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THE IMPORTANCE OF INSECT POLLINATORS FOR POLISH FOOD SECURITY

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Abstract. The purpose of this paper is to determine the effect of insect pollinators on the volume of food production in Poland, and thus to identify their role in ensuring the food security of the country. The object of the study was related to major entomophilous crop plants, i.e. rapeseed, fruit plants, fruit shrubs and permanent crops: fruit and berry plantations. The analyses were based on data from the Polish Central Statistical Office, the Institute of Horticulture, and subject literature. The results of the study indicate that insect pollinators play a key role in fruit production (absence of pollinators may result in a crop yield reduction ranging between 50% and 90%) and a significant role in rapeseed production (a possible yield reduction of approx. 20–40%). In terms of physical availability of food, Polish food security would be preserved even in the absence of insect pollinators. However, at the level of economic availability, food security would not be preserved without such pollinators, particularly in terms of fruit and food security associated with the consumption of properly balanced rations.

Key words: food security, Poland, pollination, insect pollinators

INTRODUCTION

Food is an essential product in human life. It has a special value because it enables you to satisfy your basic physiological needs, which is the primary function of food. It also caters for a variety of other human needs, including individual, social, material or spiritual needs (Małysz, 1991). Thus, apart from physiological needs, it also contributes to the satisfaction of higher-order needs, such as self-actualisation and aesthetic needs.

Access to food, despite the rapid economic development of the world, continues to be a problem. The starvation figures are estimated at more than 900 million. The problem of food shortages does not only affect residents of developing countries but also families in the European Union and the United States (Mikuła, 2012; Pawlak, 2011; Sapa, 2012). Food security will constitute to be a major challenge for agriculture as by 2050, according to the forecasts of the FAO, food demand will have doubled (Lyon, 2010).

Food security may be considered from different geographical perspectives: food security in the world or food security at the level of a country, region or individual household. At each of these levels, availability of food depends on a number of factors. The most important factor affecting food availability is the volume and the structure of the food produced, which determines the quantity and the quality of nutrients available to residents. The volume of food production is under the influence of such factors as macroeconomic situation (e.g. the level of prices of agricultural raw materials and agricultural means of production, their volatility and price relationships between them), as well as weather, climate and environmental conditions.

One of the factors influencing the volume and the quality of production of some crop plants is the presence of pollinators. Therefore, the purpose of this article is to determine the influence of insect pollinators on the volume of food produced in Poland, and indirectly, on Poland's ability to ensure food security. In addition,

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the paper offers a review of literature on the subject of importance of insect pollinators for crop harvesting, as well as estimates of the volume of production obtained with the help of pollinators. In the paper, the primary source of data was the information collected by the Polish Central Statistical Office (GUS). In addition, the author utilised figures provided by the Institute of Horticulture (formerly 'Institute of Pomology and Floriculture' – ISiK) and literature related to the subject matter.

THE CONCEPT OF FOOD SECURITY

The concept of food security has been defined repeatedly. For the first time, this term was officially defined during the 1974 World Food Summit in Rome as: "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (Trade…, 2003; Mikuła, 2012). Over time, this definition evolved. In addition to supply, the definition was extended to include aspects related to demand, as well as physical and economic availability of food. In subsequent years, the definition drew attention to food quality (the so-called nutritional safety) and food preferences resulting from social, cultural and religious factors. The World Bank (Bora et al., 2010) presented the following definition of food security "food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Bora et al., 2010).

In order to guarantee food security, the following conditions have to be fulfilled (Małysz, 1991):

- physical availability of food – which means the ability of domestic food production to meet physiological demand, at least to a minimum extent,
- economic availability of food – which means that even the weakest households, in economic terms, have access to the food they need (e.g. thanks to various forms of (social) aid),
- responsibility of food products for human health (absence of pollutants) and consumed nutritional rations (adequate level of energy and adequate proportion of nutrients).

Physical availability of food, in its most basic sense, means the relationship between the size of population and food supplies. It can be analysed at the following levels: global, national, regional, single household and individual (each human being) (Marzęda-Młynarska, 2014). The fulfilment of physical availability of food at the level of a nation is relatively easy. The other two conditions are very difficult to achieve at this level, because in each society there is a group of households which do not have access to proper quality food in economic terms. In addition, in highly developed societies food security problems are associated with consumption of food with improper balance of nutrients, resulting in obesity and related diseases.

THE IMPORTANCE OF INSECT POLLINATORS IN FOOD PRODUCTION

Plant pollination determines the possibility of obtaining crop. The main carriers of pollen are wind and animals, with the latter group dominated by insects. From among 300 main crop plants in the world, approx. 84% are entomophilous plants, i.e. pollinated by insects (Allsopp et al., 2008). Worldwide, approx. 35% plant production depends on insect pollinators (Schulp et al., 2014).

Insect pollination of crop plants is difficult to estimate in terms of value. This is due, inter alia, to the absence of conclusive results of studies related to the influence of insect pollinators on the volume of plant production. In global terms, the value of crop plants pollinated by insects has been estimated at more than EUR 150 billion, with approx. 1/3 of the total value attributable to pollination of fruit and vegetables (Gallai et al., 2009). On the other hand, the value of crop pollinated by insects in the European Union has been estimated at approx. EUR 14.6 billion annually (Leonhard et al., 2013). In the USA, the value of crop pollinated by bees, i.e. the main specifies of insects involved in pollination, increased from USD 9 billion in 1989 to nearly USD 15 billion in 2000 (Morse and Calderone, 2000). In Poland, the value of the most important crop plants pollinated by insects (rapeseed, fruit plants and fruit plantation (permanent crop)) amounted to 0.6–1.2 billion PLN in 2008 (Majewski, 2011). These figures demonstrate a significant role of insect pollination for humans. The differentiation of the following values of pollination due to the used methods, including different values determining the impact of pollinators on yields.

In Poland, the most important entomophilous crop plants are rapeseed, fruit plants, fruit shrubs and permanent crop – fruit and berry plantations. In addition, insect pollinators also have a vital function in the production of certain vegetables, as well as vegetable seeds, flowers and herbs. Insect pollination of plant flowers determines the number and the quality of fruit buds produced by the plant. Experimental studies demonstrate that the number of fruit buds in relation to the number of produced flowers decreases, even a few times, if the plant is separated from pollinators (Table 1). Moreover, absence of pollinators contributes to the deterioration of the quality of

Table 1. Primordium development in fruit by selected crops in the presence and absence of pollinators
Tabela 1. Zawiązywanie owoców przez wybrane rośliny uprawne przy obecności i braku owadów zapylających

Plant species Gatunek rośliny	Share of fruit primordia in relation to the number of flowers Udział zawiązków owoców w stosunku do liczby kwiatów (%)	
	without pollinators bez zapylaczy	with pollinators z zapylaczami
Apple Jabłonie	0.0–6.6	6.1–20.0
Pear Grusze	0.5–1.8	8.0–22.3
Sweet cherries Czereśnie	0.0–0.5	10.0–18.5
Open-pollinated cherries Wiśnie obcopylne	0.0–0.7	4.1–18.0
Self-pollinated cherries Wiśnie samopylne	6.9–15.4	18.3–33.0
Open-pollinated plums Śliwy obcopylne	0.3–1.2	11.0–25.0
Self-pollinated plums Śliwy samopylne	7.6–16.0	14.4–28.1
Black currants Porzeczki czarne	0.3–10.0	42.5–78.7
Blueberries Borówki	0.0–30.0	70.0–90.0
Gooseberry Agrest	4.0–9.0	27.0–33.0
Raspberries* Maliny*	27.0–90.0	66.0–99.9
Strawberries* Truskawki*	46.7–63.1	50.1–72.8
Rape** Rzepak**	46.0–72.0	48.6–71.4

* Misshapen fruit and approx. 20% smaller than fruits with flowers pollinated by insects.
** Number of pods more or less the same as in the case of participation of pollinators but the number of seeds in pods approx. 20–40% lower.
Source: Prabucki, 1998.
* Owoce niekształtne i ok. 20% drobniejsze niż owoce z kwiatów zapylonych przez owady.
** Liczba łuszczyn podobna jak przy udziale zapylaczy, ale liczba nasion w łuszczynach ok. 20–40% mniejsza.
Źródło: Prabucki, 1998.

fruit produced (raspberries and strawberries) or reduced number of seeds per pod (rape).

Increased number of fruit buds produced by the plant does not only apply to entomophilous plants. Also in the case of self-pollinated plants, such as cherries and plums, the number of fruit plants in the presence of pollinators was more than 2-fold higher than in the case of their absence (Table 1). This is due to the fact that while carrying the pollen, bees enable pollination of flowers with the pollen collected from other individuals (cross-pollination), which results in higher crop yields in comparison to self-pollination.

INFLUENCE OF POLLINATION ON THE VOLUME OF FOOD PRODUCTION IN POLAND

The volume of crop yield is determined by many factors, both endogenous and exogenous. Farmers may influence the volume of their crop yield by the proper choice of plant species and varieties, crop rotation, agricultural practices, use of fertilisers and pesticides, as well as insect pollinators. However, some factors determining the yield are independent of or only slightly dependent on the farmer, e.g. extreme weather events (drought, flood, hail, etc.), acts of God or harmful activities of their neighbours. Therefore, determination of the influence of a single factor is difficult.

In literature, there are significant differences in the definition of the influence of pollination on the volume of crop production. In the case of apples, melons and almonds, according to various authors, the share of crops obtained with the help of insect pollination ranges between 10 and 100%, and in the case of strawberries – from 10% to 40% (Gallai et al., 2009). This demonstrates that there is a need for conducting further studies in this regard.

From among major entomophilous crop plants in Poland, insect pollinators have the greatest influence on the crop of fruit plants, and in particular, sweet cherries and apples. In the case of these two plants, pollinators are responsible for at least half the yield. However, depending on the quoted researcher, the difference in the determination of such influence may vary significantly (Table 2).

The lowest values were determined in the case of influence of pollination on strawberries. Apart from

Table 2. Influence of pollination on the yield of selected crops
Tabela 2. Wpływ zapylania na plon wybranych roślin uprawnych

Plant species Gatunek rośliny	Influence of pollination on the yield, acc. to: Wpływ zapylania na plony wg:		
	ISiK	Ślązak, 2004	Morse and Calderone, 2000
Rape and turnip – Rzepak i rzepik	30	20	40
Apples – Jabłka	85	50	100
Pears – Gruszki	90	60	70
Plums – Śliwki	40	60	70
Cherries – Wiśnie	60	50	90
Sweet cherries – Czereśnie	95	60	90
Strawberries – Truskawki	20	30	20
Raspberries – Maliny	25	30	80
Currants – Porzeczki	85	30	ND
Gooseberries – Agrest	70	30	ND

ND – no data.
Source: Morse and Calderone, 2000; Ślązak, 2004; Ochrona…, 2010.
ND – brak danych.
Źródło: Morse i Calderone, 2000; Ślązak, 2004; Ochrona…, 2010.

rapeseed, this is the only plant with more or less the same values of influence of insect pollination determined by all the quoted studies. In other cases, the differences ranged between 30 and 55 percentage points (p.p.) (Table 2).

By taking into account the influence of insect pollinators on the volume of the yield of selected crop plants, the researchers determined the volume of the yield which could be obtained in the absence of pollinators. Calculations were made for three variants, taking into account the influence of insect pollinators on the volume of the crop yield according to three different sources: ISiK – data published by the Institute of Pomology and Floriculture in Skierniewice (present name – the Institute of Horticulture); results from two research studies: Śłązak (2004), and Morse and Calderone (2000). In this manner, certain possible intervals for the estimated value were determined.

Absence of insect pollinators may contribute to a significant reduction of crop production. In the case of estimated variants, the yield of rapeseed dropped from 2.7 billion to – depending on the adopted variant – between 1.6 billion and 2.1 billion tons. When it comes to fruit production, in the most positive scenario, they dropped by nearly 50%, and in the worst – by more than 93% (Table 3).

Table 3. Yield (production) of major entomophilous crops in Poland in 2013, and estimated yield in the absence of pollinators
Tabela 3. Zbiory głównych roślin entomofilnych w Polsce w 2013 r. oraz oszacowane ich wielkości w przypadku braku zapylaczy

Plant species Gatunek rośliny	Production obtained in 2013 (thous. t) Zbiory uzyskane w 2013 r. (tys. t)	Production without insect pollination (thous. t) Zbiory bez zapylaczy (tys. t)		
		ISiK	Śłązak, 2004	Morse and Calderone, 2000
Rape and turnip Rzepak i rzepik	2 678	1 875	2 142	1 607
Apples Jabłka	3 085	463	1 543	0
Pears Gruszki	76	8	30	23
Plums Śliwki	102	61	41	31
Cherries Wiśnie	188	75	94	19
Sweet cherries Czereśnie	48	2	19	5
Strawberries Truskawki	193	154	135	154
Raspberries Maliny	121	91	85	24
Currants Porzeczki	199	30	139	–
Gooseberries Agrest	15	5	11	–
Fruits TOTAL Owoce RAZEM	4 027	889	2 097	256

Source: own calculations based on GUS, 2015.
Źródło: obliczenia własne na podstawie GUS, 2015.

In the case of rapeseed decline in production due to lack of pollinators would not reduce consumption, because in Poland for food is spent approx. 1 billion ton rapeseed (Rosiak, 2014). Reducing production will reduce the possibility of using the plant for purposes beyond the consumption, mainly in the production of biofuels. However, you can assume that the decline in rapeseed production will increase competition between the consumption of this plant for food and energy, which in turn may increase the prices of seeds of this plant.

The decrease in the fruit yield, due to the absence of pollinators, may contribute to inability to maintain food security in terms of fruit supplies. However, it will not result in any risk to food security in terms of physical availability of food, because in the case of such agricultural raw materials as grains, potatoes, milk or meat, Poland has production surpluses (Mikuła, 2012).

Assuming that consumption of fruit will equal consumption in the 2012/2013 reporting period, when it stood at 3.1 million tons (GUS, 2015), the shortfalls in domestic production would amount to between 1 and 2.8 million tons. This would result in a significant increase in prices of the fruit available in the market. If the situation of the decline in fruit production applied to Poland only, the market gap would be filled by the fruit from imports. The increase in prices in this case would be relatively small. However, if this situation applied to Europe or the world in general, fruit prices could rise even several times (with a decrease in production by 90%), which would limit demand. At the same time, fruit would become a commodity that meets higher needs, beyond the reach of a large group of consumers with very low incomes.

A possible solution to the problem involving absence of pollinators, could be an attempt to replace them. At the current stage of technical development, pollination of crops with the use of machines is impossible. However, manual pollination, by people, is possible and is already being practised. Such a method of pollination of fruit is used in the Chinese province of Maoxian, where – as a result of the use of chemical plant protection products – bees became extinct (Partap and Ya, 2012). This method of pollination of plants requires large manpower, resulting in significant costs. In the case of Poland, the cost of pollination of apple orchards by man has been estimated at PLN 1.6–3.3 billion (Majewski, 2014). In addition, because of the short flowering time, a large number of people would have to be involved in such work.

CONCLUSIONS

Food security is a complex and challenging issue. It depends on a large number of factors. Although it is often underestimated, one of these factors is the influence of insect pollination on the crop yield.

Insect pollinators, and in particular bees, are an important link in food production. Many species of plants are fully or partially entomophilous, and their yield largely depends on the pollination of their flowers by insects. Similarly, in the case of self-pollinated plants, the presence of insect pollinators enables to increase the volume and the quality of the yield.

In Poland, one of the most important entomophilous species are fruit plants, fruit shrubs, permanent crops (fruit and berry plantations) and rapeseed. According to various studies, the presence of pollinators during the flowering process determines as much as 20% or even 100% of crop production. In the absence of insect pollinators, rapeseed harvesting figures may be approx. 20–40% lower, and fruit production may drop by almost 50%, and in some cases, more than 90%.

The studies demonstrate that in the absence of insect pollinators, and thus, in the case of a significant reduction of fruit production, Poland would not be facing any food security risks related to physical aspects. The surplus production of grain, milk and meat, if necessary, could be used to replace and supplement the deficiencies associated with fruit shortages. Nevertheless, the range of assortment of available food products, would be seriously reduced.

However, it will not be preserved food security in economy and health aspects. The limitation of fruit production in Poland up to 90% will result in a significant price increase for these products and consequently prevent their consumption among those with lower incomes. This in turn will prevent the achievement of health security for these people, because their food rations are not properly balanced.

It should also be noted that the study only involved major entomophilous crop species. In addition, absence of pollinators would have a negative effect on the harvest of vegetables, such as tomatoes and cucumbers, and would also limit production capacity in terms of vegetable seeds and herbs. Consequently, limited crop production would lead to reduced livestock production, which could limit access to such products in the long run.

In addition to the aforementioned aspects, insect pollinators also affect biodiversity, which allows for satisfaction of a number of higher-order needs, such as aesthetic needs. The foregoing indicates that the role of insect pollinators in human life is both significant and difficult to estimate.

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ZNACZENIE OWADÓW ZAPYLAJĄCYCH DLA BEZPIECZEŃSTWA ŻYWNOŚCIOWEGO POLSKI

Streszczenie. Celem pracy jest próba określenia wpływu owadów zapylających na wielkość produkcji żywności w Polsce, a przez to wskazania na ich rolę w zapewnieniu bezpieczeństwa żywnościowego kraju. Badania dotyczyły głównych uprawnych roślin entomofilnych, tj. rzepaku, roślin sadowniczych oraz krzewów owocowych i plantacji trwałych. Analizy przeprowadzono na podstawie danych Głównego Urzędu Statystycznego RP, Instytutu Ogrodnictwa oraz literatury przedmiotu. Wyniki badań wskazują na decydującą rolę owadów zapylających w zbiorach owoców (brak zapylaczy może spowodować spadek plonów od 50% do 90%) oraz znaczną rolę w zbiorach rzepaku (możliwy spadek plonów w granicach 20–40%). Bezpieczeństwo żywnościowe Polski w sensie fizycznej dostępności żywności będzie zachowane nawet przy braku owadów zapylających. Nie będzie natomiast możliwości zachowania bezpieczeństwa żywnościowego na poziomie ekonomicznej dostępności żywności (dotyczy to zwłaszcza owoców) ani bezpieczeństwa żywnościowego związanego ze spożywaniem odpowiednio zbilansowanych racji żywnościowych.

Słowa kluczowe: bezpieczeństwo żywnościowe, Polska, zapylanie, owady zapylające

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