	Low	Low	Very high	Medium	High

In table 3 the relative added value of each second crop is given in HRK ha^{-1}, with the comment that the prices stayed the same during both years of the experiment both for seed and harvested grain. The highest contribution of maize grain (for 164.9 kg ha^{-1}) was recorded in the RY treatment, whereas other two SC treatments with higher yields were WW (with 30 kg ha^{-1} more than the control) and RP (+11.6 kg ha^{-1}). Treatments with lower yields than CT were WP (-100.9 kg ha^{-1}) and FP (149.1 kg ha^{-1} lower yield if compared with O). By subtraction of the CC seed cost, relative profit, also expressed as HRK ha^{-1}, revealed that only RY had higher relative income than CT by 1199 HRK ha^{-1}, whereas all other SC treatments had negative balance due to the use of other second crop treatments.

Table 3: The relative added value (HRK ha^{-1}) as a difference in maize grain yield in comparison with the Control treatment (kg ha^{-1}), experimental site Valpovo, years 2005 and 2006.

SC trts	CT	WW	RY	FP	WP	RP
2005	0 c	315 b	1764 a	-1407 e	-917 d	136 c
2006	0 c	285 b	1534 a	-1575 d	-1101 d	96 c
SC mean	0 C	300 B	1649 A	-1491 E	-1009 D	116 C

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

Table 4: The relative profit (HRK ha^{-1}) as a difference in maize grain yield in comparison with the Control treatment (kg ha^{-1}), experimental site Valpovo, years 2005 and 2006.

SC trts	CT	WW	RY	FP	WP	RP
2005	0 b	-485 c	1314 a	-2157 e	-1692 d	-464 c
2006	0 b	-515 c	1084 a	-2325 e	-1876 d	-504 c
SC mean	0 B	-500 C	1199 A	-2241 E	-1784 D	-484 C

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

DISCUSSION

Both cereal second crops, WW and RY performed well in covering soil, if they were sown in recommended crop density. For both second crops there are previous evidences of success as second crops (Raimbault et al. 1990; De Bruin et al., 2005). Even mixtures with FP gave rather good coverage, although only half of the second crop seed was applied. Usually, as reported by Linares et al. (2008), mixtures of second crops are better for covering soil due to the uncertainty of performances of single second crop species. The only legume, FP, showed lower surviving rate, being not seeded into the soil, but broadcasted over the surface in the soybean field prior to the soybean harvest. The lower FP plant density, both in the single second crop or in the mixtures WP and RP, is mostly the effect of lower root penetration ability, together with the slower early growth, if compared with both cereal second crops. Researches done by McVay et al. (1989) and Scott et al. (1990) recorded better survival rates of legume second crops, but in both cases the second crop seed had been drilled into the soil. For this research, the lack of a heavy-duty sowing tool and still-standing pre-harvest soybean, showed the need for either other approach of legume second crop establishment, or choice of some other legume species, which will be more thriving in seeding by broadcast technique. MacRae et al. (1990) and Brumfield et al. (2000) previously showed that second crop can be economically sustainable method for maintaining sustainable economics in the organic agriculture. The relative profitability in this experiment showed that only RY treatment could be economically sustainable, which was to be expected through previous knowledge of winter rye as a second crop, connected with expressed allelopathy for this plant (Alsaadawi, 2001; Khanh et al., 2005.). Treatments WW and RP also showed higher added value in comparison with CT, but these two treatments are not sustainable enough regarding profitability, although they would fulfill other requirements regarding suitability as a second crop.

CONCLUSION

The soil coverage was the highest in the WW treatment, followed by RY and WP, whereas RP and FP showed insufficient soil coverage. The relative profit or value of the extra maize yield produced due to the treatment application and reduced for the second crop cost, was positive only for RY. The RY treatment had the highest production efficiency, whereas WP and FP revealed lower efficiency than O, thus presenting an evidence of economic sustainability risk of these treatments. Based on this research, only the RY second crop treatment can be recommended.

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