



ECONOMIC EFFECTS OF SUMMER CATCH CROPS APPLICATION IN SWEET CORN CULTIVATION

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Summary

The work presents the results of investigations conducted in 2004–2007 to evaluate the residual effect of summer catch crops ploughed as green manures on productive-economic effects of sweet corn cultivation. The experiment was carried out in east-central Poland (52°03'N, 22°33'E). The following summer catch crops were grown: phacelia, amaranth, sunflower, serradella and faba bean. The catch crop seeds were sown in 2004–2006 at three dates: on the 21st July, 4th and 18th August. The effect of summer catch crops was compared to FYM applied at the rate of 40 t·ha⁻¹. The catch crops biomass (roots + above ground parts) and FYM were incorporated in the third decade of October. Sweet corn seeds (6 kg·ha⁻¹) were sown in mid-May, in the years 2005–2007, at the between – and inter-row spacing of 65 × 20 cm. Sweet corn ears were hand-harvested at the stage of milk maturity of kernels, at the turn of August and September. During the harvest marketable yield of ears (t·ha⁻¹) and number of marketable ears per 1 ha were determined. Economic evaluation of sweet corn cultivation under diversified organic fertilization was conducted according to the standard gross margin method. The calculation was based on the 2014 prices. The highest yield and number of ears were obtained after catch crops with faba bean and phacelia sown on the 21st July and after FYM. Delaying the sowing date of catch crops resulted in a decrease in the successive yielding effect. The highest gross margin (25267.66 PLN·ha⁻¹ and 0.56 PLN per 1 ear) and profitability index (332%) were achieved in the sweet corn cultivation after catch crop with faba bean sown on the 21st July. Compared to the plot with FYM, a higher level of gross margin and profitability index were obtained after all catch crops

sown on the 21st July and the 4th August. Irrespective of investigated factors, profitability index was on a very high level amounting to 211-332%.

Key words: economic efficiency, catch crops, green manures, yield, *Zea mays* L. var. *saccharata*

INTRODUCTION

Sweet corn (*Zea mays* L. var. *Saccharata* Korn) is a valuable crop with a wide range of applications in human nutrition (Kovačević and Culjat 1993, Stone 1999). A growing interest of consumers both in sweet crop products and fresh ears has been observed in Poland. It also translates into increasing area destined to this crop cultivation, which in recent years reached between 5 and 6 thousand ha (Bereś 2010).

A crucial factor influencing successful cultivation of sweet corn is fertilization, including organic treatment (Haghighat *et al.* 2012). Due to the deficit and growing prices of FYM, which so far has been the basic natural fertilizer, catch crop cultivation intended for ploughing becomes increasingly necessary (Songin 1998, Mazur *et al.* 2013). In organic and integrated agriculture systems, green manures should become a fixed element of improving soil fertility. They positively affect biological, physical and chemical soil properties, counteract its erosion and loosen it (Snapp *et al.* 2005). They protect bioavailable nutrient forms against leaching to deeper soil layers or to groundwaters. After ploughing catch biomass undergoes mineralization, releasing nutrients for aftercrops (Collin *et al.* 2007). Catch crops are also a factor mitigating the negative effect of agriculture intensification, excessive soil compaction and unilateral mineral fertilization (Kristensen and Thorup-Kristensen 2004, Rogers *et al.* 2004).

They allow to reduce the application of herbicides and pesticides (Abdul-Baki *et al.* 1997).

Numerous investigations revealed a positive effect of ploughed spring and winter catch crops on sweet corn yielding (Turgut *et al.* 2005, Zaniewicz-Bajkowska *et al.* 2011, Dolijanovic *et al.* 2012, Rosa *et al.* 2012, Rosa 2014). It was found that yield-forming effect of catch crops depends on the species of crop cultivated for ploughing, the amount of biomass it forms and the date of ploughing.

Present work aimed at an evaluation of economic results of green manures application as summer catch crops in sweet corn cultivation. Plant sowing for green manure is not always possible at the time optimal for them. The term of catch crops sowing in the presented research was diversified in order to determine the influence of delay in their sowing on their yield forming effect.

MATERIAL AND METHOD

The field experiment was conducted in 2004-2007 at the Agricultural Experimental Station of Siedlce University of Natural Sciences and Humanities (52°03'N, 22°33'E). According to the FAO soil classification system, the soil on which the experiment was set up belongs to Luvisol group (World... 1998). Mean content of organic carbon was 0.95%; pH_{KCl} 6.0. Macroelement content in the arable layer (mean for the three years of experiment) was as follows: 18 mg N ($\text{NO}_3 + \text{NH}_4$), 71 mg P, 92 mg K, 379 mg Ca and 42 mg Mg in 1 kg of air-dried soil.

The experiment was set up on the site after winter barley in a split-block design, in four replications. The experiment area was 5670 m², a single plot area 56 m². In 2004-2006 the summer catch crops were: PA – phacelia, AS – amaranth (*Amaranthus cruentus* L.), SU – sunflower (*Helianthus annuus* L.), SA – serradella (*Ornithopus sativus* Brot.) and FB – faba bean (*Vicia faba* L. *ssp. minor*). They were sown in three terms: in 21st July, 4th August and 18th August. The norms of catch crop seeds sowing were: PA – 17 kg, AS – 3 kg, SU – 30 kg, SA – 60 kg, FB – 250 kg per 1 ha. Prior to their sowing, mineral nitrogen fertilization was applied with 20 kg N·ha⁻¹ for serradella and faba bean and 80 kg N·ha⁻¹ for phacelia, amaranth and sunflower. Phosphorus and potassium fertilization was equal for all catch crops, i.e. 26 kg P·ha⁻¹ and 66 kg K·ha⁻¹. Effects of the catch crops application were compared with the control on which 40 t·ha⁻¹ of FYM was ploughed. Green mass of all catch crops and FYM were ploughed in the third decade of October.

Sweet corn, 'Sweet Wonder F1' (Agri-Saaten) was cultivated in the years 2005-2007 in the first year after ploughing green manures and FYM. Sweet corn seeds, in the amount of 6 kg·ha⁻¹ were sown in mid-May at the spacing of 65 x 20 cm. Prior to their sowing mineral fertilization with 110 kg N, 150 kg P and 150 kg K per 1 hectare was applied on all treatments. The fertilizers were applied in the experiment in the form of ammonium nitrate, granulated triple superphosphate and 60% potassium salt. Plots were tilled in compliance with the appropriate agrotechnical rules for catch crops and sweet corn. The weed control was conducted in the corn at the stage of 3-4 leaves by means of herbicide mixture of Zeagran 340 SE (1.6 l·ha⁻¹) + Titus 25 WG (40 g·ha⁻¹) with a supplement of Trend 90 EC (0.1%) adjuvant per 250 l of water.

Sweet corn ears were hand-harvested at the stage of kernel milk maturity, which in all of the experiment fell at the turn of August and September. During the harvest, the outer leaves were removed from the ears and only 3-4 inner leaves were left. Ears were weighed and counted on each experimental plot and subsequently their marketable yield (t·ha⁻¹) and the number of marketable ears per 1 ha were determined. Marketable ears were at least 17 cm long, filled with

kernels in at least 80%. The results were verified statistically by means of multifactor ANOVA. The significance of differences of means was estimated using Tukey's test at the significance level $p = 0.05$.

Economic evaluation of sweet corn cultivation in conditions of diversified organic fertilization was conducted in the work by means of standard gross margin method (Augustyńska-Grzymek *et al.* 2000). The gross margin was calculated as a difference between the yield value and direct costs of production. The calculation did not include area payments or environmental payments for catch crop cultivation on the income side, because mineral fertilization was applied under them. The element, which directly diversified the costs of production were tested organic fertilizers, i.e. the costs of FYM application, catch crop sowing material, mineral fertilizers under the catch crops and plot tillage connected with their application. The other elements of direct costs of sweet corn production were fixed for all combinations. They included the costs of material (corn sowing material, mineral fertilizers and plant protection means), as well as human and mechanical labour outlays, established on the basis of technology used in the experiment, labour consumption of individual measures in production conditions of the Agricultural Experimental Station in Zawady. Economic evaluation was based on the prices from 2014.

The value of sweet corn production was the ratio of ears (expressed by the number of marketable ears per 1 ha) and the price of a single marketable ear, which was established as 0.80 PLN. It was the mean price in force at the turn of August and September 2014 on the Lublin Wholesale Market in Elizówka and the Warsaw Agri-Food Wholesale Market in Bronisze.

RESULTS AND DISCUSSION

Marketable yield of sweet corn ears, depending on the kind of organic fertilization fluctuated from 9.04 to 13.44 t·ha⁻¹ (Table 1). The highest was noted in cultivation after faba bean catch crop sown on 21st July (FB1). Corn cultivated after phacelia and sunflower catch crops sown on 21st July (PA1,SU1) and after FYM yielded on a similar level (12.27-12.63 t·ha⁻¹). The lowest ear yields, less than 10 t per 1 ha were harvested after amaranth, sunflower and phacelia catch crops sown on 18th August (AS3, SU3 and PA3). Despite observed differences in the crop yields on individual combinations of organic fertilizers, statistical analysis did not reveal any significance of these differences. On the other hand, significant differences were registered in the number of marketable ears harvested from 1 hectare (Table 1). The highest number of marketable ears (45201 psc·ha⁻¹) was harvested after FB1 catch crop, approximate number after FYM (41866 psc·ha⁻¹) and PA1 (41314 psc·ha⁻¹). With delayed sowing term of

individual catch crops, a decline in sweet corn ear yield was observed. It was caused by a smaller amount of biomass produced by the catch crops from the second (4th August), and particularly from the third (18th August) sowing date, in comparison with the earliest date (21st July). Smaller amount of ploughed biomass after mineralisation in soil supplied sweet corn with less nutrients. Tejada *et al.* (2008) observed that with increasing amount of biomass supplied to the soil with green manures, the yield of corn ears was growing. As was emphasized by Brzeski *et al.* (1993), the quantity of ploughed biomass is one of the key factors affecting residual yield forming effect of green manures. In the author's own studies, the least number of ears was noted on the combinations with catch crops of amaranth (AS3), serradella (SA3) sunflower (SU3) and phacelia (PA3) sown on 18th August. The number of ears harvested from these combinations ranged from 28662 to 32294 pieces per 1 ha.

Table 1. Marketable leafless sweet corn ear yield depending on the kind of organic manures (mean for 2005-2007)

Kind of organic manure	Date of catch crops sowing	Marketable ear yield	Number of marketable ears
		t·ha ⁻¹	no.·ha ⁻¹
Farmyard manure (FYM)		12.63 a*	41 866 fg
Phacelia <i>Phacelia tanacetifolia</i> Banth.	21 st July (PA1)	12.40 a	41 314 fg
	4 th August (PA2)	10.87 a	37 271 def
	18 th August (PA3)	9.78 a	32 294 abc
Amaranth <i>Amaranthus cruentus</i> L.	21 st July (AS1)	11.53 a	38 752 def
	4 th August (AS2)	10.11 a	36 032 cde
	18 th August (AS3)	9.04 a	28 662 a
Sunflower <i>Helianthus annuus</i> L.	21 st July (SU1)	12.96 a	39 380 ef
	4 th August (SU2)	12.08 a	34 201 bcd
	18 th August (SU3)	9.46 a	31 358 ab
Serradella <i>Ornithopus sativus</i> Brot.	21 st July (SA1)	12.27 a	39 498 ef
	4 th August (SA2)	11.82 a	36 446 cde
	18 th August (SA3)	10.44 a	30 874 ab
Faba bean <i>Vicia faba</i> L. <i>ssp. minor</i>	21 st July (FB1)	13.44 a	45 201 g
	4 th August (FB2)	11.87 a	39 966 ef
	18 th August (FB3)	10.94 a	34 104 bcd
* Values followed by different letters are significantly different at $p \leq 0.05$			

Source: Author's own research

Table 2. The structure of direct costs (PLN·ha⁻¹) in sweet corn cultivation depending on the kind of organic manures (average for 2005-2007)

Specification	Kind of organic manure					
	FYM	PA1, PA2, PA3	AS1, AS2, AS3	SU1, SU2, SU3	SA1, SA2, SA3	FB1, FB2, FB3
The costs of field preparation and organic fertilization for sweet corn						
Skimming after harvest of winter barley	248.00	248.00	248.00	248.00	248.00	248.00
Harrowing	–	78.00	78.00	78.00	78.00	78.00
Mineral fertilizers	–	783.17	783.17	783.17	539.74	539.74
Spreading + blending fertilizers with the soil	–	338.00	338.00	338.00	338.00	338.00
Cultivation unit	–	190.00	190.00	190.00	190.00	190.00
Seeds	–	425.00	405.00	156.00	720.00	675.00
Sowing + harrowing	–	186.00	186.00	186.00	186.00	186.00
Disking	–	165.00	165.00	165.00	165.00	165.00
Farmyard manure	4400.00	–	–	–	–	–
Spreading of FYM	450.00	–	–	–	–	–
Ploughing of catch crops and FYM	248.00	248.00	248.00	248.00	248.00	248.00
The costs of sweet corn cultivation						
Harrowing	78.00					
Cultivation	190.00					
Mineral fertilizers	1382.60					
Spreading + blending fertilizers with the soil	338.00					
Cultivation unit	190.00					
Seeds	1133.80					
Sowing	83.00					
Herbicide + spraying	330.00					
Harvest of ears + peeling of leaves	4500.00					
Total direct costs						
Total direct costs	13571.40	10886.57	10866.57	10617.57	10938.14	10893.14

FYM – farmyard manure; PA1, PA2, PA3 – phacelia catch crops sown, respectively on 21st July, and 4th and 18th August; AS1, AS2, AS3 – amaranth catch crops sown on, respectively 21st July, and 4th and 18th August; SU1, SU2, SU3 – sunflower catch crops sown on, respectively 21st July, and 4th on 18th August; SA1, SA2, SA3 – serradella catch crops sown, respectively on 21st July, 4th and 18th August; FB1, FB2, FB3 – faba bean catch crops sown, respectively on 21st July, 4th and 18th August

Source: Author's own studies

Table 3. Value, direct costs and gross margin (PLN) of sweet corn ears production depending on the kind of organic manure (average for 2005-2007)

Kind of organic manure	Production value	Direct costs production per 1 ha	Direct costs of 1 ear of sweet corn production	Gross margin		
				per 1 ha	per 1 ear of sweet corn	per 1 PLN of costs
FYM	33492.80	13571.40	0.32	19921.40	0.48	1.47
PA1	33051.20	10886.57	0.26	22164.63	0.54	2.04
PA2	29816.80	10886.57	0.29	18930.23	0.51	1.74
PA3	25835.20	10886.57	0.34	14948.63	0.46	1.37
AS1	31001.60	10866.57	0.28	20135.03	0.52	1.85
AS2	28825.60	10866.57	0.30	17959.03	0.50	1.65
AS3	22929.60	10866.57	0.38	12063.03	0.42	1.11
SU1	31504.00	10617.57	0.27	20886.43	0.53	1.97
SU2	27360.80	10617.57	0.31	16743.23	0.49	1.58
SU3	25086.40	10617.57	0.34	14468.83	0.46	1.36
SA1	31598.40	10938.14	0.28	20660.26	0.52	1.89
SA2	29156.80	10938.14	0.30	18218.66	0.50	1.67
SA3	24699.20	10938.14	0.35	13761.06	0.45	1.26
FB1	36160.80	10893.14	0.24	25267.66	0.56	2.32
FB2	31972.80	10893.14	0.27	21079.66	0.53	1.94
FB3	27283.20	10893.14	0.32	16390.06	0.48	1.50

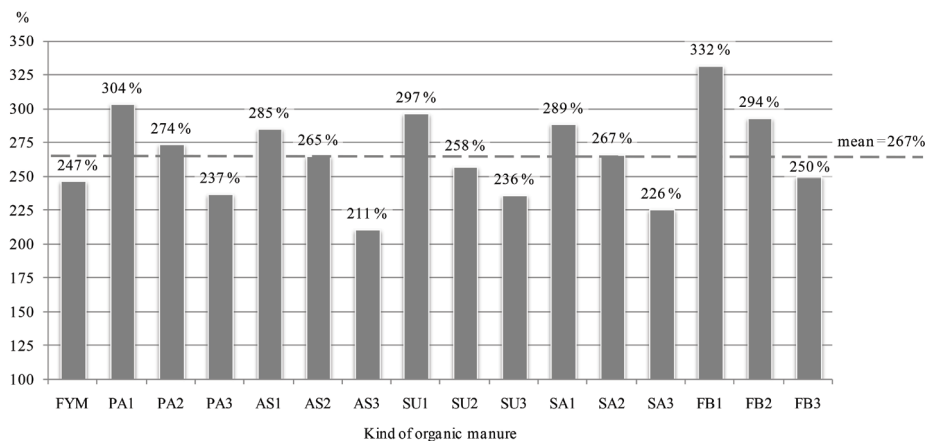
FYM – farmyard manure; PA1, PA2, PA3 – phacelia catch crops sown respectively on 21st July, and 4th and 18th August; AS1, AS2, AS3 – amaranth catch crops sown, respectively on 21st July, and 4th and 18th August; SU1, SU2, SU3 – sunflower catch crops sown, respectively on 21st July, and 4th and 18th August; SA1, SA2, SA3 – seradella catch crops sown on, respectively 21st July, and 4th and 18th August; FB1, FB2, FB3 – faba bean catch crops sown on, respectively 21st July, and 4th and 18th August

Source: Author's own studies

Structure of sweet corn ears production was variable depending on the kind of organic fertilization (Table 2). Costs incurred by the use of catch crops as green manures were by between 19.5 and 22% lower than the cost of FYM application. It was due to high price for FYM (110 PLN for 1 t). The lowest direct costs (10617.57 PLN·ha⁻¹) were paid for sweet corn cultivation after sunflower catch crop (SU1, SU2, SU3). The date of catch crops sowing did not diversify the costs incurred by their cultivation. The highest cost in the structure of direct costs incurred by corn cultivation was connected with had harvesting and leaves peeling from ears. It is consistent with the research of Szymanek and Różyńska-Boczula (2012). The authors stated that the outlays of labour connected with harvest, leaves peeling from sweet corn ears and ears wrapping in foil fluctuated

from 600 to 720 man-hours per 1 ha, depending on the cultivar grown. In the Author's own research the outlays on harvesting and leaves peeling (without foil wrapping) were estimated for 450 man hours \cdot ha⁻¹. Assuming the cost of human labour as 10 PLN per hour, it gives the amount of 4500 PLN per 1 ha. These costs may be greatly reduced by application of mechanized ear hand-harvesting. It requires a considerable single investment outlay on purchase of an appropriate combined harvester (Niedziółka *et al.* 2006). However, picked ears are characterized by better parameters, especially if they are intended for direct market supply (Niedziółka *et al.* 2004).

The highest value of production (36160.80 PLN \cdot ha⁻¹) was obtained when sweet corn was grown after faba bean sown on 21st July (Table 3). For FB1 combination the highest gross margin per 1 ha (25267.66 PLN), gross margin per 1 ear (0.56 PLN) and gross margin per 1 PLN of incurred costs (2.32 PLN) were calculated. Gross margin per 1 ha from this combination was by 27% higher than obtained on the control with ploughed FYM. In comparison with the FYM treatment increase in gross margin per 1 ha was registered also after facelia, amaranth, sunflower and serradella from the first sowing term (21st July) and after faba bean from the second term of sowing (4th August). Gross margin per 1 PLN per 1 PLN of incurred cultivation costs after almost all catch crops, except pA3, AS3, SU3 and SA3 was higher than in cultivation with FYM



FYM – farmyard manure; PA1, PA2, PA3 – phacelia catch crops sown on 21st of July, and 4th and 18th of August, respectively; AS1, AS2, AS3 – amaranth catch crops sown on 21st of July, and 4th and 18th of August, respectively; SU1, SU2, SU3 – sunflower catch crops sown on 21st of July, and 4th and 18th of August, respectively; SA1, SA2, SA3 – serradella catch crops sown on 21st of July, and 4th and 18th of August, respectively; FB1, FB2, FB3 – faba bean catch crops sown on 21st of July, and 4th and 18th of August, respectively

Figure 1. Profitability index of sweet corn ears depending on kind of organic manures (mean for 2005-2007).

Average for three years profitability index of sweet corn ears production, fluctuated from 2011 to 332% (Figure 1). Waligóra (online, 2014) emphasized that the profitability level of sweet corn cultivation is high and exceeds 200%. Ears sale for so called fresh market allows to obtain higher income than sale to the wholesaler, however it is burdened with a considerable risk resulting from a need to guarantee sales of the raw material. Wierzbicka (1998) and Waligóra and Kruczek (2003) also point to a high profitability of sweet corn cultivation. After a majority of applied catch crops the profitability index of sweet corn ears production was higher than after FYM. The highest was obtained after faba bean catch crop sown on 21st July, the lowest after amaranth catch crop sown on 18th August. Abdul Baki and Teasdale (2007) stressed that catch crops application in vegetable production and ploughed as green manure or left on the soil surface as mulch, bring not only ecological advantages, but also allows to reduce production costs and increase its profitability. Also Ceglarek and Płaza (2006) and Płaza (2008) point to economic benefits of catch crops application.

CONCLUSIONS

1. Catch crops of faba bean and facelia sown on 21st July were characterized by the best yield forming effect. Approximate production results were registered also after FYM.
2. With delayed sowing of catch crops a decrease in their yield forming residual effect was observed.
3. The highest gross margin and profitability index were obtained in sweet corn cultivation after faba bean catch crop sown on 21st July.
4. All catch crops sown on 21st July and 4th August allowed to obtain higher gross margin level and higher production profitability index of sweet corn ears production than ploughed FYM.

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