Granular Organic Fertilizers

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Granular organic fertilizers' production has recently become more popular, with the main aim of converting high-moisture organic matter, such as manure, manure mixtures, meat and bone waste or other organic matter, into pellets that are convenient to spread in the field. The pellets are usually produced with the diameter of 4 or 6 mm so that they can be easily spread with mineral or organic fertilizer spreaders. Once in the soil, organic fertilizer pellets become wet, decompose and release nutrients.

Keywords: pellets ; manure ; emissions

1. Introduction

In recent decades, enhancing agricultural productivity without harming the environment has become an increasingly important issue as the population grows [1]. In order to obtain an optimal yield, it is crucial to ensure soil health and to provide crops with the necessary nutrients. By maintaining a nutrient balance, nutrients that have been consumed by pre-crop plants can be returned to the soil with the help of fertilizers [2][3][4]. Reference [5] states that proper crop fertilization can increase crop production by as much as 30–50%. Crop cultivation technologies differ, as do nutrient needs. These needs are met by fertilizers with known levels of nutrients that can accelerate plant growth and assure higher yields [6]. In the case of organic fertilizers, up to 35 tonnes of manure per hectare can be used to meet the rates of nitrogen (N) and phosphorus (P) fertilizers, assuming a content of about 4.8 kg N t^{-1} and 1.5 kg P t^{-1} [7].

Intensive agricultural production can have a significant negative impact on the environment [8]. Extensive fertilization with both mineral and organic fertilizers and the application of conventional fertilization methods at a uniform rate have negative effects on the soil, environment and human health [9][10]. Reducing the overuse of chemical fertilizers in crop production is therefore a key factor in assuring healthier soils, healthier food, and more economical, efficient and cleaner agricultural production [11]. Unbalanced quantities of nutrients in organic and mineral fertilizers during and immediately after the fertilization process are dispersed in the environment and have a negative impact on climate change, and when released into groundwater and surface water, intensify eutrophication and acidify environmental elements [12]. Annual total agricultural emissions are around 4.6 Gt CO_{2eq} [13].

As the quantity of mineral fertilizers applied increases, soil quality deteriorates, emissions of harmful gases into the air increase, as does water pollution [14]. Meanwhile, organic fertilizers supplement the soil with organic matter and essential substances for plants, such as nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. These fertilizers are also a source of trace elements [15]. On the other hand, livestock manure applied to the soil surface or incorporated into the soil, as well as manure management and mineral N fertilizers, are the main sources of NH_3 emissions, accounting for about 52% of the total NH_3 emissions. The agricultural sector accounts for the largest share (92%) of NH_3 emissions in the European Union [16][17]. One of the most important aspects of agricultural optimization is to reduce its environmental impact, especially in terms of emissions [18]. It is very important not to spread too much fertilizer, as improper use of fertilizers reduces the efficiency of plant nutrient use and increases the overall production costs. This concept is based on the theory of precision farming. Reference [19] points out that that precision farming is associated with economically accurate farming, which requires prior knowledge of soil areas, their heterogeneity, type and history. Based on this knowledge, precision farming allows to achieve results when calculating the variable amount of fertilizer, ensures the reduction of crop growth differences in the field and the negative impact on the environment caused by leaching of too much fertilizer used for fertilization [20]. Plant nutrients that are not absorbed during vegetation significantly increase harmful gas emissions from agriculture. Excessive nitrate levels in soil due to leaching can contribute to groundwater and atmospheric pollution [21]. One way to reduce harmful gas emissions, energy consumption and expenses is to optimize the nitrogen added with fertilizers [22][23]. In addition, soil organic carbon sequestration has a great potential to reduce the negative environmental and greenhouse effects of agriculture [18].

The conversion of mineral fertilizers to organic ones is based on soil improvement and the reduction of negative environmental impacts. Rational use of fertilizers can reduce unwanted climate changes [22][24]. Reference [25] states that due to slow mineralization, organic fertilizers are leached into water more slowly than mineral fertilizers, and thus water pollution with nitrogen compounds is lower.

Livestock manure is one of the most valuable organic fertilizers, but the technological process of spreading has low productivity. In addition, manure fertilization causes significant nutrient losses. Analysis of the simulation results of granular organic fertilizer spreading showed that at a feed flow of granular organic fertilizer of 200 g s^{-1}, the distribution of pellets with the diameter of 4 mm was more even. At a feed flow of 400 g s^{-1}, organic fertilizer pellets with the diameter of 6 mm were more evenly distributed [26].

Meat and bone meal is a by-product of the meat processing industry and is increasingly used in Europe as an organic fertilizer. These fertilizers contain important nitrogen, phosphorus, potassium and calcium substances [27][28][29] that are valuable for agricultural crops. Organic fertilizers from meat and bone meal have an indirect positive effect on the environment by limiting the demand for mineral fertilizers and providing a way to dispose of large amounts of waste from the meat processing industry [30]. Depending on the type of the plant, the rate of granular organic fertilizer per hectare is from 1 to 2 tons [31]. Other authors who studied ungranulated meat and bone meal fertilizer used from 630 to 2530 kg ha^{-1} as a nitrogen fertilizer for cereals [30].

There is quite a lot of research and scientific work on the effects of organic fertilizers on soil and plants, but there are almost no studies analyzing the differences in energy and economic indicators of technological operations of the use of granular and non-granular organic fertilizers. It is also not clear how the environmental impact of granular and non-granular organic fertilizers changes.

2. Application of Granular and Non-Granular Organic Fertilizers in Terms of Energy, Environmental and Economic Efficiency

The use of organic fertilizers is important, not only for enhancing soil productivity, but also for increasing the production of waste-free, more environmentally friendly agricultural products. The analysis of this study showed that energy, environmental and economic differences were obtained between the application of granular and non-granular organic fertilizers. Assessment of the energy consumption for mechanized technological operations showed that the energy consumption for non-granulated manure (16 and 30 t ha^{-1}) for machinery, diesel fuel and working time was several times higher than for manure pellets or meat and bone meal pellets. The fact that manure fertilization is very energy intensive is confirmed by the results of research presented in other sources. Reference [32] states that the highest share of energy consumption in organic beet cultivation was accounted for by manure costs, which varied from 48 to 53%, depending on the weed control method. The results of another study showed that farmyard manure-based energy consumption accounted for the largest share of 45.0–49.3% of total energy input in organic production of winter wheat and spring barley [33].

The results of environmental impact assessment show that the average NH_3 gas emissions from granular organic fertilizers was six times lower than from non-granular farmyard manure. Reference [34] states that the use of granular poultry manure reduces the risk of environmental pollution compared to non-granular fertilizers (manure) or mineral fertilizers. The properties of the treated manure made it possible to improve the nitrogen retention, and it is therefore advisable to increase farm-scale testing using pellets in order to assess the potential for large manure surfaces and the technoeconomic assessment [35]. The most common poultry manure management practices in Poland include the use of poultry manure on the soil (spreading unprocessed poultry manure on land, improvement of fertilizer and soil, various compositions and forms such as unprocessed poultry manure, granular forms, pellets and compost) through anaerobic digestion. Examples of soil use include: use of poultry manure as unprocessed organic fertilizer, raw material for composting with other agricultural residues, raw material for processing into granular and other fertilizers mixed with mulch and minerals (e.g., dolomite, lignite, peat). Ash from burning manure can be used as an additive to fertilizers [36][37][38].

Other studies have attempted to dry poultry manure with rice husks in the sun and turning them into pellets. Drying and grinding manure reduces unpleasant smells and is used as an SRF (slow-release fertilizer) which allows for longer keeping of nutrients [39][40].

Due to the segregation of crops and livestock, manure is often concentrated on a regional scale, which may result in more nutrients than the region needs. This can lead to overuse of manure in the regions with concentrated cattle rearing, while crop-producing regions rely more on mineral fertilizers, leading to regional manure redistribution solutions to improve manure transportation. Manure recycling can be used to transport long distances and to separate P and N from each other and thus to improve their reuse. The purpose of processing is usually to reduce the mass of the manure and to concentrate the nutrients to improve their transportation. It is also important to produce fertilizer products that would replace mineral fertilizers and reduce environmental emissions. The market for new manure-based fertilizer products is still in its infancy, and storage and distribution practices still need to be developed [41].

Another 56 day incubation study was conducted to investigate the effects of alkaline organic residue pellets on: (1) the biological and chemical properties of acidic clay soils and (2) the emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The study showed that alkaline residue-based organic pellets improved soil properties and can play an important role in reducing greenhouse gases in acidic clay soils. Therefore, the use of alkaline organic residue pellets in combination with chemical fertilizers can be considered a sustainable approach to agriculture [42]. Applications of organic fertilizers (OF) and chemical nitrogen (N) fertilizers (CF) as homogeneous granulation (evenly distributed in space) and spatial heterogeneous granulation (distributed separately), where N transformation processes (nitrogen oxide (N_2O) emissions) have a significant impact, makes the spatial distribution of OF and CF promising [43]. Economic assessment showed that the lowest costs for the purchase of organic fertilizers are incurred using manure. Depending on the fertilization rate, they are equal to 128–240 EUR ha^{-1}. The highest costs are incurred when using manure pellets (400 EUR ha^{-1}). The energy consumption for drying manure is about 100 kWh t^{-1} of product [44]. As a result, manure pellets price per tonne is several times higher. Although the price of manure is lower, the fertilization with it generates lower yields as well [45]. Reference [34] states that the yields of spring wheat are 63% higher when organic granular fertilizers are used compared to non-granular fertilizers. Reference [46] found that the rice yield is about 7.21 t ha^{-1} by fertilizing with organic granular fertilizers. However, the addition of mineral fertilizers to organic (green manure and farmyard manure) fertilizers showed a significant increased plant biomass production, which upon incorporation stimulates soil biological activity [47]. Using organic matter in plant fertilization increases the microbial/chemical actions and properties of soils [48]. A balanced application of fertilizers concludes to the formation of favorable conditions for the development of microorganisms, growth of plants and for an intense and lasting enzymatic activity [49].

However, when estimating the costs for mechanized technological operations of loading, transportation and spreading, the lowest costs are obtained by fertilizing with meat and bone meal pellets (2.3 EUR ha^{-1}) and manure pellets (6.7 EUR ha^{-1}). When fertilizing with manure, depending on the fertilization rate, the costs for these technological operations are several to dozens of times higher (53.2–85.6 EUR ha^{-1}). Assessing all aspects, the lowest total costs are obtained by fertilizing with non-granular manure (16 t ha^{-1}) and meat and bone meal pellets. However, organic fertilizer pellets have a number of other advantages over manure that cannot always be monetized. Furthermore, organic fertilizer pellets have a number of other advantages [50][51], one such advantage—granular fertilizers are more suitable for modern agricultural machinery used in precision farming.

3. Conclusions

Energy consumption of fertilization with organic fertilizer pellets for mechanized technological operations was 3.2 to 4.6 times lower compared to manure fertilization (30 t ha^{-1}). The most energy efficient is the use of meat and bone meal pellets, where the total energy consumption for fertilizers and mechanized technological operations is about 4136 MJ ha^{-1}, while for non-granular manure at fertilization rates of 16 and 30 t ha^{-1}, they account for 8156 and 14,843 MJ ha^{-1}, respectively.

Analysis of different organic fertilizers under the principle of laser spectroscopy revealed that granular organic fertilizers reduce the negative impact of NH_3 emissions on the environment by 97.8% compared to non-granular manure.

Assessing the different scenarios (manure 16 and 30 t; manure pellets, meat and bone meal pellets) of organic fertilizers, which allow to achieve similar benefit from organic fertilizers by nutrient element (N, P_2O_5, K_2O) per area (130.3–136.5 EUR ha^{-1}), the lowest total costs are obtained by fertilizing with non-granular manure (16 t ha^{-1}) and meat and bone meal pellets.

The results of the analysis allow estimating the energy and economic costs of fertilizing with granular and non-granular organic fertilizers. However, in order to determine the future effectiveness of organic fertilizers, it is necessary to carry out experimental studies of the effects of these fertilizers on soil and plants, as changes in soil properties and different crop yields can provide important information to support the effectiveness.

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