GLOBAL PESTICIDE MARKET: SIZE, TRENDS, FORECASTS

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Abstract
Worldwide pesticides are used by farmers for growing more food on less land by protecting crops from pests, diseases and weeds as well as raising productivity per hectare. Also, pesticides enable farmers to produce safe, quality foods at affordable prices. Therefore, the market for agricultural pesticides is anticipated to rise by $ 26.23 billion between 2021 and 2025. Pesticide residues can be discovered in a wide range of common foods and drinks, such as prepared meals, water, wine, fruit juices, snacks, and animal feeds. Furthermore, it should be noticed that chemical pesticides have been linked to a variety of detrimental health consequences, including impacts on the skin, gastrointestinal system, nervous system, respiratory system, reproductive system, and endocrine system. The current review was carried out using an objective mixture of primary and secondary information, including inputs from key participants in pesticides industry. Also, it aims at highlighting the urgent need for a new concept in agriculture involving a drastic reduction in the use of chemical pesticides, driving the market to bio-based pesticides.

***Key words**: pesticides, market, trend, crop protection, future*

INTRODUCTION

The latest UN projections suggest that the world's population could grow to around 8.5 billion in 2030 and 9.7 billion in 2050, before reaching a peak of around 10.4 billion people during the 2080s. The population is expected to remain at that level until 2100 (UN Report, 2021).

Despite the multiple changes in agricultural systems brought about genetic advancement, biotechnologies, improved cropping technologies, in the last decades, there has been a considerable rise in the significance of pesticides, driven by the need to raise agricultural productivity and guarantee sufficient food supply for the expanding world population (Partal et al. 2013; Popa et al. 2013; Sărăţeanu et al. 2013; Partal et al. 2014; Zală et al. 2014; Bălașu et al. 2015; Gruia et al. 2016; Sărățeanu et al. 2016; Bonciu, 2018; Bonciu, 2019; Sărățeanu et al. 2019; Bonciu, 2020a; Bonciu, 2020b; Sărățeanu et al. 2020; Bonciu et al. 2021; Bonciu et al. 2022; De Souza and Bonciu, 2022a; De Souza and Bonciu, 2022b). Despite the fact that resistance is now regarded as the disease's most cost-efficient and successful control strategy, additional fungicides used is still remaining an important part of integrated disease management. Thus, farmers are extensively adopting intensive farming methods to maximize yield and minimize

damage from pests and diseases (Tuță et al. 2010; Paraschivu et al. 2011; Paraschivu et al. 2012; Paraschivu et al. 2014; Partal and Paraschivu, 2020; Cotuna et al. 2022; Paraschivu et al. 2022). In the context of climate changes some pathogens and pests tend to become more aggressive and require more efficient chemical control (Chakraborty and Pangga, 2004; West et al. 2012; Cotuna et al. 2013; Paraschivu et al. 2015; Paraschivu et al. 2017; Cotuna et al. 2018; Paraschivu et al. 2019; Juroszek et al. 2020; Cotuna et al. 2021; Paraschivu et al. 2021; Velea et al. 2021). Over the projected period of 2021–2031, it is anticipated that widespread adoption of new farming techniques and policy from government organizations will increase demand for agrochemicals, especially pesticides. The widespread use of pesticides in agriculture is a result of the affordability and effectiveness of chemical plant protection (Bernhardt et al. 2017; Hedlund et al. 2020). The development of biological plant protection methods has raised many expectations, yet most bio-pesticides still have far lower efficacy than chemical pesticides (Compant et al. 2005). Additionally, the more difficult and troublesome application of bio-pesticides and the pricey registration process do not support the dynamics of change on the global market of plant protection products (Pavela 1and Benelli, 2016; Kerr and Bullard, 2020; Isman, 2020). However, overusing pesticides puts the environment and human health at risk promoting the pesticide resistance and having a direct impact on the biodiversity of ecosystems (Gagic et al. 2017; Jallow et al. 2017; Jankowska et al. 2019; Fletcher et al. 2020; Klich et al. 2020; Serrano et al. 2020; Treder et al. 2020). According to a large number of original publications by authors from various scientific and research centers as well as literature studies, the use of plant protection chemicals is generally linked to an increased risk of health problems, such as cancer diseases, impacts on the skin, gastrointestinal system, nervous system, respiratory system, reproductive system, and endocrine system, etc (Narayan et al. 2017; Han et al. 2019; Huang et al. 2019; Tayour et al. 2019; Egbuna et al. 2020). Also, numerous studies demonstrate that bees are exposed to pesticides, although there are differences in sensitivity between bee species (Hladik et al. 2016; Woodcock et al. 2017). Despite the financial efforts of many European countries (e.g., Denmark, France, Germany, Spain, the Netherlands, the United Kingdom) to reduce pesticides use in transition to ecological farming, there are no spectacular results (Chèze et al. 2020). As long as farmers are reluctant to use non-chemical alternatives, chemical pesticides market is still on higher trend. Thus, Integrated Pest Management (IPM) is a crucial component of sustainable agriculture, which aims to produce high-quality food without harming the agricultural environment (Stenberg, 2017; Lee et al. 2019).

Considering the aspects above mentioned, the paper aimed to analyze the current status of pesticides consumption, as well as the global and European market trends and forward statements as long as water and food pollution by pesticides used in agriculture is currently a major concern in Europe.

MATERIALS AND METHODS

The research of the current study presented in this paper adopted a qualitative informative approach including books, scientific articles, news articles, reports and websites. There was identified

and synthetized relevant literature to provide an integrated overview of the current state-of-knowledge and forward statements on the article topic (Tranfield et al. 2003).

To reach the purpose of this paper there were used systematic, semi-systematic and integrative research approaches using an analytic comparation of current literature, papers, studies, reports and statistics in order to offer significant insights based on the article topic and to identify knowledge gaps within literature (Snyder et al. 2016; Snyder, 2019). Also, it was used text mining method, which is a popular text analytical technique used to extract relationships and knowledge from a large number of textual documents.

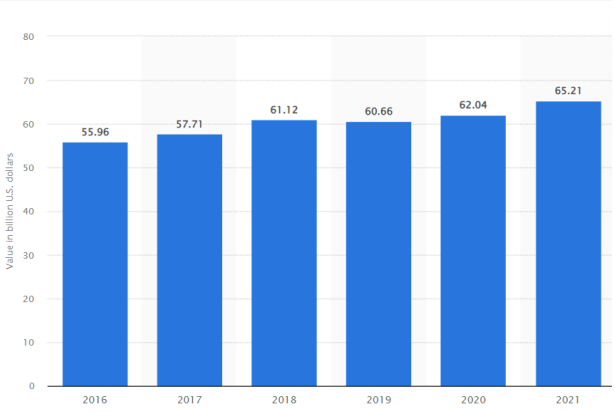
The literature, papers, studies and reports used in this review are organized into the following sections.

RESULTS AND DISCUSSIONS

Pesticides market - size, forecasts

Pesticides are substances that are used to get rid of or control a wide range of agricultural pests that can harm crops and livestock and lower farm output. Around 800 chemically active compounds are recognised for use as crop protection chemicals around the world, according to the Royal Society of Chemicals. Agrochemicals, usually referred to as agricultural chemicals, are chemical agents such as fungicides, insecticides, and herbicides that are used to control pests that harm crops, such as viruses, mites, insects and insect eggs and larvae. In order to control pests that affect crops, such as rodents, nematodes, bacteria, and others, other agricultural chemicals include agricultural agents like rodenticides, nematicides, bactericides, and others.

The size of the global pesticides market, which grew at a compound annual growth rate (CAGR) of 4.2% from 2015 to 2019, was close to $84.5 billion in 2019. Also, according to Statista (2022) the value of crop protection market reached 65.21 billion U.S. dollars in 2021 (Fig.1).



Source: Statista 2022

Figure 1. Value of global market for crop protection 2016-2021 (in billion US dollars)

The market for agricultural pesticides is anticipated to rise by $ 26.23 billion between 2021 and 2025. By 2023, it is projected to increase at a CAGR of 11.5% to reach close to $130.7 billion.This growth is a result of intensive farming practices in the pesticides industry and rapid economic growth in new economies. Some farming practices, such as monoculture drive the demand for pesticides. Growing one type of crop extensively over a vast area depletes the soil's nutrient content and leaves it largely reliant on pesticides. Also, agricultural systems like conventional agriculture and conservation agriculture require more pesticides for controlling biotic constrainers.

The pesticides market is segmented by type and by geography. The pesticides market can be segmented by type into: herbicide, insecticides, termiticides, nematicide, molluscicide, piscicide, avicide, rodenticide, fungicide and others. By geography, the pesticides market is segmented into: APAC (China, Japan, India, Australia), South America (Brazil),

Europe (UK, Germany, France, Spain, Italy, Russia), North America (USA) and MEA. Brazil, China, and the United States, according to the Food and Agriculture Organization (FAO), are substantial consumers of crop protection products. China for instance consumes over 1.8 Mn tons of pesticides annually, followed by US and Brazil with 0.4 Mn tons and 0.3 Mn tons, respectively. One of the primary factors of increased agricultural production in these nations is the widespread use of these chemicals.

Persistence Market Research has anticipated that pesticide sales across the globe will witness a growth rate of 5.5% through 2031. As of 2020, pesticides hold approximately 3/5 of overall agrochemicals volume. East Asia is anticipated to remain a key region in the pesticides business, and the market is estimated to expand at a CAGR of 5.5% during the same period (Fig.2).

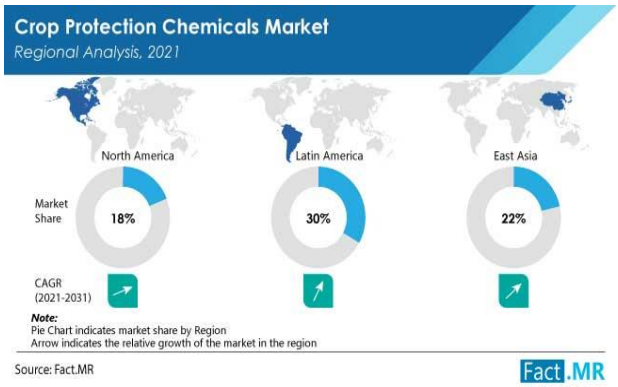
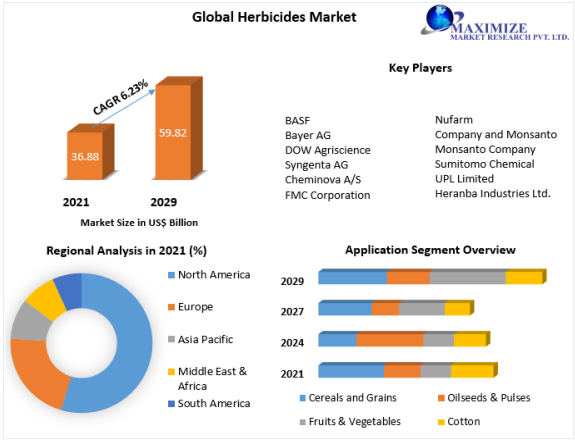


Figure 2. Crop protection chemicals market by region

China remains one of the most lucrative countries, which uses over 15 Kgs of these crop protection chemicals per hectare, followed by Brazil, which uses nearly 6 Kgs of these chemicals per hectare.

The increased consumption of crop protection chemicals across all geographies, by both developed and developing nations is responsible for the higher growth projections for the industry.

The herbicides market is the largest segment of the pesticides market, followed by fungicides and insecticides. Herbicides Market was valued at US$ 36.88 Bn in 2021 and is forecasted to reach US$ 59.82 Bn by 2029 at a CAGR of 6.23% during a forecast period (Fig.3). Going forward, the herbicides segment is expected to be the fastest growing segment in the pesticides market.



Source: https://www.maximizemarketresearch.com/market-report/global-herbicides-market/25943/

Figure 3. Herbicides Market – Global Industry Analysis and Forecast (2022-2029)

Throughout 2021-2031 the market is anticipated to recover as follows:

a. in response to the trend toward sustainable farming, demand for bio-based crop protection chemicals is predicted to increase at a noticeably faster rate in the short term.

b. longer term, it is projected that producers will boost their spending on product development in order to diversify their product lines.

c. synthetic crop protection chemicals will hold close to 50% of the market.

d. The market in Europe is anticipated to be expanding at 5.9% CAGR through 2031.

In order to meet the demand for novel molecular solutions to manage pests that have developed resistance to earlier

compounds, crop protection chemical research has recently focused on generating compounds that are safer than their older equivalents. Additionally, in the previous two years, manufacturers have launched a lot of new items, demonstrating their strict attention on product development and portfolio diversity.

Pesticides market - trends

Market valuation of crop protection chemicals is projected to reach US$ 122.1 Bn by the end of 2031.

The European Union's current strategy strives to lessen the usage of pesticides. The European Commission proposes that by 2030, EU nations should use at least 50% less pesticides overall. In this way, the European Union plans to stop the problem of the mass extinction of wild pollinators and protect biodiversity. On the other hand, reducing the amount of pesticides used in crops may mean a significant drop in yield, which will consequently lower farm incomes.

Therefore, extensive changes and an integrated strategy for agricultural and environmental policies are required. Also, the development strategy for creating new pesticides has three directions, as follows:

1. a remarkable decrease in the active ingredient required for the control of pest insects, fungi, mites, nematodes and weeds and eventually brought about a reduction in the load of pesticides to the environment.
2. lowering of pesticide residue levels in crops and the environment.
3. to seek a compound that is effective in targeting only organisms such as insects, fungi, mites, nematodes, and weeds, but not toxic against non-target organisms such as humans and beneficial organisms.

The first general trends in fungicide development are progress in the development of three major fungicides. The most common is SDHI (succinate dehydrogenase inhibitors) or those considered to be SDHI due to their chemical structure characteristics. SDHIs have become one of the largest groups of agricultural fungicides, as well as DMI (demethylation inhibitors) and inhibitors of the mitochondrial electron transport chain complex III, i.e., QoI (quinone outside inhibitors) and QiI (quinone inside inhibitors). The second general trend is the development of fungicides with a novel mode of action and a unique chemical structure. Other trends are the development of novel plant defence activators and novel natural product origin fungicides.

During the past decade, different kinds of chemical pesticides, as well as biopesticides, have been subjected to development. At least 105 chemical pesticides have been launched during the past decade or are under development: 43 fungicides, 34 insecticides/acaricides, 6 nematicides, 21 herbicides, and 1 herbicide safener (Umetsu and Shirai, 2020).

Companies have been heavily investing in the research and development of newer crop protection solutions. Biopesticides are gaining popularity as lower-environmental-impact alternatives to conventional synthetic pesticides (Essiedu et al. 2020). The US Environmental Protection Agency (EPA) identifies three classes of biopesticides: microbial, biochemical, and plant-incorporated-protectants (PIPs)(EPA, 2022). PIPs are pesticides that the plant produces itself from genetic material inserted into the plant. PIPs can result from transgenic events as well as through non-transgenic approaches like direct genome editing and the seed treatment-based method pioneered by Morflora (Olson,

2015). Microbial pesticides are whole microorganisms, including bacteria, fungi, viruses, microalgae, plant-based compounds, and recently applied RNAi-based technology that act as pesticides. Biochemical pesticides are either microbial extracts or natural products from other sources like plant extracts or yeast fermentation products that control pests by non-toxic mechanisms. Thus, growing demand for bio-based pesticides and sizable investments by major companies are considered the market's driving forces. The market for bio-based crop protection chemicals is also being driven by growing concern regarding green agricultural practices and the loss of many conventional products due to excessive use of synthetic chemicals. Additional growth of biopesticides is due to new applications for biocontrol that are not possible with synthetic crop protection.

Herbicides are poised to remain the most attractive segment in the crop protection solutions market and are anticipated to expand. Although there has been a substantial rise in the use of herbicides, the industry has so far emphasized on microbially derived phytotoxins from non-pathogenic soil microorganisms. Plant pathogens even though produce a high content of phytotoxins, it has received less attention by researchers. Introduction of new herbicide products with distinct properties based on weed selectivity, crop emergence, and other factors is boosting market growth. On the other hand, growing use of herbicide products in agricultural production is drawing a growth in the area under genetically modified crops across diverse areas.

The trend of insecticide development is changing from organophosphorus, carbamate, and synthetic pyrethroids to nicotinic and diamide insecticides. Flupyradifurone and flupyrimin, exhibiting extremely low honeybee toxicity, have been developed and subjected to practical use. The development of useful acaricides and nematicides is also progressing. Globally, scientists are adopting nanotechnology and nanoparticles (primarily the metallic nanoparticles (NPs) of zinc, gold, silver, nickel, and titanium) in the development of new, environmentally friendly pesticides (Pestovsky and Martínez-Antonio, 2017; Abd-Elsalam et al. 2019; Kremer, 2019).

Market researchers predict that biopesticides will equal synthetic (chemical) pesticides in terms of market size by the late 2040s or early 2050s (Olson, 2015).

CONCLUSIONS

Plant diseases and pests have become more common as a result of changing environmental circumstances. Climate change has a significant influence on agricultural output and pests' susceptibility. Agricultural vulnerability to various pests and diseases is increasing as a result of climate change, which has an impact on crop output. The importance of pesticides has increased significantly over the last few decades, catalysed by the need to enhance agricultural output and ensure adequate food availability for the growing global population. Also, the development of pesticides that pose a lower risk to natural enemies and useful organisms and are compatible with IPM is an important target. In addition, developing countries in Latin America have continued to be among the biggest consumers of crop protection chemicals over the past five years and are expected to maintain their dominance over the long-term forecast period of 2021–2031. This is due to a rise in demand for healthier and more sustainable foods. Also,

biopesticides have several advantages over their chemical counterparts and are expected to occupy a large share of the market in the coming period. However, many substances have been researched to demonstrate their utility as biopesticides but extensive field research is required in order to assess their efficacy for precise pest problems under diverse cropping systems.

REFERENCES

Abd-Elsalam, K.A., AlDhabaan, F.A., Alghuthaymi, M., Njobeh, P.B., Almoammar, H., (2019). Nanobiofungicides: Present concept and future perspectives in fungal control. In Nano-Biopesticides Today and Future Perspectives; Koul, O., Ed.; Academic Press: Cambridge, MA, USA, 2019, 315–351.

Baldock, D., Beaufoy, G., Brouwer, F., Godeschalk, F., (1996). *Farming at the Margins*. IEEP, LEI-DLO, London, The Hague.

Bălașu, A.Gh., Zală, C., Cristea, S., (2015). Effectiveness of treatmengts applied in fighting Pseudomonas savastanoi pv. Glycinea pathogen, in terms of 2014, location Unirea, Craila County. *Journal of Biotechnology*, 2018, S108.

Bernhardt, E.S., Rosi, E.J., Gessner, M.O., (2017) Synthetic chemicals as agents of global change. *Front Ecol Environ* 15(2), 84–90

Bonciu, E., (2018). Evaluation of cytotoxicity of the herbicide Galigan 240 EC to plants, *Scientific Papers. Series A. Agronomy*, Vol. LXI, No. 1, 175-178.

Bonciu, E., (2019). The climate change mitigation through agricultural biotechnologies. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, Vol. 49(1), 36-43.

Bonciu, E., (2020a). Aspects of the involvement of biotechnology in functional food and nutraceuticals, *Scientific Papers. Series A. Agronomy*, Vol LXIII, No. 2, 261-266.

Bonciu, E., (2020b). Study regarding the cellular activity in garlic (A. sativum) bulbs affecting by *Sclerotium cepivorum*, *Scientific Papers. Series A. Agronomy*, Vol LXIII, No. 1, 186-191.

Bonciu, E., Liman, R., Cigerci, I.H., (2021). Genetic bioengineering in agriculture-a model system for study of the mechanism of programmed cell death. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, Vol. 21(4), 65-70.

Bonciu, E., Paraschivu, M., Șuțan, N.A., Olaru, A.L., (2022). Cytotoxicity of Sunset Yellow and Brilliant Blue food dyes in a plant test system. *Caryologia* 75(2), 143-149. doi: 10.36253/caryolo-gia-1579.

Chakraborty, S., Pangga, I.B., (2004). Plant diseases and climate change. In: Gillians, M., Holmes, A (Ed.) *Plant microbiology*. London: BIOS Scientific, 163-180.

Chèze, B., David, M., Martinet, V., (2020) Understanding farmers' reluctance to reduce pesticide use: a choice experiment. *Ecol Econ*, 167,106349.

Compant, S., Duffy, B., Nowak, J., Clement, C., Barka, A., (2005) Use of plant growth-promoting bacteria for biocontrol of plant diseases: principles, mechanisms of action, and future prospects. *Appl Environ Microbiol*, 71(9), 4951–4959.

Cotuna O., Sarateanu V., Durau, C., Paraschivu M., Rusalin, G., (2013). Resistance reaction of some winter wheat genotypes to the attack of Fusarium graminearum L.Schw. in the climatic conditions of Banat plain. *Research Journal of Agricultural Science*, 45 (1), 117-122.

Cotuna, O., Paraschivu, M., Paraschivu, A.M., Sarateanu, V., (2015). The influence of tillage, crop rotation and residue management on Tan Spot (Drechslera tritici repentis Died. Shoemaker) in winter wheat. *Research Journal of Agricultural Science*, 47 (2),13-21.

Cotuna, O., Paraschivu, M., Paraschivu, M., Olaru, L., (2018). Influence of crop management on the impact of Zymoseptoria tritici in winter wheat in the contex of climate change: an overview. *Research Journal of Agricultural Science*, 50 (3), 69-74.

Cotuna, O., Paraschivu, M., Bulai, A., Toma, I., Sărăţeanu,V., Horablaga, N.M., Buzna, C., (2021). Behaviour of some oat lines to the attack of the fungus Blumeria graminis (D. C.) f. sp. avenae EM. Marchal. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 21, Issue 4, p.161-170.

Cotuna, O., Paraschivu, M., Sărăţeanu, V., Horablaga, M.N., Durău, C.C., (2022). Research regarding the contamination with Fusarium spp. of the wheat grains from the variety Triticum aestivum ssp. spelta before and after the treatment with bio-fungicide - case study. *Scientific Papers. Series A. Agronomy*, Vol. LXV, No. 1, 2022, p.266-273.

De Souza, C.P., Bonciu, E., (2022a). Progress in genomics and biotechnology, the key to ensuring food security. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 22(1), 149-157.

De Souza, C.P., Bonciu, E., (2022b). Use of molecular markers in plant bioengineering. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 22(1), 159-166.

Egbuna, C., Sawicka, B., Tijjani, H., Kryeziu, T.L., Ifemeje, J.C., Skiba, D., Lukong, C.B., (2020) Biopesticides, safety issues and market trends. In: Natural Remedies for Pest, Disease and Weed Control. *Academic Press*, 43–53.

EPA, 2022. Ingredients Used in Pesticide Products: Pesticides. What Are Biopesticides? Available online: https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides Accessed on 15 October 2022.

Essiedu, J.A., Adepoju, F.O., Ivantsova, M.N., (2020). Benefits and limitations in using biopesticides: A review. In Proceedings of the VII International Young Researchers' Conference—Physics, Technology, Innovations (PTI-2020), Ekaterinburg, Russia, 18–22 May 2020; Volume 2313, p. 080002.

Fletcher, S.J., Reeves, P.T., Hoang, B.T., Mitter, N., (2020) A perspective on RNAi-based biopesticides.*Front Plant Sci* 11,51.

Gagic, V., Kleijn, D., Báldi, A., Boros, G., Jørgensen, H.B., Elek, Z., Garratt, M.P.D., De Groot, G.A., Hedlund, K., Kovacs-Hostyanszki, A., Marini, L., Martin, E., Pevere, I., Potts, S.G., Redlich, S., Senapathi, D., Steffan-Dewenter, I., Switek, S., Smith, H.G., Takacs, V., Tryjanowski, P., Van der Putten, W.H., Van Gils, S., Bommarco, R., (2017) Combined effects of agrochemicals and ecosystem services on crop yield across Europe. *Ecol Lett*, 20(11), 1427–1436.

Gruia, L., Zală, C.R., Cristea, S., (2016). Researches on the efficacy of some fungicides in mustard alternaria black spot control. *Lucrari Stiintifice, Univeresitatea de Stiinte Agricole si Medicina Veterinara „Ion Ionescu de la Brad", Iasi, seria Agronomie*, 59 (1), 53-56.

Han, M.A., Kim, J.H., Song, H.S., (2019) Persistent organic pollutants, pesticides, and the risk of thyroid cancer: systematic review and meta-analysis. *Eur J Cancer Prev*, 28(4), 344–349.

Hedlund, J., Longo, S.B., York, R., (2020) Agriculture, pesticide use, and economic development: a global examination (1990–2014). *Rural Sociol*, 85(2),519–544.

Hladik, M.L., Vandever, M., Smalling, K.L., (2016). Exposure of native bees foraging in an agricultural landscape to current-use pesticides. *Sci Total Environ*, 542, 469–477.

Huang, W., He, Y., Xiao, J., Huang, Y., Li, A., He, M., Wu, K., (2019) Risk of breast cancer and adipose tissue concentrations of polychlorinated biphenyls and organochlorine pesticides: a hospital-based case-control study in Chinese women. *Environ Sci Pollut Res* 26(31), 32128–32136.

Isman, M.B., (2020) Botanical insecticides in the twenty-first century—fulfilling their promise? *Annu Rev Entomol*, 65,233–249.

Jallow, M.F., Awadh, D.G., Albaho, M.S., Devi, V.Y., Thomas, B.M., (2017) Pesticide risk behaviors and factors influencing pesticide use among farmers in Kuwait. *Sci Total Environ*, 574,490–498.

Jankowska, M., Łozowicka, B., Kaczyński, P., (2019) Comprehensive toxicological study over 160 processing factors of pesticides in selected fruit and vegetables after water, mechanical and thermal processing treatments and their application to human health risk assessment. *Sci Total Environ*, 652,1156–1167.

Juroszek, P., Racca, P.,Link, S., Farhumand, J.,Kleinhenz, B., (2020). Overview on the review articles published during the past 30 years relating to the potential climate change effects on plant pathogens and crop disease risks. *Plant Pathology*, 69(2), 179-193.

Kang, S., Post, W. M., Nichols, J. A., Wang, D., West, T. O., Bandaru, V., Izaurralde, R. C., (2013). Marginal lands: concept, assessment and management. *Journal of Agricultural Science*, 5(5), 129.

Klich, D., Łopucki, R., Stachniuk, A., Sporek, M., Fornal, E., Wojciechowska, M., Olech, W., (2020) Pesticides and conservation of large ungulates: health risk to European bison from plant protection products as a result of crop depredation. *PLoS One* 15(1), e0228243.

Kolmer, J.A., (2013). Leaf rust of wheat: pathogen biology, variation and host resistance. *Forests*, 4, 70–84.

Kremer, R.J., (2019). Bioherbicides and nanotechnology: Current status and future trends. In Nano-Biopesticides Today and Future Perspectives; Koul, O., Ed.; Academic Press: Cambridge, MA, USA, 2019, 353–366.

Lal, R., (2021). *Climate change and agriculture*. In Climate Change, Elsevier, 661-686.

Lee, R., den Uyl, R., Runhaar, H., (2019) Assessment of policy instruments for pesticide use reduction in Europe; learning from a systematic literature review. *Crop Prot*, 126, 104929.

Malhi, G. S., Kaur, M., Kaushik, P., (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, 13(3), 1318.

Matei, Gh., Vlăduț, V., Dodocioiu, A.M., Toader, M., (2020a). Study regarding the optimization of grain sorghum cultivation technology in the context of sustainable agriculture. *Scientific Papers. Series A. Agronomy*, LXIII (2), 145-152.

Matei,Gh., Vlăduț,V., Isticioaia, S., Pânzaru,R.L., Popa, D., (2020b). Potential of Jerusalem artichoke (Helianthus tuberosus L.) as a biomass crop. *Scientific Papers. Series A. Agronomy*, LXIII(1), 387-393.

Matei, Gh., Paraschivu, M., Drăghici, R., Popa, L. D., (2021). Technological aspects of rye cultivated in the conditions

of sandy soils in Southern Oltenia. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, 51 (1), 126-133.

Miedaner, T., Klock,e B., Flath, K., Geiger, H.H., Weber, W.E., (2012).Diversity, spatial variation, and temporal dynamics of virulences in the German brown rust (Puccinia recondita f.sp. secalis) population in winter rye. *European Journal of Plant Pathology*, 132, 23–35.

Narayan, S., Liew, Z., Bronstein, J.M., Ritz, B., (2017) Occupational pesticide use and Parkinson's disease in the Parkinson Environment Gene (PEG) study. *Environ Int* 107, 266–273.

Newton, A.C., Johnson, S.N., Gregory, P.J., (2011). Implications of climate change for diseases, crop yields and food security. *Euphytica*, 179, 3–18.

Olson, S., (2015). An Analysis of the Biopesticide Market Now and Where it is Going. *Outlooks on Pest Management,* 26 (5), 203-206.

Paraschivu, M., Paraschivu, A. M., Păunescu, G., (2011). The management of rape pathogens and pests using diverse chemical treatments. The 40th Annual Meeting of ESNA Conference Advanced Methods of a Sustainable Agriculture, 7th – 10th September 2011, Craiova, Romania. Speciall issue In *Annals of the University of Craiova, Agriculture, Montanology, Cadastre series*, 41/2, 220-224.

Paraschivu, M., Partal, E., Paraschivu, M., Oltenacu, V.C., (2012). Influence of treatment with various fungicides formulations on specific pathogens attack to tomato crops. Scientific Symposium with International Participation "65 Years of Higher Agronomic Education and 50 Years of Higher Horticulture Education in Craiova", 15th -16th November 2012, Craiova, Romania. *Annals of the University of Craiova, Agriculture, Montanology, Cadastre Series*, 42 (2), 765-770.

Paraschivu, M., Cotuna, O., Paraschivu, M., (2014). Integrated Disease Management of Fusarium Head Blight, a sustainable option for wheat growers worldwide. Scientific Symposium with International Participation" Sustainable Development in Agriculture and Horticulture", the 2nd edition, 13th -14th November 2014, Craiova, Romania. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, 44 (1), 183-187.

Paraschivu, M., Cotuna, O., Paraschivu, M., Durau, C.C., Damianov, S., (2015). Assesment of Drechslera tritici repentis (Died.) Shoemaker attack on winter wheat in different soil and climate conditions in Romania. European Biotecnology Congress the 20th August 2015, Bucharest, *Journal of Biotechnology*, 208, p. S113.

Paraschivu, M., Cotuna, O., Olaru, L.,Paraschivu, M., (2017). Impact of climate change on wheat-pathogen interactions and concerning about food security. *Research Journal of Agricultural Science*, 49(3), 87-95.

Paraschivu, M., Cotuna, O., Paraschivu, M., Olaru, L., (2019). Effects of interaction between abiotic stress and pathogens in cereals in the context of climate change: an overview. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series* XLIX (2), 413-424.

Paraschivu, M., Matei, Gh., Cotuna, O., Paraschivu, M., Drăghici, R., (2021). Reaction of rye cultivars to leaf rust (P. recondita f. sp. secalis) in the context of climate change in dry area in southern Romania. *Scientific Papers. Series A. Agronomy*, LXIV (1), 500-507.

Paraschivu, M., Matei, Gh., Cotuna, O., Paraschivu, M., Drăghici, R., (2022). Management of pests and pathogens in rye crop in dry marginal environment in Southern Romania. *Scientific Papers. Series A. Agronomy*, Vol. LXV, No. 1, 2022, p.466-474.

Partal, E., Sin, Gh., Alionte, E., (2013). The effect of management practices on the quality of wheat and maize harvest. Annals of the Academy of Romanian Scientists. *Series on Agriculture, Silviculture and Veterinary Medicine Sciences*, 2(1), 82–89.

Partal, E., Paraschivu, M., Cotuna, O., (2014). Influence of seeds treatment on the cereales production. *Research Journal of Agricultural Science*, 46(2), 270–276.

Partal, E., Paraschivu, M., (2020). Results regarding the effect of crop rotation and fertilization on the yield and qualities at wheat and maize in South of Romania. *Scientific Papers. Series A. Agronomy*, LXIII (2), 184-189.

Pavela, R., Benelli, G., (2016) Essential oils as ecofriendly biopesticides? Challenges and constraints. *Trends Plant Sci* 21(12),1000–1007.

Pestovsky, Y.S., Martínez-Antonio, A., (2017). The Use of Nanoparticles and Nanoformulations in Agriculture. Journal of Nanoscience and Nanotechnology, 17, 8699–8730.

Popa, T, Cristea, S., Zală, C.R., Manole, M.S., (2013). Research on the efficacy of fungicides for control of Monilinia laxa (Aderh. & Ruhl.) honey on plum tree. *Scientific Papers. Series A. Agronomy*, 56, 333-336.

Sărăţeanu, V., D'Ottavio, P., Argenti, G., Lombardi, G., (2013). Grassland typological characterisation: a case study in Romania, Pastoralism and ecosystem conservation, 17th Meeting of the FAO-CIHEAM Mountain Pasture Network, 5-7 June, Trivero, Italy,162-166.

Sărățeanu,V., Durău, C. C., Cotuna, O., Rechitean, D., (2016). Influence of organic fertilisation on the vegetation sward of Trisetum flavescens (L.) P. Beauv. grassland from temperate deciduous forest area (case study), nano, bio and green technologies for a sustainable future conference proceeding, SGEM, III, 277-283.

Sărățeanu, V., Suciu, C.T., Cotuna, O., Durau, C. C., Paraschivu, M., (2019). Adventive species Asclepias syriaca L. in disturbed grassland from western Romania. *Romanian Journal of Grassland and Forage Crops*, 20, 61-72.

Sărățeanu, V., Cotuna, O., Durau, C.C., Paraschivu, M., (2020). Influence of some soil features on nemoral pasture vegetation. *Romanian Journal of Grassland and Forage Crops*, 22, 65-79.

Serrano, E., Munoz, M., de Pedro, Z.M., Casas, J.A., (2020) Fast oxidation of the neonicotinoid pesticides listed in the EU Decision 2018/840 from aqueous solutions. *Sep Purif Technol*, 235, 116168.

Snyder, H., Witell, L., Gustafsson, A., Fombelle, P., Kristensson, P., (2016). Identifying categories of service innovation: A review and synthesis of the literature, *Journal of Business Research*, 69, 2401-2408.

Snyder, H., (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333-339.

Stenberg, J.A., (2017) A conceptual framework for integrated pest management. *Trends Plant Sci*, 22(9), 759–769.

Tayour, C., Ritz, B., Langholz, B., Mills, P.K., Wu, A., Wilson, J.P., Shahabi, K., Cockburn, M., (2019) A case–control study of breast cancer risk and ambient

exposure to pesticides. *Environ Epidemiol* 3(5), e070.

Tranfield, D., Denyer, D., Smart, P., (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14, 207-222.

Treder, K., Jastrzębska, M., Kostrzewska, M.K., Makowski, P., (2020) Do long-term continuous cropping and pesticides affect earthworm communities? *Agronomy* 10, 586.

Tuță, C., Paraschivu, M., Păunescu, G., (2010). The influence of different treatments to wheat baking quality in ARDS Simnic area conditions. The 6th edition of Scientific Conference with International Participation, Durable Agriculture-Agriculture of Future, and the 22nd edition of National Mycology Symposium, 19th -21th Nov. 2010 /Craiova/Romania. *Annals of the University of Craiova, Agriculture, Montanology, Cadastre series*, 40/1, p.239-242.

Umetsu, N., Shirai, Y., (2020). Development of novel pesticides in the 21st century. J. Pestic. Sci. 45(2), 54–74. DOI: 10.1584/jpestics.D20-201

United Nations Report, (2021). https://news.un.org/en/story/2022/07/1122272 Accessed 30 October 2022

Velea, L., Bojariu, R., Burada, C., Udristioiu, M.T., Paraschivu, M., Burce, R.D., (2021). Characteristics of extreme temperatures relevant for agriculture in the near future (2021-2040) in Romania. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. X, 70-75.

West,J.S.,Townsend, J.A.,Stevens,M.,Fitt, B.D.L., (2012). Comparative biology of different plant pathogens to estimate effects of climate change on crop diseases in Europe. *European Journal of Plant Pathology*, 133, 315–331.

Woodcock, B.A., Bullock, J.M., Shore, R.F., Heard, M.S., Pereira, M.G., Redhead, J., Ridding, L., Dean, H., Sleep, D., Henrys, P., Peyton, J., Hulmes, S., Hulmes, L., Sárospataki, M., Saure, C., Edwards, M., Genersch, E., Knäbe, S., Pywell, R.F., (2017). Country-specific effects of neonicotinoid pesticides on honey bees and wild bees. *Science*, 356(6345), 1393–1395.

Zală, C.R., Hălmăjan, H.V., Clinciu, C.E., Petrcu, Gh., Tabacu, D., Niculescu, A., (2014). Efficacy of different fungicides in wheat foliar diseases management. *Scientific papers. Series A., Agronomy*, 57, 379-382.

https://www.maximizemarketresearch.com/market-report/global-herbicides-market/25943/

https://www.factmr.com/report/crop-protection-chemicals-market