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INSECT POLLINATION ECONOMIC VALUE OF AGRICULTURAL OILSEEDS CROPS IN ROMANIA IN THE PERIOD 2010-2020

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Abstract. *The purpose of this research was to quantify and study the dynamics of the insect pollination economic value, vulnerability rate to pollinators decline, production/consumption ratio and matrix value after pollination loss for Romania's oilseeds crops: sunflower and rape in the period 2011 and 2020. The dependence ratio taken into consideration was 30% for sunflower and 25% for rape and also the average annual producer's price of the seeds was used in Euro/ton. The formulas used in this study are adapted. The results confirmed that insect pollination service had a positive economic impact increasing oilseeds production value in the year 2020 by about Euro 204.96 million in case of sunflower and by Euro 68.85 million in case of rape, summing Euro 273.81 million. The vulnerability rate to pollination decline in oilseeds crops was 28.57% in the year 2020. Production/consumption ratio of oilseeds was higher than 1 in the period 2013-2018, reflecting that in general consumption needs are covered by internal production, imports being rarely required. The matrix value after the pollination loss was below 1 in almost all the years. Finally, insect pollination service, especially provided by bees is very important in Romania for obtaining production gains and a higher seed quality, for increasing farmers income, for maintaining biodiversity, the quality of environment factors and the balance in the ecosystems.*

Keywords: insect pollination economic value, vulnerability rate, oilseeds crops, Romania

13. Introduction

Oilseeds crops are more and more important for their role in human diet, animal feeding, processing industry, energetic sector and from an agronomic point of view [33, 43].

That is why the world oilseeds production increased reaching 600 million MT in 2020, of which soybeans 63.8%, rape seeds 11.7% and sunflower seeds 0.5% [51, 54].

At the world level the main producing countries of sunflower are Ukraine, Russian Federation, Argentina, China and Romania and of sunflower seeds are: Canada, India, China and EU.

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The EU is an important oilseeds producer. In 2019, it harvested 29.5 million tons, of which 15.3 million tons rape and turnip seeds (51.8%), and 10.3 million tons sunflower seeds (34.9%), the two crops together accounting for 86.7% in the total output.

Since 2015, Romania is the top producer of sunflower seeds in the EU [14, 41].
The main producers of rapeseeds are Germany, Poland, Czechia, Lithuania and Romania (the 5th position) [9].

The relationship between insect pollination and agricultural performance in the vegetal sector is a good example of applied bioeconomy. As long as 80% of plants are pollinated by insects, of which 77% benefit of bees pollination, it is obviously that pollination is very important in sustaining life on the Earth [5, 6].

Sunflower and rape are among the crops whose production depends on pollinator services which are performed 70-85% by melliferous bees, bumbles and butterflies.

But, we must not forget that Sunflower (*Heliantus annuus* L.) and rape (*Brassica napus* L. *and Brassica rapa* L.) are meliferous plants belonging to the nectar-pollenous category which could produce 30-130 kg honey/ha in case of sunflower and 30-100 kg/ha in case of rape, reflecting their high importance in beekeeping [1, 5].
Bees are the most important pollinator, they could pollinate about 130 agricultural crops, the dependence degree varying between 30% and 100% depending on plant species, hybrid, technologies, climate etc and the economic value is estimated at Euro 153 billion per year [50].

In addition, the bees produce high value products (honey, pollen, propolis, royal jelly, venom, wax etc) [27, 28, 29, 30, 32, 36, 39, 42] sustaining beekeepers' income and their families welfare [31, 37, 38].

Also, bees are considered a biosensor of the environment providing precious information about the quality of the environmental factors. More than this, bees give their contribution to the maintenance of biodiversity and ecosystems balance [50].

However, the population of bees and other insects is affected by many factors among which agriculture intensification decrease pollinator richness and abundance and this is the reason why it is needed to evaluate the effects on crop production [2].

Also, the plant protection measures based on treatments with neuro-systemic insecticides (neonicotinoides) could have a lethal or sub-lethal effect which diminish the number of bees or disturb their normal life and behavior [50].

For this reason, the EU Commission has a new approach regarding the future of pollinators and the need for monitoring as they have importance for nature and human well-being [8].

The economic impact of pollination in sunflower crop depends on hybrid (Dag, 2002) and the existence of highly self-fertile hybrids [3], agronomic practices [7], crop rotation, sunflower attractiveness, nectar production, climate factors [52], floret size [49], local factors, landscape and habitat [2, 21].

The dependence degree of crop production on pollination differs from a crop to another because there are many ways to evaluate the dependency rate and economic value of pollination. Various researchers used in their calculations agricultural production measured in kg or tons/ha, number of seeds per plant, seed oil content, weight of 1,000 seeds etc. [2, 10,11, 15, 18].

The degree of dependence on pollination for sunflower crop for seeds is about 30-50% which means that for one ha it is needed 1-2 bee families to fulfill this duty. In case of rape crop for seeds, pollination could assure 25-50% production gain which means that about 4-5 bee families have to offer their service for one ha [14, 22].

Other authors opine that the use of honey bees in sunflower cultivated areas could assure a high number of seeds per flower, germination rate, oil seeds content and reduce the number of mal-formed seeds [19, 20]. Tesfay (2009) proved that honey bees could grow sunflower yield by 385 the mass of seeds, by 385 germination rate and by 36% oil content [53]. INRA, 2019 sustained that bee pollination could boost the profitability of oilseed rape [17].

Due to the existence of wind pollination and autonomous self pollination, the dependence degree of pollination of rape production is still discussed and unclear [12, 13, 26].

Yield increases could vary between 18% and 74% depending on the crop due to the pollination service made by insects [4, 19].

In this context, the paper aimed to evaluate the economic impact of insects pollination on oilseeds production in Romania suing as example the main two oilseeds crops: sunflower and rape. The period of study was 2011 - 2020 and the main indicators utilized were: (a) cultivated area, production, yield, average annual producer's price, consumption; (b) economic value of oilseeds production due to insect pollination; (c) production/consumption ratio; (d) vulnerability rate to pollinators decline and (e) matrix value due to pollinators loss.

The paper is an original one in Romania as no other similar studies were approached on insect pollination economic value in oil seeds crop growing, except in fruit trees growing [47].

2. Materials and Methods

The data were provided by National Institute of Statistics and Ministry of Agriculture and Rural Development for the period 2011-2020 regarding the following indicators: cultivated area with sunflower and rape, seeds production by crop, yield by crop, average annual price at the farm gate by crop and seeds consumption by crop.

They were mathematically and statistically processed using the following procedures:

- *Fixed basis index*, $I_{FB} = (X_n/X_1)x100$, where X_1 is the level of the indicator in the year 2011 and X_n the level of the indicator in the year 2020;

-*Dynamic analysis* of each indicator in the interval 2011-2020 reflected by trend line regression equation and coefficient of determination;

-*Economic value of seeds production by crop and for the two crops*, EV, using the formula:

$$EV = \sum_{i=1}^{n} Q_i \ x \ P_i \quad \text{......} \quad (1)$$

where: i = crop type, i_1 = sunflower and i_2 = rape; Q_i = production (tons); P_i = average annual seed price by crop at the farm gate.

-*Insect pollination economic value*, IPEV, was calculated according to the formula used by Gallai et al, (2009) [11], but adapted to the present study for two crops at the level of a country.

$$IPEV = \sum_{i=1}^{n} Q_i \ x \ D_i \ x \ P_i \quad \text{......} \quad (2)$$

where: D_i = dependence ration of crop production on insect pollination. in this study, D_i was considered 30% for sunflower crop production and 25% for rape production.

-*Vulnerability rate* of the agricultural crops to pollination decline caused by climate change and other factors, VR%:

$$VR\% = (IPEV/EV) \ x \ 100 = \frac{\sum_{i=1}^{n} Q_i \ x \ D_i \ x \ P_i}{\sum_{i=1}^{n} Q_i \ x \ P_i} \ x \ 100 \quad \text{......} \quad (3)$$

-*Comparison regarding production/consumption* by crop, $\frac{Q_i}{C_i}$,

$$\frac{Q_i}{C_i} = \frac{\sum_{i=1}^{n} Q_i - C_i}{\sum_{i=1}^{n} C_i} \quad \text{......} \quad (4)$$

where: C_i = seeds consumption of crop i.

-*The matrix after total pollination* loss (M), according to the formula:

$$M = \frac{\sum_{i=1}^{n}(Q_i\ (1-D)_i - C_i}{\sum_{i=1}^{n} C_i} \quad \text{...} (5)$$

The results were graphically illustrated and tabled and also explained. Finally, the main conclusions were drawn.

3. Results and Discussions

Romania has a high agricultural potential both in vegetal and animal production. However, during the last decade, vegetal production represents more than 60% in agricultural output value. The main crops cultivated by Romania are cereals (maize, wheat, but also barley, oats and sorghum), oils seeds crops (sunflower, rape, soybean), and vegetables. Maize, wheat, and also sunflower and rape seeds, a part of vegetables are successfully traded mainly in the EU [34, 35, 40, 41, 44, 45, 46, 48].

3.1. Cultivated area with sunflower and rape

Romania is an important EU producer of sunflower and rape seeds as reflected by the cultivated area. In 2020, sunflower was harvested from 1,170 thousand ha by +17.58% more than in 2011.
The surface covered with sunflower ranged between the minimum 995 thousand ha in 2021 and 1,283 thousand ha, the maximum level reached in 2019 (Fig. 1).

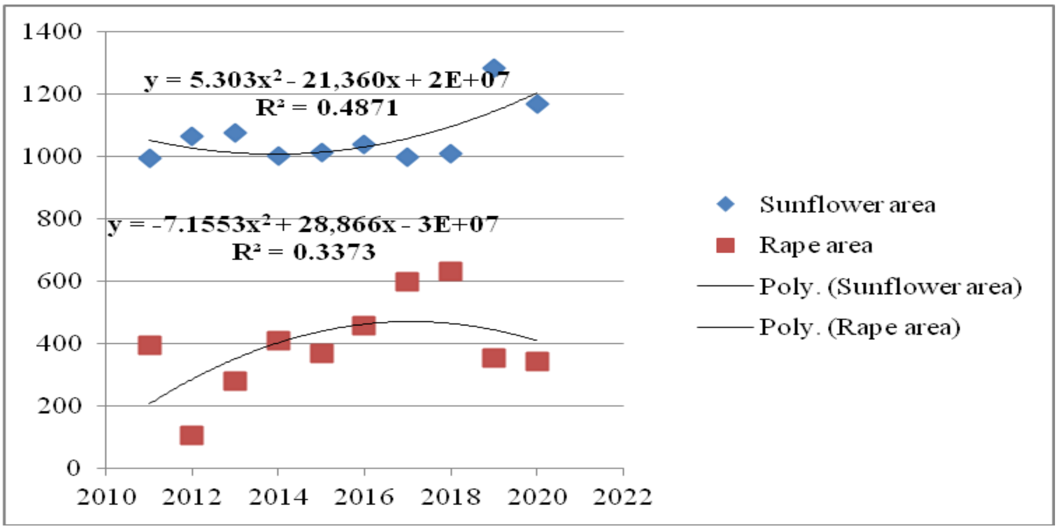

Fig. 1. Dynamics of cultivated area with sunflower and rape, Romania, 2011-2020 (Thousand ha)
Source: Own design and calculation based on the data from [23].

In case of rape, in 2020, the harvested surface accounted for 343 thousand ha being by -12.73% smaller than in 2011. In the last decade, rape was cropped on the minimum surface of 105 thousand ha in 2012, followed by an increase in the next years and then reached the peak of 633 thousand ha in 2018. Then, it substantially dropped by 45% in 2019 and 54% in 2020 (Fig. 1).

3.2. Sunflower and rape seeds production

Romania has a high potential for producing sunflower and rape seeds and the production performance allows Romania to be situated on the 1st position in the EU for sunflower and on the 5th position for rape [41, 43].

Sunflower seeds production increased by 23.19% from 1,789 thousand tons in 2011 to 2,204 thousand tons in 2020. Production varied between 1,398 thousand tons in 2012, a year with a severe drought and the maximum production of 3,569 thousand tons achieved in 2019, In 2020, production was affected by drought and fell to 2,204 thousand tons (-38.3%).

In case of rape, seed production was 728 thousand tons in 2020, by -1.495 smaller than in 2011. Rape performance was deeply affected by the bad climate conditions in 2012, when it registered the minimum level of 158 thousand tons, and also it recorded low performances in 2015, only 919 thousand tons, in 2019 just 798 thousand tons and in 2020 only 728 thousand tons. However, the peak of seeds production was 1,672 thousand tons achieved in 2017 (Fig. 2).

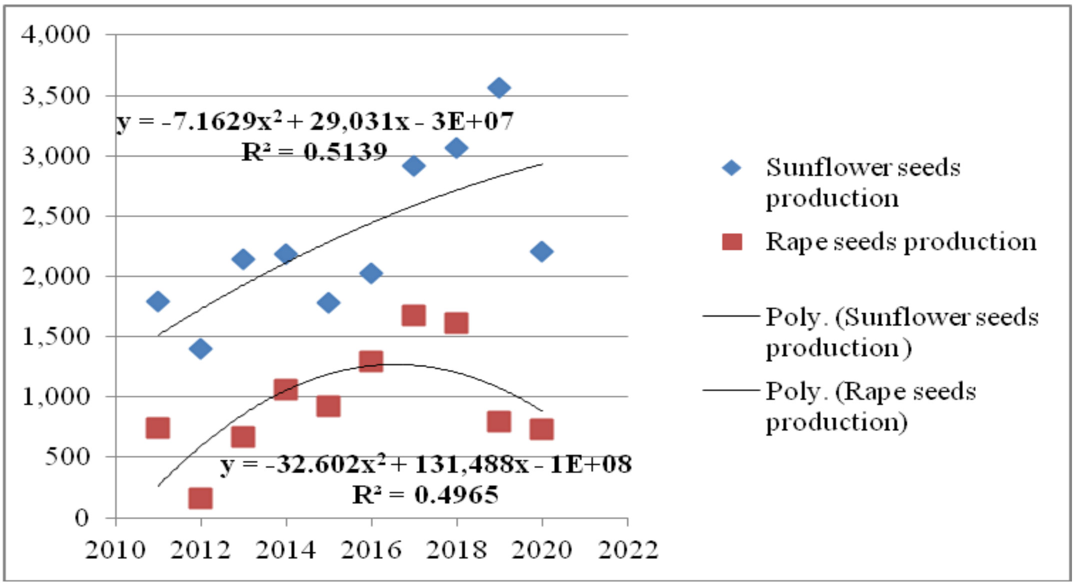

Fig. 2. Dynamics of sunflower and rape seeds production, Romania, 2011-2020 (Thousand tons)
Source: Own design and calculation based on the data from [23].

These crops like many others are particularly sensitive to weather and climate conditions. Spring frosts, summer droughts, heat waves, heavy rainfalls produced significant production losses and compromised seed quality with a deep impact on offer/demand ratio and market price.

For its sunflower seeds production, Romania passed on the top position in the EU and at present has 35% share in the EU sunflower seeds output.
In case of rape seeds production, the country is situated on the 7th position after Germany, France, Poland, Czechia, Lithuania and Hungary [9].

3.3. sunflower and rape seeds yield

The average production per surface unit increased in case of the both crops in the analyzed interval, with a substantial impact on total production. Yields were deeply influenced by the cultivated hybrids structure and their production potential, technologies applied and meteorological and hydrological factors [33].

In 2020, sunflower produced 1,883 kg seeds per ha, by +4.72% more than in 2011, while rape carried out 2,124 kg seeds per ha by +12.85% more.

In case of sunflower, yield varied between 1,310 kg/ha, the minimum level, in 2012, due to the severe drought and 3,041 kg/ha in 2018, a favorable year.
In case of rape, the maximum level accounted for 2,835 kg/ha in 2016 and the minimum performance of 1,496 kg/ha in 2012 (Fig. 3).

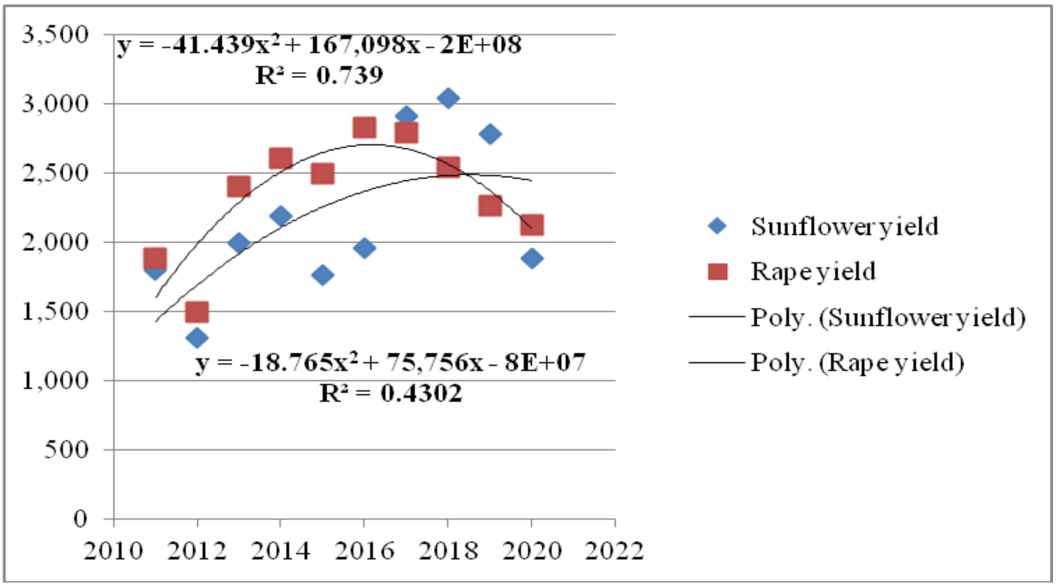

Fig. 3. Dynamics of sunflower and rape seeds yield, Romania, 2011-2020 (kg/ha)
Source: Own design and calculation based on the data from [23].

3.4. Average annual sunflower and rape seed producer's price

Seeds price level was determined by supply/demand ratio so that in the years with a higher production, the price was lower, while in case of the lower production, the price level was higher.
In case of sunflower seeds, the price in national currency ranged between RON 1.58/kg in 2011 and RON 1.5/kg in 2020. The highest price was RON 1.84/kg in 2012 and the lowest one RON 1.26/kg and also RON 1.29/kg in 2019. The price per kg rape seed varied between RON 1.34 in 2014 and RON 1.83 in 2012.
In 2020, a farmer received in average RON 1.5/kg sunflower seed and RON 1.83/kg rape seed, by -5.07% less in case of sunflower and in case of rape by +12.96% more than in 2011.

In this study, the calculation is made in Euro, so that the average price was recalculated according to the average exchange rate Euro/RON provided by National Bank of Romania.
In the period 2011-2020, the national currency "RON" registered a depreciation versus Euro which has deeply influenced the price levels in Euro per ton as used in this research.

In case of sunflower seeds, the average price at farm gate was Euro 310/ton in 2020, by -16.85% smaller than Euro 372.8 per ton in 2011.
In case of rape seeds, the average producer's price accounted for Euro 378.3/ton in 2020, being by =1.03% lower than in 2011 when its level was Euro 382.2 (Fig. 4).

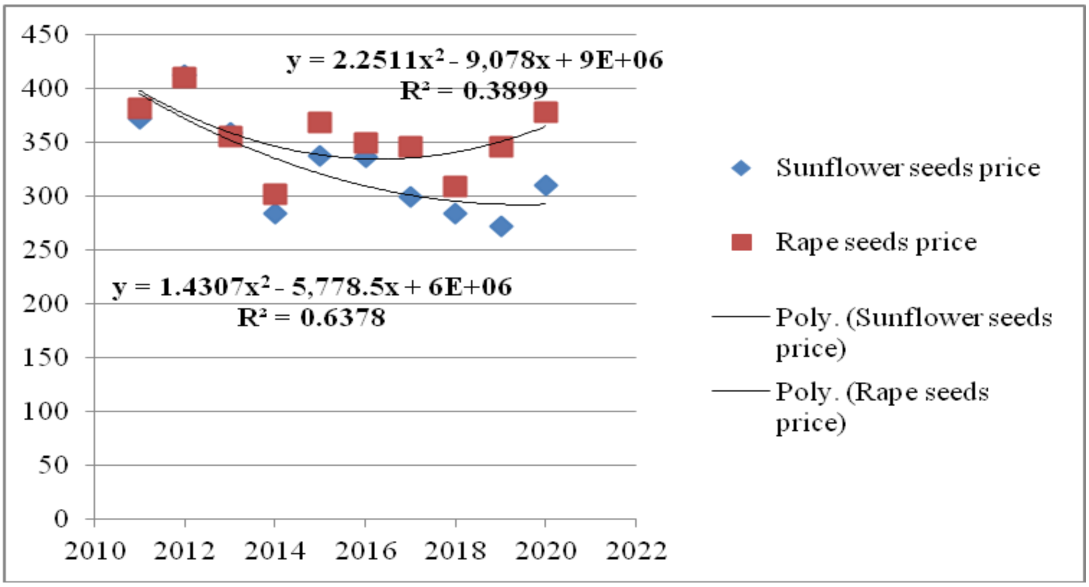

Fig. 4. Dynamics of sunflower and rape seeds producer's price, Romania, 2011-2020 (Euro/ton)
Source: Own design and calculation based on the data from [23].

3.5. Sunflower and rape seed consumption

According to Food Balances provided by National Institute of Statistics, seed consumption increased for sunflower and declined a little for rape in 2019 versus 2011.

In 2019, sunflower seed consumption reached 1,809 thousand tons being by +91.835 higher than 943 thousand tons in 2011.
In case of rape seed consumption, in 2019 it was achieved 492 thousand tons compared to 498 thousand tons in 2011, meaning by -1.21 less (Fig. 5).

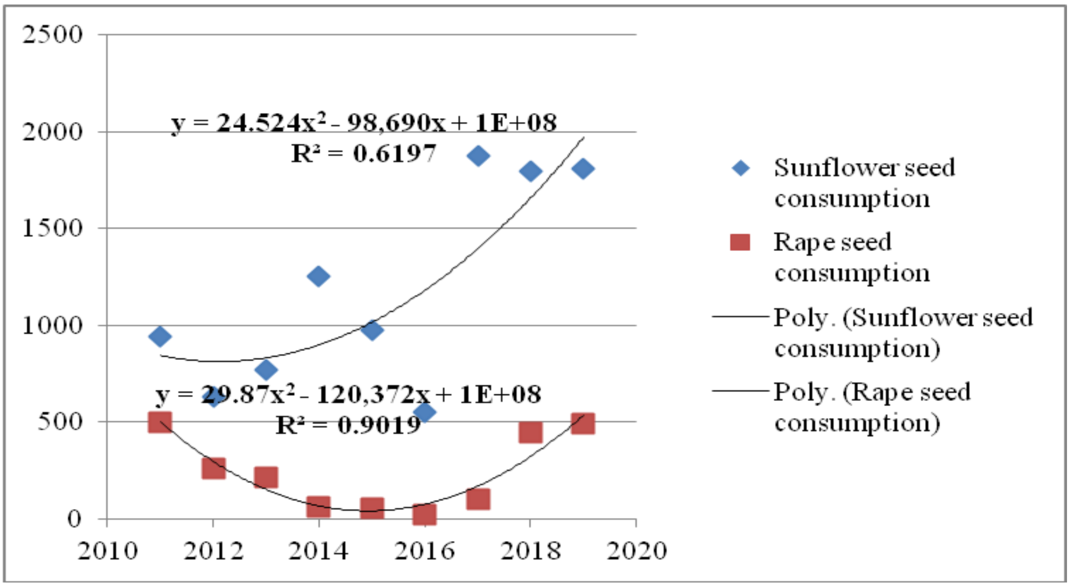

Fig. 5. Dynamics of sunflower and rape seed consumption, Romania, 2011-2020 (Thousand tons)
Source: Own design and calculation based on the data from [24, 25].

3.6. Economic value of sunflower and rape seed production

This indicator was determined based on seed production, Q_1 for sunflower and Q_2 for rape which was multiplied by average annual producer's price in Euro/ton, P_1 for sunflower and P_2 for rape.

Economic value of seed production, EV, taking into account the both crops, registered a slight increase of only + 0.95% in the period 2011-2020. In 2020, it accounted for Euro 958.4 million compared to Euro 949.3 million in 2011.

However, the peak of EV was Euro 1,452.6 million registered in 2017, while the minimum value of Euro 642.1 million was noticed in 2012, the most unfavorable year for these crops and not only (Table 1).

Table 1. Economic value of seed production, Romania, 2011-2020

	Seed production (Thousand tons)		Average annual seed price (Euro/ton)		Economic value of seed production (Euro million)		
	Q_1 Sunflower	Q_2 Rape	P_1 Sunflower	P_2 Rape	EV_1 Sunflower	EV_2 Rape	Total EV
2011	1,789	739	372.8	382.2	666.9	282.4	943.3
2012	1,398	158	412.9	410.7	577.2	64.9	641.1
2013	2,142	666	359.8	366.3	770.7	236.6	1,007.3
2014	2,189	1,059	283.5	301.5	620.6	319.3	939.9
2015	1,786	919	337.5	369.0	602.8	339.1	941.9
2016	2,032	1,293	336.2	346.6	683.1	451.0	1,135.1
2017	2,913	1,673	300.0	345.9	873.9	578.7	1,452.6
2018	3,063	1,611	283.6	309.4	868.7	498.5	1,367.2
2019	3,569	798	271.9	345.6	970.4	275.8	1,246.2
2020	2,204	728	310.0	378.3	683.2	275.4	958.4
2020/2011 %	123.19	98.51	83.15	98.97	102.4	97.52	100.95

Source: Own calculation based on the data from [23].

3.7. Insect pollination economic value

Insect pollination economic value, IPEV, for sunflower, rape and total oilseeds crops was calculated based on the economic value of seed production multiplied by production dependency ratio of insect pollination which was considered 30% for sunflower and 25% for rape.

In case of sunflower, the economic value of seed production, $IPEV_1$, achieved due to insect pollination increased from Euro 200.07 million in 2011 to Euro 204.96 million in 2020 that is by +2.44%. This was due to the ascending evolution of sunflower seed production, which had a positive impact and by the decline in seed price, which had a negative effect.

In case of rape, the economic value of pollination on seed production, $IPEV_2$, registered a slight decline of -2.48% from Euro 70.6 million in 2011 to Euro 68.85 million in 2020. This situation was also caused by the dynamics of production and price elasticity.

However, taking into account the economic value of insect pollination, ΣIPEV, on oilseeds crops, it was noticed a growth rate of +1.16% in the whole studied interval from Euro 270.67 million in 2011 to Euro 273.81 million in 2020.

Therefore, in 2020, the farmers cultivating sunflower and rape for seeds registered an additional income of Euro 273.81 million grace to the pollination service made by insects, especially by bees whose contribution is about 80% in normal conditions (Table 2).

Table 2. Insect pollination economic value, Romania, 2011-2020 (Euro million)

	$IPEV_1$- Sunflower	$IPEV_2$-Rape	ΣIPEV
2011	200.07	70.6	270.67
2012	173.16	15.22	189.38
2013	231.21	59.15	290.36
2014	186.18	79.82	266.00
2015	180.84	84.77	265.61
2016	204.93	113.00	317.93
2017	262.17	144.67	406.84
2018	260.61	124.62	385.23
2019	291.12	68.95	360.07
2020	204.96	68.85	273.81
2020/2011 %	102.44	97.52	101.16

Source: Own calculation, original results.

3.8. Vulnerability rate to insect pollination decline

A general phenomenon is pollination service decline due to the reduction in insect population caused by many factors among which could be considered the implementation of the modern technologies based on self pollinating hybrids, the use of plant protection treatments with neuro-systemic insecticides (neonicotinoides) and climate change.

For this reason, it is important to evaluate the vulnerability rate to insect pollination decrease, in this study for the first time in Romania with the example on oilseeds crops sunflower and rape.

Vulnerability rate, VR%, reflects the percentage of decline of the insect pollination economic value if pollination service is diminished.

The calculation proved that in case of oilseeds crops in Romania, in the period 2011-2020, vulnerability rate increased from 28.51% in 2011 to 28.57% in 2020. During this interval, it was registered the highest vulnerability rate accounting for 29.49% in the year 2012 considered an unfavorable year due to climate conditions (a long and severe drought). The lowest level of the vulnerability rate was 28%, recorded in 2017 and 2017 (Fig. 6).

In Europe, a study made by Holland et al (2020) on pollination limitation in four entomophilous crops (oilseed rape, sunflower, pears and pumpkin) showed that pollination service on crops is worsening due to the decline of pollinators in farmlands, but because the reduction in sunflower and rape production was just 8% and respectively 6%, it was considered that "yields in these crops were not severely pollination-limited" in the six European countries taken into consideration in this research [16].

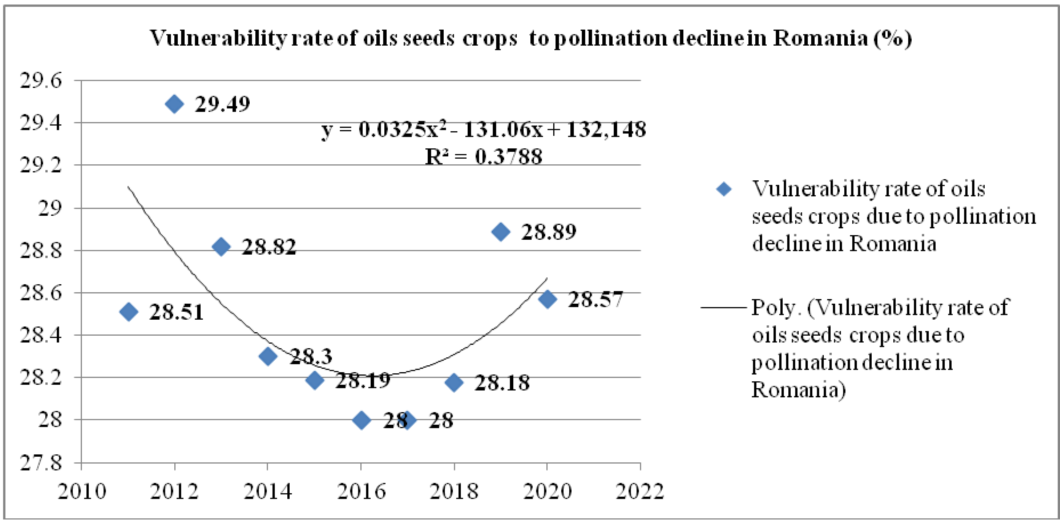

Fig. 6. Dynamic of vulnerability rate of oils seeds crops to insect pollination decline in Romania, 2011-2020 (%)
Source: Own calculation, original results.

3.9. Comparison between production and consumption of oilseeds

In order to assess the total pollination loss due to the decline in pollinators number, it was needed to determine the difference between seed production and consumption, respectively: $Q_i - C_i$, and the ratio between production and consumption: Q_i/C_i.

The results showed that Q_i/C_i in case of rape crop had higher values compared to sunflower, because the consumption of rape seeds is smaller than the one of sunflower seeds, and this happened in the period 2014-2018.

Table 3. Comparison between production and consumption for oils seeds crops in Romania, 2011-2019

	$Q_i - C_i$		$\Sigma(Q_i - C_i)$	ΣC_i	$\frac{Q_i - C_i}{C_i}$		$\frac{\Sigma(Q_i - C_i)}{\Sigma C_i}$
	Sunflower	Rape			Sunflower	Rape	
2011	846	241	1,087	1,441	0.89	0.48	0.75
2012	765	-103	662	894	1.21	- 0.39	0.74
2013	1,373	450	1,823	955	1.79	2.08	1.91
2014	934	997	1,931	1,317	0.74	16.08	1.47
2015	812	865	1,677	1,028	0.83	16.02	1.63
2016	1,479	1,269	2,748	577	2.67	52.87	4.76
2017	1,035	1,574	2,609	1,977	0.55	15.89	1.32
2018	1,268	1,166	2,434	2,240	0.71	2.62	1.09
2019	1,760	306	2,066	2,301	0.97	0.62	0.89

Source: Own calculation and original results based on the data from [24, 25].

Analyzing Q_i/C_i for the both oilseeds crops, the results were higher than 1 in the period 2013-2019 and especially in 2016, when this ratio was 4.76, the maximum value. In 2011, 2012 and 2019, this ratio was smaller than 1 (Table 3).

3.10. The matrix after total pollination loss

Taking into account Q_i/C_i values and the dependence degree on pollination, it was calculated the matrix after total pollination loss according to Gallai (2009) formula, adapted for oilseeds crops in Romania.

The results are presented in Table 4 and show that M value was below 1 in almost the whole analyzed period, except the year 2013 when M value was over 1 and the year 2016 when M > 3.

Therefore, the farmers have to be aware of the importance of insect pollination in sustaining crop production, product quality, biodiversity of cultivated crops and insects world.

Table 4. Matrix after total pollination loss

	$Q_i\ (1-D)_i\ -\ C_i$ (Thousand tons)		$\frac{\sum_{i=1}^{n}(Q_i\ (1-D)_i\ -\ C_i}{\sum_{i=1}^{n} C_i}$ (Thousand tons)	$\sum_{i=1}^{n} C_i$ (Thousand tons)	$\frac{\sum_{i=1}^{n}(Q_i\ (1-D)_i\ -\ C_i}{\sum_{i=1}^{n} C_i}$
	Sunflower	Rape			
2011	309.3	56.2	365.5	1,441	0.2536
2012	345.6	-142.5	203.1	894	0.2271
2013	730.4	283.5	1,013.9	985	1.0290
2014	277.3	732.25	1,009.55	1,317	0.7665
2015	276.2	635.25	911.45	1,028	0.8866
2016	869.4	945.75	1,815.15	577	3.145
2017	161.1	1,155.75	1,316.85	1,977	0.6660
2018	349.1	763.25	1,112.35	2,240	0.4965
2019	689.3	106.5	7954.8	2,301	0.3458

Source: Own calculation and original results based on the data from [24, 25].

Conclusions

(1) This research proved the first time in Romania that insect pollination service has definitely a positive economic impact increasing oilseeds production value in the year 2020 by about Euro 204.96 million in case of sunflower and by Euro 68.85 million in case of rape.

Therefore, the farmers have to make use of insect pollination service for obtaining production gain, additional incomes, for preserving biodiversity and protecting environment quality.

(2) In 2020, the value of the production gain for the both oilseeds crops: sunflower and rape, due to insect pollination accounted for Euro 273.81 million.

(3) The vulnerability rate to pollination decline in oilseeds crops in Romania was 28.57% in the year 2020, which is an alarm bell for taking measures to sustain pollinators, farmers, beekeepers, biodiversity and ecosystems.

(4) The production/consumption ratio of oilseeds was over 1 in the period 2013-2018, which is a positive aspect reflecting that consumption needs were well covered by internal production, imports being required only in the year 2011, 2012 and 2019.

(5) The matrix value after the pollination loss was below 1in almost the whole studied interval, except 2013 and 2016 when it was higher than 1.

(6)As a final conclusion, insect pollination service, especially the one provided by bees is very important in Romania for the sustainable development of oilseeds production, for obtaining production gains and a higher seed quality, for increasing farmers income and profitability of their business, for maintaining biodiversity, the quality of environment factors and the balance in the ecosystems and for strengthening the good relationships between agronomists and apiculturists for sustaining both the vegetal agriculture and beekeeping sector.

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