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Influence of Changes in the Prices of Fertilizers and Fuels on the Profitability of Production of Selected Agricultural Crops

Summary. The prices of raw materials necessary for production play an important role in the production decisions of farmers, and thus in shaping the level of supply of agricultural raw materials. The constant increase in the prices of raw materials for production increases its costs. Therefore, it should be noted that the rising prices of fuel and fertilizers affect the decisions and profitability of plant production. In connection with the above, this study attempts to indicate the impact of changes in fertilizer and fuel prices on the profitability of production of selected agricultural crops in Poland. The paper uses secondary data on the price level of fertilizers, fuels and selected agricultural products, as well as the structure of their production costs. Based on the sensitivity analysis, the potential impact of the increase in fuel and fertilizer prices on the profitability of the production of selected species was indicated. The results showed that the increase in the prices of the above-mentioned raw materials can significantly affect the economic efficiency of the production activity.

Key words: prices, fertilizers, fuels, profitability of production, agricultural crops

JEL Classification: Q11, Q14

Introduction

Agriculture, as a specific branch of the national economy, is strongly dependent on factors beyond the farmers' control (Lidsky et al., 2017). It should be noted that the agricultural sector traditionally plays an important role in the Polish economy (Bryła 2015, Central Statistical Office 2021). It should be mentioned that agricultural production systems are increasingly energy-intensive (Dimitrijević et al., 2020). The increase in the agricultural potential depends to a large extent on the level of use of industrial means of production. In this context, mineral fertilizers are very important, as they are the most yield-generating agricultural factor with high potential (Piwowar, 2011). The vast majority of the demand for mineral fertilizers comes from commercial farms. It should be noted that the price level significantly influences the producers' decisions as to the type and amount of fertilizers used on the farm (Dudkowsky et al. 2014). It should also be mentioned that energy, especially oil and derivatives, is considered as a key factor of production in the economy, including agriculture (Taghizadeh-Hesary et al., 2019).

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For most field crops, the volatility of input material prices is the main risk factor, and the second most important factor is yield volatility. The remaining risk categories are much less important. This suggests that the production risk caused by price increases seems to be one of the main problems in plant production (Harwood et al., 1999, El Benni, & Finger, 2012). Therefore, the volatility of yields and the prices of factors of production favor the emergence of difficulties in predicting the volume of production, revenues, costs and losses (Jerzak, 2008, Vach, 2016).

The prices of raw materials necessary for production play an important role in the production decisions of farmers and breeders, including the management of the cultivation area or determining the size of livestock, and thus in shaping the level of supply of agricultural raw materials (Nigatu et al., 2020). The constant increase in fuel and labor prices increases production costs (Hůla et al., 2008, Kovacev et al., 2011). Therefore, it should be noted that rising fuel and fertilizer prices affect the decisions and profitability of plant production (Skalsky et. Al., 2008). The basic raw materials in plant agricultural production include fertilizers (currently mainly mineral / artificial fertilizers) and fuels. Chemical fertilizers are widely used in agricultural crops, and their production requires high inputs of direct energy, especially in the nitrogen fertilizer industry (Asgharipour et al., 2012). Despite the growing production costs, modern commercial plant production without the use of fertilizers is rather impossible (except for organic farming), especially assuming the desire to obtain more and better crops. Without the use of fertilizers, yields would be significantly reduced regardless of the use of other technological operations such as tillage, plant protection, irrigation, etc. (Dawson et al., 2011, Klikocka et al., 2019, Dimitrijević et al., 2022).

It should be noted that the level of fertilizer prices reached one of the highest levels in history in 2022, after In February, Russia invaded Ukraine. It is worth noting that Russia is the largest exporter of fertilizers in the world. Together with Ukraine, Russia is responsible for a significant part of the world's fertilizer production. The Russian-Ukrainian war has aggravated the already very tense situation of the global supply of these products. It should be pointed out that since 2020, due to shortages of employees related to COVID-19 and the resulting downtimes of factories, we have been observing very high instability on the fertilizer market. The economic sanctions imposed by the international community on Russia caused the country to suspend the export of many goods. Although the import of fertilizers from Russia has not been banned, the Russian Ministry of Industry and Trade, in retaliation for the imposition of many severe sanctions, recommended fertilizer producers to temporarily suspend the export of their products. Russia announced export restrictions on fertilizers until May 2023, explaining its decision by the need to ensure sufficient supply for domestic farmers. As a result, global fertilizer prices rose to record levels in 2022 (Purdue University/CME Group Ag Economy Barometer report for additional survey results, 2022). In the context of the current political and economic situation, it should be noted that the production of nitrogen fertilizers requires natural gas, and at the same time some fertilizer components, such as phosphorus and potassium, are extracted. Only a few countries in the world have adequate resources and access to this raw material to be able to effectively produce fertilizer. These countries include China, Russia, the USA, India and Canada, which are the world's five largest producers of fertilizers. It should be emphasized that Russia, Canada, the European Union, China and Belarus are the world's five largest exporters of fertilizers, and thus the current unstable political situation leads to an increase in the prices

of both raw materials and fertilizers (Report Impacts and Repercussions of Price Increases on the Global Fertilizer Market from the U.S. Department of Agriculture, 2022).

With this in mind, it can be seen that the relationship between agricultural commodities and crude oil has become increasingly tight in recent years through the promotion of biofuels policy. A similar situation also takes place in the case of vertical integration between the market of fertilizers, agricultural raw materials and fuels. Therefore, this study attempts to assess the potential impact of changes in fertilizer and fuel prices on the profitability of production of selected agricultural crops. The increase in the prices of fertilizers and fuels over the last two years has prompted measures to assess the potential effect of the increase in prices of the above-mentioned raw materials for the profitability of production of selected agricultural crops.

Data and methods

This study aims to assess the level and structure of cereal production in Poland, to assess the structure of plant production costs in Poland and to indicate the impact of changes in fertilizer and fuel prices on the profitability of production of selected agricultural crops in Poland. This topic was taken due to the fact that through the influence of prices on the level of supply and demand in the market of agricultural products, they become an important factor shaping the profits of the enterprise. They can be a valuable guide to making decisions as to the development, reduction, abandonment or change of the profile of production activity in the agricultural sector. Farmers making decisions regarding farm production pay a lot of attention to the profitability of production. In agricultural production, it is determined by the relationship between the prices of production factors and the prices of agricultural products that producers receive on the market. Therefore, it is important to analyze and learn about changes in the prices of means of production necessary for agricultural activity, such as fertilizers and fuel. Therefore, the increase in the prices of the indicated factors of production translates into a decrease in the profitability of production (Jeznach 2007, Piwowa 2011).

The potential impact of the increase in fertilizer and diesel oil prices on selected agricultural species was made on the basis of the sensitivity analysis of the financial effect to changes in the price level of the above-mentioned raw materials. In the study, a sensitivity analysis was performed using the internal rate of return for a given price sensitive to changes in selected raw materials. The sensitivity analysis will provide information on the possible effects of changes in the prices of factors influencing the production efficiency, and thus allow to abstract the critical factors (Sobczak, Sobczak 2021). Sensitivity analysis is an analysis that is based on predicting the outcome, using variable patterns that affect the results. The assumption of this method is that the future cannot be predicted and therefore the actual values of individual variables included in the investment account will deviate from those assumed. The main task of the sensitivity analysis is to calculate the turning point, which means that the cost of the product sold equals the revenue. Sensitivity analysis answers the question: "How will the efficiency of the activity change when the value of the input parameter changes?", i.e. it answers the question "what will happen if ...". Thus, this method allows you to test the sensitivity of specific parameters to changes in the values of the relevant factors affecting their value. The sensitivity analysis used in the study was performed using the NPV (net present value) method. This made it possible to determine how much the level of production profitability will change if fuel prices increase by 5%, 10% and 15%,

respectively, and fertilizer prices increase by 10%, 25%, 50% and 75%, respectively, and other variables remain at the previous level.

For the implementation of the above-mentioned secondary data from the Local Data Bank of the Central Statistical Office, Statistical Yearbooks of the Central Statistical Office of Poland, MODR data, and the e-petrol portal were used. The analyzes were carried out for wheat, barley and rape. These species were selected because of their importance in plant agricultural production in Poland and the differentiation of the cost level and specificity of crops.

Research results

Agricultural production is based on agricultural land resources. In the case of Poland, in 2020 they occupied 14 681.6 thousand hectares. In the internal structure of agricultural land, the largest area was occupied by the land under sowing - 10 741.9 thousand hectares, and then permanent grassland - 350.2 thousand hectares, while permanent meadows were cultivated on the area of 2 775.1 thousand hectares, and permanent pastures on the area of 414.5 thousand hectares.

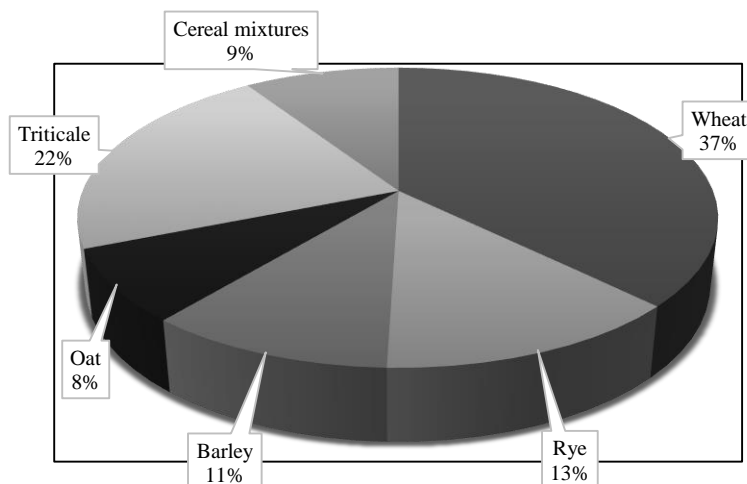


Fig. 1. Structure of the area of cereal crops in Poland in 2020

Source: own study based on the Central Statistical Office.

As indicated by the analyzes carried out in 2020, the area of cereal sown in Poland amounted to 7,411 hectares, of which wheat had the largest share, ie 37% of the area. The next species in terms of the sown area was triticale (22% of the area, rye (13% of the area) and barley 11% of the area (Figure 1).

The harvest of cereals in 2015-2020 ranged from 28 million tonnes to 35.7 million tonnes (Figure 2). Despite the decrease in the area of cereals sown in Poland reported by the Central Statistical Office, their crops are gradually increasing. This is the result of the use of production intensification.

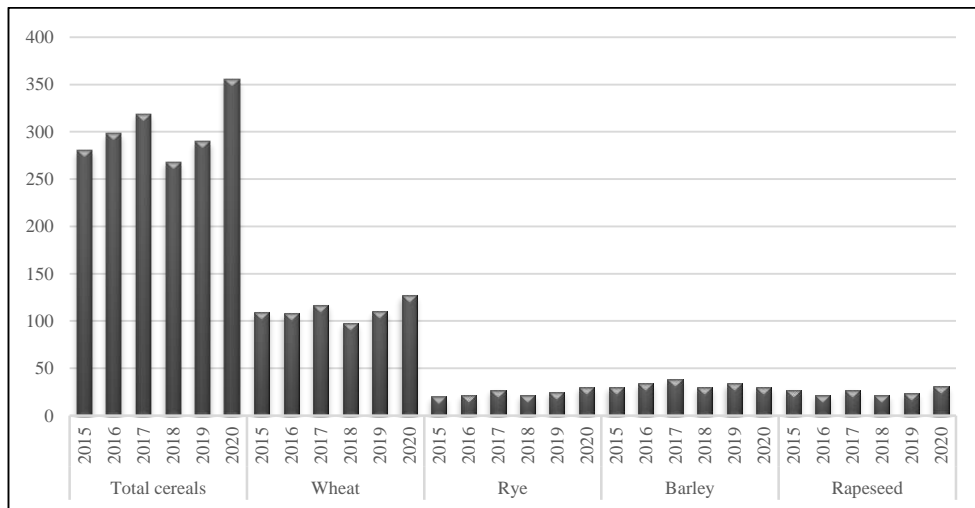


Fig. 2. Harvest of selected cereals in 2015-2020 (in millions of decitons)

Source: own study based on the Central Statistical Office.

In the long term, the yield of all cereals in Poland shows an upward trend. In 2015-2020, the yield of cereals in the country was from 3.73 tonnes/hectare to 4.78 tonnes/hectare. (Figure 3). The greatest increase in yields occurred in the case of barley. It should be noted that due to the significant sensitivity of plant agricultural production.

In connection with the above, it should be noted that, as already mentioned, the agricultural production of cereals plays an important role in the plant production sector in Poland.

As already mentioned in the introduction, fertilizers are an important production factor in the case of agricultural plant production. According to the data from the Central Statistical Office (Figure 4). Mineral fertilizer consumption in 2015-2020 per 1 hectare of arable land minimally. It should be mentioned that nitrogen fertilizers had the largest share in the structure of fertilizer use. It is important that in this group of mineral fertilizers there was a decrease in consumption, which is mainly dictated by the adaptation by producers of regulations aimed at limiting the use of nitrogen fertilizers in agricultural production.

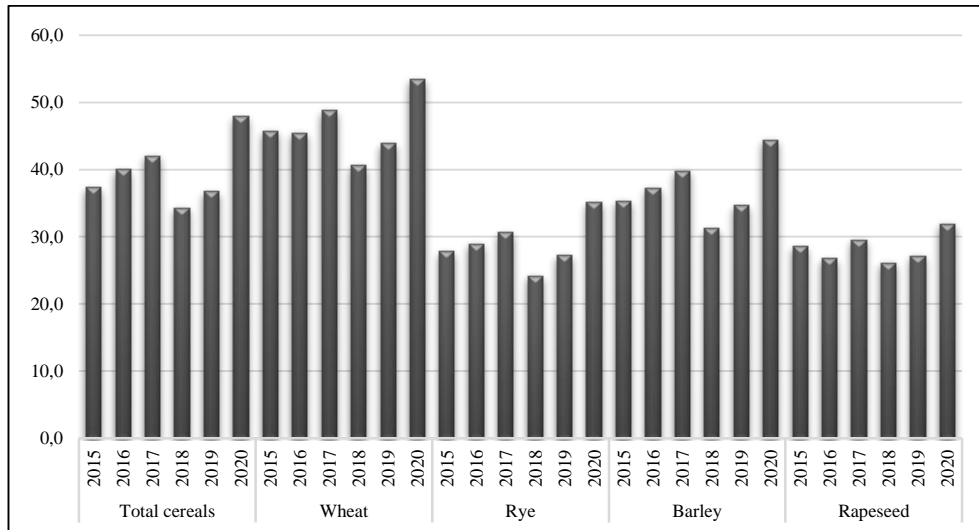


Fig. 3. Yields per 1 hectare of selected cereals in 2015-2020 (in decitons)

Source: own study based on the Central Statistical Office.

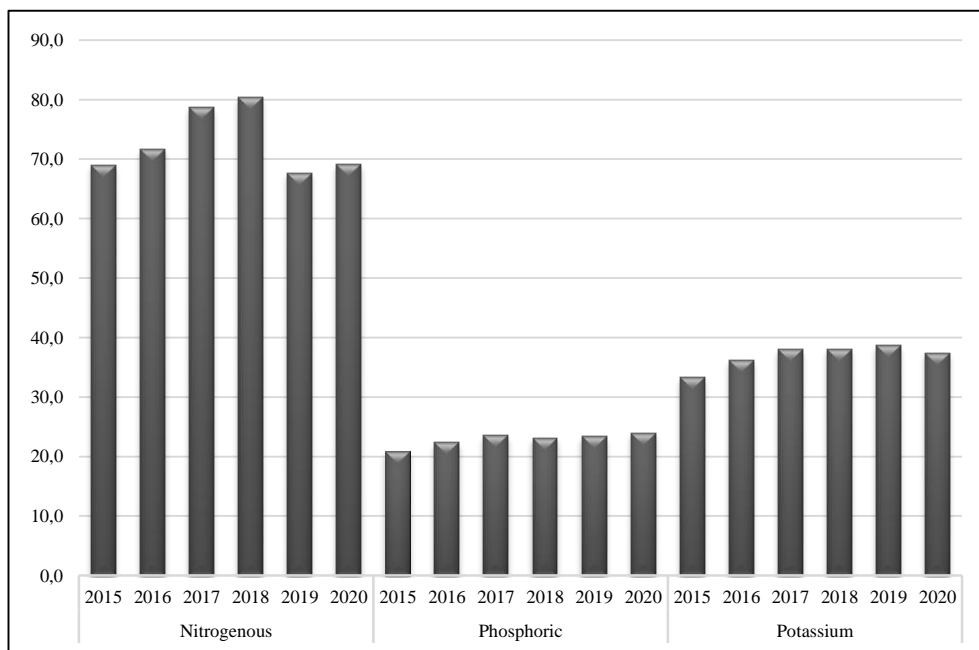


Fig. 4. Consumption of mineral fertilizers per 1 hectare of agricultural land in 2015-2020 (in kilograms in terms of farming years)

Source: own study based on the Central Statistical Office.

As already mentioned, diesel oil is an important production factor affecting the profitability of agricultural production. The conducted analyzes showed that in the analyzed period fuel prices were gradually increasing (Chart 5). In 2021, this price reached PLN 5.25, i.e. PLN 1.22 higher than in 2015. It should be noted that this was the highest price in the period considered. Diesel prices also reached a high level in 2019, where the average price of diesel oil fluctuated around PLN 5.09.

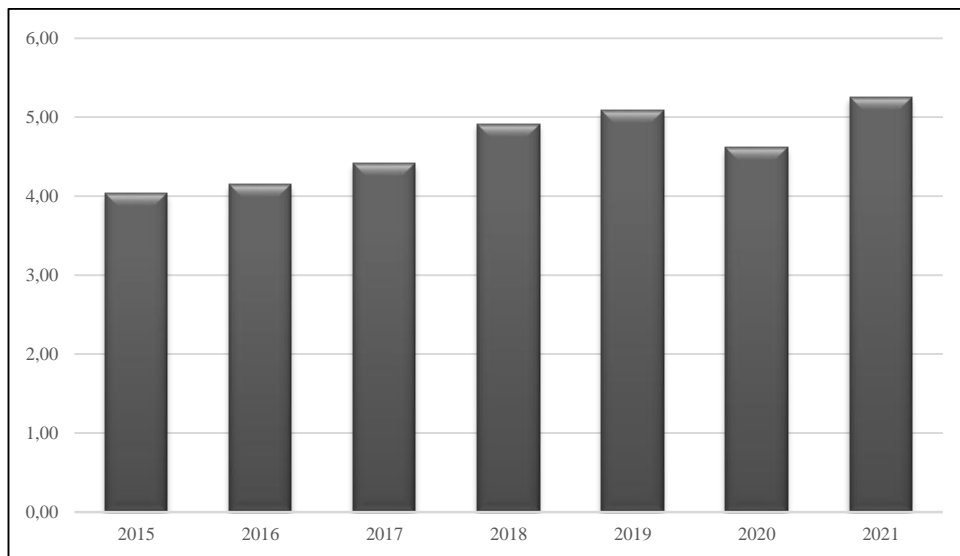


Fig. 5. Average price of diesel oil in 2015-2020 (PLN / liter)

Source: own study based on e-petrol.pl.

In the case of wheat prices in 2017-2021, their significant variability in individual years is noticeable, but with an upward trend, from PLN 66.83/deciton to PLN 96.76/deciton (Figure 6). A similar situation took place in the case of barley prices, the prices of which increased from PLN 61.04 / deciton to PLN 78.27 / deciton. The largest increase was recorded in the case of rape prices, which increased by over 53% over the analyzed period. It should be noted that in this case there is no correlation between the price of selected species and the prices of fertilizers and diesel oil. On the other hand, the average price of wheat was related to the level of harvest in particular years.

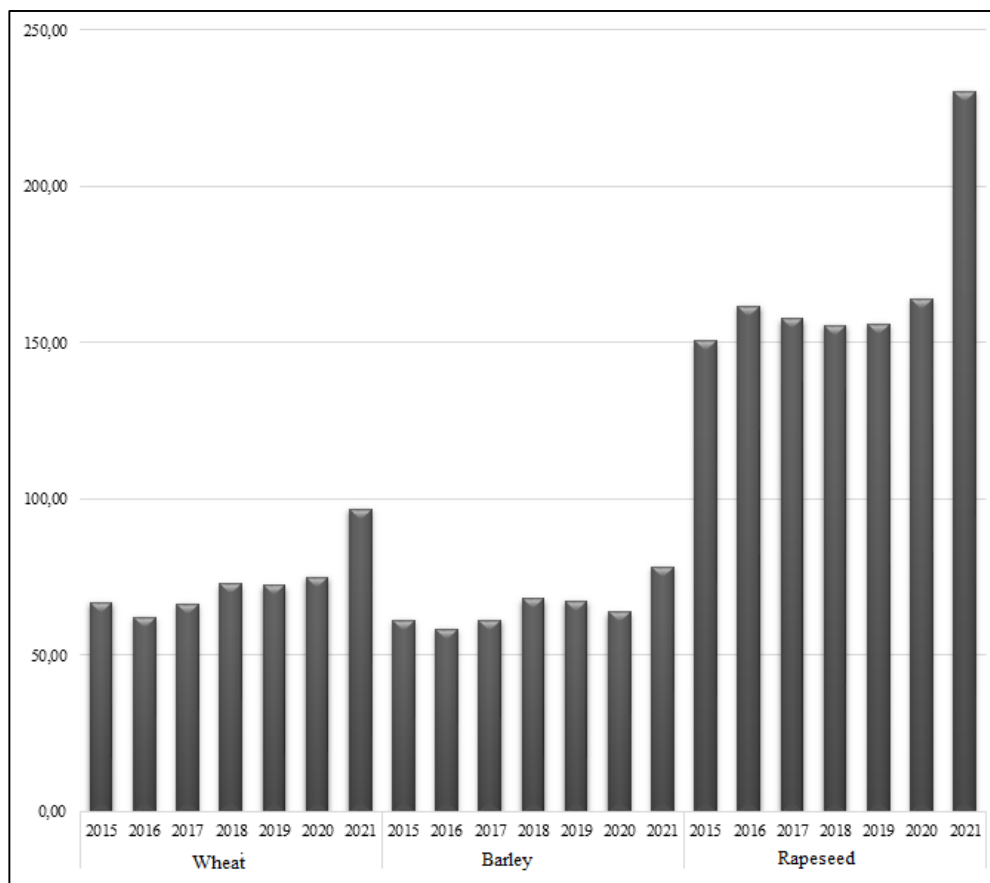


Fig. 6. Average price of selected species in 2015-2021 (PLN / deciton)

Source: own study based on the BDL.

The analysis of the prices of mineral fertilizers showed that in the years 2018-2021 there was a significant increase in them (Figure 6). The greatest increase was recorded in the case of single granular superphosphate, the price of which increased over almost 7-times. It should be noted that a general upward trend in the prices of mineral fertilizers can be observed from mid-2018. Throughout the analyzed period, the prices of individual fertilizers increased by: ammonium nitrate (143%), calcium ammonium nitrate (165%), urea (158%) Granulated single superphosphate (590%), 40% enriched superphosphate (67%), potassium salt (65%), potassium sulfate (43%), amofoska (by 60%).

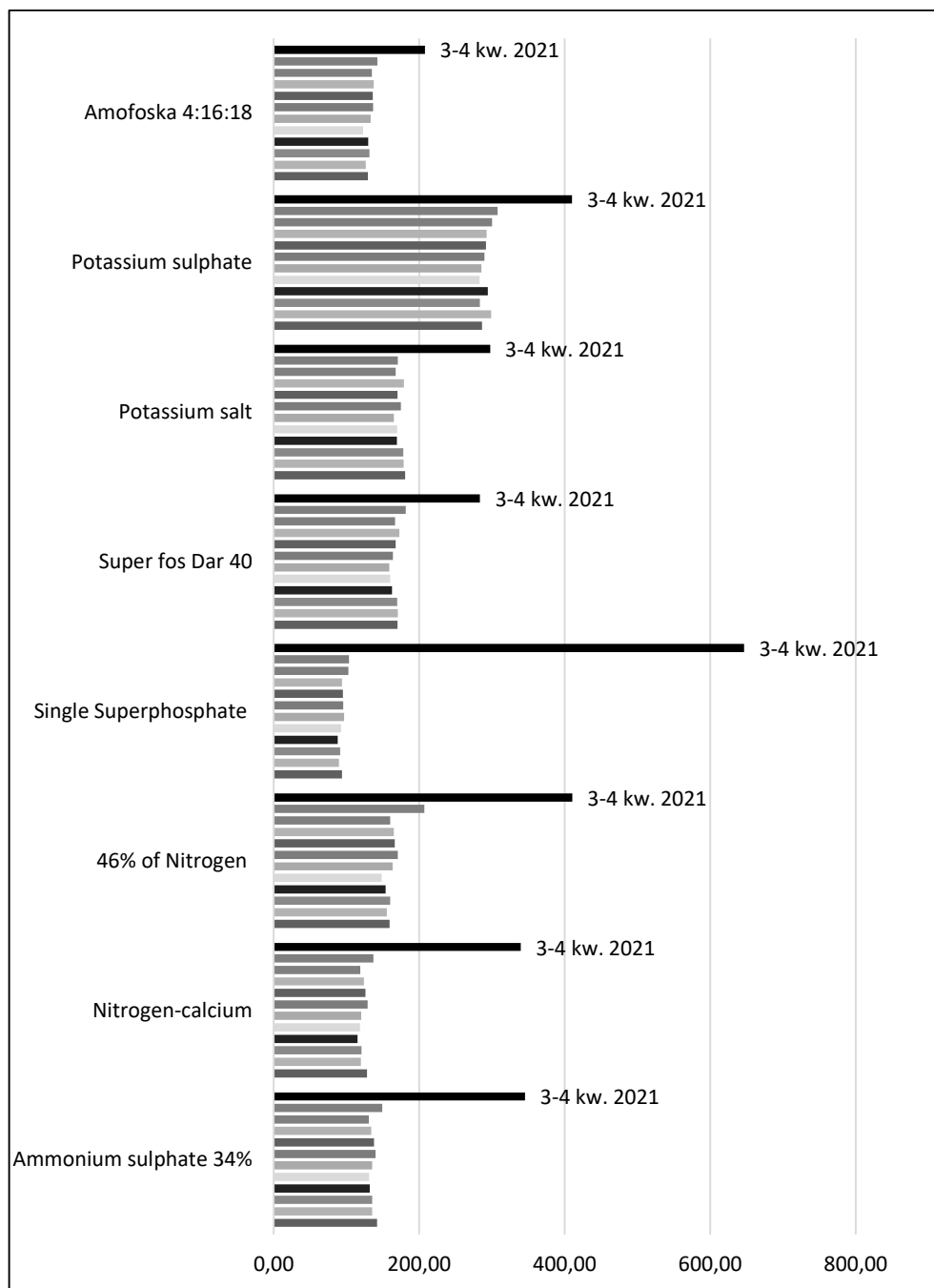


Fig. 7. Average prices of fertilizers in the period 1-2Q 2018-3-4Q 2021 (PLN / ton)

Source: own study based on BDL.

The structure of cereal production costs in Poland for individual species is similar, therefore it was decided to present an example of the cost structure on the example of wheat, barley and rape. The average sum of wheat production costs per 1 hectare is PLN 5,256, barley PLN 4,394 and rapeseed PLN 5,269 (Table 1). The purchase costs of mineral fertilizers have the largest share, i.e. in the range of 26-33 %, the above-mentioned. The work of the tractor also has costs, which in this case is related in 90% to the cost of diesel oil and oscillates around 13-17% of the total costs. It should be noted that the total costs of fertilizers and tractor work account for over 43% of the total. Therefore, the increase in these costs significantly translates into the overall cost-consumption of this production, and thus into the financial result of the conducted activity.

Table 1. The structure of production costs of selected species in 2021 (per 1 hectare)

Costs	Winter wheat	Spring barley	Rape
Seed material	11%	8%	8%
Fertilization	26%	27%	33%
Plant protection chemicals	4%	3%	10%
Services	12%	12%	8%
Tractor work	17%	18%	13%
Tax	3%	3%	3%
Crop insurance	1%	1%	3%
Depreciation	14%	16%	13%
Human labor costs	12%	12%	10%
Total costs (PLN):	5 256,00	4 394,00	5 269,00

Source: own study based on MODR.

In the case of the following study, the sensitivity analysis allowed to calculate the limit level of application of individual factors that ensure the achievement of a certain production break-even point for selected grades. In this way, it makes it possible to obtain information on the permissible deviations of individual explanatory variables, at which the production of selected grades is still profitable. As a result, it made it possible to determine the potential impact of different structures of fuel and fertilizer prices, and thus generated costs, on the profitability of wheat, barley and rape production. The table below shows how the NPV will change in the case of an increase in the analyzed factors of production.

Table 2. The results of the sensitivity analysis for agricultural production

Change	Change of NPV
5% increase in fuel prices	-1.88%
10% increase in fuel prices	3.59%
15% increase in fuel prices	-5.31%
10% increase in fertilizer prices	-2.49%
25% increase in fertilizer prices	-3.68%
50% increase in fertilizer prices	-9.46%
75% increase in fertilizer prices	-15.75%

Source: own calculations.

The sensitivity analysis performed showed that the increase in fuel and fertilizer prices may significantly affect the economic efficiency of the conducted activity. Although this decrease in percentage seems to be lower than the percentage increase in prices, with the relatively low economic efficiency of the investment in the case of cereals, this change may be significantly felt by farmers.

Conclusion

The increase in the agricultural potential depends to a large extent on the level of use of industrial means of production. On the other hand, the prices of raw materials necessary for production play an important role in the production decisions of farmers and breeders, including the management of the cultivation area or determining the size of livestock, and thus in shaping the level of supply of agricultural raw materials. The increase in the prices of fertilizers and fuels, which took place in the last two years, prompted the undertaking of the research discussed in the study.

Analyses provided by other researchers regarding the effects of oil and fertilizer prices show conflicting results. The results of research carried out, among others, by Abbott et al., (2008), Mitchell, (2008), Chang and Su, (2010), analyzes showed that fuel prices have a significant impact on agricultural markets. However, a different opinion was expressed by, for example, Zhang et al. (2010). The results of the analyzes presented in this study indicate that in recent years the prices of one of the main factors of production in agricultural production, ie. the prices of fertilizers and fuels, and more specifically diesel oil, have increased significantly. Due to their large share in the total production costs in the main agricultural crops, these changes significantly affect the economic efficiency of the production conducted. The analyzes showed that the prices of these factors grow disproportionately fast in relation to the increase in the prices of agricultural produce, which contributes to the reduction of production efficiency and, consequently, to the deterioration of the financial situation of farms. The sensitivity analysis showed that a further increase in the prices of diesel oil and fertilizers may adversely affect the financial efficiency of agricultural production.

At the same time, it should be noted that this assumption and study are subject to a significant level of error, which results, among others, from the fact that agricultural production is largely dependent on weather conditions, which may affect the level of prices of agricultural products. In addition, a change in fuel prices may contribute to an increase in indirect costs related to production, and thus the direct impact of the increase in fuel and fertilizer prices on the profitability of production will not be fully reliable.

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