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# AGRONOMIC AND ECONOMIC CHARACTERISTICS OF COMMON WHEAT AND SPELT PRODUCTION IN AN ORGANIC FARMING SYSTEM

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**ABSTRACT**

**Background.** This study investigated the agronomic and economic determinants of production of selected common wheat and spelt cultivars in an organic farming system. The aim of the study was to identify the production and economic factors which determine profitability of spelta growing in the regime of organic farming in comparison with common wheat. Knowledge related to production costs is an important element of improving the competitiveness of cultivation of these species.
**Material and methods.** The experiment had a randomized complete block design with four replications. Common wheat and spelt were grown in an organic farming system during a two-year field experiment. The analysis of economic effectiveness was calculated according to agricultural accounting standards.
**Results.** The total costs associated with the production of spelt cultivars significantly exceeded the total costs of common wheat production. This difference was attributed to direct costs, in particular seed prices. Spelt generated marginally higher agricultural incomes that were closely related to the higher market prices of spelt grain. The highest income margin ratio of 2.61 was noted for the late-sown spelt cv. Speltz T. The profitability ratio was lowest (2.16) for the early-sown spelt cv. Roter S.
**Conclusion.** Spelt production was characterized by considerably higher total costs than common wheat due to higher direct costs, in particular seed prices. Delayed sowing increased the agricultural incomes generated by spring cultivars of both common wheat and spelt.

**Key words:** production costs, revenues to cost ratio, technology, *Triticum*

## INTRODUCTION

The social and economic transformations occurring in Poland induce changes in agriculture and contribute to the popularity of organic farming. The growth of the organic farming sector has proceeded with irregular bursts – the number of organic farms and organic processing plants had increased substantially up to 2013, while in 2014 their number decreased to 25,427 from 27,093 in 2013 (Raport..., 2015). The noted drop was associated with a decrease in profitability, in particular the fluctuating prices of organic products. Despite state grants for organic farming, profitability is largely determined by consumer purchasing power and Polish consumers are not always able to afford the more expensive organic products. However, the current increase in incomes and growing levels of environmental awareness are likely to boost Polish consumers' interest in organic products in the future. The average monthly income in the Polish business sector increased from PLN 3603.42 in 2013 to PLN 4304.95 in February 2017 (GUS, 2014; 2017).

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Common wheat and spelt are among the most common agricultural crops that are widely used in the production of baked goods and other foods. The demand for both crops is very high, and spelt is widely produced in organic farms.

Spelt (*Triticum spelta* L.) is one of the oldest subspecies of wheat. Archaeological findings indicate that three wheat subspecies – spelt, emmer and einkorn – as well as barley and panic grass were already being cultivated in Poland 4000 to 4500 years ago. By contrast, the cultivation of common wheat, the most widespread crop in contemporary agriculture, began only 2000 years ago in Europe (Tyburski and Babalski, 2006). Spelt was reintroduced into Poland in the 8$^{th}$ century. It was widely cultivated until the 13$^{th}$ century, after which it was replaced with other cereals (Gąsiorowski, 2004; Kuś and Jończyk, 2005). The popularity of spelt was revived only in the last decade of the 20$^{th}$ century (Achramowicz *et al*., 1999) with the onset of organic farming and the rise of the health-conscious market. Spelt has lower soil requirements than common wheat (Achramowicz *et al*., 1999), it does not require intensive fertilization or pest protection (Wolfe *et al*., 2008), therefore, it is more suited for organic farming. Spelt grain is tightly covered with the lemma and palea and this offers natural protection against pests and diseases thus making the species more resistant to pathogens (Kordan *et al*., 2007).

Spelt yield is determined by the quality of the soil environment and agronomic practices. According to the Research Center for Cultivar Testing (COBORU), the average yield of hulled spelt kernels (gross yield) was 6.59 Mg·ha$^{-1}$ in 2015 and was in the range from 4.73 Mg·ha$^{-1}$ to 9.33 Mg·ha$^{-1}$. The average yield of hull-less spelt grain (net yield) was 5.08 Mg·ha$^{-1}$ (COBORU, 2015).

The aim of the study was to identify the production and economic factors which determine profitability of spelta growing in the regime of organic farming in comparison with common wheat.

## MATERIAL AND METHODS

Common wheat and spelt were grown in an organic farming system during a two-year field experiment conducted in 2010-2011 at the Agricultural Experiment Station in Tomaszkowo, which belongs to the University of Warmia and Mazury in Olsztyn (53°43' N; 20°24' E).

The experimental factors were:

1. Cultivars: two spring cultivars of *Triticum aestivum* L. and two spring cultivars of *Triticum spelta* L.
2. Sowing date: optimal sowing date and sowing date delayed by 14 days.

The following cultivars were evaluated: spelt cultivars Roter Sommerkolben (Roter S.) and Speltz T. aus Tzaribrod (Speltz T.) and common wheat cultivars Trappe and Waluta. In each experimental year, spelt and common wheat were sown on two dates: the optimal date (14 April 2010 and 12 April 2011) and a date delayed by 14 days. Both crops were cultivated in an organic farming system without mineral fertilization. In Poland organic farming is regulated by the Act of 25 June 2009 (Journal of Laws, No 116, item 975). The preceding crop was potato fertilized with 30 Mg·ha$^{-1}$ of manure. Conventional soil cultivation treatments were applied with disk harrowing and ploughing in autumn and harrowing in early spring. The field was harrowed before sowing to control weeds. The experiment had a randomized complete block design with four replications, and it was established on soils of very good rye complex with pH 5.3, relatively high content of P (98 mg·kg$^{-1}$ soil) and moderate content of K (162.5 mg·kg$^{-1}$ soil) and Mg (60.9 mg·kg$^{-1}$ soil). ST – sowing terms: STI – first date (optimal) on 14 April (2010) and 12 April (2011), STII – second date 26 April (2010) and 24 April (2011). The experimental design has been described in detail in a previous study (Zuk-Golaszewska *et al*., 2015).

All calculations were performed in line with Polish agricultural accounting bookkeeping methodology (Goraj, 2000), including the conventional division into direct and indirect costs, to determine basic cost and revenue categories according to the following plan (Augustyńska-Grzymek *et al*., 2009):

1) direct costs (DC),
2) indirect costs (IC),
3) total costs (TC),
4) unit production costs (UC).

The unit costs associated with tractors and machinery and the costs of the applied agronomic treatments were calculated according to the methodology of the Institute

for Agricultural Engineering, Automation and Electrification (Muzalewski, 2007). All costs and prices were converted to EUR based on the exchange rate quoted by the National Bank of Poland on 20 April 2017 at EUR 1 = PLN 4.25.

Two-year average yields were the main criterion in the economic analysis. The results were analyzed statistically by analysis of variance. Differences between treatments were determined with the use of Tukey's test at a significance level of $P < 0.05$. All calculations were performed in the Statistica 10® program.

## RESULTS AND DISCUSSION

The results of this study revealed considerable differences between crop species, cultivars and sowing dates. In the organic farming system the common wheat yields were higher than the spelt yields. Common wheat cv. Trappe was characterized by the highest yield, which averaged 2607 kg·ha$^{-1}$ and was approximately 700 kg·ha$^{-1}$ higher than the yield of the most productive spelt cultivar cv. Roter S. (Table 1). The tested cultivars responded to changes in sowing date and in 2010 the wheat cultivars sown with a 14--day delay were characterized by lower yields. The yield of spelt cv. Speltz T. increased considerably by up to 16%. Delayed sowing increased yields by 18% (spelt cv. Roter S.) and 23% (common wheat cv. Waluta) in 2011. In general, late-sown cereals require less weed control due to a shorter growing season (Tyburski and Babalski, 2006). In a study by Sulewska *et al.* (2008), cereal cultivars responded differently to delayed sowing. Delayed sowing did not compromise the productivity of the lower yielding cv. Bauländer, but it decreased the yield of cv. Schwabenkorn on average by 0.64 Mg·ha$^{-1}$. In organic farming systems higher seeding rates are recommended to minimize weed growth (Drews *et al*., 2002).

The economic analysis revealed that tractor and machine operation generated the highest costs. Total tractor and machine costs were 156.30 EUR·ha$^{-1}$. Combine harvesting was the most cost-intensive operation at 54 EUR·ha$^{-1}$, followed by manure fertilization, which exceeded 23 EUR·ha$^{-1}$ (Table 2).

**Table 1.** The yields of the analyzed common wheat and spelt cultivars in experimental years (Żuk-Gołaszewska *et. al*., 2015)

| Cultivar | | Experimental year | | | | Cultivar |
|---|---|---|---|---|---|---|
| | | 2010 | | 2011 | | |
| | | Sowing Date ST | | | | |
| | | ST-I | ST-II | ST-I | ST-II | |
| | | Hulled grain yield, kg·ha$^{-1}$ | | | | |
| Trappe | | 1952 | 1866 | 3075 | 3535 | 2607 |
| | ST-I-ST-II | - 86 | -4% | + 460 | +14% | |
| Waluta | | 1667 | 1615 | 2791 | 3455 | 2382 |
| | ST-I-ST-II | - 52 | -3% | + 664 | +23% | |
| Roter S. | | 1636 | 1811 | 1908 | 2262 | 1904 |
| | ST-I-ST-II | + 175 | +10% | + 354 | +18% | |
| Speltz T. | | 1168 | 1362 | 2124 | 2270 | 1731 |
| | ST-I-ST-II | + 194 | +16% | + 146 | + 6% | |
| $HSD_{0.05}$* | | ns | | | | 664 |
| Mean | | 1606 | 1664 | 2475 | 2880 | |
| $HSD_{0.05}$ | | 456 | | | | |

* $HSD_{0.05}$ – Honest Significant Difference
ns – non-significant difference

**Table 2.** Costs associated with tractor and machine operation in common wheat and spelt production

| Type of treatment | Unit cost of tractor operation EUR·ha$^{-1}$ | Unit cost of machine operation EUR·ha$^{-1}$ | Unit cost of tractor and machine operation EUR·ha$^{-1}$ | Number of labour hours h·ha$^{-1}$ | Value in EUR·ha$^{-1}$ |
|---|---|---|---|---|---|
| Manure loading, 40% of costs | 18.19 | – | 18.19 | 0.50 | 9.09 |
| Manure fertilization, 40% of costs | 32.71 | 13.62 | 46.33 | 0.50 | 23.16 |
| Disk harrowing | 18.19 | 5.69 | 23.88 | 0.30 | 7.16 |
| Deep ploughing | 32.71 | 8.35 | 41.06 | 0.50 | 20.53 |
| Cultivator tillage | 18.19 | 1.53 | 19.72 | 0.40 | 7.89 |
| Harrowing × 2 | 18.19 | 0.78 | 18.96 | 0.30 | 11.38 |
| Sowing | 18.19 | 11.81 | 30.00 | 0.60 | 18.00 |
| Harvest | – | 67.88 | 67.88 | 0.80 | 54.31 |
| Transport | 18.19 | 4.64 | 18.19 | 0.20 | 4.78 |
| Total | | | | 4.10 | 156.30 |

Despite the above, the relevant costs did not differ significantly from those noted in conventional farming systems. Similar results were reported by Winnicki *et al*. (2013) where the costs associated with tractor and machine operation in the production of spring barley was 151 EUR·ha$^{-1}$. In fenugreek production, the above costs were determined at 58-63 EUR·ha$^{-1}$ (Bieńkowski *et al*., 2015). In large area farms, machine costs are generally lower due to higher productivity, larger output and improved organization of agronomic treatments and production processes.

Total costs, the value of the produced grain and financial results are determined by individual factors, in particular the prices of agricultural materials and the market price of grain. Organic farming does not require expensive fertilizers and crop protection products, however, crop yields are significantly lower than in conventional production systems. Production costs and the value of grain are presented in Table 3. Payments for organic farming, direct payments which substantially increase the value of the produced commodities, and the relevant indicators were taken into consideration in the calculations. Despite lower yields the value of the spelt grain was similar to the value of the common wheat grain, mainly due to the higher market prices of spelt grain. The demand for spelt grain is immense. The late-sown spelt cv. Roter S. was characterized by the highest revenue value, which exceeded 1226 EUR·ha$^{-1}$, and the production value of spelt cv. Speltz T. was determined at 1138.16 EUR·ha$^{-1}$. Production costs were higher in spelt than in common wheat, in particular in spelt cv. Roter S. (519.81 EUR·ha$^{-1}$) where the relevant costs were approximately 27.5% higher in comparison with common wheat. In the evaluated organic farming system chemical crop protection agents were not used and the only fertilizer was manure applied to the preceding crop.

Agricultural income was highest for the late-sown spelt cv. Roter S. at 706.8 EUR·ha$^{-1}$, and it was determined at 701.9 EUR·ha$^{-1}$ for the late sown spelt cv. Speltz T. (Table 4). The highest profitability ratios were noted for the late-sown spelt cv. Speltz T. (2.61) and the late-sown common wheat cv. Trappe (2.57). Common wheat cv. Trappe and spelt cv. Speltz T. generated similar incomes. Delayed sowing improved economic efficiency.

Better production results and economic outcomes were achieved in late-sown spelt and common wheat, which could be attributed to lower weed pressure (a shorter growing season) and greater nutrient availability. Weeds are difficult to control in organic

farming, therefore, delayed sowing enables crops to effectively compete for nutrients with various weed species (Tyburski and Babalski, 2006). According current recommendations, spring wheat can be sown very early because it is highly resistant to spring freezing. In principle, spring wheat should be sown as soon as weather conditions allow field work. Late--sown wheat is usually characterized by rapid growth and development, which reduces the number of spikes and decreases productivity and yields. Late sowing often contributes to the loss of plants during the growing season and a decrease in thousand seed weight (PIORIN, 2014). However, the analyzed cultivars responded differently to the delayed sowing, and the common wheat cv. Trappe was most resistant to this experimental factor.

**Table 3.** Average production costs and income of *T. aestivum* and *T. spelta* grown in an organic farming system

| Specification | Cultivar | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Trappe | | Waluta | | Roter S. | | Speltz T. | |
| Sowing date | ST-1 | ST-2 | ST-1 | ST-2 | ST-1 | ST-2 | ST-1 | ST-2 |
| Grain yield, kg·ha$^{-1}$ | 2513 | 2701 | 2229 | 2535 | 1772 | 2036 | 1646 | 1816 |
| Grain price, EUR·kg$^{-1}$ | 0.2353 | 0.2353 | 0.2353 | 0.2353 | 0,4000 | 0.4000 | 0.4000 | 0.4000 |
| Direct payments | 225.88 | | | | | | | |
| Payments for organic farming | 185.88 | | | | | | | |
| Production value, EUR·ha$^{-1}$ | 591.29 | 635.53 | 524.47 | 596.47 | 708.80 | 814.40 | 658.40 | 726.40 |
| Total revenue, EUR·ha$^{-1}$ | 1003.06 | 1047.29 | 936.24 | 1008.24 | 1120.56 | 1226.16 | 1070.16 | 1138.16 |
| Production costs, EUR·ha$^{-1}$ | | | | | | | | |
| Total direct costs | 192.71 | 192.71 | 196.47 | 196.47 | 304.71 | 304.71 | 221.18 | 221.18 |
| Materials (seeds) | 93.88 | 93.88 | 97.65 | 97.65 | 205.88 | 205.88 | 122.35 | 122.35 |
| Organic fertilizer: | 98.82 | | | | | | | |
| *Cattle manure 30 t*40%* | | | | | | | | |
| Crop protection | 00.00 | | | | | | | |
| Gross margin | 810.35 | 854.59 | 739.76 | 811.76 | 815.86 | 921.46 | 848.99 | 916.99 |
| Total indirect costs: | 215.10 | 215.10 | 215.10 | 215.10 | 215.10 | 215.10 | 215.10 | 215.10 |
| cost of operating tractors and machines | 156.30 | | | | | | | |
| labor costs | 17.36 | | | | | | | |
| agricultural tax | 21.88 | | | | | | | |
| other indirect costs (+10%) | 19.55 | | | | | | | |
| Total costs | 407.81 | 407.81 | 411.57 | 411.57 | 519.81 | 519.81 | 436.28 | 436.28 |

**Table 4.** Indicators of economic efficiency associated with the production of *T. aestivum* and *T. spelta* in an organic farming system

| Specification | Cultivar | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Trappe | | Waluta | | Roter S. | | Speltz T. | |
| Sowing date | ST-1 | ST-2 | ST-1 | ST-2 | ST-1 | ST-2 | ST-1 | ST-2 |
| Income, EUR·ha$^{-1}$ | 595.3 | 639.5 | 524.7 | 596.7 | 600.8 | 706.4 | 633.9 | 701.9 |
| Gross margin rate, % | 80.8 | 81.6 | 79.0 | 80.5 | 72.8 | 75.1 | 79.3 | 80.6 |
| Income rate, % | 59.3 | 61.1 | 56.0 | 59.2 | 53.6 | 57.6 | 59.2 | 61.7 |
| Unit production cost, EUR·kg$^{-1}$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 |
| Revenues to cost ratio | 2.46 | 2.57 | 2.27 | 2.45 | 2.16 | 2.36 | 2.45 | 2.61 |

Organically grown wheat is characterized by lower profitability than wheat cultivated in a conventional farming system. The results of a study conducted by Gugała *et al*. (2015), which investigated winter wheat production, are presented in Table 5. In our study, the profitability ratio ranged from 2.16 (216%) to 2.61 (261%) in an organic farming system. In the cited study by Gugała *et al*. (2015), the profitability ratio of winter wheat exceeded 164.5% only in 2014. Total production costs in a conventional farming system are twice as high as in an organic farming system due to higher costs associated with the purchase of mineral fertilizers and crop protection products (Gugała *et al*., 2015). According to Czułowska (2013) and Skarżyńska (2010), mineral fertilization is the most cost-intensive agronomic treatment and it can account for more than 60% of total production costs. Similar results were reported by Adamska and Paczkowski (1999) who found that fertilization rates, in particular the rate of nitrogen fertilization, were the main determinant of production costs.

**Table 5.** Economic analysis of winter wheat production in 2012, 2013 and 2014 (Gugała *et al*., 2015)

| Specification | Unit | Year | | |
|---|---|---|---|---|
| | | 2012 | 2013 | 2014 |
| Production value without payments | EUR·ha$^{-1}$ | 1820.00 | 1535.29 | 1498.82 |
| Production value with payments | | 2034.16 | 1725.88 | 1713.11 |
| Specific cost | | 863.13 | 843.66 | 867.25 |
| Gross margin | | 1171.04 | 882.29 | 845.86 |
| Indirect cost | | 43.66 | 53.92 | 46.00 |
| Total cost | | 906.77 | 887.31 | 910.89 |
| Income per 1 ha without payments | | 913.22 | 647.99 | 587.93 |
| Income per 1 ha with payments | | 1127.39 | 838.65 | 802.21 |
| Profitability index with payments, % | | 224.30 | 194.50 | 188.10 |
| Profitability index without payments, % | – | 200.70 | 173.00 | 164.50 |

## CONCLUSIONS

The prospects for spelt and common wheat production are influenced by numerous factors, but mostly by market prices and profitability. Growing levels of health awareness can decrease the consumption of common wheat and increase the popularity of spelt among consumers. Health concerns and environmental awareness are the main drivers behind the growth of organic farming. The results of the study investigating common wheat and spelt grown in an organic farming system support the following conclusions:

- spelt production was characterized by considerably higher total costs than common wheat due to higher direct costs, in particular seed prices;
- delayed sowing increased the agricultural incomes generated by spring cultivars of both common wheat and spelt.

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## CHARAKTERYSTYKA AGRONOMICZNO-EKONOMICZNA UPRAWY EKOLOGICZNEJ PSZENICY ZWYCZAJNEJ I PSZENICY ORKISZ

**Streszczenie**

W pracy zaprezentowano badania dotyczące uwarunkowań produkcyjno-ekonomicznych wybranych odmian pszenicy zwyczajnej i pszenicy orkisz w systemie uprawy ekologicznej. Wykazano, że koszty całkowite uprawy odmian pszenicy orkisz były znacznie wyższe od kosztów odmian pszenicy zwyczajnej. Wpływ na to miały koszty bezpośrednie, których poziom w największym stopniu generował zakup materiału siewnego. Z kolei dochód rolniczy w niewielkim stopniu był korzystniejszy w przypadku uprawy orkiszu i był ściśle związany z wyższym poziomem uzyskiwanych cen na rynku. Najkorzystniejszy wskaźnik ekonomicznej efektywności, wynoszący 2.61, wystąpił w orkiszu odmiany Speltz T. w przypadku opóźnionego terminu siewu.

**Słowa kluczowe:** koszty produkcji, technologia, *Triticum*, wskaźnik opłacalności