Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 1, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC VALUE OF POLLINATION OF ORCHARDS, CASE OF MOLDOVA AND POLAND

Janusz MAJEWSKI[1], Daniela POPA[2], Agnieszka SOBOLEWSKA[1]

[1]Warsaw University of Life Sciences - SGGW, Department of International Economics and Agribusiness, 166 Nowoursynowska St., 02-787 Warsaw, Poland, Phones: 048/225934112; 048/225934108; E-mails: janusz_majewski@sggw.edu.pl; agnieszka_sobolewska@sggw.edu.pl
[2]State Agrarian University of Moldova, 44, Mircesti st., MD-2049, Chisinau, Republic of Moldova; E-mail: d.popa@uasm.md

Corresponding author: janusz_majewski@sggw.edu.pl

Abstract

The aim of the paper was to estimate the economic value of pollination of fruit plants in Moldova and Poland and to determine the factors differentiating these values. The study presents the characteristics of fruit growing in the studied countries. Then, using the method of production value obtained as a result of pollination, the values of pollination of the main fruit plants in Moldova and Poland in 2014-2018 were estimated. In both countries, the value of pollination in orchards increased, in Moldova from EUR 33.8 million in 2014 to EUR 95.7 million in 2018. In Poland, the value of pollination in orchards increased from EUR 512.9 million in 2014 to EUR 679.6 million in 2018. The pollination value of 1 hectare of an orchard in Moldova increased from EUR 447.6 in 2014 to EUR 1038.7 in 2018, and in Poland from EUR 2053 in 2014 to EUR 2830.2 in 2018. The variation in pollination values for individual species resulted from differentiation purchase prices and the yield.

Key words**:** *pollination, economic value of pollination, dependency ratio method*

INTRODUCTION

Agriculture uses a variety of services provided by the natural environment [10]. The development of conventional agriculture, focused on maximizing production, has negative effects on the environment. The intensification of agriculture leads to a reduction in biodiversity in the natural environment [13] and a reduction in the value of services provided by ecosystems [12]. To counteract this, a comprehensive approach to the functions performed by agriculture should be approached through the development of multifunctional agriculture [5] or sustainable [8]. In both of these concepts, beekeeping is an important element, providing people and the natural environment with many goods and services.

Among the services provided to the environment by beekeeping, plant pollination is the most important. By pollinating plants, beekeeping has a positive effect on biodiversity, the natural environment and the yield of crops [11, 25, 23]. It is estimated that about 35% of food produced in the world depends on pollination by pollinating insects, especially by the honey bee (*Apis mellifera*) [24]. Out of 115 species of the world's major crops, 87 of them depend on animal pollination. For 70 plant species, the impact of pollination on yields can be described as at least significant [11, 14, 16]. Among the crops with the highest importance of pollination in terms of height and quality of crops are fruit plants [11, 19, 7].

The world value of pollination of arable crops was estimated at EUR 153 billion per year, of which over 30% was fruit pollination [6]. In addition to research on the global value of pollination of crops, the values for regions or individual countries were also estimated. It was estimated, among others the values of pollination of crops for European Union countries [15] and also for the USA [19], Poland [26, 17], England [2], Brazil [7] and other countries. Research was also carried out on the pollination value for individual plants. Many of these works concerned pollination of apple trees [22]. Research on the estimation of

the value of pollination of other fruit plants was conducted much less frequently.

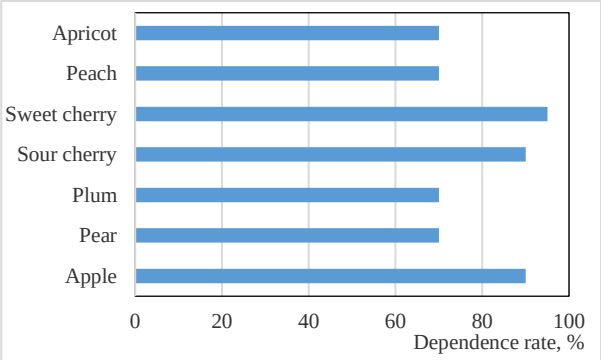

Fig.1. Pollinator dependence of yields of selected orchards plants, in %
Source: own Authors' elaboration based on [10].

The study attempts to estimate the pollination value of the main fruit plants in Moldova and Poland. According to the authors' knowledge, this type of research has not been conducted in Moldova. The authors only know the studies on the efficiency of sunflower pollination in Moldova [3]. In Poland, however, research was conducted on the determination of the value of pollination of crops [26, 17]. However, no studies on the value of pollination of fruit plants were conducted in both countries. The selection of fruit plants for analysis resulted, apart from the above, from the large influence of pollination on the yield of these plants (Fig. 1). The novelty in the study is, on the one hand, the determination of the pollination value of fruit plants in the years 2014-2018 for the studied countries, and, on the other hand, a comparison of the obtained pollination values of fruit plants and an attempt to indicate the reasons for the obtained differences. There are no studies in the literature indicating the value of pollination of fruit plants per unit area of these crops.
The main purpose of the study is to compare the pollination values of the main fruit plants in Moldova and Poland, and to attempt to identify factors that differentiate the pollination values. As part of this objective, the value of pollination of the main fruit plants (apple, pear, plum, cherry, sweet cherry, apricot and peach) was estimated using the production value obtained as a result of insects pollination (the dependency ratio method). The value of pollination for individual fruit plants was estimated for countries and per one hectare of cultivation.

MATERIALS AND METHODS

The dependency ratio method was used to estimate the value of pollination of fruit plants in Moldova and Poland. It is the method most often used to estimate the value of pollination of crops [6, 1, 4, 9, 18], therefore the obtained results can be compared with the results of other authors. In the dependency ratio method, the production value of entomophilous plants (in our case, fruit plants) is corrected by the indicator determining the influence of pollinating insects on the yield (*D*). In order to estimate the production value, the average annual fruit buying-in prices in Moldova and Poland obtained from the National Statistics Bureau of the Republic of Moldova and from Statistics Poland (Polish statistical office) were used. Data from the National Bank of Moldova and National Bank of Poland were used to convert pollination values in euro. For this purpose, the average annual exchange rates provided by the national banks of Moldova and Poland were used.
For each of the fruit plants, the value of pollination by insects was estimated according to the formula [6]:

$$EVP = D * P * Q$$

where:
EVP - plant pollination value,
D - dependence of crops on pollination by insects,
P - average annual purchase price of fruit of the plant species,
Q – annual production volume of a the plant species.
Values estimated in this way for individual fruit plants were summed up for individual countries. Moreover, the obtained values were related to the cultivation area of individual plants in the studied countries, estimating the average pollination values of 1 hectare of fruit plants.

RESULTS AND DISCUSSIONS

Characteristics of fruit production in Moldova and Poland

Horticulture production is an important part of agriculture. Fruit plants provide fruit which, apart from vegetables, are a source of vitamins and microelements, being an important element of the human diet.

Table 1. Area and structure of fruit trees cultivation in Moldova and Poland in 2014-2018

Specification	2014	2015	2016	2017	2018
Moldova					
Total, in thousands of hectares	75.52	93.04	91.92	95.04	92.11
share, in %					
Apple	59.4	59.2	57.5	56.5	56.1
Pear	2.4	2.1	2.6	2.9	3.0
Plum	21.1	20.4	21.2	20.7	21.7
Sour cherry	3.5	3.3	3.5	4.4	3.9
Sweet cherry	3.3	3.4	3.6	3.8	4.0
Apricot	3.3	3.2	3.5	3.8	4.1
Peach	7.1	8.3	8.1	7.9	7.2
Poland					
Total, in thousands of hectares	249.76	246.22	242.21	241.10	240.14
share, in %					
Apple	70.6	73.3	73.2	73.1	73.1
Pear	4.0	3.7	3.2	3.2	3.2
Plum	6.6	5.6	6.0	5.9	6.0
Sour cherry	12.8	12.0	12.1	12.2	12.2
Sweet cherry	4.3	3.9	4.0	4.0	4.1
Peach and apricot	1.6	1.5	1.5	1.5	1.5

Source: Authors' own calculation on the basis of data from Statistical Yearbook of the Republic of Moldova 2019, Chisinau 2019 and Statistical Yearbook of Agriculture 2019, Warsaw 2020 [25, 26].

The area of orchards in Moldova and Poland in 2014-2018 is presented in Table 1. Apple trees prevail in the structure of orchards in both countries. In the analyzed period, they accounted for 56 to 59% of the orchard area in Moldova. In Poland, the share of apple trees in orchards was 70-73%. In the case of Moldova, plums, whose share in the orchard area ranged from 20-22%, and peaches with 7-8% in the orchard area, played an important role in the orchard area. On the other hand, in Poland, apart from apple trees, cherries had a significant share in the orchard area, with about 12%. In the case of other fruit plants in Poland, their share did not exceed 8% of the orchard area (Table 1). The varied surface structure of orchards in the studied countries may result from natural conditions. Moldova has a milder climate than Poland, therefore peaches and apricots have a greater share in the structure of fruit crops. Poland, on the other hand, has good natural conditions for apple cultivation, therefore their share in the structure of fruit crops in Poland is the highest (Table 1).

The production of fruit from orchards in the years 2014-2018 in Moldova and Poland was characterized by an increase, however, with significant differentiation in individual years (Table 2).

Table 2. The volume of fruit production from trees and their structure in Moldova and Poland in 2014-2018

Specification	2014	2015	2016	2017	2018
Moldova					
Total, in thousands of tonnes	477.3	467.5	570.0	634.5	857.4
share, in %					
Apple	77.5	65.8	72.2	76.8	77.6
Pear	1.0	1.3	0.9	0.7	0.6
Plum	15.3	21.4	17.5	14.7	15.5
Sour cherry	0.9	1.3	0.7	0.8	0.9
Sweet cherry	1.6	2.7	1.3	1.7	1.4
Apricot	1.5	2.2	3.8	2.1	1.1
Peach	2.1	5.3	3.6	3.3	2.9
Poland					
Total, in thousands of tonnes	3,611.9	3,572.8	4,055.6	2,651.5	4,483.9
share, in %					
Apple	88.5	88.7	88.9	92.1	89.2
Pear	2.0	1.9	2.0	2.1	2.0
Plum	2.9	2.7	2.7	2.2	2.7
Sour cherry	4.9	5.0	4.8	2.7	4.5
Sweet cherry	1.3	1.3	1.3	0.7	1.3
Peach and apricot	0.3	0.3	0.3	0.2	0.3

Source: Authors' own calculation on the basis of data from Statistical Yearbook of the Republic of Moldova 2019, Chisinau 2019 and Statistical Yearbook of Agriculture 2019, Warsaw 2020 [25, 26].

The variability of the harvest in the following years was largely due to weather conditions. In Moldova, the increase in production was around 80%, and in Poland around 20%. This differentiation resulted from a larger scale of production in Poland than in Moldova. In addition, it can be concluded that fruit production in Poland is well developed, while in Moldova this development is still progressing.

Apples dominate in the structure of fruit production from trees in both analyzed countries. Their share in fruit production is higher than that in the orchard area due to higher yields than in the case of other fruit plants (Table 3). In Moldova, plums also had a relatively large share (15-21%) in fruit production. The share of other fruits usually did not exceed 5% of fruit production in Moldova. On the other hand, in Poland, apples accounted for 88-92% of fruit production in the analyzed period. Among the remaining fruits, cherries were of the greatest importance (3-5% of fruit production).

Table 3. Yields of fruit from fruit trees in Moldova and Poland in 2014-2018, tonnes per hectare

Specification	2014	2015	2016	2017	2018
Moldova					
Apple	8.3	5.6	7.8	9.1	12.9
Pear	2.8	3.0	2.0	1.6	1.9
Plum	1.7	2.0	1.3	1.2	2.2
Sour cherry	3.1	3.9	2.3	3.0	3.3
Sweet cherry	2.9	3.5	6.6	3.6	2.5
Apricot	1.9	3.2	2.7	2.8	3.7
Peach	4.6	5.3	5.1	4.7	6.7
Poland					
Apple	18.1	17.6	20.3	13.8	22.8
Pear	7.4	7.5	10.4	7.1	11.8
Plum	6.4	6.8	7.5	4.1	8.4
Sour cherry	5.5	6.1	6.6	2.4	6.9
Sweet cherry	4.5	5.1	5.6	2.1	6.1
Peach and apricot	3.0	3.3	3.1	1.5	3.3

Source: Authors' own calculation on the basis of data from Statistical Yearbook of the Republic of Moldova 2019, Chisinau 2019 and Statistical Yearbook of Agriculture 2019, Warsaw 2020 [25, 26].

There were no significant changes in the structure of fruit production from orchards in Moldova and Poland in 2014-2018. In most cases, the differences in the structure of fruit production in the analyzed years did not exceed 1 percentage point. The exception in the case of Poland is the production of sour cherries in 2017, when their share in fruit production decreased by over 40% compared to the previous year, which resulted from a drop in yields of over 4 tons per hectare. This was due to the fact that 2017 was characterized by bad weather conditions for fruit cultivation and the yields this year for all species of fruit plants in Poland were significantly lower than in the other analyzed years (Table 3). Additionally, in the case of cherries, the increase in purchase prices was not as high as in the case of other fruits, which resulted in a decrease in their share in the value of pollination of fruit plants.

The yielding of fruit plants results from many factors, related both to the species and varieties of cultivated plants, as well as to the production technology and natural conditions. When comparing the yield of fruit plants in Moldova and Poland, it can be noticed that in Poland, significantly higher yields were obtained in most species than in Moldova. This is due to the greater specialization of agriculture in Poland than in Moldova. Only in the case of peach and apricot yields, the differences can be considered slight, which may result from better natural conditions for growing these plants in Moldova than in Poland.

Economic value of pollination of fruit plants in Moldova and Poland - comparative analysis

Pollination is an essential procedure to obtain fruit from orchards. Most often, pollination of plants is carried out using the honey bee. The economic value of pollination is estimated to indicate the importance of this treatment for horticulture. It can also be the basis for determining the value of paying a beekeeper for using bees for pollination or for creating apiculture policy.

The value of pollination of fruit plants in 2014-2018 in Moldova increased almost threefold, from EUR 34 million in 2014 to almost EUR 96 million in 2018 (Table 4). It was influenced by both the increase in the

area of horticultural crops and the increase in the purchase prices of the produced fruit. In Poland, in the same period of time, the value of pollination in orchards also increased from almost EUR 513 million in 2014 to EUR 680 million in 2018 (Table 4). The lower growth rate of the pollination value in Poland compared to Moldova resulted from relatively small changes in the production volume. It is also worth noting that the highest value of pollination of fruit plants was achieved in both countries in 2017.

Table 4. The economic value of pollination of selected fruit plants in Moldova and Poland in 2014-2018, EUR million

Specification	2014	2015	2016	2017	2018
Moldova					
Total, in million EUR	33.8	57.7	64.1	102.0	95.7
share, in %					
Apple	66.4	64.7	71.1	76.1	73.5
Pear	1.6	1.9	1.0	0.8	1.0
Plum	13.4	15.2	12.1	11.7	11.4
Sour cherry	2.9	3.4	2.3	2.0	3.1
Sweet cherry	8.1	7.0	3.9	4.1	5.6
Apricot	3.5	2.9	5.5	2.4	2.1
Peach	4.1	4.9	4.1	2.8	3.4
Poland					
Total, in million EUR	512.9	713.8	596.2	694.8	679.6
share, in %					
Apple	70.8	74.3	73.1	77.1	77.0
Pear	4.1	3.3	4.3	3.4	4.3
Plum	2.7	3.3	3.4	3.3	2.5
Sour cherry	8.8	9.2	9.1	8.7	6.7
Sweet cherry	12.3	8.4	8.6	6.4	8.6
Peach and apricot	1.3	1.6	1.5	1.1	1.0

Source: Authors' own calculation on the basis of data from Statistical Yearbook of the Republic of Moldova 2019, Chisinau 2019 and Statistical Yearbook of Agriculture 2019, Warsaw 2020; National Bank of Moldova (BNM); National Bank of Poland (NBP) [20, 21, 25, 26].

In the case of Poland, it was the year with the lowest fruit production among the analyzed years. The highest value of pollination this year resulted from high purchase prices. Therefore, it can be concluded that in the years of crop failure, the purchase prices increase more than the decrease in production. The same was true in Moldova, where despite the higher fruit production in 2018 by more than 30% than the year before, the estimated value of pollination in orchards was higher in 2017.

The differences in the global value of pollination of fruit plants in Moldova and in Poland result from a significant difference in the size of the studied countries. Therefore, it is worth comparing the estimated values of pollination of fruit plants per hectare of orchards.

The average value of pollination in an orchard in Moldova in 2014 was EUR 447.6 per hectare and was almost five times lower than in Poland (Table 5).

This difference resulted from lower yields and lower fruit purchase prices in Moldova compared to Poland.

Table 5. The economic value of pollination of selected fruit plants in Moldova and Poland in 2014-2018, EUR per hectare

Specification	2014	2015	2016	2017	2018
Moldova					
Apple	500.1	677.7	862.1	1,445.8	1,360.0
Pear	300.5	555.3	258.0	303.7	330.9
Plum	364.9	625.5	456.2	496.0	832.1
Sour cherry	1,115.9	1,262.4	770.0	1,154.5	1,429.8
Sweet cherry	479.2	555.5	1,085.1	682.3	533.0
Apricot	259.5	368.1	354.6	376.3	487.4
Peach	284.8	461.1	397.5	609.2	548.4
Average	447.6	619.7	697.2	1,073.3	1,038.7
Poland					
Apple	2,060.6	2,939.3	2,460.7	3,037.6	2,981.3
Pear	2,088.5	2,530.8	3,259.1	3,047.6	3,770.7
Plum	846.4	1,708.0	1,412.5	1,602.2	1,163.4
Sour cherry	1,405.7	2,208.6	1,853.7	2,055.0	1,556.4
Sweet cherry	5,860.2	6,286.1	5,304.1	4,609.5	5,987.7
Peach and apricot	1,601.6	3,159.7	2,345.1	2,150.7	1,832.9
Average	2,053.6	2,899.2	2,461.5	2,881.6	2,830.2

Source: Authors' own calculation on the basis of data from Statistical Yearbook of the Republic of Moldova 2019, Chisinau 2019; Statistical Yearbook of Agriculture 2019, Warsaw 2020; National Bank of Moldova (BNM); National Bank of Poland (NBP) [20, 21, 25, 26].

In the following years, the differences between the value of pollination of an orchard hectare in Moldova and in Poland decreased

and in 2018 the average value of pollination of an orchard hectare in Moldova was approximately 1.8 times lower than in Poland.
In Moldova, the highest estimated pollination values were for cherries and apples. This was due to the relatively highest yielding of these crops as compared to other fruit plants in Moldova. Additionally, in the case of cherries, the high purchase prices of these fruits had an impact on the high pollination value, compared to other fruits from trees.
In Poland, the highest pollination value was estimated for sweet cherries in all the years studied. The value of hectare pollination in these orchards was estimated at EUR 4,610-6,286 per hectare (Table 5). Such a high value of pollination resulted mainly from the high purchase prices of cherries, significantly higher than in the case of other fruit from trees in Poland. For other tree fruits, the orchard hectare pollination value was at least EUR 2,000 lower. The lowest pollination values for fruit trees were obtained in Poland for plums and cherries, for which the pollination value in 2018 was EUR 1,153 per hectare and EUR 1,556 per hectare, respectively.
The diversity of the pollination value of fruit plants in Moldova and Poland was significant. The increase in fruit purchase prices in Moldova in the analyzed period resulted in a significant increase in the estimated value of pollination in orchards. In the case of Poland, the average value of pollination in orchards was more stable. However, the presented values still differ significantly in individual years.

CONCLUSIONS

Pollination of entomophilous crops is a critical procedure that determines the possibility of obtaining a crop. Their amount and quality largely depend on the pollination most frequently carried out by bees.
Horticultural plants are a group of cultivated plants, the yield of which depends to a large extent on pollination by insects. This share in the literature is usually estimated at 70% to 100% of the yield. This proves the key role of pollinating insects in obtaining crops of these plants.
The conducted research allows to conclude that the value of pollination of fruit plants in Moldova and Poland varies depending on the plant species and the year of research. This is due to the diversity of plant yields in the following years, as well as the volatility of the purchase prices of fruit.
The estimated value of pollination in orchards in Moldova in 2014 amounted to EUR 33.8 million and increased to EUR 95.7 million in 2018. In Poland, this value increased from EUR 512.9 million in 2014 to EUR 679.6 million in 2018. The difference in the value of pollination results, among others, from countries of various sizes. Per hectare of orchards, the value of pollination in Poland was 1.8 to almost five times higher than in Moldova. This was due to the higher productivity of orchards in Poland than in Moldova and higher fruit purchase prices.
The presented results indicate a decisive role of pollinating insects, especially honey bees, in the obtained yields of fruit plants. It is also worth paying attention to the fact that the pollination of orchards by insects not only determines the amount of crops, but also improves their quality..

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