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Article

Impact of Reducing Fertilizers and Pesticides on Sunflower Production in Romania versus EU Countries

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Abstract: The Farm-to-Fork strategy was the starting point for this study. Farmers in Romania and other member states expect a decrease in agricultural production in the main crops, due to the reduction of the quantities of fertilizers and pesticides allowed to be used. The article aims to highlight these quantities currently used, as well as the correlation with the realized productions, before the application of the mentioned strategy. The sunflower farming system was the object of the analysis, for which purpose the cultivated areas and the productions obtained in Romania were studied and compared to those in Germany, Spain, France, Italy, Hungary and Poland. It was found that in Romania, in the period 2010–2019, small amounts of fertilizers and pesticides were applied. Romania occupies the last position among the countries under analysis, both in terms of fertilizers and pesticides. To obtain a ton of sunflower in Romania, the nitrogen fertilizers used were 19.2 kg N active nutrient, with a negative deviation of −45.5 kg N active nutrient compared to Germany. The P_2O_5 phosphorus fertilizers used in Romania represent 7.48 kg of the active phosphorus nutrient with a negative deviation of −13.09 kg/ha compared to Spain. Potassium fertilizers used in Romania comprise 2.68 kg of active potassium nutrient used to obtain a ton of sunflower and have a negative deviation of −22.66 kg/ha compared to Poland. The pesticides used in Romania for sunflower cultivation represent 0.35 kg total pesticides used per ton and have a negative deviation of −2.48 kg compared to Spain, the largest consumer. In the event that a unit reduction of 50% for pesticides and 20% for fertilizers is applied, according to the Farm to Fork Strategy, the impact will be unequal on the productions obtained, both quantitatively and qualitatively.

Keywords: sunflower crop; fertilizers; pesticides; EU strategies

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1. Introduction

Climate change has led to a number of measures at EU level to reduce the negative effects; these measures are part of the Green Deal strategy, with the two components: Farm-to-Fork and Biodiversity. The Farm-to-Fork strategy envisages a transition to a resilient and nature-friendly food system. According to this strategy, certain targets have been set for the reduction of pesticides, fertilizers and antimicrobials [1]; these goals outline the future direction for agriculture in relation to the EU's ongoing concern about food sustainability [2]. In this regard, the European Commission has determined the progress made by each Member State in meeting the two pesticide reduction targets in the Farm-to-Fork strategy [3]. All Member States must formulate plans so that by 2030, the proportion of organically cultivated areas will reach 25% in each country [4]. EU financial support will be used to implement environmental measures as well as to increase agricultural production [5]. The eco-innovative aspects of plant varieties are distinguished by the environmental benefits but also by feed processing and food production [6].

Sunflower is cultivated globally, ranking fourth after corn, wheat and rice crops [7,8]; the argument for cultivating large areas with this crop is given by its multiple uses [9]. Cultivated hybrids and varieties are characterized by irregular periods of vegetation, cropping systems, ecoclimatic conditions and different harvest destinations [10]. Sunflower crops, together with soybeans and rapeseed, are fundamental oil crops grown in the European Union [11].

Sunflower crops located in southern and eastern Europe could be more directly affected by heat stress and drought during the development period, leading to major production losses, fatty acids, changes and reduced oil content [12].

The sunflower sector has managed to maintain its competitiveness through continuous innovation in genetics, cultivation practices and value-added research that has led to greater market segmentation [13].

Soils favorable for sunflower are those with high fertility, medium texture (clayey or loamy-sandy soils), deep and with high water retention capacity, with a pH between 6.5 and 7.5 [14]. Other research has shown that on calcareous and alkaline soils, foliar fertilization is an effective and curative means of treating Zn, Fe and Mn deficiencies [7,8].

In the sunflower cultivation system, it has been identified that the critical phases in nutrient supply are during the growth period, the formation of the first true pair of leaves, the inflorescence formation phase and the actual flowering [11]. Most nutrients are consumed by the sunflower in the first two months, at the beginning of flowering, when it accumulates two thirds of the amount of nitrogen, phosphorus and calcium, three-quarters of the amount of potassium and 9/10 of the amount of magnesium, etc. [15].

To obtain 100 kg of sunflower seeds, some authors recommend using 1.8–3.5 kg of nitrogen (N), 0.29–0.27 kg of phosphorus (P_2O_5) and 0.38–1.65 kg of potassium (K_2O) [16] and according to other authors, 4–6 kg of nitrogen (N), 1.5–2.3 kg of phosphorus (P_2O_5) and 7.5–12 kg of potassium (K_2O) [17].

From the production of grains, 50–90% is made on the basis of nitrogen translocated from the basal leaves, but also from the stem (in smaller quantities) in calatidium [18,19]. Nitrogen deficiency (N) can occur under the following conditions: low organic matter soils, light-textured varieties, depleted soils in the intensive farming system, soils with excess moisture, acidic soils with a pH of less than six, alkaline soils with a pH higher than eight [19,20].

Phosphorus consumption is most intense at the beginning of the differentiation of the primordia of the container and until full flowering, when the sunflower consumes 60–70% of what is needed [19,21].

Potassium consumption is most intense in the period between 8 and 10 leaves and full flowering, when sunflower plants consume between 90 and 100% of potassium requirements [19,21].

Potassium (K_2O) deficiency can occur under the following conditions: low-potassium soils, light-textured varieties on which nitrogen has been leached by heavy rains or irrigation, soils with low organic matter, acidic soils with a higher pH of less than 6 [19,20]. Exogenous application of potassium (K) has been reported to increase abiotic resistance and crop yield [22].

Sunflower has over 30 diseases and by improving it, it has achieved excellent tolerance to the best known, but this crop remains a plant in which production is greatly affected by the attack of pathogens; these are the main limiting factors of worldwide production [19,23].

Weeds, limiting factors, contribute to the total compromise of the culture [24]; the use of herbicides in the agricultural sector counteracts this aspect [25].

Genetic improvement in sunflowers has solved the problems associated with insect attacks on this crop [26]. Sunflower crops are attacked by about 20 species of insects of major or medium economic importance [19,21]. Production losses caused by pathogens can range from 4–5 to 100%, depending on the rate of infected plants in a field, their distribution and the climatic conditions during the growing season [27].

The transition to the cultivation of sunflower hybrids was a qualitative leap that ensured an increase in production and an increase in oil content [19]. In Romania, the hybrids approved for sunflower in the period 1970–1990, were registered in the Official Catalog of crop varieties in Romania [28]. Hybrids increase their production and stability and play a key role in reducing pesticide doses [29,30].

Climate change and the practice of monoculture have, however, led to a significant decrease in sunflower production [31]. Agro-meteorological conditions have a direct impact on production [32]. Depending on the vegetation phase, the plants have different requirements for the water factor [33]. The drought resistance of sunflower is explained by the peculiarities of the root system and by the tolerance to temporary dehydration of the tissues [34]. All the aspects presented determine directly and indirectly the ideal germination of the field by sunflower [35]. The optimization of fertilizers and also the density of plants lead to the achievement of economic and environmental objectives in sustainable agriculture [36]. At present, in order to increase crop yields, effective management is needed [37].

Reducing the use of agricultural inputs will lead to a reduction in the agricultural production of sunflower and a decrease in its competitiveness in export markets. In this situation, farmers will adapt their technologies: cultivation of hybrids with high production potential and resistance to drought, disease and pests, the optimal time and depth suitable for sowing, but also the level of fertilization and plant protection [38].

The increase in the price of sunflower will implicitly lead to an increase in the price of the oil resulting from processing [39]; the increase in sales is justified by the high rate of increase in consumption [40].

The article aims to highlight the place where Romania is in the hierarchy of the EU countries, in terms of the amounts of fertilizers and pesticides used in sunflower cultivation considering the context of the strategy from Farm-to-Fork.

2. Materials and Methods

This paper is based on an extensive documentary basis, using the bibliographic method and highlights the quantities of pesticides and fertilizers used in the sunflower cultivation system in Romania compared to the main EU-producing countries.

The statistical sites used were Faostat [41], Eurostat [42] and OEC [43].

The period covered by the study was 2010–2019, and the main indicators analyzed, which were processed based on the data taken from the sites mentioned above, are: areas cultivated with sunflower; total and average production for sunflower in Romania compared to France, Germany, Poland, Italy and Hungary; global imports and exports of sunflower oil, including EU member states; quantities of fertilizers and pesticides used in the studied countries. The research results were presented in tabular and graphical form, using Microsoft Office.

During the research, the multiannual average consumption of fertilizers and pesticides was calculated, and the analysis of trends was performed based on linear and polynomial equations.

For each studied indicator, the following statistical indicators were determined [44]:

$$\text{Arithmetic mean}: \ \overline{X} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

$$\text{Standard deviation}: \ s = \sqrt{\frac{\sum (x_i - \overline{X})^2}{n-1}} \tag{2}$$

$$\text{Coefficient of variation}: \ V = \frac{s}{\overline{X}} \cdot 100 \tag{3}$$

In order to shape the link between the indicators mentioned and the quantities of fertilizers and pesticides used in the main sunflower-growing countries of the EU, the simple linear regression model was used y = ax + b. where we denoted with x the independent variable and with y the variable dependent on x. The coefficients, real numbers a and b, were determined using the "Least squares" method, based on the actual data recorded.

Was solved the system of two linear equations with unknowns, a and b:

$$\begin{cases} a\sum_{i=1}^{n} x_i^2 + b\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} x_i y_i \\ a\sum_{i=1}^{n} x_i + nb = \sum_{i=1}^{n} y_i \end{cases}. \quad (4)$$

The solution obtained was:

$$a = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{n\sum x_i^2 - \left(\sum x_i\right)^2}. \quad (5)$$

$$b = \frac{\sum y_i \sum x_i^2 - \sum x_i \sum x_i y_i}{n\sum x_i^2 - \left(\sum x_i\right)^2} \quad (6)$$

The validation of the regression model was done using the coefficient of determination R^2 (R squared or determination coefficient), which was calculated using the formula:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(y_i - \hat{y}_{icalc}\right)^2}{\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2} \epsilon\ [0,1]. \quad (7)$$

It was denoted by n—the number of records, and $\hat{y}_{icalc}$ represents the estimated value of the variable y, according to the linear model.

The value of the coefficient of determination R^2 indicates the proportion in which the variation of variable y is determined by the variation of the variable x.

3. Results and Discussions

According to data published by Eurostat in the period 2010–2019, the total area cultivated with sunflower in the studied countries from the European Union varied from one year to the other. Romania is the main grower of sunflower during the analysis period, and Poland has the smallest areas utilized for this crop. The smallest total area cultivated with sunflower at the level of these countries was recorded in 2010 (2.79 million ha), and the most representative was recorded in 2013 (3.46 million ha). The multiannual average of the area cultivated with sunflower in the countries studied in the European Union, was 3.19 million ha [42].

The multiannual average for the total area cultivated with sunflower for the countries under study varied between 0.004 million ha and 1.05 million ha.

The total production and average yield/ha recorded in the sunflower crop during the analysis period (2010–2019) in the countries covered by the study will be presented and analyzed in the continuation of the study (Figure 1).

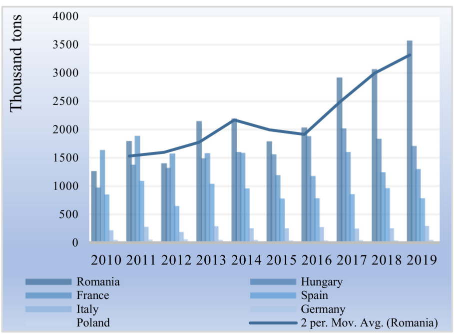

Figure 1. Total production of sunflower farming system, in the EU countries, in the period 2010–2019 [42].

The average yield per hectare in **Romania** oscillated from 1.31 tons/ha to 3.04 tons/ha, with a multiannual average of 2.13 tons/ha, which places Romania in fourth place, after Hungary, Italy and France (Figure 2).

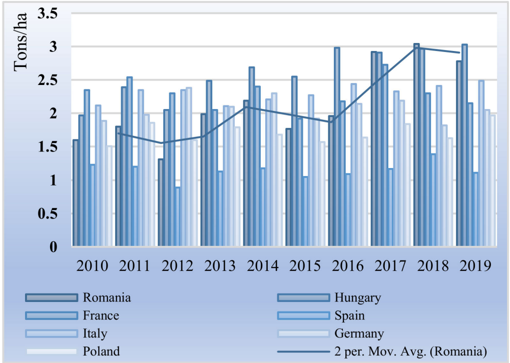

Figure 2. Average production/ha for the crop, in the EU countries in the period 2010–2019 (tons/ha) sunflower [42].

Romania is on the first place in terms of the area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 1.05 million ha. Considering the analyzed period, it can be easily seen that the growth trend of the areas cultivated with sunflower by the Romanian farmers, in the last three years of the period. Romania cultivated over 1.2 million ha of sunflower; this trend can be explained by the orientation towards crops more resistant to the increasingly frequent droughts of recent years as well as by the fact that sunflowers pay farmers relatively well in conditions of low rainfall.

Romania occupied the first place in the ranking of sunflower-producing countries within the EU with a multiannual average for the total production of 2.27 million tons in the period 2010–2019, which varied both depending on the cultivated areas and on the average production, being influenced by a series of technological factors used. In Romania, oily plants are comprised of an essential category of cultures, on behalf of the generally favorable conditions, as an outcome of the annual surfaces and productions registered [45,46].

It can be noted that the multiannual average for the average production/ha of sunflower in the countries under study varied between 2.60 tons/ha and 1.18 tons/ha, and Romania ranked fourth, with 2.13 tons/ha, even though it had the largest cultivated areas and a total production that also places it first; this fact demonstrates that for Romanian farmers the sunflower crop remains an extensive culture and that there are still reserves to increase performance by resorting to state-of-the-art technologies and reducing dependence on climatic factors.

For **Romania**, the regression function y = 1.7413x + 348.06, reflecting the area cultivated with sunflower (thousand ha) and the average production per ha (kg/ha), as well as the coefficient of determination R^2 = 0.1248, denotes a weak direct link between the cultivated area and the average production, respectively 12.5% of the variation in yield is due to the variation of the area. The arithmetic average of the cultivated areas in the period 2010–2019 was 1.02 million ha, and without the years 2010 and 2019 respectively, it was 1.02 million ha. The coefficient of variation of the cultivated areas in the period 2010–2019 is quite small, V = 11.63% (Figure 3A).

In Figure 3B, the regression function for **Romania** is y = 0.7398x + 497.76 and shows the correlation between the total sunflower production (thousand ha) and the yield per ha (kg/ha), as well as the coefficient of determination R^2 = 0.8806, which reflects a fairly strong direct link between the total production and the average yield per hectare; thus, 88% of the increase in total production is due to the increase in the average yield per hectare. The arithmetic average of total productions between 2010 and 2019 was 2214.46 thousand tons. The coefficient of variation of total productions in the period 2010–2019 is significant, V = 33.72% (Figure 4).

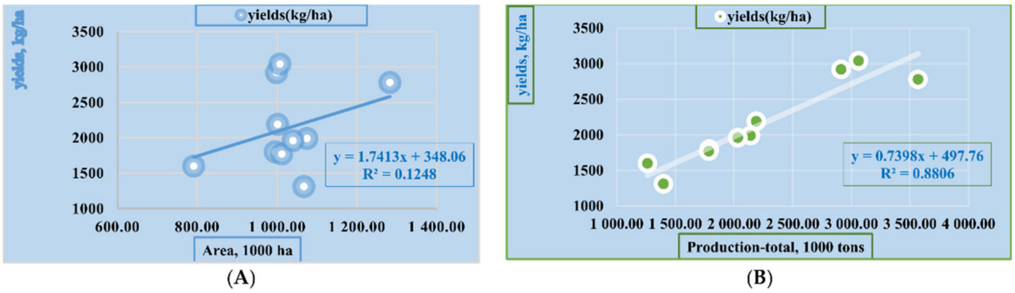

Figure 3. (**A**) Romania—Correlation between the areas cultivated with sunflower and the average production [42]. (**B**) Romania—Correlation between the average yield per hectare for sunflower and the total production [42].

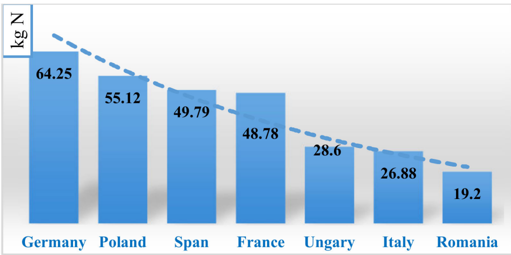

Figure 4. Multiannual average amount of nitrogen (kg) used for obtaining a ton of sunflower in the main European countries [41].

In **Romania**, total sunflower production recorded increasing values during the analysis period. Considering the fact that Romania ranks first in terms of areas under sunflower crops, the total production also placed it in the first place; however, there are oscillations in the total production during the analysis period, oscillations that were due to unfavorable weather conditions, especially the lack of precipitation and the onset of drought. Another important factor is the technology applied and certainly the degree of nutrient provision of the plant. In order to increase performance in the oilseeds sector, Romanian farmers must adapt to climate change, paying attention to the following technological aspects: to use early varieties and hybrids with high production potential and resistance to drought, diseases and pests; choose the best sowing period according to the humidity and temperature of the soil, ensure an optimal level of fertilization, maintenance of the crop and harvesting [47].

The average yield per hectare in **Romania** oscillated from 1.31 tons/ha–3.04 tons/ha, with a multiannual average of 2.13 tons/ha which places Romania in fourth place, after Hungary, Italy and France.

Spain is in second place in terms of the area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 0.65 million ha. The smallest area cultivated with sunflower was in 2019, 0.62 million ha, and the largest area cultivated with sunflower was in 2013, respectively 0.86 million ha, registering a decrease in 2019 (−0.23 million ha) compared to 2013. It is noted that Spain reduced the areas under sunflower crops during the analysis period.

In **Spain,** total sunflower production recorded oscillating values in the analysis period between 1172.41 thousand tons (2016) and 1110 thousand tons (2019). Considering the fact that **Spain** ranks second in terms of areas under sunflower crops, the total production ranked it fourth. The average yield per hectare in **Spain** oscillated between 0.89 tons/ha–1.39 tons/ha, with a multiannual average of 1.18 tons/ha, which places **Spain** in the last place for this indicator.

France is in third place in terms of the area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 0.62 million ha. The smallest area cultivated with sunflower was in 2016, 0.53 million ha, and the largest area cultivated with sunflower was in 2019, respectively 0.77 million ha, registering an increase in 2019 (+0.24 million ha) compared to 2016. It is noted that France had an oscillating evolution in terms of areas under sunflower cultivation during the analysis period.

In **France,** the total sunflower production recorded oscillating values during the analysis period with a multiannual average of 1520.94 thousand tons. We have to consider the fact that France is ranked third in terms of areas under sunflower crops (658.92 thousand ha multiannual average), and also in terms of total production (1520.94 tons multiannual average) and average production/ha (2.29 tons/ha multiannual average).

Hungary is in fourth place in terms of the area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 0.60 million ha. The smallest area cultivated with sunflower was in 2010, 0.50 million ha, and the largest area cultivated with sunflower was in 2017, respectively; 0.69 million ha, registering an increase in 2017 (+0.19 million ha) compared to 2010. It is noted that Hungary had an oscillating evolution in terms of areas under sunflower crops during the analysis period.

Hungary recorded a multiannual average production of 2.43 tons/ha, occupying the first position in the ranking of the countries studied, followed by Italy with 2.33 tons/ha and France with 2.29 tons/ha. Romania achieved 81.67% of the multiannual average recorded in Hungary for the average production/ha and 93.44% of the multiannual average recorded by Italy and France, which shows the technological advance of these countries for sunflower crops.

In **Hungary,** the total production of sunflowers recorded increasing values until 2017 (2022.23 thousand tons) after which it recorded consecutive decreases until 2019 (1598.02 thousand tons). In view of the fact that Hungary ranks fourth in terms of areas under sunflower cultivation, the total production placed it in second place. The average yield per hectare in Hungary oscillated between 1.97 tons/ha and 3.03 tons/ha, with a multiannual average of 2.60 tons/ha, which places **Hungary** in first place for this indicator.

Italy is in the fifth place in terms of area under sunflower crops, with a multiannual average in the period 2010–2019 of 0.11 million ha. The smallest area with sunflower was cultivated in 2010, 0.10 million ha, and the largest area cultivated with sunflower was in 2013, respectively 0.12 million ha, registering an increase in 2013 (+0.02 million ha) compared to 2010. It is noted that Italy had an oscillating evolution in terms of areas under sunflower crops during the analysis period.

In **Italy**, total sunflower production recorded oscillating values in the analysis period between 185.49 thousand tons (2012) and 299.88 thousand tons (2019). Considering that **Italy** ranks fifth in terms of areas under sunflower crops (114.11thousand ha multiannual average), the total production placed it in fifth place (258.72 thousand tons multiannual average). The average production per hectare in Italy oscillated between 2.11 tons/ha and 2.49 tons/ha, with a multiannual average of 2.33 tons/ha, which places **Italy** in second place for this indicator.

Germany is in the sixth place in terms of area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 0.02 million ha. The smallest area with sunflower was cultivated in 2016, 0.01 million ha, and the largest area cultivated with sunflower was in 2019, 0.03 million ha, respectively, registering an increase in 2019 (+0.02 million ha) compared to 2016. It is noted that Germany recorded a decrease in the areas under sunflower crops by 2016, followed by an increase from year to year, until 2019.

In **Germany**, total sunflower production recorded oscillating values in the analysis period between 35.3 thousand tons (2015) and 95 thousand tons (2019). Given that **Germany** ranks sixth in terms of areas under sunflower cultivation (23.46 thousand ha multiannual average), the total production also placed it in sixth place (50.04 thousand tons multiannual average). The average yield per hectare in Germany hovered between 1.82 tons/ha and 2.49 tons/ha, with a multiannual average of 2.11 tons/ha, which places **Germany** in fifth place for this indicator.

Poland is in seventh place in terms of the area cultivated with sunflower, with a multiannual average in the period 2010–2019 of 0.004 million ha. The smallest area with sunflower was cultivated in 2015, 0.001 million ha, and the largest area cultivated with sunflower was in 2019, respectively 0.014 million ha, registering an increase in 2019 (+0.013 million ha) compared to 2015. It is noted that Poland had a decreasing evolution for the cultivated areas until 2015, followed by an increase from one year to another until 2018, pursued by a sharp decrease in 2019, down to 0.002 million ha.

In **Poland,** total sunflower production recorded oscillating values in the analysis period between 2.1 thousand tons (2015) and 32.46 thousand tons (2019). In view of the fact that **Poland** ranks seventh in terms of areas under sunflower crops (4.09 thousand ha multiannual average), the total production placed it in last place (7.78 thousand tons multiannual average). The average yield per hectare in **Poland** oscillated between 1.51 tons/ha and 2.2 tons/ha, with a multiannual average of 1.77 tons/ha, which places **Poland** in sixth place for this indicator.

Considering that the global area for sunflower crops, the profit obtained from selling the seed assortments and the hybrids, the wide range of companies that have businesses associated with the production and commerce of sunflower seeds, the trend of the effort for obtaining the biggest market share is greater and resilient [48].

Sunflower (*Helianthus annuus* L.) is considered an important industrial culture due to the good quality of the oil it produces, which can be used for cooking [22]. But it is found that worldwide, according to OEC World data [43] in the year 2019, the largest exporting countries of sunflower oil or raw sunflower oil, were Ukraine (USD 3.4 billion), Russia (USD 1.73 million), Argentine (USD 434 million), the Netherlands (USD 389 million) and Hungary (USD 249 million), and the countries with the largest imports of sunflower oil and saffron were India (USD 1.71 billion), China (USD 869 million), the Netherlands (USD 496 million), Iran (USD 464 million) and Spain (USD 440 million). We note the Netherlands which practically, without being an important grower of sunflower are very active in the sunflower oil trade, being the fourth exporter and the third largest importer worldwide.

Given that sunflower is the third oleaginous plant on the world market of oilseeds, with 45 million tons of grains per year, and that it occupies the fourth position in the vegetable oils market, the implementation of a sustainable growth technology in sunflower production is a necessity [31]. Given that sunflower is the third oilseed plant on the world oilseed market, high interest in oilseeds will lead to increased production and trade. The growing demand for oilseeds will lead to an expansion in production [49]. Although Romania has the largest areas cultivated with sunflower as well as a total production, placing it in first place within the countries studied, in terms of its processing and the share of sunflower oil exported by Romania, it represents 1.29%; this aspect emphasizes the fact that in terms of sunflower processing and increasing the added value on the product, Romania is deficient and needs to focus in the future on increasing the processing of sunflower production, especially in the context of the conflict in Ukraine, which has essentially removed from the market the first two major exporters of sunflower oil in the world.

The Black Sea territory, principally Russia and Ukraine, have had a long history in producing sunflower [50]. In 2022, many countries restricted exports of cereals, technical and oilseed plants, as well as products made by processing them, including sunflower oil, especially the main exporters—Ukraine and Russia. There is a real economic opportunity for Romania to legislate and impose on companies in the field of agriculture and which cultivate, store, trade and process sunflowers, to increase the processing degree of the obtained productions.

Romania is not among the main countries importing sunflower oil but can get there through an appropriate policy to promote local processing. Romania has a good performance in the production and export of sunflower seeds, being ranked first in the EU-28. The volume and quality of sunflower seeds has continuously increased, as well as the exported quantity [51].

In continuation of the analysis and in order to justify the productivity of the sunflower crop both in Romania and in the countries covered by the study, aspects related to the use of fertilizers and plant protection products used in the agriculture of these countries will be highlighted, namely France, Germany, Italy, Romania, Spain, Poland and Hungary.

Thus, the need to apply chemical fertilizers to the sunflower crop lies in the increase in water retention capacity for the soil and the poor fertility of the soils. Nitrogen and phosphorus are effectively driven from the leaves and stems of sunflower into the capitula at the same time with their maturation [15]. Potassium is absorbed more in the stems than in the leaves and has a continuous influx towards the capitulum, catalyzing the formation and circulation of carbohydrates in phospholitic processes. Some microelements (boron, molybdenum, iron, copper, etc.) have an important role in balancing the mineral nutrition of the plant, in its enzymatic activity, the accumulation of protein, oil, increasing resistance to diseases and ecological stresses etc.

The doses of sunflower fertilizers are established according to the planned production and the specific agrochemical indices of the soil (Table 1).

Table 1. Recommended doses of recommended chemical fertilizers for sunflowers, depending on soil fertility and production.

No. Crt.	Planned Production	Soils Poorly Provided with Nutrients			Soils Medium Provided with Nutrients			Soils Well Provided with Nutrients		
	tons/ha	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
		kg/ha								
1.	2.0	80	85	80	70	40	45	60	-	-
2.	2.5	94	110	100	80	65	65	70	25	30
3.	3.0	107	130	120	95	85	85	85	50	50
4.	3.5	117	150	135	105	110	100	95	70	65

Source: [15].

In the specialty literature, it is specified that the application of manure before the establishment of the sunflower crop, has an impact in reducing the doses by 2 kg N/tons, 1.5 kg P_2O_5/tons, and 2.5 kg K_2O/tons, and if the manure is applied to the preceding plant, doses are reduced by 1 kg N/tons, 1 kg P_2O_5/tons and 1 kg K_2O/tons [15]; this is due to the fact that semi-fermented cattle manure contains on average 22% dry matter and 0.5% nitrogen, 0.25% phosphorus, 0.6% potassium, 0.05% sulfur, 0.5% calcium, 0, 2% magnesium, 4 g boron/t and 2 g copper/t [19].

Nitrogen doses are recommended for sunflower cultivation after wheat and other plants before autumn, spring cereals, early potatoes, but nitrogen doses are higher by 10 kg N/ha after corn, 15 kg/ha after late potatoes and sugar beet; this is because these precursor plants are high consumers of nutrients [52,53]. Manure gives good results in sunflower, the production increases being 800–1000 kg/ha. The recommended doses are 20 t/ha, on soils with lower fertility, which are also supplemented with mineral fertilizers. The administration of manure should be done in the fall, before the autumn plowing.

The quantities of chemical fertilizers used in the sunflower-producing countries will be further highlighted, and for this aspect, the multiannual average (2010–2019) of the quantities of chemical fertilizers and pesticides used per hectare cultivated and the average yield per hectare (tons) achieved have been taken into account, highlighting the amount (kg) of chemical fertilizers and pesticides that are used to obtain one ton of sunflower (Figure 4).

Environmental factors, especially the supply of water and nitrogen (N) influence the folial surface of the plant [17].

For the analysis period 2010–2019, the consumed quantities of nitrogen in each country to obtain one ton of sunflower will be detailed, as follows (Figure 5):

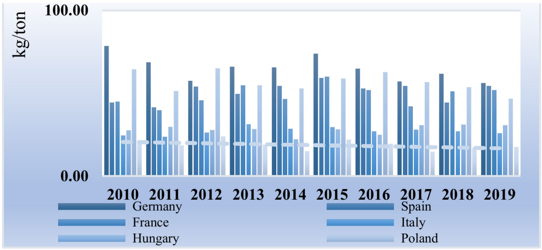

Figure 5. Average amount of nitrogen fertilizers used in the EU countries for obtaining one ton of sunflower (kg/ton), 2010–2019 [41].

Regarding the use of phosphorus fertilizers (P_2O_5) for the sunflower crop, **Romania** is placed in sixth place with an amount of 7.48 kg of phosphorus (P_2O_5) used to obtain a ton of sunflower, with a negative deviation of (−13.09 kg/ha) compared to Spain, which is the largest consumer of phosphorus fertilizers (P_2O_5) among the countries under study. Phosphorus has an important role in fructification, carbohydrate and lipid synthesis, advancing the percentage of oil in the seeds. In an optimal balance between nitrogen and phosphorus, vegetative and generative growths increase resistance to diseases and drought, contribute to obtaining seeds with high biological value. In the first phase of growth, the use of phosphorus is slow, advancing much in the period of formation of the capitulum until the total flowering (Figure 6).

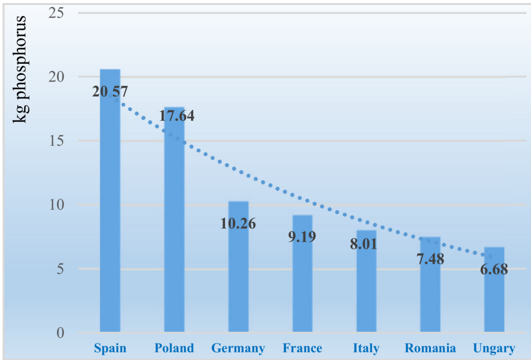

Figure 6. Average amount of phosphorus (kg) used to obtain one ton of sunflowers in the main European countries. 2010–2019 [41].

For the analysis period 2010–2019, the consumed quantities of phosphorus in each country to obtain one ton of sunflower will be detailed, as follows (Figure 7):

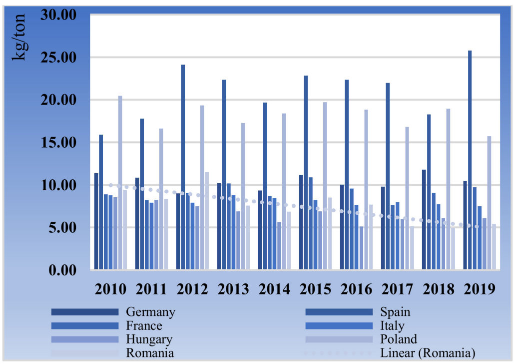

Figure 7. Average amount of phosphorus fertilizers (P_2O_5) used in the EU countries for obtaining one ton of sunflower (kg/ton), 2010–2019 [41].

With regard to potassium fertilizers (K_2O), for the sunflower crop, **Romania** is positioned on the last place in terms of potassium consumption (K_2O), with an amount of 2.68 kg of potassium (K_2O) used to obtain one ton of sunflower, and a negative deviation of (−22.66 kg) compared to **Poland**, which is the largest consumer of potassium fertilizers (K_2O) among the countries under study (Figure 8). Potassium (K_2O) has a decisive role in sunflower nutrition, being consumed in much higher quantities than at other field crops. At the same time, unlike other species, the roots of this plant have a great ability to extract it from hardly soluble forms of the soil. Potassium participates in carbohydrate and lipid metabolism, directly influencing the oil content of seeds. Potassium (K_2O) deficiency reduces vegetative growth and oil content, increasing plant susceptibility to disease and drought. For the analysis period 2010–2019, the consumed quantities of potassium in each country to obtain one ton of sunflower will be detailed, as follows (Figure 9):

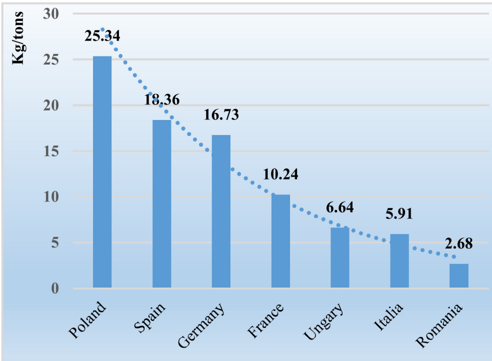

Figure 8. Average amount of potassium (kg) used to obtain one ton of sunflower in the main European countries. 2010–2019 [41].

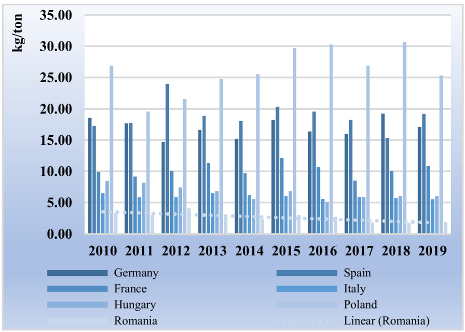

Figure 9. The average amount of fertilizers with K_2O used in the EU countries for obtaining one ton of sunflower (kg/ton), 2010–2019 [41].

In the continuation of the study, aspects related to combating diseases and pests, weeds specific to the infection and infestation of the sunflower farming system are considered. Sunflower can be affected by a number of diseases which, when the favourable attack conditions are met, can be devastating and the entire production can be compromised. In most cases, diseases occurring in the sunflower farming system affect the stem and leaves, stopping the plant from developing; these diseases are: white rot (*Sclerotinia sclerotiorum*), grey rot (*Botrytis cinerea*), manna (*Plasmopara halstedii*), brown staining and stem breaking *Diaporthe helianthi* f.c. *Phomopsis helianthi*), black staining or blackening of strains (*Leptosphaeria lindquistii* f.c. *Phoma macdonaldi*), rusting (*Puccinia helianthi*), septoriosis (*Septoria helianthi*), alternariosis (*Alternaria helianthi*), white rusting (*Albugo tragopogonis*).

At the current stage of development of science, for preventing and combating the complex of diseases that sunflower farming system may face, more measures are needed, both phytotechnical and chemical treatments. The agrofitotechnical measures aim at the proper rotation of the crop, the incorporation into the soil of the plant residues after the harvest, the assurance of an optimal density, the optimum fertilization, without the excess nitrogen that sensitizes the plants, the use of hybrids with increased resistance etc. [52].

As chemical measures we mention seed treatment and treatments during the vegetation period. Treatment of seed with fungicides is of great importance for the prevention of mana-attack and other diseases transmitted by seeds and/or soil. In the specialty literature, it is recommended to apply one or more treatments with a specific fungicide approved for this culture during the growing season [16]. Treatment with fungicide for sunflowers should be carried out preventively, before the actual infections occur, at latest when the first symptoms appear. Since the culture can be attacked by many pathogens, it is important to use a broad-spectrum fungicide with a long duration of action. Thus, it will cover as long as possible the protection of the culture and also will protect it from the most common diseases [35].

Regarding the treatment of sunflower seeds, it should also be mentioned that Romania is facing an extremely rapacious pest for the young plants of sunflower and corn, *Tanymecus dilaticollis*. There were years of culture when the treatment of seeds with neonicotinoid substances was banned, the only ones effective in combating this pest, and the damage was huge and led to the replacement of the crops.

Weeds can, moreover, compromise sunflower farming systems if proper and timely measures are not taken. Production losses are given by the degree of weeding of the sunflower crop, which in the first 4–6 weeks after sprout have a slow growth, associated with a small number of plants at m^2 creating a competition from the beginning between the crop plant and the weed, with a major advantage in favor of weeds [19].

The weeds, by their number, by their rapacity for space, water and food, win the battle, causing great damage to the sunflower crop, which varies between 30 and 80%, depending on the degree of infestation, leading even to the total compromise of the crops, in the case of the infestation with the costreium *(Sorghum halepense*) from the rhizomes. Besides the preventive and agrotechnical methods, the chemical methods (herbicide) represent perhaps the most important method of preventing and fighting weeds [16].

In the sunflower crop, in order to record a high efficiency in weed control, several treatment schemes can be applied depending on the dominant species (Table 2):

The main pests that may infest the sunflower farming system are the Earthen beetle (*Opatrum sabulosum*), the wireworms (*Agriotes* sp.), the corn rat (*Tanymecus dilaticollis*), the small plum louse (*Brachycaudus helichrysi*), the sunflower moth (*Homoeosoma nebulella*). Over the last ten years, more and more attacks have been recorded on sunflowers. The areas where the largest areas with sunflowers in Romania are cultivated coincide with those of maximum favorability for the maize raisin attack: south and south-east of the country. In the autochthonous specialty literature, it is maintained that the sunflower is a host plant for the corn duck, the attack of this pest is dangerous when the plants are in the first stages of vegetation, as in the case of maize (from arise to four leaves), only that in the case of the sunflower, if the plants are gnawed from the parcel, then they are totally compromised.

Although the genetic modification is important for the resistance to herbicides (glyphosate), pests (sunflower moth) and white rot as well as for the chemical composition of the oil, the studies remained at the laboratory level, in controlled conditions, due to crossbreeds that may occur with wild species of Helianthus [18]. To date, the commercial sunflower has not been genetically modified by transgenic amelioration [54].

Regarding pesticides-total, in the sunflower crop, **Romania** is ranked last in terms of pesticide-total consumption, with a quantity of 0.35 kg of pesticides-total used to obtain a ton of sunflower, with a negative deviation of 2.48 kg compared to Spain, which is the largest consumer of pesticides-total of the countries studied, in the sunflower crop. The application of pesticides is intended to repel, destroy or control any pest or to regulate the growth of sunflower (Figure 10). Following the analysis, the consumption of fertilizers and pesticides in the countries studied will be presented.

Table 2. Recommended sunflower treatments for weed control.

No. Crt.	Weed Type	Recommended Treatments
1.	On the surfaces infested with annual dichotyledonous and monocotyledonous weeds the dicotyledonous species being dominated	Preemergent: immediately after sowing
		Postemergent: in vegetation, when the sunflower has 4–6 leaves, annual grass weeds 2–4 leaves before twinning
2.	In the plots infested with dicotyledonous, monocotyledonous annual and perennial weeds including Sorghum halepense from rhizomes	Treatment 1: at sowing to control annual monocotyledonous weeds (*Setaria. Echinochloa.*) from seeds
		Treatment 2: in vegetation (postemergent) when the sunflower plant is in the phase of 4–6 leaves to control annual dicotyledonates (in the phase of 2–4 leaves)
		Treatment 3: intended to combat the species *Sorghum halepense* from rhizomes that are also made in vegetation (post-emergent) when the costreium has a height of 15–25 cm and sunflower plants 4–6 leaves

Source: [18].

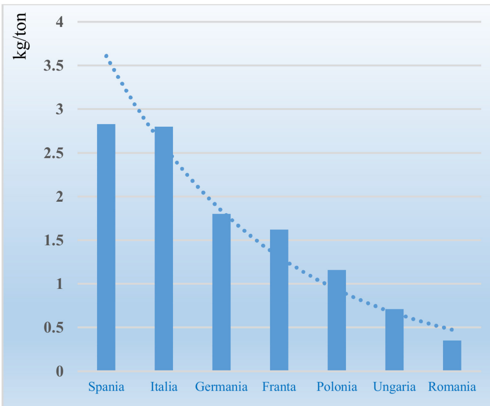

Figure 10. Average amount of pesticides-total (kg) used to obtain a ton of sunflower in the main European countries, 2010–2019 [41].

For the analysis period 2010–2019, the consumed quantities of pesticides-total in each country to obtain one ton of sunflower will be detailed, as follows (Figure 11):

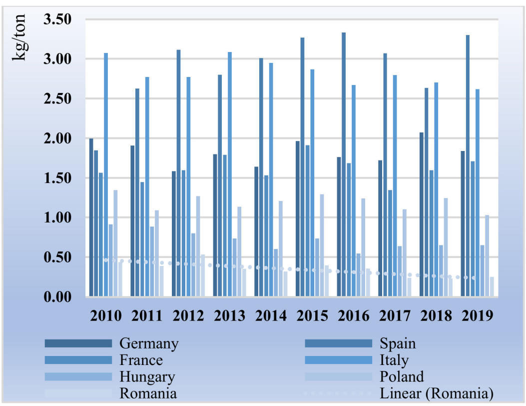

Figure 11. Average amount of pesticides-total (kg) used in the EU countries for obtaining one ton of sunflower (kg/ton), 2010–2019 [41].

Regarding nitrogen fertilizers (N), at the sunflower crop, **Romania** is positioned on the last place in terms of nitrogen consumption (N), with an amount of 19.02 kg of nitrogen (N) used to obtain one ton of sunflower, with a negative deviation of (−45.05 kg) compared to Germany, which is the largest consumer of nitrogen fertilizers (N) among the countries under study. It is worth mentioning that nitrogen has a special role for the nutrition of sunflowers. The maximum consumption of nitrogen is in the period from the formation of the capitulum to the full flowering; its deficiency makes the plants remain small and thin, with its foliar surface and its capacity of low assimilation, which leads to a poor increase in capitula and seeds, but increasing the percentage of dry seeds. Excess nitrogen leads to a lush vegetative growth, to the detriment of the generative one, the leaves, being more succulent, becoming susceptible to diseases and pests. Consequently, the oil content decreases and the protein content increases.

Romania is in last place in the consumption of fertilizers with nitrogen (N), with a multiannual average of 19.2 kg nitrogen (N) consumed to obtain one ton of sunflower. The dose of nitrogen (N) per hectare for the conditions in Romania is between 60 and 100 kg per hectare and exceeding them can lead to the decrease in the oil content in the grains [19]. It has a total multiannual production of 2279.16 tons and an average production/ha of 2.13 tons per hectare with a negative deviation of (−45.05 kg/ton) compared to Germany, which is the first country ranked for the consumption of fertilizers with nitrogen (N). In Romania there is an oscillating evolution of nitrogen (N) consumption in sunflower culture, the years with the highest consumption were 2012 and 2015 and the years with the lowest consumption were 2014 and 2017.

For Romania, the linear regression between the amount of nitrogen (N) used and the average yield per hectare of sunflower during 2010–2019 was achieved, according to the data in Table 3.

Table 3. Annual quantity of nitrogen (N) fertilizers used and the average production/ha of sunflower in Romania.

Specification	UM	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual quantity of fertilizers with nitrogen (N) (a.i.)	kg/ha	31.82	33.2	31.37	37.49	32.99	38.83	38.26	42.57	51.35	48.62
Average sunflower production	kg/ha	1600	1800	1310	1990	2190	1770	1960	2920	3040	2780

Source: [41,42] and own processing.

In **Romania,** according to Figure 12, in which the linear regression model is presented, we observe the direct connection between the quantity of nitrogen (N) and the sunflower production, respectively; 76% of the increase in sunflower production is due to the increase in the amount of nitrogen (N).

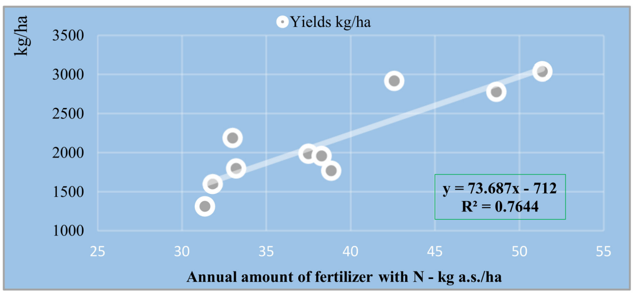

Figure 12. Romania—Linear regression between the annual amount of fertilizers with N used and the average production/ha [41].

Romania is on the penultimate place in the consumption of fertilizers with phosphorus (P_2O_5), with a multiannual average of 7.48 kg phosphorus (P_2O_5), consumed to obtain one ton of sunflower. The dose of phosphorus (P_2O_5) per hectare for the conditions in Romania is between 60 and 125 kg/ha, and this quantity has a primordial influence on sunflower production but also on their oil content; this aspect is due first of all to the fact that the

Romanian farmers do not have sufficient financial resources, and secondly to the lack of water that makes the phosphorus to be more difficult assimilated by the plants [19].

The area used by Romania during the analysis period varied, with a multiannual average of 1.05 million ha, a total multiannual production of 2279.16 tons and an average production/ha of 2.13 tons/ha, with a negative deviation of (−13.09 kg/ton) compared to Spain which is the first country ranked in fertilizer consumption with P_2O_5. The consumption of fertilizers with phosphorus (P_2O_5) registered in Romania to obtain one ton of sunflower has oscillated during the analysis period, with the highest consumptions in 2010, 2012, 2015, and since 2017 there is an increasing trend (7.72 kg per ton in 2019).

For Romania, the linear regression between the amount of phosphorus (P_2O_5) used and the average yield per hectare of sunflower during 2010–2019 was achieved, according to the data in Table 4.

Table 4. Annual quantity of fertilizers with phosphorus (P_2O_5) used and the average production per ha of sunflower in Romania.

Specification	UM	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual quantity of fertilizers with P_2O_5	kg/ha	12.83	13.38	12.23	12.39	12.88	14.41	14.02	16.17	20.65	21.47
Average sunflower production	kg/ha	1600	1800	1310	1990	2190	1770	1960	2920	3040	2780

Source: [41,42] and own processing.

For **Romania**, the linear regression between the amount of potassium (K_2O) used and the average yield per hectare of sunflower during 2010–2019 was achieved, according to the data in Table 5.

Table 5. Annual quantity of K_2O fertilizers used and the average production/ha of sunflower in Romania.

Specification	UM	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual quantity of fertilizers with K_2O	kg/ha	5.36	5.02	3.78	3.65	3.27	4.64	4.85	6.17	7.19	9.84
Average sunflower production	kg/ha	1600	1800	1310	1990	2190	1770	1960	2920	3040	2780

Source: [41,42] and own processing.

In Figure 13, according to the linear regression model, we observe the direct connection between the amount of phosphorus (P_2O_5) and sunflower production, respectively; 69% of the increase in sunflower production is due to the increase in the amount of fertilizer by phosphorus (P_2O_5).

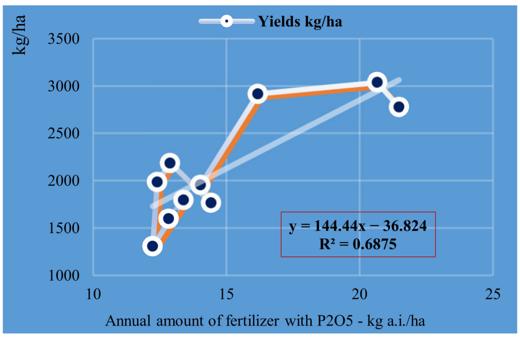

Figure 13. Romania—Linear regression between the annual amount of fertilizers with P_2O_5 used and the average production/ha [41].

Technologically speaking, the optimal period for the incorporation of phosphorus and potassium fertilizers in the soil is with autumn ploughing, but they can also be applied at the beginning of spring, following to be incorporated in the soil as deeply as possible, through works with the cultivator. A part of the phosphorus (P_2O_5), and potassium (K_2O) fertilizers can be applied together with the nitrogen (N) fertilizers, at the same time as the sowing [19].

Sunflower reacts very well to folial fertilization [7,8]. Two treatments are applied: the first in the 4–6 leaf phase and the second at the beginning of the capitulums. Solutions with concentrations of 0.5 to 1.0% in volumes of 300 to 500 L/ha are used for each treatment. It is advisable to add boron. Their concentration in the nutrient fluid must be 0.1–0.5% microfertilizer.

For **Romania**, in Figure 14, according to the linear regression model, we observe the direct connection between the amount of potassium (K_2O) and sunflower production, respectively 46% of the increase in sunflower production is due to the increase in the amount of potassium (K_2O) fertilizers.

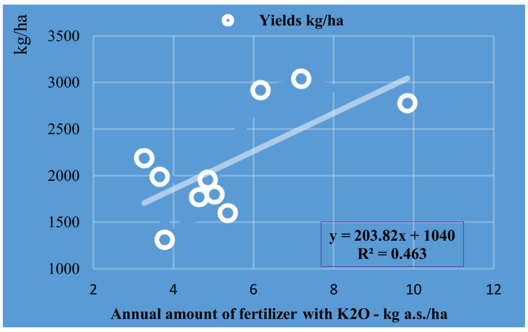

Figure 14. Romania—Linear regression between the annual amount of fertilizers with K_2O used and average production/ha [41].

Romania ranks last in the consumption of fertilizers with potassium (K_2O) with a multiannual average of 2.68 kg potassium (K_2O) consumed to obtain one ton of sunflower. The recommended potassium dose (K_2O) per hectare for the Romanian conditions is 30–80 kg/ha, but the sunflower extracts large quantities of potassium from the soil, and its reaction on well-supplied soils is insignificant when supplemented with fertilizers with potassium (K_2O) [19]. The area used by Romania during the analysis period varied, with a multiannual average of 1059.72 thousand ha, a total multiannual production of 2279.16 tons and an average production/ha of 2.13 tons, with a negative deviation of (−22.66 kg/ton) compared to Poland which is the first country ranked for fertilizer consumption with potassium (K_2O). In the period 2010–2014, the consumption of fertilizers with potassium (K_2O) for obtaining one ton of sunflower in Romania decreased (1.49 kg/ton in 2014), registering increases until 2019 when the value of 3.54 kg/ton of sunflower was reached.

Romania is on the last place in terms of pesticide-total consumption, with a multiannual average of 0.35 kg pesticide-total consumed to obtain one ton of sunflower. The area used by Romania during the analysis period varied, with a multiannual average of 1059.72 thousand ha, a total multiannual production of 2279.16 tons and an average production/ha of 2.13 tons, with a negative deviation of (−2.48 kg/ton) compared to Spain, which is the first country ranked at pesticides-total consumption. In Romania, also, there is a trend of decreasing the consumption of pesticides in sunflower cultivation, with a maximum in 2012 of 0.53 kg/ton to 0.18 kg/ton in 2018.

For Romania, it is shown in Figure 15, according to the linear regression model, the reverse link, very weak connection between the production of sunflower and the quantity of pesticides used. The link between the average production per hectare of sunflower and pesticides cultivation is direct if we do not observe the minimum quantities of pesticides allocated: in 2018—0.56 kg/ha, respectively in 2019—0.57 kg/ha (Figure 16).

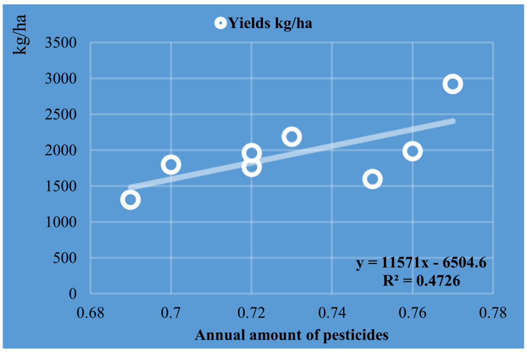

Figure 15. Romania—Linear regression between the annual quantity of pesticides used and average of total production/ha [41].

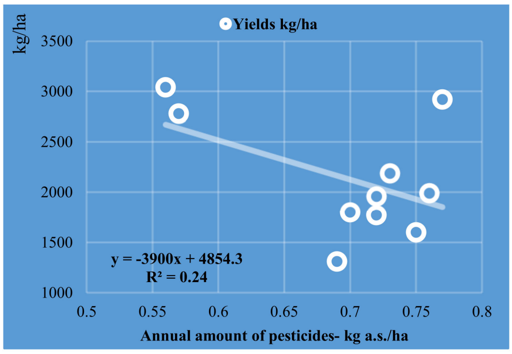

Figure 16. Romania—Linear regression between the annual quantity of pesticides used and average production/ha (2010–2017) [41].

Germany is the largest consumer of N fertilizers, with a multiannual average of 64.25 kg nitrogen (N) consumed to make one ton of sunflower. The area used by Germany during the analysis period varied, with a multiannual average of 23.46 thousand ha and a multiannual total production of 50.04 tons and an average production/ha of 2.11 tons, with a positive deviation of (+45.05 kg/ton) compared to Romania which is the last country ranked for the consumption of fertilizers with nitrogen for sunflower crops in the period 2010–2019. The years that highlight the increase in the use of these types of fertilizers are 2010 and 2015.

Germany is in third place in fertilizer consumption with phosphorus (P_2O_5), with a multiannual average of 10.26 kg phosphorus (P_2O_5), consumed to obtain one ton of sunflower. The area used by Germany during the analysis period varied, with a multiannual average of 23.46 thousand ha, a multiannual total production of 50.04 tons and an average production/ha of 2.11 tons, with a positive deviation of (+2.78 kg/ton) compared to Romania which is the penultimate country ranked in fertilizer consumption with P_2O_5. In Germany, the trend of decreasing fertilizer consumption with phosphorus (P_2O_5) in the sunflower crop is noted. The years with the highest consumptions were 2010 and 2015, but in 2019 the amount of 10.15 kg of fertilizers with phosphorus (P_2O_5) was used to obtain a ton of sunflower.

Germany is in third place in fertilizer consumption with potassium (K_2O), with a multiannual average of 16.73 kg potassium (K_2O), consumed to obtain one ton of sunflower. The area used by Germany during the analysis period varied, with a multiannual average of 23.46 thousand ha, a multiannual total production of 50.04 tons and an average production per ha of 2.11 tons, with a positive deviation of (+14.05 kg/ton) compared to Romania which is the last country ranked for fertilizer consumption with potassium (K_2O). During the analysis period, the consumption of fertilizers with potassium (K_2O) for obtaining a ton of sunflower oscillated, the years with the highest consumptions were 2010, 2013 and 2018, and the years with the lowest consumptions were 2012 and 2017.

Germany ranks third at pesticide-total consumption, with a multiannual average of 1.8 kg pesticide-total consumed to obtain one ton of sunflower. The area used by Germany during the analysis period varied, with a multiannual average of 23.46 thousand ha, a total multiannual production of 50.04 tons and an average production/ha of 2.11 tons, with a positive deviation of (+14.05 kg/ton) compared to Romania, which is the last country classified at pesticide-total consumption. During the analysis period, in Germany the consumption of pesticides to obtain a ton of sunflower was relatively constant, the years with higher consumption were 2015 and 2018.

Poland is in second place in the consumption of fertilizers with nitrogen (N), with a multiannual average of 55.12 kg nitrogen (N) consumed to obtain one ton of sunflower. The area used by Poland during the analysis period varied, with a multiannual average of 4.09 thousand ha, a multiannual total production of 7.78 tons and an average production/ha of 1.77 tons, with a positive deviation of (+35.92 kg/ton) compared to Romania, which is the last country ranked for the consumption of fertilizers with nitrogen (N), but standing out for greater use in the years 2010, 2012, 2016.

Poland is in second place in fertilizer consumption with phosphorus (P_2O_5), with a multiannual average of 17.64 kg phosphorus (P_2O_5), consumed to obtain one ton of sunflower. The area used by Poland during the analysis period varied, with a multiannual average of 4.09 thousand ha, a multiannual total production of 7.78 tons and an average production per hectare of 1.77 tons, with a positive deviation of (+10.16 kg/ton) compared to Romania which is the penultimate country ranked for fertilizer consumption with P_2O_5. During the analysis period, the consumption of fertilizers with phosphorus (P_2O_5) for the sunflower crop had a decreasing trend, in 2010—24.11 kg/ton of sunflower were used, and in 2019—15.41 kg/ton.

Poland ranks first in the consumption of fertilizers with potassium (K_2O), with a multiannual average of 25.34 kg potassium (K_2O) consumed to obtain one ton of sunflower. The area used by Poland during the analysis period varied, with a multiannual average of 4.09 thousand ha, a total multiannual production of 7.78 tons and an average production per ha of 1.77 tons, with a positive deviation of (+22.66 kg/ton) compared to Romania which is the last country ranked for the consumption of fertilizers with potassium (K_2O). During the analysis period, the amount of fertilizer with potassium (K_2O) used to obtain one ton of sunflower had an increasing trend, from 2011 to 2016. In the period 2017–2019, consumption fluctuated, but the year 2019 registered a decrease compared to the previous year (25.33 kg per ton).

Poland is ranked fifth in total pesticide use, with a multiannual average of 1.16 kg pesticides-total consumed to obtain one ton of sunflower. The area used by Poland during the analysis period varied, with a multiannual average of 4.09 thousand ha, a total multiannual production of 7.78 tons and an average production/ha of 1.77 tons/ha, with a positive deviation of (+0.81kg/ton) compared to Romania, which is the last country classified at the pesticides-total consumption. In Poland, during 2010–2019, the consumption of pesticides slightly oscillated, but until 2015 there is an increasing trend, after which there is a decrease in their use in sunflower cultivation (1.08 kg/ton in 2019).

Spain is in third place in the consumption of fertilizers with N, with a multiannual average of 56.84 kg N consumed to obtain one ton of sunflower. The area used by Spain during the analysis period varied, with a multiannual average of 733.31 thousand ha, a total multiannual production of 866.19 tons and an average production/ha of 1.18 tons/ha, with a positive deviation of (+30.59 kg/tons) compared to Romania which is the last country ranked for the consumption of fertilizers with nitrogen (N). In Spain the consumption of nitrogen (N) fertilizers was generally over 50 kg/ton of sunflower, the years with lower consumptions highlighted were 2010, 2011, 2013 and 2018.

Spain ranks first in fertilizer consumption with phosphorus (P_2O_5) with a multiannual average of 20.57 kg phosphorus (P_2O_5) consumed to obtain one ton of sunflower. The area used by Spain during the analysis period varied, with a multiannual average of 733.31 thousand ha and a total multiannual production of 866.19 tons and an average production per hectare of 1.18 tons, with a positive deviation of (+13.09 kg/ton) compared to Romania which is the penultimate country ranked for fertilizer consumption by phosphorus (P_2O_5). The consumption of fertilizers with phosphorus (P_2O_5) during the analysis period for the sunflower crop in France oscillated: by 2012, there were annual increases, after which the consumptions decreased until 2014. The year 2019 stands out with the highest consumption of fertilizers with phosphorus (P_2O_5) for obtaining one ton of sunflower in the analysis period (25.79 kg per ton).

Spain is in second place in fertilizer consumption with potassium (K_2O), with a multiannual average of 18.36 kg potassium (K_2O) consumed to obtain one ton of sunflower. The area used by Spain during the analysis period varied, with a multiannual average of 733.31 thousand ha, a total multiannual production of 866.19 tons and an average production per ha of 1.18 tons, with a positive deviation of (+15.68 kg/ton) compared to Romania which is the last country ranked for fertilizer consumption with potassium (K_2O). Oscillations in the period of analysis of fertilizer consumption with potassium (K_2O), to obtain a ton of sunflowers were also highlighted in Spain, the country that had the highest consumption in the years 2015, 2012 and 2016, but the variations in the period were not major.

Spain ranks first in pesticide use-total, with a multiannual average of 2.83 kg of pesticides consumed to obtain one ton of sunflower. The area used by Spain during the analysis period varied, with a multiannual average of 733.31 thousand ha, a total multiannual production of 866.19 tons and an average production/ha of 1.18 tons/ha, with a positive deviation of (+2.48 kg/ton) compared to Romania, which is the last country classified at pesticides-total. In Spain, the consumption of pesticides to obtain one ton of sunflower has increased during the analysis period from 1.85 kg/ton in 2010 to 3.30 kg/ton in 2019. The year 2018 showed a reduction in the increasing trend of this type of consumption, reaching the level of 2.63 kg/ton of sunflower.

France ranks fourth in the consumption of nitrogen (N) fertilizers, with a multiannual average of 48.78 kg nitrogen (N) consumed to obtain one ton of sunflower. The area used by France during the analysis period varied, with a multiannual average of 628.02 thousand hectares, a total multiannual production of 1520.94 tons and an average production ha of 2.29 tons per hectare, with a positive deviation of (+29.28 kg per tons) compared to Romania which is the last country ranked in the consumption of fertilizers with nitrogen (N). It is noted that France compared to the multiannual average also has years with more significant consumption and these are 2015 and 2013.

France is in fourth place in fertilizer consumption with phosphorus (P_2O_5), with a multiannual average of 9.19 kg phosphorus (P_2O_5) consumed to obtain one ton of sunflower. The area used by France during the analysis period varied, with a multiannual average of 628.02 thousand ha, a multiannual total production of 1520.94 tons and an average production/ha of 2.29 tons, with a positive deviation of (+1.71 kg/ton) compared to Romania which is the penultimate country ranked in fertilizer consumption with phosphorus (P_2O_5). In France, during the analysis period, the consumption of phosphorus (P_2O_5) fertilizers for one ton of sunflower increased from 6.13 kg/ton in 2010 to 10.15 kg/ton in 2019. The years with the highest consumptions, stood out to be 2013 and 2015.

France is in fourth place in fertilizer consumption with potassium (K_2O) with a multiannual average of 10.24 kg potassium (K_2O) consumed to obtain one ton of sunflower. The area used by France during the analysis period varied, with a multiannual average of 628.02 thousand ha, a total multiannual production of 1520.94 tons and an average production per ha of 2.29 tons, with a positive deviation of (+7.56 kg per ton) compared to **Romania** which is the last country ranked for the consumption of fertilizers with potassium (K_2O). In France, the consumption of fertilizers with potassium (K_2O) had oscillating values during the analysis period, of which we note the year 2015 with a consumption of

12.55 kg per ton, the highest value being recorded in 2011 with 8.09 kg per ton of sunflower, highlighted as the lowest consumption.

France ranks fourth at pesticides-total consumption, with a multiannual average of 1.62 kg pesticides-total consumed to obtain one ton of sunflower. The area used by France during the analysis period varied, with a multiannual average of 628.02 thousand ha, a total multiannual production of 1520.94 tons and an average production/ha of 2.29 tons/ha, with a positive deviation of (+1.27 kg/ton) compared to Romania, which is the last country classified at pesticides-total consumption. In France, during the analysis period, the consumption of pesticides for obtaining a ton of sunflower has increased steadily, the years with lower consumption were 2011, 2017 and 2010.

Hungary ranks fifth in the consumption of nitrogen (N) fertilizers with a multiannual average of 28.6 kg nitrogen (N) consumed to obtain one ton of sunflower. The area used by Hungary during the analysis period varied, with a multiannual average of 605.58 thousand ha, a total multiannual production of 1585.88 tons and an average production per ha of 2.60 tons, with a positive deviation of (+9.4 kg/ton) compared to Romania which is the last country ranked in the consumption of fertilizers with nitrogen (N). In Hungary, the consumption of nitrogen (N) fertilizers remained almost constant during the analysis period and the years with lower consumption were 2014 and 2016.

Hungary ranks fifth in fertilizer consumption with potassium (K_2O), with a multiannual average of 6.64 kg potassium (K_2O) consumed to obtain one ton of sunflower. The area used by Hungary during the analysis period varied, with a multiannual average of 605.58 thousand ha, a total multiannual production of 1.585.88 tons and an average production per ha of 2.60 tons, with a negative deviation of (−3.96 kg per ton) compared to Romania which is the last country ranked in terms of consumption of fertilizers with potassium (K_2O). In Hungary, the consumption of fertilizers with potassium (K_2O) was relatively constant until 2016, between 5.29 and 6.17 kg per ton of sunflower, 2017 recording a maximum (8.37 kg per ton of sunflower), and then a decreasing trend.

Hungary ranks seventh in fertilizer consumption with phosphorus (P_2O_5), with a multiannual average of 6.68 kg phosphorus (P_2O_5) consumed to obtain one ton of sunflower. The area used by Hungary during the analysis period varied, with a multiannual average of 605.58 thousand ha, a multiannual total production of 1.58 tons and an average production/ha of 2.60 tons, with a negative deviation of (−0.8 kg/ton) compared to Romania which is the penultimate country ranked for fertilizer consumption with phosphorus (P_2O_5); moreover, in **Hungary**, the decrease in the consumption of phosphorus (P_2O_5) for obtaining a ton of sunflower by 2016 is noted, after which a slight upward trend is noted, reaching a consumption of 6.75 kg/ton of sunflower in 2019.

Hungary is ranked sixth in total pesticide consumption, with a multiannual average of 0.71 kg pesticide-total consumed to obtain one ton of sunflower. The area used by Hungary during the analysis period varied, with a multiannual average of 605.58 thousand ha, a total multiannual production of 1.58 tons and an average production/ha of 2.60 tons, with a positive deviation of +0.36 kg/ton compared to Romania, which is the last country classified at pesticides-total consumption. Hungary also reduced the consumption of pesticides in sunflower crops from 1.04 kg/ton in 2010 to 0.57 kg/ton of sunflower in 2019.

Italy is on the penultimate place in the consumption of nitrogen (N) fertilizers, with a multiannual average of 26.88 kg nitrogen (N) consumed to obtain one ton of sunflower. The area used by Italy during the analysis period varied, with a multiannual average of 114.11 thousand ha, total multiannual production of 258.72 tons and an average production/ha of 2.33 tons/ha, with a positive deviation of (+7.68 kg/ton) compared to Romania, which is the last country ranked for the consumption of fertilizers with nitrogen (N). The consumption of nitrogen (N) to obtain one ton of sunflower in Italy had an increasing trend until 2013, after which it decreased slightly until 2019, when it was 25.77 kg/ton.

Italy is in fifth place in fertilizer consumption with phosphorus (P_2O_5), with a multiannual average of 8.01 kg P_2O_5 consumed to obtain one ton of sunflower. The area used by Italy during the analysis period varied, with a multiannual average of

114.11 thousand ha, a total multiannual production of 258.72 tons and an average production/ha of 2.33 tons, with a positive deviation of (+0.53 kg/ton). Compared to Romania which is the penultimate country ranked in fertilizer consumption with phosphorus (P_2O_5). In Italy, the consumption of fertilizers with phosphorus (P_2O_5) during the analysis period had a decreasing trend, starting with 2013 in order to achieve in 2019 a value of 7.57 kg/ton of sunflower obtained.

Italy ranks sixth in the consumption of fertilizers with potassium (K_2O), with a multiannual average of 5.91 kg potassium (K_2O) consumed to obtain one ton of sunflower. The area used by Italy during the analysis period varied, with a multiannual average of 114.11 thousand ha, a total multiannual production of 258.72 tons and an average production per ha of 2.33 tons, with a positive deviation of (+3.23 kg/ton) compared to Romania which is the last country ranked for the consumption of fertilizers with K_2O. In Italy, the years 2010 and 2011 are noted with high consumptions of fertilizers with K_2O used to obtain one ton of sunflower (9.08 kg/ton and 8.60 kg/ton respectively). Since 2012, the consumption is substantially lower, being between 5.07 and 5.78 kg/ton, and the year 2019 reduces the consumption to 4.76 kg/ton of sunflower achieved.

Italy is the second largest consumer of pesticides-total, with a multiannual average of 2.80 kg pesticides-total consumed to obtain one ton of sunflower. The area used by Italy during the analysis period varied, with a multiannual average of 114.11 thousand ha, a total multiannual production of 258.72 tons and an average production/ha of 2.33 tons, with a positive deviation of (+2.45 kg/ton) compared to Romania. which is the last country ranked at pesticides-total consumption. In Italy, during the analysis period, there is a constant reduction in pesticide consumption from 3.51 kg/ton of sunflower in 2010 to 2.09 kg/ton in 2019.

4. Conclusions

Research on the sunflower crop system has highlighted the following aspects of the main specific indicators analyzed for the countries studied:

1. Romania is in first position, with 1.02 million ha in the average multiannual area cultivated with sunflower, and Poland occupies the last position with 0.002 million ha.
2. Romania is the country with the highest total multiannual sunflower production (2214.46 thousand tons), and the lowest total multiannual production was recorded by Poland (4.60 thousand tons).
3. Hungary ranks first in the ranking of countries studied by average production, with 2.62 tons/ha, and Spain is the country with the lowest average yields/ha, respectively, at 2.14 tons/ha.
4. The analysis of fertilizer and pesticide consumption highlighted the following:
    - Germany is the largest consumer of nitrogen fertilizers, with a multiannual average of 64.25 kg N consumed to obtain a ton of sunflower, and Romania ranks last in the consumption of nitrogen fertilizers, with a multiannual average of 19.2 kg N consumed to get a ton of sunflower.
    - Spain ranks first in the consumption of P_2O_5 fertilizers, with a multiannual average of 20.57 kg P_2O_5 consumed per ton of sunflower, and Hungary ranks last in the consumption of P_2O_5 fertilizers, with a multiannual average of 6.68 kg P_2O_5 consumed to get a ton of sunflower.
    - Poland ranks first in the consumption of K_2O fertilizers, with a multiannual average of 25.34 kg K_2O consumed to obtain a ton of sunflower, and Romania ranks last in the consumption of K_2O fertilizers with a multiannual average of K_2O 2.68 kg K_2O consumed to get a ton of sunflower.
    - Spain ranks first in total pesticide consumption, with a multiannual average of 2.83 kg of pesticides consumed to obtain a ton of sunflower, and Romania ranks last in total pesticide consumption, with a multiannual average of 0.35 kg of pesticides-total consumed to obtain a ton of sunflower.

5. The paper highlighted the situation of fertilizer and pesticide consumption in Romania. Linear regression models found that the amounts of nitrogen (N) used most influenced the increase in production (76%), followed by the amounts of phosphorus (P_2O_5), 69% and the amounts of potassium used (K_2O), 46%.
6. We propose that the decision to reduce the consumption of chemical fertilizers and pesticides be taken on the basis of the real situation in each European country, as reducing the amount of fertilizers and pesticides will certainly have an effect on sunflower production.
7. We recommend that in the countries analyzed, with such different climatic conditions, technical progress, input consumption level, crop irrigation rate etc., the reduction of the quantities of chemical fertilizers and pesticides proposed in the Farm-to-Fork strategy be differentiated, firstly taking into account all the average yields/ha of sunflower.
8. Climate change requires a reduction in any pollutants, but the reduction in the amount of fertilizers and pesticides used in EU agriculture, mentioned in the Farm-to-Fork strategy, should be done considering the European average, the level of access/use of technological progress in each country and especially the impact on average and total sunflower production, respectively; moreover, both climate change and the restriction of exports of sunflower and oil will contribute to a deficit in the world market, and EU farmers, including Romania, can improve their trade balance by increasing the processing of production.

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