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Scale insects /Hemiptera, Coccoidea/ as a source of natural dye and other useful substances

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Abstract

For centuries some scale insect species have been used for the production of dye (*Porphyrophora polonica*, *P. hameli, Kermes vermilio, Kerria lacca*), wax (*Ceroplastes ceriferus, C. irregularis, Ericerus pela*), lac and shellac (*K. lacca*); these hemipterons are also the source of honeydew. Nowadays, some of them (*Dactylopius coccus*) deliver natural pigment which is used for yoghurt, sweets and soft drinks production.

Polish cochineal is considered to be a historical and well-earned species for Poland. During Jagiellonian times it constituted one of the more important factors in national economy contributing to the country's prosperity and the society's well-being. Also today it could be used in many sectors of the economy, e.g. in food production. One of the factors which makes it more difficult to use species of the *Porphyrophora* genus in mass production of carmine dye is a too little content of dyeing substance in the bodies of these insects and a too large content of fat (about 30% of body mass) which inhibits the process of fabrics dyeing. An additional, though not less important problem is a remarkable disappearance of *P. polonica* and *P. hameli* which is related with the damage of their natural habitats. The phenomenon of scale insect disappearance and the need for its protection was noticed back in the eighteenth century. It ought to be stated that all over the world, *P. polonica* is considered to be a rare species which deserves protection. Nowadays, the introduction of syn-

thetic dyes into commerce has significantly decreased the demand for dye lac, the source of which is *K. lacca*, though it is still used for a commercial production of lac and shellac. Also wax which is obtainable from *Ericerus pela* has a wide ranging usage in many branches of economy especially due to its unique physical properties.

In recent years one could observe an increase in the interest in scale insects which are a source of natural substances used in the production of food, medicines, cosmetics as well as the renovation of precious fabrics. Such a tendency is partially prompted by a growing demand for the so-called ecological products among consumers. Despite certain faults, natural dyes are regarded as additives that are safe for health, hence one should expect that the importance of insects, including scale insects as a potential source of natural substances is likely to increase. It is, however, conditioned by research the results of which may improve commercial rearing of scale insects and the process of natural dye, wax, lac and shellac production.

Introduction

Scale insects are primarily known as crop pests. In the subtropical and tropical climate zones they lead on the list of pests to grape-vine, olives, tea, lime trees and shrubs as well as ornamental plants. However, apart from pest, within the group of scale insects there are also species which are the source of many valuable and useful substances used by other insects and man too. They deliver natural dye, lake, wax and honeydew.

Knowledge on useful scale insects is less popular, and the information on these species is usually scattered in separate, hard to access older publications. In Polish and foreign publications there is a lack of research analyses concerned with useful scale insects. This paper is an attempt to supplement the existing knowledge on this group of insects with a particular emphasis on species used for a commercial production of dye, lac and wax. The present paper considers species used presently or in the past for a commercial production as well as species which are distinguished by a significant amount of delivered substances the use of which has been documented in print.

Characteristics of useful species of scale insects

Scale insects excreting dyeing substances, lake and wax belong to five families: Margarodidae, Dactylopiidae, Kermesidae, Kerridae and Coccidae. It is difficult to determine the exact number of species which deliver useful substances. Many scale insect species are a source of the discussed substances, which were used in the past for man's own needs, but due to their small number and small amount of excreted substances, the knowledge on their usefulness is limited. Scale insects of the *Porphyrophora* genus are a good example of such a state of knowledge. All the species of this genus are likely to be a source of carmine dye, provided that they occur in large numbers (VAHEDI & HODGSON, 2007).

In the group of dyeing scale insects which belong to the *Porphyrophora* genus, three species (*Porphyrophora polonica*, *P. hamelii* and *P.sophorae*) were the main source of carmine dye in Europe and West Asia. In Egypt, this dye was obtained probably from *P. hirsutissima* (Hall) (CARDON, 2003).

Table 1. Check list of the useful scale insects (Hemiptera, Coccoidea)

Species	Family	Hostplant	Place of settlement on plant	Excretory substance
Porphyrophora polonica (L.)	Margarodidae	20 of plant genera from 15 families, mainly on: *Scleranthus perennis*, *Hieracium pilosella, Silene inflata, Agrostis canina* .	roots, hypocotyl, undergrounds plant organs	carmine dye
Porphyrophora hamelii Brandt	Margarodidae	f. Poaceae: *Poa* sp., *Phragmites* sp., *Aeluropus* sp.	roots, hypocotyl, undergrounds organs	carmine dye
Porphyrophora sophorae (Archangelskaya)	Margarodidae	f. Fabaceae *Sophora* sp. *Glycyrrhiza* sp. *Hedysarum* sp.	roots, hypocotyl, undergrounds organs	carmine dye
Dactylopius coccus Costa	Dactylopiidae	*Opuntia* sp. *Nopalea cochenillifera*	above-ground parts of plants	cochineal dye
Kermes vermilio (Planchon)	Kermesidae	*Quercus* sp. mainly on: *Quercus coccifera.*	shoots	kermes dye
Kermes ilicis L.	Kermesidae	f. Fagaceae: *Quercus coccifera*, *Quercus* sp.	shoots	kermes dye
Kerria lacca (Kerr)	Kerridae	160 plant species from 22 families	shoots	lac dye, lac
Ceroplastes ceriferus (Fabricius)	Coccidae	122 plant species from z 46 families	stalks and twigs	wax
Ceroplastes irregularis Cockerell	Coccidae	f. Asclepiadaceae: *Sarcobatus* f. Asteraceae: *Artemisia* sp., *Chrysothamnus* sp. f. Chenopodiaceae: *Atriplex* sp. *Atriplex* sp., *Eurotia* sp.	shoots	wax
Ericerus pela (Chavannes)	Coccidae	f. Oleaceae: *Chionanthus sp.*, *Fraxinus* sp., *Ligustrum* sp., *Syringa* sp.	shoots	wax

In life cycle of females of the *Porphyrophora* genus there are three developmental stages: the first and second (cyst) larval stages and an adult. However, in the development of males, apart from larvae of the first and second larval stages, one can observe also prepupa and pupa stages. The presence of both male and female larvae of the second stage in the form of a cyst, the so-called "earthly pearls" are the phenomenon of the development of all the species of the *Porphyrophora* genus and of the whole Margarodidae family (Fig. 1).

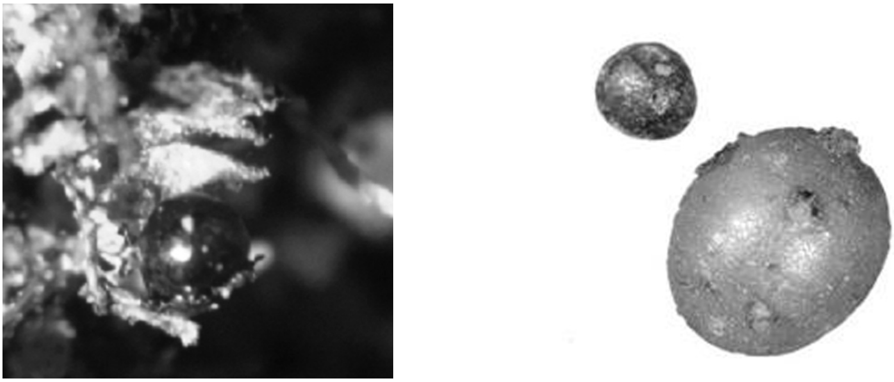

Figure 1. *Porphyrophora* polonica cysta stadium (B. Łagowska, K. Golan)

Cysts are round, deprived of antennae and legs but they have a mouth apparatus and an ability to feed. They usually have an intense colour due to the presence of a dye. All the species spend most of their lives in sandy soil; feed on the root system of host plants. *P. polonica* is a polyphagous species. In Europe it occurs on host plants which belong to 15 families and 20 genera (Yaschenko, 1990). In Poland it is usually registered mainly on *Scleranthus perennis* L. and *Hieracium pilosella* L. more rarely on *Silene infata* Salisb. and *Agrostis canina* L. Recently it has been registered also on *Thymus serpyllum* L. and *Corynephorus canescens* (L.) (Kawecki, 1985; Łagowska *et al.*, 2008). The life cycle of *P. polonica* in Poland was studied by Łagowska *et al.* (2008). However, *P. hamelii* lives on several grass species (*Poaceae*), and *P. sophorae* on plants of the Fabaceae family (Tab. 1).

Dactylopius coccus occurs in Central and South America. Its presence has been confirmed also in South Africa, on Madagascar and the Canary Islands. It develops on the above the ground parts of different species of cactuses of the *Opuntia* genus and on *Nopalea cochenillifera* (L.) (Brunello, 1973; Donkin, 1977). Female specimens live for about 120 days, sucking sup plants which, however, does not influence the cactuses longevity which may reach up to 150-years-old. Males live up to a few days, fecundating many females during their lifetime. Pigment (carminic acid) which constitutes around 10% of dry mass of a female body, because of its unpleasant bitter taste which functions to deter natural enemies of this scale insect species. *D. coccus* is reared in special plantations which are adequately taken care of.

Species of the *Kermes* genus are connected with oak trees. They live on shoots of the *Quercus ballotae, Q. coccifera, Q. ilex, Q. suber, Q. toza* (Hoy, 1963). *Kermes vermilio* is a viviparous, monovoltive species which overwinters in a form of the first stage larva (Marotta *et al.*, 1999). It develops one generation during a year. Young larvae appear in May and at the beginning of June. They are active for a few days after which they settle on young twigs. Adult females lay around 2000 eggs on average. Their dry bodies (Fig. 2) were used as a source of dye (Leonardi, 1920).

Figure 2. Dry females of *Kermes vermilio* from *Quercus coccifera* (M. Börnchen)

Kerria lacca comes from India and is also known in China, Azerbaijan and Georgia. It is registered on 160 plant species of 22 families, most often on species of the Leguminosae family (www.sel.barc.usda.gov). This species develops on wooden parts of trees forming dense colonies on 2-3-year-old twigs.

About 120 larvae and 40 females live on 1 cm^2 of a plant. Females are viviparous, during June-July a single female can give birth to 420-980 larvae (Chadżibejli, 1983). Their body is covered with a layer of resinouos substance (excretion from glands), the colour of which depends on a host species. *K. lacca* is a source of lac dye and wax.

In India the rearing of two races of this species is carried out, and they are called Rangeeni and Kusumi. Each of them develops on a different host plant, has a different length of life cycle and excretes wax, which differs in terms of properties. However, in terms of morphology they constitute one species (Varsheney, 1976; Sequeira & Bezkorowayny, 1998; Sharma, 1991; Sharma & Ramani, 1997).

Species of the *Ceroplastes* genus (*C. ceriferus* (Fabricius)) *C. irregularis* Cockerell and *Ericerus pela* (Chavannes) are sources of wax substances (OHGUSHI & NISHINO, 1975). *Ceroplastes* ceriferus is a parthenogenetic species which develops in North America within one generation yearly. Females develop for four larval stages and overwinter. Males were not observed. In June each of these young females lay on average over 1000 eggs out of which larvae develop after 2-3 weeks. *C. ceriferus* is a polifagous species which has been observed to occur on over 122 plant species of 46 families (Tab. 1) (KOSZTARAB, 1996).

Ericelus pela originally comes from China, but is present also in Japan, Korea and the Far East. It lives on 40 host plant species of the Oleaceae, Anacardiaceae, Malvaceae, Verbenaceae family (Tab. 1). In the tropics, E. pela may develop in two generations a year. In the subtropical zone only one generation develops, while in the moderate climate it needs two years for one generation to develop. The development of females takes place for two larval stages, whereas that of males for two larval stages, prepupa and pupa. Female larvae settle on the upper part of leaves and do not form concentrations. Male larvae appear slightly later, forming colonies on the bottom part of leaves. After moult the female larvae move to two-year-old twigs, they moult and become females. Slightly earlier male larvae appear on twigs where they undergo a further development forming numerous concentrations around the twigs. On average, around 200 male larvae may settle on $1cm^2$ of a twig (QIN, 1997).

Honeydew producing species constitute a separate group of useful scale insects. Honeydew is a substance characteristic to some Hemiptera, including aphids, scale insects and psyllids (KOTEJA, 1996). Scale insects excrete large amounts of honeydew which is rich in sugar and which, in a warm and dry climate, dries quickly forming initially white granules which become brown with time. Honeydew was also mentioned in the Bible, in which its crystallised form was probably considered to be manna falling down from they sky which fed the Israelites exiled from Egypt by Ramses II (IMMS, 1990). On the Sinai Peninsula, on tamarix, the two strongly honeydew producing species of scale insects from the Pseudococcidae family occur *Trabutina mannipara* (Ehr.) and *Naiacoccus serpentinus* Green. *T. mannipara* probably was the source of the famous manna from the sky eaten by the Israelites. In the Near East, farmers still collect honeydew granules early in the morning, before they are eaten up by ants. They are sweet and sticky like crystallised honey and can be stored. One can use them to sweeten drinks and, when mixed with honey or nuts they may be used to bake cakes of a characteristic flavour. Every morning one may collect about 2 kg of such “manna”. Ants as well as other insects (including bees, wasps, house flies, predatory and parasitic insects) make use of this honeydew (BOCZEK, 2001). Honeydew is collected by bees and transformed in a bee hive into very valuable honeydew honey which characteristically has different properties than nectarial honey (they have a higher content of mineral compounds, amino-acids, a richer combination of polysaccharides, substances of antibacterial activity, higher ph) (GAŁUSZKA, 1996).

Larval stages and young females of many scale insects especially those living in the tropical and subtropical climate zones are capable of excreting large amounts of honeydew. There are no diaspidids (Diaspididae) within the scale insects group, which feed on the contents of parenchyma cells and excrete large amounts of wax and so not produce honeydew (KOTEJA, 1996). The greatest honeydew productivity can be seen in older larvae of the second stage and young females during the intensive growth period. The greatest amounts of honeydew are excreted at night (KOTEJA, 1996; GOLAN, 2008).

In the case of honeydew producing scale insects, because of the commonness of this phenomenon only species present in Poland were taken into consideration. They belong to several families (Tab. 2) but their participation in the overall amount of honeydew excreted by heteropterons is small, mainly because of a small number of colonies of honeydew producing species.

Table 2. The scale insects (Hemiptera, Coccoidea) producing honeydew in Poland

Family	Species of scale insect	Host plant	Place of settlement on plant
Pseudococcidae	*Paroudablis piceae*	*Picea* sp.	pins
	Phenacoccus aceris	polyphag on trees and	leaves
	Spinococcus calluneti	heather (*Calluna* sp.) bilberry (*Vaccinium* sp.)	on plant
	Ceroputo pilosellae	*Hieracium* sp. and other herbs	on plant
Kermesidae	*Kermes roboris*	oak (*Quercus* sp.)	stems and shoots
	Kermes querqus	oak (*Quercus* sp.)	stems and shoots
Coccidae	*Physokermes piceae*	spruce (*Piceae* sp.) fir (*Pinus* sp.)	shoot ramification
	Ph. hemicryphus	spruce *Piceae* sp. fir (*Pinus* sp.)	shoot ramification
	Eulecanium sericeum	fir (*Pinus* sp.)	stems and shoots
	Nemolecanium graniforme	fir (*Pinus* sp.)	pins
	Parthenolecanium fletcheri	thujas (*Thuja* sp.)	twigs and pins
	P. pomeranicum	taxuses (*Taxus* sp.)	twigs and pins
	P. corni	Polyphag of decidous trees and shrubs	stems and shoots

Commercial production of dyes, lac and wax

Before synthetic dyes were used on the world market to dye textures, make paint or for cosmetic purposes man used dyes exclusively from natural sources (Donkin, 1977). These substances were taken mainly from different plant species. Dyes taken from the bodies of heteropterons called ‘dyeing scale insects’ are exceptional. Commercial production of dyes from the bodies of scale insects has a long history also in Poland, where it is connected with *P. polonica*. Many indirect proofs point out to the fact that it was already known to the Slavs. As a species delivering natural dye, it was initially collected for one’s own use, and in the fifteenth century and the first half of the sixteenth it was exported from Poland to Italy, Holland, France, England, Turkey and Armenia. The “scale insect industry’“ developed in the area between the Volga and the Rhine rivers, but the species was centrally present in Poland and the Ukraine (Jakubski, 1934).

According to fourteenth-fifteenth-century sources, *P. polonica* was collected in many places throughout Poland of that time which implies that almost the whole country was the area of its exploitation. The harvest was begun usually on 24 June and lasted for 2 – 3 weeks. According to Jakubski (1934) mainly cysts were collected by means of digging out of the plants, the roots of which were shaken onto sheets of material and then were put back to the ground. Probably females which appeared two weeks later were also collected. During the scale insect collecting an iron spatula and a wooden handle were used. The collected specimens were killed with boiling water and were consequently dried in the sun or in a bread baking oven. Then they were pulped or ground, then dissolved in rye acid and cooked with yarn destined to be dyed. The final stage involved rinsing of the yarn in cold water. Such a technique aimed at freeing of the dye from fats contained in the scale insect body which would spoil the dying process. The aim of this kind of technique was to free the red dye from fatty substances. Fabrics (mainly silk), wool, leather, mane, horse’s tails, parchment and ink were dyed in this way. In order to achieve an intensive carmine dye one required 4 pounds of scale insects to dye 1 pound of silk. And out of one ha of land one could collect about 1 pound of cysts or females, and one worker was able to dig out daily at most a quarter of a pound of these insects (Jakubski, 1934). *P. polonica* was used also in many other ways, for instance as a legal tender at clearance undertakings among traders or in court disputes. It was also used as cosmetics to beautify the face, as medicines or strengtheners, as well as a component of paints (Jakubski, 1934; Verhecken & Woulters, 1989).

Trade in scale insects took place usually in June-July and it was concentrated in the hands of Jews and Armenians. The objects of export included dried and powdered cysts probably along with females, and lumps of a fist size formed after vinegar or butter was added to the powder. The goods were transported in leather sacks or special containers, the content of which was measured with the help of the so called stones (the weight of a stone in Poland was 32 pounds). It is estimated that trade in scale insects generated income of 300 thousand florins a year, out of which 10% went to the treasury. A scale insects tribute was collected for the right to 'dig the scale insects', initially it was paid in goods, and then in money, e.g. a county as a tax payer paid 1 mark (JAKUBSKI, 1934).

With time the *P. polonica* had little and little significance on the market. Gradually its store had been used up, because of both, excessive exploitation and systematic decrease of waste lands which were a natural habitat of the scale insect's host plants. Meanwhile, it was forced out from the market by other dyeing scale insects which had a smaller fat content and greater dye content, and later also by synthetic dyes.

In ancient times *P. polonica* was not the only source of red dye. Pigments obtained in a similar way out of the bodies of *Porhyrophora hameli* females and *Porphyrophora sophorae* were also the object of trade. *P. hameli* was commonly registered in salty soils up until the end of the 19th century, and in the Middle Ages it was the source of dye which was traded mainly in Asia Minor, it played an especially important role in the economy of Armenia. In 1437-1438 in Constantinople one could receive from 5.3-9.8 grams of gold for 1 gram of dry insects of this species (CARDON, 2007). In the 20th century the process of a successive decrease of the area of salty soils started to take place which was one of the reasons for this species to die out. For this reason it was registered in the red book of the former USSR and Armenia. At present there is research carried out on the system of protection of this precious species (SARKISOV & SARKISIAN, 1979; SARKISOV *et al.*, 1988; SARKISOV *et al.*, 1990).

The red kermes dye was obtained from females of the *Kermes* genus, mainly from *K. vermilio* species. This dye was known in the ancient times in the Mediterranean region and in Central Europe (VERHECKEN & WOULTERS, 1989). It was used on a large scale until the end of the 19th century. However, since less and less dye was obtained along with high costs of pick, just like in the case of previous species it was forced out from commercial production by cochineal dye obtained from *Dactylopius coccus* females.

Cochineal dye reached Europe from Mexico in the beginning of the 16th century and quickly supplanted dyes obtained from other scale insect species. Commercial production of cochineal dye has survived up to this day and is still taking place in Mexico, Peru and the Canary Islands. The females of this species are reared on cactus farms but are also collected on wild-grown cactuses. Cactus crops together with cochineal scale insects are taken particular care of. They are often enclosed against domestic animals or covered by paper which protects the scale insect females against parasites, wind and rain. At cold nights bonfires are made to protect the insects against cold (www.botgard.ucla.edu). Thanks to such treatment and care *D. coccus* forms resistant to unfavourable weather conditions that produce highest quality dye were selected.

Females after copulation capable to lay eggs contain the greatest amounts of cochineal dye. A yellow drop of excretion which appears on their body signifies adequate time for their collection. Females are collected by hand using simple tools, usually a brush and snap, and then they are killed by drying in the sun or in an oven. Newer technologies of dye production involve the following stages: boiling of the collected insects in water, filtration, cleansing the dye that fell on the bottom of a container as well as drying (www.idrc.ca). In order to obtain 1 kg of dry females one has to collect from 100 000 to 150 000 living specimens. Yearly from 150 to 180 tons of dry females can be obtained, and according to some sources a yearly production amounts to even 300 tons (www.fao.org/docrep).

Peru is the greatest producer of cochineal dye as it delivers over 80% of world production; the remaining percentage comes from the Canary Islands. Dry females or ready dye are exported to Europe, the USA and Japan (IQBAL, 1993; http://www.fao.org/docrep).

The greater part of cochineal dye production is used in cosmetics industry. In food industry, because of its possible allergic impact, there are certain restrictions in the usage of this dye. Application of cochineal dye in the production of food is allowed in North America and Europe but with some limits, for instance in Denmark it is used only for alcoholic beverages, in Sweden its usage was extended to sweets but in Finland it is banned entirely. In Poland it is allowed as an addition to certain foods (E 120) which is used as marinate for poultry and jam, jelly and candy tinting.

At present there is also a commercial production of lac dye out of the protective coatings produced by females of *Kerria lacca* species. The collection of protective coatings with females takes place still before larvae come out (VERHECKEN & WOULTERS, 1989). The collected material is ground and undergoes extraction during which dead females and other impurities are removed. The dye is obtained after acidifying of the water extract. It may have different shades ranging from purple, through red to brown depending on additives used. In ancient times lace dye was used in India as a cosmetic and to dye wool and silk, and in China to dye leather. At the present China, Japan and Thailand used lake dye as an additive to foods (drinks, jams). The history of production and trade in the lake dye goes back to the eighteenth century and has continued until today but to a limited extent. At present it is difficult to assess the world's trade in the lake dye. Only India informs about the extent of its exports which in 2006 amounted to 20 thousand tons (www.ilri.ernet.in).

Also the commercial rearing of *K. lacca* has been taking place for the production of lac and shellac. Protective coatings collected after larvae had left them, can also be used for the production of lac and shellac. After the dye is removed from coatings one can obtain lac out of which, following a special treatment (involving melting and filtration under pressure, extraction with dissolvent, whitening) one can also have shellac. In India, there is a research institute which specializes in the improvement of *K. lacca* rearing and production process of lac. The amount of lac harvest depends on the race of the insect, host plant species and production process. On average out of one tree one can have from 1-10 kg of lac. After processing, shellac constitutes 50% of the initial harvest amount. Today India, Thailand and China are the major producers of resin coating and its derivatives. Total yearly production of lac in India is estimated to amount to 20 thousand tons. India and Thailand are the major exporters of lac products, while China destines nearly its entire production (83 tons) for its own use. Bangladesh, Vietnam, Sri Lanka are smaller producers (www.veganspciety.com). The trade in lac and shellac at present points out to a decreasing tendency as a result of synthetic production of these substances in Thailand. In mid-1950s, India produced about 50 tons of lac and in 1992-93 it produced only 4.5 tons. At the time the export of lac to the United States, Western Europe and Russia fell from 29 tons to about 7 tons a year (www.fao.org/docrep; www.vegansociety.com).

In the past, females of the *Ceroplastes* genus were used for wax production which was used for e.g. candle production in India. At present soft scale *Ericerus* pela is used for the commercial production of wax. It is one of the most early recognized species by man. In China it was known and used for wax production as early as 960-1276. At present wax is delivered by specimens of this species living on *Fraxinus chinensis* Roxb. and *Ligustrum lucidum* Thunb. For wax production male larvae of the second stage are used exclusively. Wax excretion takes place step by step. Initially, it is excreted in small amounts, later it increases and after moult of larva and its moving to the stage of prepupa, the wax excretion almost stops. These biological phenomena were used for commercial production of wax. Therefore, in the beginning of May, tubes containing male larvae are put on trees out of which they instantly move to the bottom part of leaves. Best quality wax is collected just before males flying off during the so-called 'wax flowers' period, through cutting of thin shoots with scale insects on them or by scrapping away the specimens off thick and healthy shoots. Meanwhile, in distant provinces females which deliver male larvae for wax production are reared. Spatial isolation protects the infection of reared larvae with parasites.

Wax is melted through boiling or evaporation. Boiling is a more traditional and more often used method, though the quality of thus obtained wax is lower. It is boiled in water in the ratio of 2 units of wax to 1 unit of water, until it melts.

Then it forms a surface, liquid layer and is removed into a form in which it rests until coagulation. Such wax is taken out, and the remaining bodies of pupae are put into big baskets and washed until yellow colouring is gone. The entire wax collection is placed in a container, boiled for the second time, placed in forms again and left for coagulation (Li, 1985; Qin, 1997).

Wax has a wide-ranging use. In China it has been used for centuries to produce candles. Due to the easiness to mould it is also used in the production of airplane parts, cable and other electric devices isolation, high quality paper, car paste, artificial flowers and fruit. It is also used in the production of medicines and energizers, as a medium to minimize bleeding, to ease the pain or strengthen muscles. In contemporary medicine in China it is used to cure epilepsy, skin diseases and rheumatism. In horticulture and agriculture it is used to protect the cut tissues from damage or wetness (www.cross-century.-com). In China annual production of wax reaches on average 300 tons. Despite the presence of other wax substances on the market e.g. paraffin, Chinese wax is still produced because it has higher temperature of melting (83°-86°C, paraffin 50°-60°C), and its production is safe for the environment.

Summary

Scale insects are not only pests of crop plants, but also a source of useful substances which can be used in economy. Commercial production of dye out of scale insects bodies has a long history, and some species such as *P. polonica* and *P. hamelii* had an important impact on Poland's and Armenia's economic situation since the fourteenth through to the sixteenth century. At present the production of cochineal dye is carried out to a large extent. This dye is resistant to high temperature, light and oxygenizing processes (www.idrc.ca). Despite a number of advantages resulting from its use in many countries some restrictions were introduced to control the usage of this natural dye. They result from side effects which may come out after consumption of products containing cochineal dye. These include numerous breathing allergies (bronchial asthma) and tactual allergies (vaso-motor swelling) (www.alergia.org.pl).

A quickly developing market for cochinelian dye in Peru contributed to a growing interest in the remaining scale insect species which used to be sources of natural dye and can still be used for such purposes (Debray & Pathak, 1972; Donkin, 1977; Baranyvots, 1978; Sarkisov & Sarkisan, 1979; Schweppe & Roosen-Runge, 1979; Lloyd, 1980; Ziderman, 1990; Böhmer, 2000) including renovation of precious arrases and in food production. A too small amount of dying substance and too much fat (more than 30% of body mass) in the bodies of insects of the *Porphyrophora* genus is one of the factors which hamper the usage of these insects for mass production of carmine dye. Fat makes it more

difficult to dye fabrics (Verhecken & Woulters, 1989). An additional problem, though not less important is a noticeable disappearance of *P. polonica* and *P. hamelii* mainly associated with the damage of their natural habitats. The disappearance of *P. polonica* (Polish cochineal) and the need for its protection was first observed already in the eighteenth century. According to Jakbuski (1934) already in 1731 Breynius stated: 'everyone who neglects precious treasure which nature has given to us deserves contempt. The only chance to preserve the natural populations of *P. polonica* in Poland is a legal means of protection in a form of habitat protection as well as its inclusion in the red list of endangered species (Łagowska & Golan, 2006; Łagowska *et al.*, 2006; 2008). The perspective of kermesidae species usage for dye production is made more difficult due to high costs of insect collection. Therefore, nowadays only enthusiasts are involved in kermesidae dye production.

The introduction of synthetic dyes on the market essentially lowered the market demand for lac dye which is obtainable from *K. lacca* but it is still used for a commercial production of lac and shellac. Also wax which is obtainable from *E. pela* has a wide ranging usage in many branches of industry, mainly due to its unique physical properties.

In recent years one could observe an increase in the interest in scale insects which are a source of natural substances used in the production of food, medicines, cosmetics as well as the renovation of precious fabrics. Such a tendency is partially prompted by a growing demand for the so-called ecological products among consumers. Despite certain faults, natural dyes are regarded as additives that are safe for health, hence one should expect that the importance of insects, including scale insects as a potential source of natural substances is likely to increase. It is, however, conditioned by research, the results of which may improve commercial rearing of scale insects and the process of natural dye, wax, lac and shellac production.

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Czerwce /Hemiptera, Coccoidea/ jako źródło naturalnych barwników i innych użytecznych substancji

Streszczenie

Od wieków niektóre gatunki czerwców wykorzystywane były do produkcji barwników (*Porphyrophora polonica*, *P. hameli, Kermes vermilio, Kerria lacca*), wosku (*Ceroplastes ceriferus, C. irregularis, Ericerus pela)*, laku i szelaku (*K. lacca*); pluskwiaki te są również źródłem spadzi. W dzisiejszych czasach nadal niektóre z nich (*D. coccus*) dostarczają naturalnego pigmentu wykorzystywanego w produkcji jogurtów, słodyczy i napojów w przemyśle spożywczym.

Czerwiec polski jest historycznym i „zasłużonym" dla Polski gatunkiem. W dobie Polski Jagiellonów stanowił jeden z ważnych czynników gospodarki narodowej przyczyniając się do świetności państwa i dobrobytu społeczeństwa. Również w dzisiejszych czasach mógłby być stosowany w wielu dziedzinach gospodarki, np. w przemyśle spożywczym. Jednym z czynników utrudniających wykorzystanie gatunków z rodzaju *Porphyrophora* do masowej produkcji karminowego barwnika jest zbyt mała zawartość substancji barwiącej w ciałach tych owadów oraz zbyt duża zawartość tłuszczu (około 30% masy ciała), który utrudnia proces farbowania tkanin. Dodatkowym, niemniej ważnym problemem, jest zauważalne zanikanie *P. polonica* i *P. hameli*, związane głównie z niszczeniem naturalnych środowisk ich występowania. Zjawisko zanikania czerwca polskiego i potrzebę jego ochrony dostrzeżono już w XVIII wieku. Należy zaznaczyć, że w świecie *P. polonica* uznawany jest obecnie za gatunek rzadki, zasługujący na ochronę. W dzisiejszych czasach wprowadzenie do handlu syntetycznych barwników znacznie zmniejszyło zapotrzebowanie na

barwnik lakowy, którego źródłem jest *K. lacca*, ale nadal gatunek ten jest wykorzystywany do komercyjnej produkcji laku i szelaku. Również wosk pozyskiwany z *Ericerus pela* ma szerokie zastosowanie w wielu gałęziach przemysłu, głównie ze względu na swoje niepowtarzalne właściwości fizyczne.

W ostatnich latach zauważa się wzrost zainteresowania czerwcami, które są źródłem naturalnych substancji stosowanych do produkcji żywności, leków, kosmetyków i renowacji cennych tkanin. Tendencja ta jest w pewnym stopniu wymuszona wzrastającym popytem na tzw. produkty ekologiczne wśród konsumentów. Pomimo pewnych wad naturalne barwniki postrzegane są przez konsumentów jako dodatki bezpieczne dla zdrowia i należy oczekiwać, że znaczenie owadów, w tym czerwców, jako potencjalnego źródła naturalnych substancji będzie w przyszłości wzrastało. Warunkiem jednak jest przeprowadzenie szeregu prac badawczych, których rezultaty ulepszą komercyjną hodowlę czerwców i proces produkcji naturalnych barwników, wosku, laku i szelaku.