ECONOMIC VALUE OF POLLINATION OF MAJOR CROPS IN POLAND IN 2012

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Abstract. Bees are the single most important species of pollinators in Poland. They are responsible for 90-95% of pollination carried out by insects. Their importance has been growing due to the wild pollinators' population being reduced by humans. In Poland, over 1.28 million beehives were in operation in 2012. This number only satisfies 53% of the minimum pollination needs of major entomophilous plants at the peak of their flowering. This also affects the yield of the plants and a decline in the quality of the crop.

The yield values obtained by pollination and losses resulting from the low number of pollinators for selected crops have been estimated in the paper. The major entomophilous plants flowering at approximately the same time included rape and agrimony, apple, pear, plum, sweet and sour cherry orchards as well as currant and gooseberry. The plantation yield obtained in Poland in 2012 owing to the pollination by bees is valued at EUR 825.1 million, and losses resultant from too low number of pollinators are estimated at EUR 728.5 million.

Key words: Poland, pollination, economic effects of pollination.
JEL code: Q57

Introduction

Beekeeping is an important sector of agriculture. Bees provide their products to humans, the most important of which is honey. Apart from that pollen, propolis, royal jelly, beeswax and bee venom are also obtained from bees. On the contrary, apiculture plays the role of service providers of sorts in the pollination of plants, including domesticated plants. Pollination is the chief advantage derived from the breeding of bees. It is estimated that, by pollinating plants, these insects contribute benefits to the economy which are from ten to even a hundred times greater than the value of their products (Prabucki, 1998). It is estimated that the production of approximately one third of food produced globally is directly or indirectly dependent on plant pollination by bees (Gojmerac, 1983).

In Poland's geographical zone, approximately 78% of all plant species are pollinated by insects; such plants are referred to as entomophilous plants (Prabucki, 1998). Domesticated plants are among them. In Poland, there are about 60 species of cultivated plants dependent on pollination, mainly performed by bees (Banaszak, 1987). In economic terms, rape and agrimony, fruit plants and shrubs, most perennial permanent stock as well as buckwheat belong to the most important entomophilous plants cultivated in Poland. Pollinators also play an important role in the production of vegetable seeds, herbs, and flowers.

The most important role in insect pollination is played by *Apidae*, including honeybees, which account for approximately 90-95% of the pollination by insects (Bornus, 1982).

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The importance of honeybees in the pollination of plants is increasing. This is caused, *inter alia*, by (Majewski, 2011):

- changes in the production technology;
- large areas of monocultures hindering the access of pollinators living in the wild to plants;
- limiting the area of non-farming land;
- environmental pollution;
- improper use of plant protection products.

The predominant role of bees in the pollination of entomophilous plants in Poland indicates the need to investigate the economic value of pollination. The purpose of this article is to determine the number of bee colonies needed for the pollination of major entomophilous crops in Poland in 2012. An attempt has also been made to determine the value of the harvest obtained owing to the pollination as well as the estimated losses resulting from an insufficient number of pollinators as compared with the needs. The study included the following plants: rape and agrimony, fruit plants, including apple trees, pear trees, plum trees, sweet and sour cherries trees as well as shrubs and perennial permanent stock, which included strawberries, raspberries, currants, and gooseberries.

The study used data from the Central Statistical Office in Warsaw, Apiculture Department in Pulawy of the Institute of Horticulture in Skierniewice (formerly the Institute of Pomology and Floriculture), the National Bank of Poland and the Polish Ministry of Agriculture and Rural Development as well as literature. Statistical data were used among other things to indicate the size of major cultivations of entomophilous plants in Poland and to determine the value of the harvest obtained owing by pollination. The impact of bees on the size of the crops was determined based on the literature.

In determining the economic value of pollination, it was assumed that bees pollinate plants flowering approximately at the same time to an equal degree. This assumption was also used in the estimation of the yield obtained from crops without pollination and with full pollination. The economic value of pollination was estimated as the value of the crop obtained owing to pollinators (the difference between the actual value of the crop and the potential value of the crop without accounting for pollination). In turn, a loss resulting from an insufficient number of pollinators was established as the difference between the achievable value of the harvest in the case of full pollination and the actual value of the harvest.

Research results and discussion

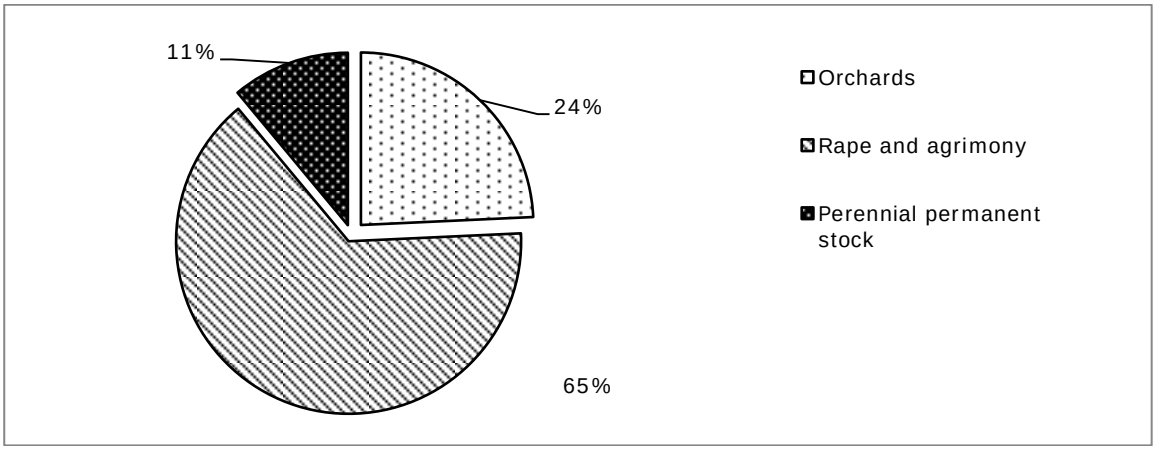
Pollinating needs of domesticated plants in Poland

Pollination is a necessary process for the obtaining of fruit or seed yield. In the case of entomophilous plants, pollination is carried out by insects. An absence or a small number of pollinators decreases the size of the crop obtained and reduces their quality. Also in the case of self-pollinated plants, the presence of pollinators increases the size and the quality of crops.

The principal role of bees in the pollination of plants results from a number of premises. Firstly, these insects live in swarms ranging from several to tens of thousands of individuals which enables a significant area of crop pollination. Secondly, in bees the whole colony overwinters, rather than fertilised mother only, as it is in other insects. As a result, as early as at the onset of spring, bees are capable of pollinating a significant number of plants. Thirdly, these insects can be transported to plantations, depending on the needs connected with their pollination. Another favourable feature of using bees to

ISSN 1691-3078; ISBN 978-9934-8466-1-8
Economic Science for Rural Development
No. 34, 2014

pollinate is their so-called floral fidelity. It consists in that during its flight a bee only visits flowers one plant species. Importantly, this also results in a possibility of obtaining bee products which in the case of Poland are the main source of revenue earned by beekeepers.



Source: author's construction based on Produkcja upraw rolnych i ogrodniczych (Production of Agricultural and Horticultural Crops in 2012), 2013, GUS Warszawa

Fig. 1. **The structure of major entomophilous plants in Poland in terms of cultivation area in 2012**

The main crops that require pollination by insects in Poland are rape and agrimony, fruit plants and shrubs, and perennial permanent stock. The arable land area used for the cultivation of rape and agrimony represented two thirds; whereas, orchards, nearly a quarter of farmland where entomophilous plants are cultivated (Figure 1). The area covered by these crops has increased by 36% since 2000, resulting in increased pollination needs by over 30%. This was due to an increase in the cultivation area of rape and agrimony by over 60% and an increase in apple orchard area by 18%. The cultivation area of raspberries has grown by 125% and that of currants by 33%. In the case of other plants, over the same period, the cultivation area has decreased by a percentage ranging from less than 5% for sweet cherry orchards to almost 50% in the case of gooseberry plantations.

Table 1

Dates of major entomophilous domesticated plants flowering and the number of hives needed for the pollination of 1 ha of plantation area

Type of crop	Flowering period	Number of colonies to pollinate1 ha		
		Minimum*	Average	Maximum
Apple trees	5.05 - 20.05	3	4	6
Pear trees	5.05 - 15.05	3	4	6
Plum trees	20.04 - 20.05	4	5	8
Sour cherry trees	1.05 - 15.05	4	5	8
Sweet cherry trees	25.04 - 5.05	4	5	8
Rape and agrimony	25.04 - 15.05	2	3.5	6
Strawberries	10.05 - 5.06	1	1.5	2
Raspberries	25.05 - 25.06	2	3.5	6
Currants	25.04 - 10.05	2	3.5	6
Gooseberries	20.04 - 5.05	2	3.5	6

* - Minimum - means the number of hives needed to pollinate the plants calculated on the basis of the minimum recommendations provided in the literature; Average - calculations were performed taking into account the average of the most frequently indicated intervals; Maximum - the highest value provided in the literature was applied.

Source: author's calculations based on Prabucki, 1998

ISSN 1691-3078; ISBN 978-9934-8466-1-8
Economic Science for Rural Development
No. 34, 2014

A different number of pollinators is required for the pollination of individual plants. There are different indications in the literature as to the required number of colonies for a good pollination of the planted area. The most common values are displayed in Table 1. It is obvious that an increase in the number of bees is bound to lead to a better pollination of plantations, but the efficiency of additional colonies will be decreasing.

Table 2

The number of colonies needed for the pollination of selected crops in Poland in 2012

Type of crop	The pollination needs to the min/ave/maximum extent	Number of hives (in thousand)
Orchards	Minimum*	875
	Average	1145
	Maximum	1751
Rape and agrimony	Minimum	1441
	Average	2521
	Maximum	4322
Fruit shrubs and perennial permanent stock	Minimum	199
	Average	337
	Maximum	551
Total	Minimum	2515
	Average	4004
	Maximum	6623
Plants with a similar flowering period	Minimum	2412
	Average	3834
	Maximum	6359

* - Explanation as in Table 1

Source: author's calculations

The greatest demand for the pollination of domesticated plants in Poland occurs from April 25th to mid-May. It is the period when the major entomophilous domesticated plants bloom, namely, rape and agrimony, fruit plants and currants as well as gooseberries. They represent over 90% of the entomophilous plants investigated. These plants "compete" with each other for pollinators, as the number of bee colonies in Poland, which amounted to more than 1.28 million hives in 2012 (Semkiw, 2012), does not meet the pollination needs of those crops (Table 2).

The literature data on the number of colonies needed for the pollination of selected domesticated plants are diverse. Therefore, the number of hives needed for the pollination of such plants was determined for the three options set out in Table 1. In each scenario, the number of colonies in Poland in 2012 was too small for a full pollination of flowering plants investigated in a comparable period. In the minimum sufficiency scenario, the number of colonies was only sufficient for the pollination of 53% of the areas where the plants studied are grown. In the two other variants, this percentage amounted to 33% (the average scenario) and 20% (the maximum scenario).

The largest share in the pollination needs was claimed by rape and agrimony plantations. Depending on the variant adopted, the share of these crops ranged from 60 to 68 per cent of the pollination needs for plants flowering at that time. This is due to a large area covered by these crops. The number of bees in Poland is insufficient even for a minimum pollination of the entire area where rape and agrimony are grown. Orchards are responsible for a significant proportion of the pollination needs for plants flowering roughly at the same time. This proportion varies, depending on the scenario, in the range of 28-36%. The share of currants and gooseberries represented approximately 4% of the pollination needs for plants flowering roughly at the same time, irrespective of the variant.

ISSN 1691-3078; ISBN 978-9934-8466-1-8
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The importance of pollination for selected crops

Pollination is a procedure which enables an increase in the yield potential of fruit or seeds. It also results in enhancing the crop quality. Pollination does not guarantee obtaining high yields, since between the pollination of plants and harvesting there may be situations such as frost and hail which cause yield losses. However, other procedures such as fertilisation, plant protection, irrigation etc., are applied to ensure the maximum utilisation of the plants' yield potential.

Table 3

The effect of pollination on the yield of selected crops

Plant species	The effect of pollination on yield (in%) per	
	ISiK *	Morse and Calderone 2000; Losey 2006
Apple trees	85	100
Pear trees	90	70
Plum trees	40	70
Sour cherry trees	60	90
Sweet cherry trees	95	90
Rape and agrimony	30	90
Currants	85	-
Gooseberries	70	-
Strawberries	85	20
Raspberries	70	90

* - data from the Institute of Pomology and Floriculture (ISiK). Plant Protection Scheme Safe for Bees (in Polish). Retrieved: http://www.opisik.pulawy.pl, Access: 15.04.2010

Source: ISiK 2010; Morse and Calderone, 2000; Losey, 2006

The effect of pollination is varied on the size of the crop yield. The results of studies on the impact of pollination on crop yields vary significantly (Gallai et al., 2009). This is evidenced by the results presented in Table 3. The differences in the effect of pollination on yield range from 5 to 60 percentage points.

The average yield and the number of colonies in 2012, the estimated yields achievable in the absence of pollination and in the case of full pollination of these plants were determined based on the data from the Institute of Pomology and Floriculture (presently the Institute of Horticulture) regarding the size of the effect of pollination on the crop yield of domesticated plants.

Table 4

The average yield of major entomophilous domesticated plants and estimated yields of these plants with pollination and without pollination in 2012

Plant species	Average yield (in t / ha)	Yields without pollinators (in t / ha)	Yields with pollinators (in t / ha)
Apple trees	14.78	4.04	26.94
Pear trees	5.95	1.14	11.4
Plum trees	5.31	4.05	6.74
Sour cherry trees	5.2	3.05	7.63
Sweet cherry trees	3.54	0.36	7.14
Rape and agrimony	2.59	2.16	3.08
Currants	4.35	1.19	7.93
Gooseberry	5.25	2.51	8.36

Source: author's calculations

The largest difference in the yields estimated was observed in plants with the highest impact of pollination, i.e. sweet cherry orchards, pear and apple orchards as well as strawberries (Table 4). These differences may result from differences related with the plant species studied, differences in the weather or from methodological differences in the conducted research projects.

ISSN 1691-3078; ISBN 978-9934-8466-1-8
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The estimated value of pollination of selected crops in Poland in 2012

Estimating the value of pollination of plants is a complicated issue. In order to determine it, the following methods are frequently used:

market method;

cost methods (replacement cost, restoration cost, cost of preventing damage);

product value method as obtained owing to pollination.

Estimating the value of pollination by using the market method consists in determining the market price of pollination services. The market price of pollination services, which equals the value of pollination, is determined by juxtaposing the supply side represented by beekeepers with the demand side represented by entomophilous crop owners. In Poland, there is no market for plant pollination services; on the contrary, beekeepers often pay for the opportunity of placing beehives on plantations, mostly rapeseed plantations. Therefore, it can be indicated that the value of pollination in Poland amounts to zero.

In assessing the value of pollination methods one can distinguish the replacement cost method or the restoration cost method as well as the cost of preventing damage method. The costs that would have to be incurred to replace pollination are determined in the replacement cost method. An alternative solution for pollination by insects is the so-called mechanical pollination performed by humans. Such a method of pollination can be encountered in China, in the province of Maoxian (Mburu et al., 2006) where the bees have died out as a result of poisoning and people were compelled to take over. For example, it takes between 45 to 90 minutes for a human to pollinate one apple or pear tree. For the pollination of one hectare of such plants a single individual would require from 150 to over 300 days (Allsopp et al., 2011). The value of pollination as determined by this method would amount to the cost of employing people to perform the pollination. One should also take into account the costs involved in the preparation of the workstation. In turn, the cost of preventing damage method determines the costs associated with the prevention of incurring losses due to the lack or limitation of the number of pollinators.

The value of pollination for crops is most frequently determined by establishing the value of the products obtained by pollination. The yield obtained owing to pollinators is determined as the difference between the yields of the plants subject to pollination and those that have not been pollinated. The resultant amount is subsequently multiplied by the market price of the product. The calculation should also include the costs connected with the renting of hives for pollination. The difficulty in determining the value of pollination in this approach stems from the varied data on the effect of pollinators on crop yields. In the present study, the method of products obtained by pollination was applied to estimate the economic value of pollination of selected crops. The amounts are provided in PLN as well as in Euro (Table 5).

The largest differences in yields obtainable per hectare between pollinated and unpollinated plantations were established in the case of sweet cherry orchards: over PLN 41 thousand (EUR 9.8 thousand)[2]. For the most significant entomophilous crops, from the point of view of the Polish economy, i.e. rape and agrimony as well as apple orchards, the differences amounted to EUR 438 and EUR 3997 respectively.

[2] The amount in EUR was calculated based on the average FX rate of PLN in 2012, estimated on the basis of the National Bank of Poland's data at the level of PLN 4.185

ISSN 1691-3078; ISBN 978-9934-8466-1-8
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Table 5

Estimated value of the pollination of selected crops and losses arising from an insufficient number of pollinators in Poland in 2012

Plant species	Difference between the yield of the plantation with and without pollination		The value of plant pollination by bees		The value of pollination by bees given full pollination		Losses resulting from the insufficient number of pollinators	
	in PLN/ha	in EUR/ha	in million PLN	in million EUR	in million PLN	in million EUR	in million PLN	in million EUR
Apple trees	16729	3997	1729.6	413.3	3256.8	778.2	1527.2	364.9
Pear trees	20934	5002	120.9	28.9	227.7	54.4	106.8	25.5
Plum trees	4494	1074	46.1	11.0	86.8	20.7	40.7	9.7
Sour cherry trees	15693	3750	281.1	67.2	529.3	126.5	248.2	59.3
Sweet cherry trees	41095	9820	253.4	60.5	477.1	114.0	223.7	53.5
Rape and agrimony	1831	438	700.4	167.4	1318.9	315.1	618.5	147.8
Currants	12067	2883	286.5	68.5	539.5	128.9	253	60.5
Gooseberry	21187	5063	35.0	8.4	65.8	15.7	30.8	7.4
Total	-	-	3453.0	825.1	6501.9	1553.6	3048.9	728.5

Source: author's calculations

The estimated value of the pollination of selected crops in 2012 amounted to over EUR 825 million. Half of this amount was the value of the pollination of apple orchards; whereas, rape and agrimony as well as other fruit plants each represented ca. 20% of the total. The value of the pollination of currants and gooseberries equalled less than 10% of the estimated amount.

As for the number of colonies that would have ensured a full pollination in 2012, the value of the pollination of plants encompassed by the present study would have amounted to EUR 1.55 billion. The losses incurred as a result of the absence of bee colonies to ensure a full pollination of crops were estimated at EUR 728.5 million (Table 5).

Summary and conclusions

Pollination is the most important task of bees, frequently underestimated by people. The economic effects obtained owing to pollination exceed the value of apicultural products by a multiple. This results from an increase in crop yields and an enhancement of crop quality.

The estimated crop value of major entomophilous plants in Poland in 2012, obtained by pollination, amounted to more than EUR 825 million. The value of the crops obtained by the pollination of apple orchards was estimated at more than EUR 413 million; for rape and agrimony it was estimated at more than EUR 167 million, EUR 68 million for currant, EUR 67 million for sour cherry orchards, and EUR 60 million sweet cherry orchards. These amounts confirm the significance of pollination of crops by insects. The number of bee colonies is too small to pollinate all the entomophilous plant cultivations which gives rise to losses. In 2012, the crop losses for major entomophilous plants resultant from too small number of pollinators amounted to EUR 728 million.

ISSN 1691-3078; ISBN 978-9934-8466-1-8
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The conclusions of the study and recommendations are as follows:

1. The growing importance of bees as pollinators of plants should be included in the national agricultural policy as well as the European Union's policy, and adequate support should be provided to beekeepers. This is even more evident by the fact that the effects of pollination by bees are consumed by plantation owners.
2. The limited knowledge on the role of pollinators in crop yielding results in a lack of willingness to use the services of pollinators.
3. The diverse impact of pollination on crop yields of entomophilous plants hinder the correct estimation of yields obtained by pollination by insects. It is, thereby, necessary to continue research in this scope.
4. Research on determining the economic value of pollination should be continued, particularly, on the role of pollinators in improving the crop quality of entomophilous plants and in the natural environment. It is advisable to develop new methods or to refine existing ones for estimating the economic value of pollination.

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