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THE SALE AND CONSUMPTION OF MEANS OF PRODUCTION IN AGRICULTURE IN POLAND DURING THE COVID-19 PANDEMIC

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The COVID-19 pandemic affected the functioning of agriculture and food systems worldwide, including Poland. The industry of production means and services designated for agriculture is a crucial component of the food economy and a factor in agricultural development. The study aims to identify and evaluate changes in the sales and consumption of agricultural inputs in Poland and the impact of these changes on the dynamics of agricultural production. The research period covers the years 2017-2021, with a particular focus on 2020-2021, which marks the span of the COVID-19 pandemic. The study employs various research methods, including critical literature analysis, a descriptive approach, the comparative method, verbal logic, and descriptive statistical methods. The data utilised in the paper are sourced from the Main Statistical Office and the Institute of Agricultural and Food Economics - National Research Institute. During the years 2017-21, the sale and use of agricultural production means in Poland varied, reaching a peak level during the COVID-19 pandemic. In 2021, the dominant sales involved plant protection products, feeds, and agricultural machinery, while in 2020, mineral fertilisers were prominent. An increase in the sale of cereal sowing material was noted in 2020/21, especially wheat seeds. Energy consumption in agriculture primarily came from liquid fuels, with a noted decrease in energy use since 2019. The pandemic did not significantly affect the dynamics of energy consumption. In conclusion, the conducted analysis indicated that the influence of the sale and consumption of production means on production in Polish agriculture during the examined period was insignificant. Such a dependency should be identified over a more extended period. The strongest relationship was observed between global agricultural production exchanges and changes in the use of mineral fertilisers.

Keywords*: agriculture, means of production in agriculture, COVID-19 pandemic, agricultural production*

INTRODUCTION

The global pandemic of COVID-19 has been a critical factor in determining the functioning of societies and economies worldwide in recent years (Baldwin & Tomiura, 2020). According to official statistics, the COVID-19 pandemic caused almost 700 million infections, leading to over 6.9 million deaths (Worldometer, 2023). From an economic point of view, the pandemic has had a profound and far-reaching influence on the global economy (Ali et al., 2020; Barro et al., 2020; Maier and Brockmann, 2020; Laing, 2020; Czech et al., 2020), and its adverse effects are compared to the global financial crisis of 2008-2009 or the Great Depression of 1929-1933 (Susskind and Vines, 2020; Chen and Yeh, 2021; Li et al., 2022). The dynamic increase in the number of infections and deaths due to COVID-19 forced authorities worldwide to implement various restrictions and blockades to stop the spread of the virus (De Vos, 2020; Koh, 2020; Wielechowski et al., 2020). As a result, these actions caused significant disruptions in international and local supply chains, ultimately leading to a large decline in GDP in 2020 (Mahajan and Tomar, 2021).

The unexpected onset of the COVID-19 pandemic impacted the functioning of agriculture and food systems globally, including in Poland (Siche, 2020; Beckman and Countryman, 2021; Dudek and Śpiewak, 2021; Okolie & Ogundeji, 2022). Furthermore, it engendered escalating concerns regarding the lack of food security on a global scale (Roubík et al., 2022). The rapid spread of the virus, followed by the partial closure of the economy, led to unprecedented and simultaneous supply and demand shocks in the food system (Gruère and Brooks, 2021; Jędruchniewicz and Wielechowski, 2022). Disruptions in the supply chain affected food prices (Bairagi et al., 2022).

The lockdowns and movement restrictions imposed in the early stages of the pandemic incited a panic buying frenzy among consumers, resulting in a sharp increase in demand for basic food and agricultural products (Prentice et al., 2020).

Agriculture largely relies on the use of means of production such as fertilisers, seeds, labour force, fuel, and energy (Lamichhane & Reay-Jones, 2021; Bański & Mazur, 2021). It has been pointed out that disruptions caused by COVID-19 could lead to decreased agricultural production efficiency (Aromolaran & Muyanga, 2020). Fertilisers play a pivotal role in agriculture, and the industry demonstrated resilience during the COVID-19 pandemic (Ilinova et al. 2021). The pandemic particularly affected the global fertiliser sector (Höhler & Lansink, 2021). Despite initial resilience, global fertiliser prices dropped in May 2020 due to disruptions in production and supply but reached a record level by 2022 (USDA, 2022). High-quality seeds are vital for agricultural productivity (Elias, 2018).

The pandemic, along with governmental restrictions, potentially threatened seed production, trade, and certification, impacting global food chains. Although seed prices experienced mixed effects, countries highly reliant on imports or at a higher risk of food insecurity felt pronounced effects (Alliance for Science, 2020). Agriculture's energy demand extends from cultivation to storage (Kaygusuz, 2011). The uncertainty induced by the pandemic severely impacted the energy market (Kahn et al., 2022). While the initial demand contraction led to a decline in energy prices, the demand revival in subsequent years caused significant price increases in fossil fuel markets (Gilbert et al., 2021).

The conducted study of changes in sales and consumption of agricultural inputs is relevant to assessing the causes of changes in the functioning of farms in Poland. Jędruchniewicz and Wielechowski (2023a) observe that the impact of the National Bank of Poland during the COVID-19 pandemic on agricultural prices was both direct and indirect, influencing the increase in production costs in Polish agriculture. Jędruchniewicz and Wielechowski (2023b) note that only in 2020 did the prices of goods purchased for current agricultural production decrease. However, in 2021, the costs of materials and services, along with other costs in agriculture, including wages, increased at a record pace. The production means and services industry for agriculture is a vital component of the food economy. It is a factor in the development of agriculture. This industry is the fastest to implement technical progress. Machines and devices are becoming increasingly modern and specialised. The mechanisation of work in agriculture is a natural process of moving away from labour-intensive production. Farms are also supplied with increasingly efficient and new products and solutions in the range of services provided. These results in increased productivity and efficiency of the factors of production used in agriculture (Bański and Mazur, 2021). Enhancing the agriculture sector with machinery increases labour productivity in this sector (Pawlak, 2017).

To the best of our knowledge, there are few studies analysing the impact of the COVID-19 pandemic on the agricultural input market in Poland during this period. This issue requires broader attention. Understanding these changes and the profound effects of the pandemic on the agricultural input market is crucial for comprehending and determining the significance of one of the channels through which the pandemic impacts agriculture. This understanding is also vital for developing effective strategies to address potential crisis-like challenges in the future. The results of these analyses can contribute to further research that expands and deepens the understanding of how changes in farms' use of inputs affect their economic situation and development.

RESEARCH METHODS

The study aims to identify and assess changes in the sales and consumption of agricultural production means in Poland, as well as the impact of these changes on the dynamics of agricultural production. The research period covers the years 2017-2021, with particular emphasis on 2020-2021, the period of the COVID-19 pandemic. This research timeframe allows for comparative analyses during and before the pandemic.

The study uses various research methods, including critical literature analysis, descriptive approach, comparative method, verbal logic, and descriptive statistics methods.

The data used in the article come from the Central Statistical Office (GUS) and from analyses of the Institute of Agricultural and Food Economics of the National Research Institute (IERiGŻ) conducted by a team led by A. Zalewski.

RESEARCH RESULTS

The level and dynamics of sales and consumption of means of production in agriculture in Poland

The analysis of data from Table 1 indicates that in 2017-21, the highest level of sales of mineral fertilizers (in terms of pure ingredient) occurred in the first year of the COVID-19 pandemic (almost 2.45 million tonnes), and calcium fertilizers in 2018 (almost 2.08 million tonnes). The pandemic period did not significantly affect the structure of mineral fertilizers sold in Poland, where nitrogen fertilizers were most important (approx. 60%). Total sales of animal fodder reached the highest level in 2020 (Table 1). However, in 2021, plant protection products and agricultural machines, equipment, and tools were the most sold. This means that the sales of the vast majority of the analysed means of production in agriculture in Poland were the highest during the COVID-19 pandemic.

In the analysed period of 2017-21, the dynamics of sales of means of production in agriculture in Poland varied (Table 2). On average, the largest increases occurred in 2017. They were also significant in 2020 and 2021. However, the years 2018 and 2019 were weaker for this industry. Sales of any analysed means of production in agriculture did not increase yearly. The sector has generally performed very well during the COVID-19 pandemic. Only the sales of mineral

fertilizers increased in 2020 and decreased a year later (7.5%). This was due to a decline in sales of nitrogen fertilizers (7.4%). Within five years, sales of mineral fertilizers increased only once in 2020. This resulted from a significant drop in the prices of these fertilizers. However, in each year of the pandemic, the sales of calcium fertilizers, plant protection products, fodder, as well as machines, devices, and tools increased. In total, during the pandemic, the sales of plant protection products increased the most (11%), while the sales of animal fodder increased the least (1%). During this time, the sales of any collective means of production in agriculture in Poland did not decrease. In detail, the sales of insecticides decreased dramatically (75.5%). This resulted from the European Union's policy and the deadline to withdraw some plant protection products from sale.

Table 1. The level of sales of the main means of production in agriculture (tonnes)

Items	2017	2018	2019	2020	2021
Mineral fertilizers (pure ingredient)	2380174	2357814	2327396	2448675	2363480
Nitrogenous	1513714	1434838	1436402	1548753	1434558
Phosphorous	330493	346994	348292	315380	330290
Potassic	535966	575982	542701	584542	598632
Lime	1693058	2075296	1408340	1437218	1473682
Total plant protection products (active substance)	25075	23178	24281	24628	26973
Insecticides	1809	1761	2761	618	676
Fungicides and seed treatments	7213	8303	7155	9708	10482
Herbicides	13655	11371	11675	12798	14299
Total fodder	10468295	10513836	10498530	10536820	10598439
For pigs	2420632	2536404	2417167	2464635	2573398
For cattle	1097882	1134115	1150338	1215953	1288288
For poultry	6361717	6420544	6597214	6539711	6307690
Machinery, technical equipment and tools (constant prices, million PLN)	1449	1419	1422	1425	1558

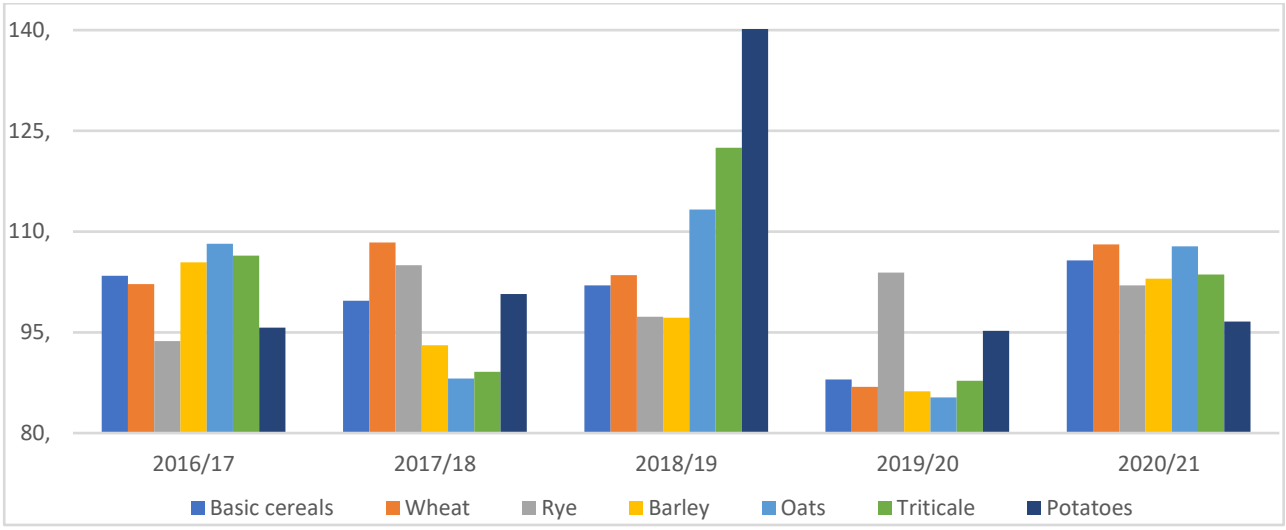
Source: based on GUS (2020-2023) and unpublished data from the Statistics Poland.

Table 2. Annual sales rates of leading means of production in agriculture (tonnes)

Items	2017	2018	2019	2020	2021
Mineral fertilizers (pure ingredient)	95.4	99.1	98.7	105.2	96.5
Nitrogenous	97.6	94.8	100.1	107.8	92.6
Phosphorous	93.7	105.0	100.4	90.6	104.7
Potassic	90.9	107.5	94.2	107.7	102.4
Lime	137.7	122.6	67.9	102.1	102.5
Total plant protection products (active substance)	102.5	92.4	104.8	101.4	109.5
Insecticides	122.3	97.3	156.8	22.4	109.4
Fungicides and seed treatments	92.2	115.1	86.2	135.7	108.0
Herbicides	107.6	83.3	102.7	109.6	111.7
Total fodder	110.0	100.4	99.9	100.4	100.6
For pigs	116.8	104.8	95.3	102.0	104.4
For cattle	119.8	103.3	101.4	105.7	105.9
For poultry	106.2	100.9	102.8	99.1	96.5
Machinery, technical equipment and tools (constant prices, million PLN)	101.0	97.9	100.2	100.2	109.3

Source: own calculations based on (GUS, 2021; 2023) and unpublished data from the Statistics Poland.

High-quality seeds are one of the most important elements of increasing production in any agricultural system (Elias, 2018). In the analysed years, the dynamics of certified seed sales in Poland were significantly variable (Figure 1). The 2019/20 marketing year was frail. Whereas, in the marketing year of 2020/21, during the COVID-19 pandemic, 179.1 thousand tonnes of certified seed of basic cereals were sold. Wheat had the largest share (47%). Additionally, 72.7 thousand tonnes of potatoes were sold. At that time, the sale of all cereal seeds increased. Wheat sales increased the most (8.1%). However, the sale of seed potatoes decreased (3.4%).



Source: own calculations based on GUS (2020-2023).

Figure 1. Sales indicators of certified seed (tonnes, previous period = 100)

Energy is a crucial means of production in every sector. The level and changes in the consumption of the leading energy carriers in agriculture in Poland will be analysed, which include solid fuels, liquid fuels, gaseous fuels, electricity, and heat.

Table 3. Consumption of energy carriers in Polish agriculture (TJ)

Energy Carriers	**2017**	**2018**	**2019**	**2020**	**2021**
Energy Total	161339	164641	160452	160082	159771
Solid Fuels	61215	59939	51674	51567	49731
Hard steam coal	38480	37960	30960	31238	25200
Peat and wood	20995	20644	19618	19979	23790
Brown coal	800	670	550	200	160
Liquid Fuels	88250	92757	96380	96034	97339
Diesel	84590	88858	93130	93130	93984
Light fuel oil	3010	3440	2795	2838	3247
Gaseous Fuels	4766	4449	4908	5028	5195
Liquefied petroleum gas (LPG)	252	2852	2990	2852	2668
High methane natural gas	1189	997	1254	1472	1770
Biogas	395	331	360	370	347
Electricity	6188	6674	6628	6649	6603
Heat	900	800	770	775	850

Source: based on Zalewski (2019) and Zalewski (2022).

The data analysis from Table 3 indicates that in 2017-21, the highest energy consumption came from liquid fuels. Their share increased from 57.4% in 2017 to 60.9% in 2021. The largest part of these fuels was heating oil (96.6%). Energy consumption in agriculture from solid fuels decreased from 37.9% in 2017 to 31.1% in 2021. The remaining energy sources accounted for a small share. The most significant change in this area occurred in 2021. Then, energy consumption from hard steam coal dropped to 25.2 thousand TJ, and increased from peat and wood to 23.8 thousand TJ.

In the analysed period, total energy consumption increased by 8.3%. However, since 2019, there has been a visible downward trend in energy consumption (Table 4). This trend mainly concerned the use of solid fuels. Each year, their consumption decreased. The most significant decline was in 2019 (13.8%). This year, the consumption of the most considerable number of energy carriers decreased. However, an upward trend is visible in using liquid and gaseous fuels. Only in one year, their consumption decreased. Overall, the COVID-19 pandemic did not significantly affect the dynamics of energy consumption. In 2020-21, its total consumption decreased by 0.4%. This was due to austerity policies rather than the pandemic. During this time, the largest increase in consumption concerned high methane natural gas (41.1%), peat and wood (21.3%), and light fuel oil (16.2%). However, the largest declines concerned the use of brown coal (70.9%) and hard steam coal (18.6%).

Table 4. Annual consumption rates of energy carriers in Polish agriculture (TJ)

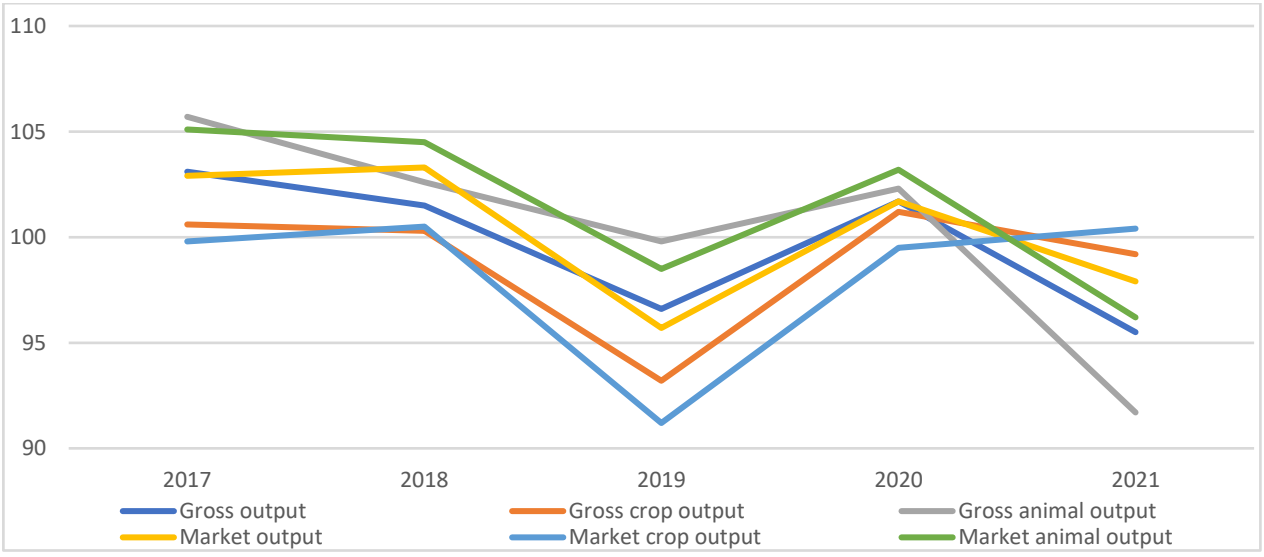
Energy Carriers	**2017**	**2018**	**2019**	**2020**	**2021**
Energy Total	109.3	102.0	97.5	99.8	99.8
Solid Fuels	98.6	97.9	86.2	99.8	96.4
Hard steam coal	98.7	98.6	81.6	100.9	80.7
Peat and wood	98.4	98.3	95.0	101.8	119.1
Brown coal	81.9	83.8	82.1	36.4	80.0
Liquid Fuels	119.0	105.1	103.9	99.6	101.4
Diesel	120.0	105.0	104.8	100.0	100.9
Light fuel oil	100.0	114.3	81.3	101.5	114.4
Gaseous Fuels	107.8	93.3	110.3	102.4	103.3
Liquefied petroleum gas (LPG)	103.3	100.0	104.8	95.4	93.5
High methane natural gas	117.7	83.9	125.8	117.4	120.2
Biogas	110.6	83.8	108.8	102.8	93.8
Electricity	105.3	107.9	99.3	100.3	99.3
Heat	100.0	88.9	96.3	100.6	109.7

Source: own calculations based on Zalewski (2019) and Zalewski (2022).

Sales and consumption of means of production in agriculture depend mainly on the economic situation in agriculture as well as in the economy, price situation, and conditions specific to a particular means of production. In the analysed period, the current and forecasted economic situation in the agricultural sector, economic growth, and the relationship between the dynamics of prices of agricultural products sold and the dynamics of prices of goods and services purchased by farmers (price scissors) changed significantly. The best year in terms of overall sales dynamics and consumption of means of production in agriculture was 2017. This was due to favourable factors. The economic situation and price relations were beneficial for agriculture. The years 2018-19 were worse regarding current and forecasted economic conditions. However, in 2019, the price scissors index was at a record high (112.1). Such conditions contributed to the general deterioration of the agricultural means of production market at that time. The years of the COVID-19 pandemic were generally favourable for agriculture in terms of economic conditions. However, economic growth and price scissors were unfavourable in 2020. In general, favourable conditions during the pandemic improved sales and consumption of means of production in agriculture in Poland.

The use of means of production versus production in agriculture

The important elements of analysing the functioning of the food economy, especially agriculture, are changes taking place in the agricultural means of production market. The level of supply of agriculture with means of production and services affects the volume of production and influences, most often in the long term, the efficiency of production processes and production factors in this sector. However, the prices of means of production are an important factor determining the demand reported by farms for these means, and above all, they are one of the key reasons shaping the income situation of agriculture.



Source: own calculations based on GUS (2020-2023)

Figure 2. Annual agricultural production rates (PLN, constant prices)

In real terms, the value of annual global and agricultural commodity production increased in 2017, 2018, and 2020. However, in 2019 and 2021, the value of these productions decreased (Figure 2). The dynamics of global and animal commodity production and global plant production were the same in particular years, although the decrease in this production in 2021 was negligible. However, the plant commodity production changes, which *"... constitutes the sum of sales of agricultural products in procurement centres and at marketplaces*" (GUS, 2023), were different. They increased in 2018 and 2021 and decreased in 2017, 2019, and 2020. Their changes were also influenced by changes in stocks. As indicated, changes in agricultural production also depend on the level of use of means of production. Strong growth in all types of global production in 2017 was correlated with a significant increase in the use of all means of production. A more detailed analysis indicates that the dynamics of global plant production was influenced by the sales of mineral fertilizers and plant protection products (postponed by one year). However, it is difficult to indicate a relationship between changes in fodder sales and animal production. In the first year of the COVID-19 pandemic, the moderate increase in production was driven by an increase in the consumption of almost all types of means of production. However, the significant decline in global production in 2021 was only associated with a substantial decline in the use of mineral fertilizers. At that time, the decline in production was primarily influenced by the deteriorating economic situation and the unfavourable price scissors the previous year.

CONCLUSIONS AND DISCUSSION

Farms' input endowment is a key factor in the efficiency of their production and development. In the period 2017-21, the situation in individual years regarding sales, consumption, and prices of means of production in agriculture varied. The level of sales of almost all analysed means of production in agriculture in Poland was the highest during the COVID-19 pandemic. In 2021, the most sold were plant protection products, animal fodder, agricultural machinery, equipment, and tools, and 2020 mineral fertilizers. However, sales of calcium fertilizers were the highest in 2018. Regarding sales dynamics of agricultural means of production, the best years were 2017 and the time of the pandemic. The economic situation and price relations in agriculture primarily influenced such changes. Research by Ilinova et al. (2021) indicates that in the world, as in Poland, the fertilizer industry has demonstrated resilience in the supply chain during the COVID-19 pandemic.

Using high-quality seeds is important for the efficiency of agriculture (Elias, 2018). In the analysed years, the dynamics of the sale of certified seed material in Poland varied. In the fiscal year 2020/21, that is, during the COVID-19 pandemic, the sale of seed material for all cereals increased. The sale of wheat seeds increased the most (8.1%). However, the sale of seed potatoes decreased (3.4%). The OECD (2020) assessed that the pandemic could have negatively impacted the seed market and, consequently, agriculture and the global food chain.

The analysis indicates that between 2017 and 2021, the largest energy consumption in Polish agriculture came from liquid fuels. The energy consumption from solid fuels dropped to 31.1% in 2021. Other energy sources constituted a small share (Zalewski, 2019; Zalewski, 2022). The most significant change in this area occurred in 2021. At that time, energy consumption from hard coal dropped to 25.2 thousand TJ and increased from peat and wood to 23.8 thousand TJ. However, a downward trend in overall energy consumption has been visible since 2019. The COVID-19 pandemic generally did not significantly affect the dynamics of energy consumption. In 2020-21, its total consumption decreased by 0.4%. During this time, the largest reduction concerned the consumption of lignite (70.9%) and energy hard coal (18.6%).

The performed analysis showed that the impact of sales and consumption of means of production on production in Polish agriculture during the period of study was not significant. Such dependencies should be analysed over a longer period of time. The strongest relationship was observed between changes in global agricultural production and changes in the use of mineral fertilizers. The annual changes in agricultural production are more significantly influenced by reasons other than the use of means of production in agriculture. However, Aromolaran and Muyanga (2020) estimated that during the pandemic, disruptions in the supply and availability of these means will result in reduced agricultural production.

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REFERENCES

1. Ali, M., Alam, N., & Rizvi, S.A.R. 2020. Coronavirus (COVID-19)—An epidemic or pandemic for financial markets. *Journal of Behavioral and Experimental Finance*, 27, 100341. https://doi.org/10.1016/j.jbef.2020.100341 .
2. Alliance for Science. 2020. COVID-19 disrupts Africa's seed supply, threatening food security. Available at: https://allianceforscience.org/blog/2020/06/covid-19-disrupts-africas-seed-supply-threatening-food-security/
3. Aromolaran, A. B., & Muyanga, M. 2020. Impact of COVID-19 on agriculture, food systems and rural livelihoods in Nigeria. *Future Agricultures Consortium*. https://doi.org/10.19088/APRA.2020.005 .
4. Bairagi, S., Mishra, A., & Mottaleb, K. 2022. Impacts of the COVID-19 pandemic on food prices: Evidence from storable and perishable commodities in India. *PLoS One*, 17(3), e0264355. https://doi.org/10.1371/journal.pone.0264355 .

5. Baldwin, R., & Tomiura, E. 2020. *Thinking ahead about the trade impact of COVID-19.* In Baldwin, R., & Weder di Mauro, B. (Eds.), Economics in the time of COVID-19, pp. 59– 71.
6. Bański, J., & Mazur, M. (2021). Means of Production in Agriculture: Farm Machinery. In Transformation of Agricultural Sector in the Central and Eastern Europe after 1989 (pp. 119-128). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-73766-5_9 .
7. Barro, R. J., Ursúa, J. F., & Weng, J. 2020. The coronavirus and the great influenza pandemic: Lessons from the "spanish flu" for the coronavirus's potential effects on mortality and economic activity (No. w26866). *National Bureau of Economic Research*. https://doi.org/10.3386/w26866m.
8. Beckman, J., & Countryman, A. M. 2021. The importance of agriculture in the economy: impacts from COVID-19. *American journal of agricultural economics*, 103(5), 1595-1611. https://doi.org/10.1111/ajae.12212
9. Chen, H. C., & Yeh, C. W. 2021. Global financial crisis and COVID-19: Industrial reactions. *Finance Research Letters*, 42, 101940. https://doi.org/10.1016/j.frl.2021.101940 .
10. Czech, K., Wielechowski, M., Kotyza, P., Benešová, I., & Laputková, A. 2020. Shaking stability: COVID-19 impact on the Visegrad Group countries' financial markets. *Sustainability*, 12(15), 6282. https://doi.org/10.3390/su12156282 .
11. De Vos, J. 2020. The effect of COVID-19 and subsequent social distancing on travel behavior. *Transportation research interdisciplinary perspectives*, 5, 100121. https://doi.org/10.1016/j.trip.2020.100121 .
12. Dudek, M., & Śpiewak, R. 2022. Effects of the COVID-19 pandemic on sustainable food systems: Lessons learned for public policies? The case of Poland. *Agricultur*e, 12(1), 61. https://doi.org/10.3390/agriculture12010061 .
13. Elias, S. G. 2018. The importance of using high quality seeds in agriculture systems. *Agricultural Research & Technology*, 15(4), 1-2. https://doi.org/10.19080/ARTOAJ.2018.15.555961 .
14. Gilbert, A., Bazilian, M.D., & Gross, S. 2021. The emerging global natural gas market and the energy crisis of 2021-2022. Brookings, report, December. Available at: https://www.brookings.edu/wp-content/uploads/2021/12/FP_20211214_global_energy_crisis_gilbert_bazilian_gross.pdf
15. Gruère, G. Brooks, J. 2021. Viewpoint: Characterising early agricultural and food policy responses to the outbreak of COVID-19. *Food Policy*, 100, 102017. https://doi.org/10.1016/j.foodpol.2020.102017 .
16. GUS. (2020-2023). Statistical Yearbook of Agriculture. Statistics Poland, Warsaw.
17. Höhler, J., & Lansink, A. O. 2021. Measuring the impact of COVID-19 on stock prices and profits in the food supply chain. *Agribusiness*, 37(1), 171-186. https://doi.org/10.1002/agr.21678 .
18. Ilinova, A., Dmitrieva, D., & Kraslawski, A. 2021. Influence of COVID-19 pandemic on fertilizer companies: The role of competitive advantages. *Resources Policy*, 71, 102019. https://doi.org/10.1016/j.resourpol.2021.102019 .
19. Jędruchniewicz, A., & Wielechowski, M. 202). COVID-19-related state aid programs for agriculture in Poland. Agrarian perspectives XXXI, Prague-Czech. Available at: https://ap.pef.czu.cz/en/r-12193-conference-proceedings
20. Jędruchniewicz, A., & Wielechowski, M. 2023(a). Polityka pieniężna NBP a ceny produktów rolnych w czasie COVID-19 (NBP monetary policy and agricultural prices during COVID-19). Studia i Prace Kolegium Zarządzania i Finansów (*Studies and Papers of the College of Management and Finance*), (193), 243-258.
21. Jędruchniewicz, A., & Wielechowski, M. 2023(b). Prices of Means of Production in Agriculture and Agricultural Prices and Income in Poland During the COVID-19 Pandemic. Annales Universitatis Mariae Curie-Skłodowska, sectio H – *Oeconomi*a, 57(3), 139-156. https://doi.org/10.17951/h.2023.57.3.139-156
22. Khan, K., Su, C. W., & Zhu, M. N. 2022. Examining the behaviour of energy prices to COVID-19 uncertainty: A quantile on quantile approach. *Energy*, 239, 122430. https://doi.org/10.1016/j.energy.2021.122430
23. Kaygusuz, K. 2011. Energy services and energy poverty for sustainable rural development. *Renewable and sustainable energy reviews*, 15(2), 936-947. https://doi.org/10.1016/j.rser.2010.11.003 .
24. Koh, D. 2020. COVID-19 lockdowns throughout the world. *Occupational Medicine*, 70(5), 322-322. https://doi.org/10.1093/occmed/kqaa073 .
25. Khan, K., Su, C. W., & Zhu, M. N. 2022. Examining the behaviour of energy prices to COVID-19 uncertainty: A quantile on quantile approach. *Energy*, 239, 122430. https://doi.org/10.1016/j.energy.2021.122430
26. Laing, T. 2020. The economic impact of the Coronavirus 2019 (Covid-2019): Implications for the mining industry. *The extractive industries and society*, 7(2), 580-582. https://doi.org/10.1016/j.exis.2020.04.003 .
27. Lamichhane, J. R., & Reay-Jones, F. P. 2021. Impacts of COVID-19 on global plant health and crop protection and the resulting effect on global food security and safety. *Crop Protection*, 139, 105383. https://doi.org/10.1016/j.cropro.2020.105383 .
28. Li, W., Chien, F., Waqas Kamran, H., Aldeehani, T. M., Sadiq, M., Nguyen, V. C., & Taghizadeh-Hesary, F. 2022. The nexus between COVID-19 fear and stock market volatility. *Economic research-Ekonomska istraživanja*, 35(1), 1765-1785. https://doi.org/10.1080/1331677X.2021.1914125 .
29. Mahajan, K., & Tomar, S. 2021. COVID-19 and supply chain disruption: Evidence from food markets in India. *American journal of agricultural economics*, 103(1), 35-52. https://doi.org/10.1111/ajae.12158 .

30. Maier, B. F., & Brockmann, D. 2020. Effective containment explains subexponential growth in recent confirmed COVID-19 cases in China. *Science*, 368(6492), 742-746. https://doi.org/10.1126/science.abb4557 .
31. Okolie, C., & Ogundeji, A.(2022. Effect of COVID-19 on agricultural production and food security: A scientometric analysis. *Humanities and Social Sciences Communications*, 9(1). https://doi.org/10.1057/s41599-022-01080-0 .
32. Pawlak, J. 2017. Wyposażenie w ciągniki a wydajność pracy w rolnictwie (Equipment with tractors and the value of the agricultural output). *Problemy Inżynierii Rolniczej (Problems of Agricultural Engineering*). 4(98), 65–74.
33. Prentice, C., Chen, J., & Stantic, B. 2020. Timed intervention in COVID-19 and panic buying. *Journal of Retailing and Consumer Services*, 57, 102203. https://doi.org/10.1016/j.jretconser.2020.102203 .
34. Roubík, H., Lošťák, M., Ketuama, C. T., Procházka, P., Soukupová, J., Hakl, J., ... & Hejcman, M. 2022. Current coronavirus crisis and past pandemics-What can happen in post-COVID-19 agriculture?. *Sustainable Production and Consumption*, 30, 752-760.
35. Siche, R. 2020. What is the impact of COVID-19 disease on agriculture?. *Scientia Agropecuaria*, 11(1), 3-6. http://dx.doi.org/10.17268/sci.agropecu.2020.01.00 .
36. Susskind, D., & Vines, D. 2020) The economics of the COVID-19 pandemic: an assessment. *Oxford Review of Economic Policy*, 36(Supplement_1), S1-S13. https://doi.org/10.1093/oxrep/graa036 .
37. USDA. 2022. Impacts and Repercussions of Price Increases on the Global Fertilizer Market. Available at: https://www.fas.usda.gov/data/impacts-and-repercussions-price-increases-global-fertilizer-market
38. Wielechowski, M., Czech, K., & Grzęda, Ł. 2020. Decline in Mobility: Public Transport in Poland in the time of the COVID-19 Pandemic. *Economies*, 8(4), 78. https://doi.org/10.3390/economies8040078 .
39. Worldometer. 2023. COVID-19 Coronavirus. Available at: https://www.worldometers.info/coronavirus/
40. Zalewski, A. (ed.). 2019. Rynek środków produkcji dla rolnictwa. Stan i perspektywy (The market for agricultural inputs. Status and prospects). No 46, IERiGŻ-PIB, Warsaw. Available at: http://www.ierigz.waw.pl/publikacje/analizy-rynkowe/rynek-srodkow-produkcji-dla-rolnictwa
41. Zalewski, A. (ed.). 2022. Rynek środków produkcji dla rolnictwa. Stan i perspektywy (The market for agricultural inputs. Status and prospects). No 49, IERiGŻ-PIB, Warsaw. Available at: http://www.ierigz.waw.pl/publikacje/analizy-rynkowe/rynek-srodkow-produkcji-dla-rolnictwa