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[1] Faculty of Agrobioengineering and Animal Husbandry, Siedlce University of Natural Sciences and Humanities, Prusa 14, 08-110 Siedlce, Poland
e-mail: marek.nieweglowski@uph.edu.pl
[2] Department of Agriculture, Vocational State School of Ignacy Mościcki in Ciechanów, Narutowicza 9, 06-400 Ciechanów, Poland
[3] Family farm in Niemirki 54, 08-304 Jabłonna Lacka, Poland

MAREK NIEWĘGŁOWSKI[1], MARIA SZCZYGIELSKA[1], KRZYSZTOF KAPELA[1], ANNA SIKORSKA[2], EWA KRASNODĘBSKA[3], KRYSTYNA ZARZECKA[1], MAREK GUGAŁA[1]

An economic evaluation of the use of nitrogen fertilization and growth biostimulants in the production of maize grown for grain

Ekonomiczna ocena stosowania nawożenia azotem i biostymulatorów wzrostu w produkcji kukurydzy uprawianej na ziarno

Summary. The study aimed to determine the impact of using biostimulants and nitrogen fertilization on the profitability of growing two cultivars of maize grown for grain with different FAO earliness class. The studies were conducted in three vegetation seasons of 2015–2017. Data comes from a farm specializing in plant production. The economic assessment was made using the European Union (EU) method based on the standard gross margin (SGM). Operating income and profitability ratios were also calculated. Yields of studied maize cultivars were varied; on average, in the three examined years, the 'P8400' cultivar gave the best yield – 11.68 t ha^{-1}, using nitrogen fertilization 160 kg N ha^{-1} and biostimulant Asahi SL. The lowest yield was obtained for the 'PR38N86' cultivar – 6.7 t ha^{-1}, lacking nitrogen fertilization and without a growth stimulator. The highest profitability index (calculated with subsidies) on average over three years of research was achieved with nitrogen fertilization 120 kg N ha^{-1} and without the use of a growth biostimulant, for the 'P8400' cultivar – 188.54%, and the 'PR38N86' cultivar – 185.27%.

Keywords: maize, nitrogen fertilization, biostimulant, yield, income, profitability

INTRODUCTION

The determinant of farming, important from the farmer's point of view, is achieving the production and economic goal, consisting in producing the right amount of agricultural products and ensuring satisfactory farmers' income [Duer et al. 2002, Stanger et al. 2008].

Income obtained from a farm is a measurable effect of agricultural activity, and is also the economic result of the farmer's decisions. The profitability of production of selected agricultural products can be expressed by the level of operating income and the profitability indicator [Zegar 2008, James et al. 2010, Keramidou et al. 2013, Czyżewski et al. 2019].

The profitability or unprofitability of a given production is indicated by the account of costs incurred and income obtained. Therefore, the results obtained depend on the production potential of farms: land resources, labour and capital, their quality and manner of use, but they also depend on external operating conditions independent of the producer, e.g. weather or market conditions [Meza et al. 2008, Reidsma et al. 2009, Skarżyńska 2019]. The profitability of growing maize for grain depends on many factors that most strongly affect the amount of yield, i.e. the course of weather conditions during the entire growing season and the demand and supply situation on commodity exchanges of maize grain [Wolf and Van Diepen 1995, Szmigiel and Oleksy 2006, Spurtacz et al. 2008]. Other authors [Księżak and Bojarszczuk 2010, Gugała et al. 2015] also draw attention to the fact that the profitability of growing maize is closely related to the yield difference of individual cultivars. Hanson et al. [1993] consider that profitability of maize depends on plants preceded by maize in a crop rotation.

The authors [Davis et al. 2012] concludes that efficiency, profitability and nutrient balance depends on applied crops scheme. Other authors [O'Brien et al. 2001] believes that cost-effectiveness of maize crop is relative to irrigation costs of that crop.

According to Spurtacz et al. [2008], the profitability of maize cultivation depends on the expenses incurred for soil cultivation, fertilization, chemical protection, as well as on the amount of obtained crop, costs of grain harvesting and drying, as well as the market price.

The aim of the study was to determine the impact of using biostimulants and nitrogen fertilization on the profitability of cultivating two cultivars of maize grown for grain with different FAO earliness class in the 2015–2017 growing seasons.

MATERIAL AND METHODS

The profitability analysis of maize for grain depending on the biostimulants used and nitrogen fertilization was based on data from a farm specializing in plant production, located in Poland, in the Sokołów poviat in the Mazovia voivodeship (52°30'N and 22°26'E). Field experiment was carried out in 2015–2017, testing two cultivars of maize: medium early – 'P8400' (FAO 240) and medium late 'PR38N86' (FAO 280). The experiment was set up in a split – split – plot arrangement in three repetitions. The area of a single harvesting plot was 30 m^2. Yields of cultivars were tested depending on nitrogen fertilization: control object – without nitrogen (0 kg N ha^{-1}), nitrogen dose 80 kg N ha^{-1}, 120 kg N ha^{-1} and 160 kg N ha^{-1} and the biostimulant used: control object – without the use of a biostimulant, Asahi®SL biostimulant, Improver® biostimulant and Zeal® biostimulant. The nitrogen dose was applied once before sowing. Biostimulants Asahi®SL and Improver® were used on two dates: at 4 leaf stage (BBCH 14) and 8 leaf stage (BBCH 18), whereas biostimulant Zeal® was used on single date – at 6 leaf stage (BBCH 16). Asahi®SL biostimulant was used in two doses of 0,60 dm^3 ha^{-1}, Improver® was used in first dose of 1,00 dm^3 ha^{-1} and second dose of 0,60 dm^3 ha^{-1} and biostimulant Zeal® was used in single dose of 2,00 dm^3 ha^{-1}. The production value was determined on the basis of yield obtained from an area of 1 ha with 15% humidity. The cost-effectiveness of maize cultivation is determined by the relation between value of the yield obtained and production costs incurred, which they consists of all the elements throughout the production chain. Among all the costs, the largest share are direct costs, which includes costs of seeds, fertilizers, plant protection products and machinery costs.

The economic assessment was made using the method operating in the European Union (EU) based on the standard gross margin (SGM) [Augustyńska-Grzymek et al. 2000, Andersen et al. 2007, Střeleček et al. 2011, Zawadzka and Strzelecka 2012]. Operating income and profitability ratios were also determined, calculated as:

$$\text{Profitability ratio} = \text{production value}/\text{total costs of production} \times 100\%$$

In case of profitability ratio with direct subsidies, the costs of production was also considered with the direct subsidies.

The selling price of maize grain used in the economic analysis corresponded to the average market price in a given season (100.83 EUR t^{-1} in 2015, 106.52 EUR t^{-1} in 2016, 101.92 EUR t^{-1} in 2017). The production value includes subsidies in accordance with the standards for calculating the direct surplus. On the surveyed farm, it was a uniform and complementary area payment (178.57 EUR ha^{-1} in 2015, 178.77 EUR ha^{-1} in 2016 and 179.2 EUR ha^{-1} in 2017). Prices and production value were converted from PLN to EUR according to the exchange rate announced by the European Central Bank, according to which direct payment rates for individual years were calculated (2017 – 1 EUR = 4.3042 PLN, 2016 – 1 EUR = 4.3192 PLN, 2015 – 1 EUR = 4.2448 PLN).

RESEARCH RESULTS AND DISCUSSION

The profitability of maize cultivation is closely related to the yield and the price of grain sale [Księżak and Bojarszczuk 2010, Lorenz et al. 2010]. When analysing the yield of the examined maize cultivars grown for grain, it was found that in the three examined years, on average, the ‘P8400’ cultivar – 9.68 t ha^{-1} yielded better than the ‘PR38N86’ cultivar – 9.01 t ha^{-1}.

When analysing the yield of ‘P8400’ maize depending on the nitrogen fertilization dose and biostimulants used, it was found that the highest grain yield was obtained using a nitrogen fertilization dose – 160 kg N ha^{-1} and the Asahi SL biostimulant, maize grain yield averaged to – 11.68 t ha^{-1} for three analysed growing seasons (tab. 1). However, in the case of ‘PR38N86’ maize, the highest grain yield was obtained using a nitrogen fertilization dose – 120 kg N ha^{-1} and Asahi SL biostimulant, maize grain yield was on average – 10.91 t ha^{-1} (tab. 2). These results are consistent with the research of Bogucka et al. [2008] .

Table 1. Profitability of ‘P8400’ maize production depending on the nitrogen fertilization and growth biostimulant (average from 2015–1017)

Specification	‘P8400’															
	0 kg N ha^{-1}				80 kg N ha^{-1}				120 kg N ha^{-1}				160 kg N ha^{-1}			
	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver
Crop (t ha^{-1})	6.94	7.70	7.41	7.45	9.04	10.44	10.32	9.35	10.36	11.27	10.67	10.16	10.19	11.68	11.38	10.49
Production value without subsidies (EUR ha^{-1})	717.45	797.02	767.58	770.15	933.38	1076.05	1063.55	966.13	1070.08	1162.36	1100.79	1047.59	1050.44	1203.93	1172.48	1082.91
Production value with subsidies (EUR ha^{-1})	896.30	975.87	946.43	949.00	1112.23	1254.91	1242.40	1144.98	1248.93	1341.21	1279.64	1226.44	1229.29	1382.78	1351.33	1261.76
Direct costs (EUR ha^{-1})	517.81	560.85	544.91	554.09	581.86	623.90	608.21	617.64	603.29	655.81	640.63	649.81	638.42	707.67	684.25	702.17
Direct surplus (EUR)	378.50	415.02	401.52	394.91	530.37	631.01	634.19	527.33	645.64	685.39	639.01	576.63	590.87	675.11	667.08	559.59
Indirect costs (EUR ha^{-1})	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02
Total costs (EUR ha^{-1})	576.83	619.87	603.93	613.11	640.88	682.92	667.24	676.67	662.31	714.83	699.65	708.83	697.44	766.70	743.27	761.19
Income from cultivation 1 ha (with subsidies) (EUR ha^{-1})	319.47	356.00	342.49	335.89	471.35	571.99	575.17	468.31	586.62	626.37	579.99	517.61	531.84	616.09	608.06	500.57
Income from cultivation 1 ha (without subsidies) (EUR ha^{-1})	140.62	177.15	163.64	157.04	292.50	393.14	396.32	289.46	407.77	447.52	401.14	338.76	352.99	437.24	429.21	321.72
Profitability ratio with subsidies (%)	155.51	157.48	156.42	155.33	173.50	183.89	186.28	169.39	188.54	187.72	183.03	173.29	176.31	180.56	181.97	165.91
Profitability ratio without subsidies (%)	124.50	128.62	126.79	126.15	145.58	157.70	159.47	142.95	161.53	162.70	157.46	148.05	150.67	157.22	157.90	142.40

Source: calculations based on own studies (calculating PLN into EUR according to the average European Central Bank rates, which was used to convert direct payment rated in 2015–2017 – 1 EUR = 4.2894 PLN)

Table 2. Profitability of ‘PR38N86’ maize production depending on the nitrogen fertilization and growth biostimulant (average for 2015–2017)

Specification	‘PR38N86’															
	0 kg N ha^{-1}				80 kg N ha^{-1}				120 kg N ha^{-1}				160 kg N ha^{-1}			
	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver	Control object	Asahi SL	Zeal	Improver
Crop (t ha^{-1})	6.70	6.89	6.77	6.83	8,51	9.33	8.98	9.27	10.04	10.91	9.96	10.10	9.80	10.46	10.03	9.54
Production value without subsidies (EUR ha^{-1})	693.98	713.33	700.19	706.50	877.35	960.91	926.02	955.74	1034.44	1125.29	1027.66	1041.47	1013.22	1078.66	1035.04	985.83
Production value with subsidies (EUR ha^{-1})	872.83	892.18	879.04	885.35	1056.20	1139.76	1104.87	1134.59	1213.29	1304.15	1206.51	1220.32	1192.07	1257.51	1213.89	1164.68
Direct costs (EUR ha^{-1})	510.53	553.42	537.54	546.67	574.33	616.24	600.60	609.98	595.85	648.04	632.89	642.02	630.79	699.38	676.16	693.85
Direct surplus (EUR)	362.29	338.75	341.50	338.69	481.86	523.52	504.27	524.61	617.44	656.11	573.62	578.30	561.28	558.12	537.73	470.83
Indirect costs (EUR ha^{-1})	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02	59.02
Total costs (EUR ha^{-1})	569.55	612.44	596.56	605.69	633.35	675.26	659.63	669.00	654.87	707.06	691.91	701.04	689.81	758.41	735.18	752.88
Income from cultivation 1 ha (with subsidies) (EUR ha^{-1})	303.27	279.73	282.48	279.67	422.84	464.50	445.25	465.59	558.42	597.09	514.60	519.28	502.26	499.10	478.71	411.81
Income from cultivation 1 ha (without subsidies) (EUR ha^{-1})	124.42	100.88	103.63	100.82	243.99	285.65	266.40	286.74	379.57	418.24	335.75	340.43	323.41	320.25	299.86	232.96
Profitability ratio with subsidies (%)	153.22	145.67	147.28	146.62	166.86	168.95	167.61	169.80	185.27	184.45	174.23	174.21	172.61	165.76	164.94	154.65
Profitability ratio without subsidies (%)	121.81	116.46	117.29	117.09	138.62	142.46	140.48	143.06	157.96	159.15	148.37	148.69	146.68	142.17	140.61	130.90

Source: calculations based on own research (calculating PLN into EUR according to the average European Central Bank rates, which was used to convert direct payment rated in 2015–2017 – 1 EUR = 4.2894 PLN)

The size of dry grain yield was determined by the nitrogen dose. Nitrogen dose of 120 kg N kg^{-1} increased this feature by 2,65 t ha^{-1} on average, compared to the control object. Whereas, as a result of increasing nitrogen dose to 160 kg N ha^{-1}, the dry grain yield substantially decreased by 0,15 t ha^{-1} on average, compared to the object with 120 kg N kg^{-1} dose. The size of dry grain yield was the smallest on the control object – on average 6,28 t ha^{-1} (tab. 3).

Interaction between nitrogen doses and genetic feature was noted (tab. 3). 'PR38N86' cultivar, after use of 120 kg N ha^{-1} dose, obtained the highest value of the discussed feature, compared to the control object. 'P8400' cultivar obtained the biggest dry grain yield after use of 120 kg N ha^{-1} and 160 kg N ha^{-1} doses, whereby the differences between them where statistically insignificant.

Table 3. The dry grain yield (t ha^{-1}) depending on cultivar and nitrogen doses

Nitrogen doses	Cultivars		Average
	'PR38N86'	'P8400'	
Control object	5.98	6.57	6.28
80 kg N ha^{-1}	7.73	8.55	8.14
120 kg N ha^{-1}	8.61	9.26	8.93
160 kg N ha^{-1}	8.31	9.25	8.78
Average	7.66	8.41	–
$LSD_{0.05}$ for: nitrogen doses – 0.12, cultivars – 0.08, interactions: cultivars × nitrogen doses – 0.17			

Biostimulants increased the dry grain yield from 0.14 to 0.68 t ha^{-1}, compared to the control object (tab. 4). The highest value of this feature – on average 8.42 t ha^{-1}, was noted on object no. 2, on which the biostimulant Asahi SL was used. The value of dry grain yield was lower on other objects (1, 3 and 4) and where 7.74 t ha^{-1}, 8.08 t ha^{-1} and 7.88 t ha^{-1}, respectively.

Table 4. The dry grain yield (t ha^{-1}) depending on cultivars and types of biostimulants used

Types of biostimulants used	Cultivars		Average
	'PR38N86'	'P8400'	
Control object	7.52	7.96	7.74
Asahi SL®	7.92	8.93	8.42
Zeal®	7.62	8.54	8.08
Improver®	7.57	8.20	7.88
Average	7.66	8.41	–
$LSD_{0.05}$ for: types of biostimulants used – 0.13, cultivars – 0.08, interactions: cultivars × types of biostimulants used – 0.14			

Interaction between types of biostimulants used and genetic feature was noted (tab. 4). ‘PR38N86’ and ‘P8400’ cultivars had higher value of the discussed feature after use of all types of biostimulants, compared to the control object. With ‘PR38N86’ cultivar, the biggest dry yield was noted after use of Asahi SL biostimulant, and it was significantly smaller on other objects (3 and 4). Whereas the differences between biostimulants Zeal and Improver and the control object where statistically insignificant. On the other hand, with ‘P8400’ cultivar the significantly lowest dry yield was noted after use of Improver biostimulant.

The total production value, together with direct payments for individual types of crops, was diversified and averaged for three growing seasons for the ‘P8400’ cultivar from 896.30 EUR ha^{-1} – for crops without growth biostimulants and no nitrogen fertilization to 1382.80 EUR ha^{-1} – for cultivation with Asahi SL growth biostimulant and nitrogen fertilization 160 kg N ha^{-1}. These values for the ‘PR38N86’ cultivar ranged from 872.83 EUR ha^{-1} – for crops without growth biostimulants and lack of nitrogen fertilization to 1304.15 EUR ha^{-1} – for crops with Asahi SL growth biostimulant and nitrogen fertilization 120 kg N ha^{-1}. This diversity was primarily due to the yield obtained in individual technologies for growing maize for grain. The obtained results are consistent with the research of Księżak and Bojarszczuk [2010], who confirmed that high productivity determines the competitiveness of maize cultivation.

Direct costs of growing maize for grain for particular combinations of nitrogen dose and growth biostimulants varied and averaged for the three examined years from 510.53 EUR ha^{-1} (variant without growth biostimulant and dose of 0 kg N ha^{-1}) for the ‘PR38N86’ cultivar to 707.67 EUR ha^{-1} (variant with Asahi SL growth biostimulant and nitrogen dose of 160 kg N ha^{-1}) for the ‘P8400’ cultivar. These differences resulted from additional costs incurred for growth biostimulant treatments and the use of additional nitrogen fertilization, which resulted in an average increase in direct costs compared to the object where no growth biostimulants and nitrogen fertilization were used. Besides the cost of biostimulant, in direct costs there were also included costs of seeds, mineral fertilizers, plant protection products and machinery costs.

Direct surplus from 1 ha of maize cultivation for individual cultivation technologies calculated as the average for the three studied years, for the ‘P8400’ cultivar ranged from 378.50 EUR ha^{-1} (variant without biostimulant and without nitrogen fertilization) to 685.39 EUR ha^{-1} (variant with the Asahi SL biostimulant and nitrogen fertilization 120 kg N ha^{-1}). However, for the ‘PR38N86’ cultivar, it ranged from 338.69 EUR ha^{-1} (variant with Improver biostimulant and without nitrogen fertilization) to 656.11 EUR ha^{-1} (variant with Asahi SL biostimulant and nitrogen fertilization 120 kg N ha^{-1}). It was determined by cultivation technologies.

Income from cultivation of 1 ha, including direct payments, depended on the amount of obtained crop and production costs. On average, for the studied years, it ranged from 279.67 EUR ha^{-1} (variant with Improver biostimulant and without nitrogen fertilization) for the ‘PR38N86’ cultivar to 626.37 EUR ha^{-1} (variant with Asahi SL biostimulant and nitrogen fertilization 120 kg N ha^{-1}) for the ‘P8400’ cultivar.

When comparing the profitability indicator (calculated with subsidies) of two studied cultivars over three years of research, it should be stated that the most favourable and stable direction of maize production was the cultivation of maize for grain with nitrogen fertilization 120 kg N ha^{-1} and without the use of growth biostimulant, for the 'P8400' cultivar – 188.54% (tab. 1), and for the 'PR38N86' cultivar – 185.27% (tab. 2). The lowest indicator was achieved in the absence of nitrogen fertilization and the use of Asahi SL biostimulant for the 'PR38N86' cultivar – 145.67%. Greater yield stability and costs incurred for production, and lower grain moisture at the time of harvest is the basis for obtaining the highest income from 1 ha of maize cultivation for grain. In addition, studies have shown that the use of growth biostimulants and nitrogen doses above 120 kg N ha^{-1} is not economically justified.

CONCLUSIONS

The conducted economic analysis of maize cultivated for grain indicates that it is a profitable plant production department. Its profitability depends on many factors, however, it is mainly based on the yield obtained and the purchase price achieved. Studies have shown that the use of growth biostimulants and nitrogen doses over 120 kg N ha^{-1} was economically unjustified. Therefore, obtaining stable yields, without the possibility of predicting seed sales prices, should determine among producers a thorough analysis of direct costs incurred for production and the possibilities of reducing them.

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Streszczenie. Celem przeprowadzonych badań było określenie wpływu nawożenia azotem i stosowania biostymulatorów na opłacalność uprawy dwóch odmian kukurydzy uprawianej na ziarno o różnej klasie wczesności FAO. Badania były prowadzone w trzech sezonach wegetacyjnych 2015–2017. Dane pochodzą z gospodarstwa rolnego specjalizującego się w produkcji roślinnej. Oceny ekonomicznej dokonano funkcjonującą w Unii Europejskiej (UE) metodą opartą na standardowej nadwyżce bezpośredniej (SGM – standard gross margin). Obliczono też dochody z działalności oraz wskaźniki opłacalności. Plonowanie badanych odmian kukurydzy było zróżnicowane, średnio w trzech badanych latach najlepiej plonowała odmiana 'P8400' – 11,68 t ha^{-1}, w wariancie doświadczenia z zastosowaniem nawożenia azotem – 160 kg N ha^{-1} i biostymulatora Asahi SL. Najmniejszy plon uzyskano dla odmiany 'PR38N86' – 6,7 t ha^{-1}, przy braku nawożenia azotem i bez stymulatora wzrostu. Najwyższy wskaźnik opłacalności (liczony z dopłatami) średnio na przestrzeni trzech lat badań osiągnięto przy nawożeniu azotem 120 kg N ha^{-1} i bez stosowania biostymulatora wzrostu, dla odmiany 'P8400' – 188,54%, a dla odmiany 'PR38N86' – 185,27%.

Słowa kluczowe: kukurydza, nawożenie azotem, biostymulator, plon, dochód, opłacalność

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