It is crucial for beekeepers to have spare queen bees in early spring. Additional queens can be introduced into colonies that have lost their own queen bees in the winter. They can also be introduced into new colonies which have been divided early in the spring. This is particularly important in Poland because of the severe winters, cold springs and short vegetative period. Introduction of spring queen bee imports from outside Europe, is popular among beekeepers (Wilde, 2000). Due to climatic differences, young queen bees from outside Europe were available in the early spring, when in Poland the rearing of queens is impossible. Instead of expensive imports, methods for wintering queen bees can be developed. Such methods could become a breakthrough in the applied apicultural technologies. First of all these methods are inexpensive - after the breeding season, beekeepers have mating nuclei with egg laying queen bees. Second - the small colonies overwintered as nuclei, grow in strength during the spring. Then, they can be divided, and the new queens reared the next season can be introduced into the queenless parts. And third - when there are egg laying queens in the spring, the beekeepers can divide the colonies early, and increase the number of productive colonies for the late flow.

**INTRODUCTION**

The aim of this study was to develop an effective method which provides for additional queen bees to overwinter in mating nuclei. The assay was carried out in the years 2005-2008 (three wintering seasons) in three places in Poland: the Department of Zoology and Beekeeping at the West Pomeranian University of Technology in Szczecin, Division of Apiculture, University of Life Science-SGGW in Warsaw, and the Apiculture Division at the University of Warmia and Mazury in Olsztyn. Experimental colonies were created and kept in two types of nuclei: in a trapezoid, top-bar mating nucleus [TB] and in a mini-plus nucleus [MP]. The highest number of colonies survived in Szczecin (63%), less in Warsaw (31%), and the least in Olsztyn (20%). In the TB nuclei, only 2% of the colonies overwintered successfully. In the MP nuclei with one colony, 65% overwintered successfully, and in MP with two colonies - 45% overwintered successfully.

**Keywords:** wintering season, queen bees, mating nuclei.
brings about a six-fold increase in its honey productivity (Farrar, 1971). According to Woyke (1984), honey bee colonies with one-year-old queens, produced 27% more honey than those with two-year-old queens. Wilde (2000) and Wilde et al. (2002) report that about 50% less honey was collected from colonies with three-year-old queens than from those with one-year-old queens. Bee colonies with young queen bees are also less likely to develop a swarming impulse (Zeiler, 1985; Siuda and Wilde, 2002; Wilde, 2006).

The first attempts at wintering spare queen bees, date back to the 60s of the previous century. Most often, young queen bees were wintered in small nuclei (Olejniczak, 2002) or in small colonies (Pidek, 2003). Most tests were carried out in a bee yard. Single queen bees were placed in the original hive, in a compartment composed of several honeycombs, separated by a tight board (Bornus and Szymankiewicz, 1968; Ostrowska, 1974). This method of wintering was not adopted in practice, though, because of the high labor input and material costs.

Several queen bees were also wintered in cages called “queen banks,” in a hive. However, due to the antagonistic behavior of the surrounding bees, the queens were injured (Woyke, 1988; Jasiński, 1995). In one bee colony, the attempts to winter several freely moving queen bees deprived of their stingers, also failed (Paleolog, 2001).

Efforts were made to keep queen bees outside the hive in the winter (Foti et al., 1962; Wyborn et al., 1993; Prabucki et al., 2003). But so far, no satisfactory results have been achieved. During wintering, nosema disease developed in the attendant bees (Kostecki, 1976; Prabucki et al., 1982; Gliński and Chmielewski, 1994; Sokół and Romaniuk, 2000; Muszyńska, 2001; Czekońska, 2002; Tomaszweska, 2002). After some time, it was found that bees originating from healthy colonies were affected by Nosema apis (El-Shemy and Pickard, 1989).

Wintering queen bees in mating nuclei is cheap compared to the cost of importing queen bees. This is because, queen-rearing beekeepers have at their disposal a great number of nuclei with egg laying queens. Earlier, these nuclei with egg laying queens had to be eliminated after the breeding season (Wilde, 2004). The reasons mentioned above, triggered the search for a way to develop an effective method of overwintering spare queen bees in mating nuclei.

MATERIALS AND METHODS

The assay was carried out in the years 2005-2008 (three wintering seasons), in the following centers:

1. Department of Zoology and Beekeeping, West Pomeranian University of Technology in Szczecin (northwestern Poland)
2. Division of Apiculture, Warsaw University of Life Science - SGGW (central Poland)
3. Apiculture Division, University of Warmia and Mazury in Olsztyn (northeastern Poland)

Queens-sisters of Apis mellifera carnica subspecies were reared every year in queenless rearing colonies. On the 9th day, capped queen cells were transferred to an incubator (T=34.5°C and RH=80%). After emergence, the queens were marked with numbered plastic discs. Then, they were placed in small transport cages with 10 attendant worker bees. They waited in the cages before being introduced into the experimental colonies.

Experimental colonies were created and kept in two types of nuclei: a trapezoid, top-bar mating nucleus [TB] (with a comb size of 13.5 top × 9 bottom × 9 height cm) and a multi-super nucleus with six combs in the box, in frames measuring 215 x 163 mm - mini-plus nucleus [MP]. All the nuclei were supplied with comb foundations. In order to extend the nest area for a wintering colony in trapezoid nuclei, supers with six honeycombs were added (frame size: 148 x 125mm). After the nuclei were stocked with worker bees
of *Apis mellifera carnica* subspecies, they were transferred to a dark cellar for two days (T=10°C). TB was stocked with ca. 100g bees, and MP with ca. 250g bees in one box. Seven/eight-day-old queen bees were instrumentally inseminated with 8 μl semen from a Carniolan drone. When the queens started egg laying, the colonies’ diet was supplemented with candy. Each year, winter feeding of the colonies started 15th August and ended 15th September. The colonies to be wintered in MP were fed syrup (5 : 3, sugar : water), and those to be wintered in TB were fed candy, in several portions.

The colonies prepared for wintering were randomly divided into the following groups:

I TB trapezoid, top-bar mating nucleus
II TBS trapezoid, top-bar mating nucleus with a super
III MP1/2 mini-plus twin-nucleus (two colonies, each wintering on three combs of the nucleus, separated in the middle by a vertical board)
IV MP1 mini-plus nucleus, one colony wintering on six combs in a whole box

The colonies in each group were divided into two subgroups: A - wintered on a bee yard and B - wintered in a cellar.

From 20th Aug. to 15th Dec. all nuclei were in a bee yard. In the autumn, when the temperatures fell below 0°C for a few consecutive nights, half the colonies were transferred to a cellar (T=4-5°C and RH=ca. 65-75%).

Once a month, the wintering colonies were examined with a stethoscope. Based on the emitted sounds, the course of wintering was assessed. When sound assessment was difficult, it was always possible to lift the nucleus cover for a quick look at the colonies.

For Olsztyn, the temperature and humidity data were obtained from the measurements of the UWM meteorological station, for Warsaw - from the SGGW meteorological station in the Ursynów quarter, and for Szczecin - from the service: *Weather Underground* (http://www.wunderground.com). The average daily air temperatures for Poland for the last 30 years, referred in this paper as “perennial data”, were also obtained from the UWM meteorological station in Olsztyn.

Two and three-way ANOVA was carried out. Significance of difference between the means (x) was determined by Duncan’s multiple range test. The data in percentages to be used in statistical calculations, were converted by the arcsine transformation (Bliss). The means differing significantly (p < 0.05) were marked with different small letters.

**RESULTS**

**1.1 Weather conditions**

Weather conditions could have considerably affected the results of the research. That is why throughout the assay, temperature and relative humidity of air were regularly measured. The two-way analysis of variance (research place and season) did not show significant interaction between the place of the investigation and the consecutive wintering seasons (F=0.090, p<0.985).

While the colonies were wintering, the average monthly air temperatures for each center were similar to the perennial average (Fig. 1a). In the late autumn and in the winter, the highest average temperatures were in Szczecin, average temperatures were lower in Warsaw and the lowest average temperatures were in Olsztyn (Fig. 1a). In the early spring, the highest temperature was in Warsaw, and the lowest in Szczecin. Average monthly temperatures for individual centers, were slightly higher than the perennial average temperatures.

The average relative air humidity during wintering was very similar in all centers (Fig. 1b). It ranged between 76.2% and 92.4% from November to March. During the first spring months, it decreased in all centers. In April, the average relative air humidity was highest in Szczecin (75.7%), and lowest in Olsztyn (63.4%).

Average monthly temperatures differed significantly in the consecutive wintering seasons (F=15.728, p<0.001).
In the 2005/2006 season, the average air temperature in November (8.9°C) was considerably higher than the average in other seasons, and higher than the perennial average (2.7°C - Fig. 1c). In January 2005/2006, the average temperature (-7.1°C) was significantly lower than the average temperatures for the 2006/2007 and 2007/2008 seasons: 3.4°C and 0.9°C, respectively; and lower than the perennial average (-2.9°C). The frost-period in the 2005/2006 season, lasted until March when the average temperature was -1.2°C. In March, the average temperature was significantly lower than the perennial average (1.2°C) and lower than the average temperatures in the 2006/2007 and 2007/2008 seasons: 6.2 and 3.1°C, respectively. The average air temperatures in the individual seasons in April, were similar to the perennial average and ranged between 6.7°C and 8.0°C.
The average monthly relative air humidity for the three locations in the consecutive seasons was very similar from November to March, and ranged between 84.1% and 92.8% (Fig. 1d). In the first spring months, the humidity fell in all locations. In April, the significantly lowest average ($F_2= 5.4, p<0.005$) was observed in the 2006/2007 season (60.6%), and the highest in the last 2007/2008 season (81.7%).

1.2. Survival of colonies

The place where the queen bees were wintered (a bee yard or an underground wintering building) did not significantly affect the differences in the survival of the colonies ($F_1 = 0.562, p = 0.454$). Consequently, the rest of our report contains the total results, without referring to the colonies as being split into the subgroups: A (colonies wintering on a bee yard) and B (colonies wintering in a cellar).
1.2.1. Survival of colonies in three locations

Wintering the queen bees in trapezoid nuclei without a super (group I, TB) was not successful in any of the locations and seasons. That is why this assay group is not presented in Table 1, nor in the following description of the results.

The two-way ANOVA indicated a highly significant interaction between the assay groups and apicultural seasons as well as the place of the research \( F_2^2 = 3.324, p = 0.001 \).

The queen bees overwintered most effectively in Szczecin. In the 2007/2008 season, 19% of them survived in trapezoid top-bar nuclei with a super (gr. II, TBS), 81% in twin mini-plus nuclei (gr. III, MP1/2), and as many as 95% in one-box mini-plus nuclei (gr. IV, MP1 - Tab. 1).

In Warsaw and Olsztyn, queen bees in trapezoid nuclei with a super (gr. II, TBS) did not survive the winter in any season.

In the last year 2007/2008, in Warsaw, most colonies survived in twin and single-colony mini-plus nuclei (gr. III, MP1/2 and gr. IV, MP1), i.e. 75% and 68%, respectively.

In 2005/2006 in Olsztyn, most colonies (32%) survived in twin-colony mini-plus nuclei (gr. II, MP1/2). In 2007/2008 most colonies (46%) survived in the same nuclei type, yet wintered as a single colony (gr. IV, MP1).

In total, in all three seasons, the significantly highest percentage of queen bees were those that survived the winter in Szczecin (63%). In Warsaw, a significantly high percentage of queens (31%) survived the winter, than in Olsztyn (20%) (Tab. 1).

### Table 1

<table>
<thead>
<tr>
<th>Center</th>
<th>Year</th>
<th>Group</th>
<th>Centers in total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>II (TBS)</td>
<td>III (MP1/2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>% ± sd</td>
</tr>
<tr>
<td>Szczecin</td>
<td>2005/2006</td>
<td>20</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2006/2007</td>
<td>23</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2007/2008</td>
<td>21</td>
<td>19* ± 0.4</td>
</tr>
<tr>
<td>Warszawa</td>
<td>2005/2006</td>
<td>6</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2006/2007</td>
<td>20</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2007/2008</td>
<td>18</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td>Olsztyn</td>
<td>2005/2006</td>
<td>19</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2006/2007</td>
<td>20</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td></td>
<td>2007/2008</td>
<td>20</td>
<td>0.0* ± 0.0</td>
</tr>
<tr>
<td>Groups in total</td>
<td>167</td>
<td>2* ± 0.2</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30* ± 0.5</td>
<td>36* ± 0.5</td>
</tr>
</tbody>
</table>

**Group II (TBS) – trapezoid polystyrene mating nuclei with a super**

**Group III (MP1/2) – one-box mini-plus nuclei with two colonies**

**Group IV (MP1) – one-box mini-plus nuclei with one colony**

Different small letters indicate significance of differences for p<0.05.
1.2.2. Survival of queen bees in different nuclei types

In total, of all the centers and seasons, the significantly highest percentage of queen bees that survived in the colonies (65%) were those that occupied the whole box of a mini-plus nucleus (gr. IV, MP1). A significantly high percentage of queen bees that survived in the colonies (47%) were those that occupied half a mini-plus nucleus. But only 2% of queen bees survived in the colonies that occupied trapezoid top-bar mating nuclei with a super (gr. II, TBS) (Tab. 1).

1.2.3. Survival of queen bees in different seasons

Survival of queen bees in different seasons varied. In total, of all the centers, significantly more queen bees (50%) survived the 2007/2008 winter which was the last year of the study, than in 2006/2007 and 2005/2006: 36% and 30%, respectively. Compared to the last year, the survival rate in 2006/2007 and 2005/2006 was 14% and 20% smaller, respectively.

1.3. Survival of colonies in consecutive wintering months

The number of living colonies gradually decreased in the consecutive wintering months in all the centers, groups, and years of the research (Fig. 2).

1.3.1. Average monthly survival of colonies in different locations

On the average, of all the three seasons and nuclei types, the fewest colonies died in Szczecin (Fig. 2). In October - January more than 80% survived, and by the end of the wintering season, the survival rate fell in March to 60% of the initial value. In Warsaw and in Olsztyn, the survival rate decreased similarly. During the first two months, 90% of the colonies survived. Then, the survival rate suddenly dropped. In December, 60% of the colonies survived, and by the end of wintering, only 20% survived in Warsaw and ca. 5% in Olsztyn.

On the average, of all the three seasons and locations, the colonies in trapezoid top-bar nuclei with a super (gr. II, TBS) already started to suddenly die in December (40% of the living colonies). By the end of wintering in March, only a few of them survived (Fig. 3). The colonies in one half of the mini-plus nucleus (gr. III, MP1/2) overwintered successfully till January. A decrease was observed in this group (gr. III, MP1/2) after January, and eventually 47% of the colonies survived the winter. Wintering was most successful for the colonies in the whole box of a mini-plus nucleus (gr. IV, MP1), where single losses were distributed evenly, throughout the whole wintering season (Fig. 3).

Fig. 2. Average survival of colonies in consecutive months in three locations (%).
On the average, of all the locations and nuclei types for the first wintering season of 2005/2006, the fewest colonies survived between January and March (Fig. 4). During the next wintering season, the fewest colonies survived in January and February 2007. In the last season; 2007/2008, single colonies started dying in December. Losses were evenly distributed throughout the wintering period.

The most frequent cause of losses of colonies was insufficient nutrition, as 71.4% died from hunger (Fig. 5). Starving colonies often suffered from dysentery (9.5%). Quite often (10.2%), the bees did not move to upper sections of the trapezoid top-bar nuclei with a super (gr. II, TBS), even though there was still food left. A sudden population drop of bees was observed in 8.9% of the colonies.

Fig. 4. Average survival of colonies (%) in the consecutive months of three wintering seasons.

Fig. 3. Average survival of colonies from different groups in the consecutive months of wintering season (%).
Explanation: TBS - trapezoid, top-bar mating nucleus with a super; MP1/2 mini-plus twin-nucleus; MP1 mini-plus nucleus, one colony wintering on six combs in a whole box.
DISCUSSION

Successful wintering of bees is significantly affected by atmospheric conditions, especially by the number of days with severe frost as well as by the number of days with thaws. During the first and the second wintering season, extremely low temperatures occurred (even -30°C), which weakened the effectiveness of queen bee wintering, to 30% and 36%, respectively. Weather conditions considerably improved the last year, which resulted in a higher survival rate of the wintering queen bees (50%). The wintering success was different in the three different places. Most colonies survived the winter in Szczecin (63%), less in Warsaw (31%), and the least in Olsztyn (20%). These results were probably caused by lower winter temperatures in the two latter locations as compared with Szczecin.

Also, other authors (Bornus et al., 1974; Bobrzecki, 1976; Ostrowska, 1984; Prabucki et al., 2003) have pointed out the effect of temperature on the success of overwintering bee colonies. Pechhacker and Kasjanow (2004) believe that bees should winter in an outdoor temperature of around 0°C, as in such conditions the intensity of heat generated by bees, which reflects the level of their metabolism, is minimal. Sowa et al. (1983) wintered the colonies indoors, at a temperature ca. 4°C, and the survival rate was 93.95%.

During the wintering period, relative air humidity was very high (ca. 90%) in all the research centers and seasons. Such high humidity shortens the life of wintering bees (Ostrowska, 1984; Muszyńska, 2004; Skubida, 2004b; Roman, 2007).

According to Bratkowski (1998), the most decisive factor affecting bee survival in winter is the strength of bee colonies. The results of our research prove that it is not satisfactory to overwinter queen bees in trapezoid top-bar mating nuclei (TB) either in a bee yard or in a cellar as independent units. Only 2% of these queen bees survived the winter. Maul and Schneider (1991) were able to overwinter such small colonies in a cellar only when they replaced the worker bees in the colonies three or four times. Bornus and Szymankiewicz (1968) successfully overwintered 50% of queen bees in mating nuclei, which were placed between two bee colonies wintering in one hive. In such conditions, bees in the nuclei took advantage of the heat generated by the neighbouring colonies.

The colonies wintering in mini-plus nuclei (MP) had better chances for survival because of an extended nest area. This area gave both a greater storage potential as well as a larger number of bees, and at the same time - there was a smaller production of thermal energy per bee. In our assay, in mini-plus nuclei, 47% of the wintered colonies survived the winter on three
honeycombs (gr. III, MP1/2), and 65% on six honeycombs (gr. IV, MP1). There is definitely less heat loss in the case of a bigger cluster because of the favorable relation of the cluster size to its surface, and because of greater heat production. In weak colonies, the mechanism is the same, yet with an adverse effect.

Wintering of spare queen bees in mating nuclei is difficult, because of the small number of bees and the small nest surface. Food scarcity was the most common cause of the dying of colonies (71.4%). Starving colonies often suffered from dysentery. Defecation into the nest was observed in 9.5% of wintered colonies.

In trapezoid top-bar mating nuclei with a super (gr. II, TBS), bees quite frequently (10.2%) did not get to the upper sections, even though there was still food left. This may have resulted from rearing brood in the lower sections late in the autumn, and then the bees remained in the lower sections.

The sudden population drop in 8.9% of the wintered colonies is difficult to explain, yet it may be attributed to the phenomenon of single bees leaving the hive during a wintering season.

CONCLUSIONS
Trapezoid top-bar mating nuclei are unsuitable for self-wintering of bee colonies in Poland, because of their small size.

The best conditions for wintering of spare queen bees were in mini-plus nuclei, when the colonies occupied the entire box (six combs).

ACKNOWLEDGEMENTS
The assay was carried out thanks to the support of the Ministry of Science and Higher Education - as Own Research Project No 2 P06Z 058 28. We would like to thank the head of this project Prof. Dr. hab. Jarosław Prabucki, for effectively managing this experiment for 3 years.

REFERENCES


ZIMOWANIE ZAPASOWYCH MATEK PSZCZELICH W ZMODYFIKOWANYCH ULIKACH WESELNYCH


Streszczenie

Posiadanie zapasowych matek wczesną wiosną jest bardzo ważne dla pszczelarzy. Matki te można poddać do rodzin, które straciły własne matki zimą. Można je również poddać do wczesnych odkładów. Ma to szczególne znaczenie w Polsce, charakteryzującej się srogimi zimami, chłodnymi wiosnami i krótkim sezonem wegetacyjnym.

Celem badań była próba opracowania skutecznej metody zimowania zapasowych matek pszczelich w ulikach weselnych. Doświadczanie przeprowadzono w latach 2005-2008 (3 zimowle) równolegle w trzech jednostkach: Katedrze Zoologii i Pszczelictwa Zachodniopomorskiego Uniwersytetu Technologicznego w Szczecinie, Samodzielnej Pracowni Hodowli Owadów Użytkowych SGGW w Warszawie i Katedrze Pszczelictwa Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Rodzinki z matkami unasienionymi sztucznie 8 μl nasienia w wieku 7-8 dni przygotowane do zimowli podzielono losowo na następujące grupy:

I TS trapezoidalny snozowy ulik weselny.
II TSN trapezoidalny snozowy ulik weselny z nadstawką.
III MP1/2 dwurodzinny ulik mini-plus (dwie rodzinki, każda zimująca na 3 plasterkach w połowie ulika, przedzielonej pionową przegrodą).
IV MP1 ulik mini-plus, jedna rodzinka zimująca na 6 plasterkach w całym korpusie.

Rodzinki w każdej grupie podzielono na 2 podgrupy: A - zimowane na pasieczysku i B - zimowane w piwnicy.

Miejsce zimowania matek (toczek lub stebnik) nie wpłynęło istotnie na zróżnicowanie przeżywalności rodzinek (F = 0,562, p = 0,454). Nie udało się przezimować matek w ulikach trapezoidalnych bez nadstawki (gr. I, TS) w wszystkich ośrodkach oraz latach badań. W sumie, ze wszystkich miejscowości i sezonów, wysoko istotnie najwięcej matek (65%) przeżyło w rodzinkach zimujących pojedynczo w korpusie ulika mini-pluss (gr IV, MP1). Najwięcej rodzinek przeżyło w Szczecinie (63%), mniej w Warszawie (31%), a najmniej w Olsztynie (20%). W ulikach TS przezimowano tylko 2%, a w ulikach MP zasiedlonych pojedynczo - 65% i 45% przy zasiedleniu przez dwie rodzinki. Trapezoidalne snozowe uliki weselne, ze względu na swoje niewielkie wymiary, nie nadają się do samodzielnego zimowania rodzinek pszczelich w Polsce. Najkorzystniej zapasowe matki zimowały w ulikach mini-pluss, gdy rodzinki zajmowały cały korpus (6 plasterków).

Słowa kluczowe: zimowla, matki pszczele, uliki weselne.