SCIENTIFIC WORKS OF THE LITHUANIAN INSTITUTE OF HORTICULTURE AND LITHUANIAN UNIVERSITY OF AGRICULTURE. SODININKYSTĖ IR DARŽININKYSTĖ. 2009. 28(3).

Optimization of time and expediency of *Incurvaria capitella* Cl. number regulation

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Investigations were conducted in black currant plantations (Minsk district) in 1994–2008. The objects of researches were black currant cultivars growing in Belarus and currant bud moth (Lampronia (*Incurvaria) capitella* Cl.).

The objective of researches was to develop currant bud moth monitoring system in black currant plantations based on phenological forecast of pest development. There was applied original synthetic phytophage sex pheromone considering a degree of different currant cultivar damage.

An algorithm of phenological forecast of currant bud moth development was worked out. It gave an opportunity to determine beforehand the optimum time of registering of caterpillars leaving their wintering places, imago flight dynamics and carrying out a complex of chemical and agrotechnical measures. The attractiveness of the original synthetic phytophage sex pheromones was studied. It was determined that as a dispenser for the synthetic sex pheromone it is preferable to use the insulin cork or rubber black tube with a. i. content 1 mg/dispenser. It is determined that mid-early cultivars ('Minay Shmyrev', 'Partisanka') under conditions of Belarus are damaged by black currant moth much stronger than the mid and mid-late ones. The least pest-damaged cultivar is mid-late 'Zolushka'.

Key words: attractiveness, black currant, cultivar damage, development forecast, *Incurvaria capitella*, monitoring, pheromone.

Introduction. Currant bud moth *Lampronia* (*Incurvaria capitella*) Cl. is a constant representative of currant fauna in all the regions of this crop cultivation. The phytophage damages both black and red currant, however, prefers a black one (Labanowska, 2003). Black currant bud damage do not using the protective measures in years of mass pest development can reach 80–100 %, what practically leads to full crop loss. Basing on literary data, the most strongly damaged are early cultivars (Савздарг, 1960). Some features of the phytophage development complicate its monitoring, abundance and spread restriction. Already during black currant bud swelling, which depending on weather conditions can be observed even in February, the first wintering caterpillars leave the shelter places and bite into currant buds. To catch visually the beginning of pest appearance from wintering places it is necessary

to carry out periodic (in 3–4 days) observations in plantations since February and prior to the beginning of currant bud breaking. This is rather laborious and expensive (Крикунова и др., 2007). It shows an urgency of investigations, which would improve the methods of doing records and optimize the terms of protective measures.

Being in buds the caterpillars feed prior to the beginning of black currant blossoming. The pest pupation starts in the top soil layer during the period of floral racemes advancing before mass black currant blossoming. The butterfly flight starts in May and coincides with black currant blossoming termination. As currant bud moth imago are active for a very short period of time, that is from 6.30 to 9.30, certain difficulties monitoring their abundance and timely revealing the focuses of their distribution are created. The female lays eggs in pulp of green berries. The hatched caterpillars within several days eat seeds of berries, and then disappear in shelters for wintering (Ярчаковская, 2000).

So, high phytophage harmfulness, the latent way of life of a harmful stage, low and short imago activity determine the expediency of carrying out the researches on working out the methods and techniques of its monitoring on different by maturation cultivars.

For terms optimization and the expediency of realization of these or the other actions for plant protection by working out the modern strategies of insect pest population control a great attention is given to the development and use of phenological forecasts of phytophage development and also studying host-plant cultivars infection. The use of synthetic sexual pest pheromones (SSP) for their number monitoring is also rather perspective.

In connection with the above-stated, the purpose of our researches was working out the algorithm of phenological forecast of currant bud moth development for optimization the terms of conducting pest abundance assessments and protective measures, creation of the synthetic sexual phytophage pheromone for timely revealing the focuses of its occurrence, an estimation of various currant cultivars infestation by the phytophage for determining the expediency of carrying out sprayings.

Objects, methods and conditions. The observations of currant bud moth development phenology, collection of biological material, field and farming trials were conducted in black currant plantations of fruit-growing farms, Minsk district (“Zubki”, “Agroconcern Kletsky”, “Uzdensky”), in 1994–2006. The observations on the assessment of black currant cultivars phytophage infestation were started on an experimental plot of Fruit-growing Institute (Minsk district) in 2003–2004. The attractiveness of local samples of currant bud moth synthetic sex pheromones was evaluated in fruit-growing plantations of the farm “Zubki” (Minsk district) in 2007 and 2008.

The objects of researches were the regionalized in Belarus black currant cultivars (‘Minaj Shmyrev’, ‘Partizanka’, ‘Katyusha’, ‘Odzhebin’, ‘Kantate’, ‘Belarusskaya sladkaya’) and currant bud moth (*Lampronia* (*Incurvaria*) *capitella* Cl.).

Investigation of migration dynamics of currant bud moth wintered caterpillars from wintering places to buds, their harmful activity period, dynamics of leaving for pupation was done by daily observations of ten registered black currant bushes colonized by moth. From the moment of buds swelling 50 buds were inspected on

tops of branches of each registered bush and the number of pest caterpillars feeding in them was recorded. The observations of caterpillar development were done by their individual maintenance on currant branches free of other pests (1 caterpillar on a branch). The duration of pupae development was studied by their individual development in not less than 20 test tubes with soil. An establishment of butterflies fly out dynamics was done in entomological insect cages. Insect cage size was 30 x 30 x 50 cm and it was in a form of a wooden frame fitted from three sides by a kapron sieve and from the fourth side glazed by sliding glass, cage's bottom and top – from wood. The cage's bottom was filled with 5–6 cm volume sifted soil layer. Black currant branches colonized by bud moth last age caterpillars (400–500 individuals) were placed in each cage. Every 2 days from the moment of fly out beginning butterfly number was recorded. Observations on imago life duration, female fecundity were done on currant branches under gauze insulators put on a wire frame, where the just flied out individuals were placed (15 insulators having 1 female and 2 male in an insulator). The insulators were daily inspected. After butterflies were killed by opening berries, the number of eggs laid by a female was recorded. Dynamics of caterpillars hatching, their feeding duration in berries and periods of diapause leaving were determined by periodic (every three days from the beginning of egg laying) 100 berries opening taken from the pest-infested plantation.

The evaluation of black currant cultivar damage by bud moth was done by inspecting 50 buds on each of 10 registration bushes of each cultivar and recording the pest-damaged buds after the phytophage brought full damage.

The itinerary inspections and estimation of currant plantation phytosanitary condition were done by the standard methods (Алехин и др., 1988; Грин и др., 1996).

Systematization, generalization and statistic processing of the collected material for creating the algorithm of phenological forecast of currant bud moth development were done by the method of correlation and regression analysis (Zar, 1996; Уланова, Забелин, 1990). Relations between constant indicators and the application of the investigated relationships for the forecasting equations were done by multiple regression analysis method. Reliability of the developed evaluations was verified by F – Fisher's criterion and t – Student's criterion, supposing 95 % significance level. The meteorological data necessary for the calculations have been obtained from agrometeorological stations, located close to the place of the researches.

For doing a primary estimation of attractiveness of currant moth synthetic sexual pheromone (SSP) samples before black currant blossoming the plots were selected with a high pest number. During blossoming on selected plots pheromone-glue traps of the type Atrakon-A with various samples of synthetic sex pheromones provided by the employees of Elementary Synthesis Scientific-Research Laboratory of Belarussian State University were hung out. The experiments were accomplished in 5–7 repetitions (1 repetition – 1 trap). Traps were numbered and hung out in the top part of black currant bush. The traps were located along the plot in a randomized way in a distance of not less than 30 m from each other and from planting edge. The trap records were done regularly every 7 days. The caught butterflies were recorded and taken away from a sticky surface. For experiments a sticky mass "Vinilon" was used. Glutinous

loose leaves in traps were replaced as required. Attractiveness of all the presented SSP samples was estimated by average number of caught butterflies.

Results. Based on systematization and statistic analysis of results of 13 summer observations on bud moth biology and phenology, the algorithm of pest development forecast, i.e., periods of phytosanitary situation monitoring in black currant plantations, was developed.

By working out logic forecasting model of currant bud moth development the influence of different environmental factors on speed of the pest development (relative air humidity, rainfall sum, photoperiod duration, and minimum, maximum and average daily air temperature) was evaluated. It is determined that the main predictors of forecast are air temperature (minimum, maximum and average daily), rainfall sum and also photoperiod duration.

Mathematical forecasting model of currant bud moth development is expressed by a series of multifactorial and monofactorial linear and polynominal regression equations depicting quantitative characteristics of relations of forecasted phenomena and the environmental conditions. The close relations between the investigated phenomena were evaluated as reliable, if correlation coefficients ($r_{y,x}$ and $R_{y,x1,x2\ldots xi}$) were equal to 0.7 and more. By predictors selection for mathematical forecasting model development the chosen indicators should not correlate among themselves ($r_{x,x1} < 0.4$).

It is determined that a primary point for phenological forecast development is a date of maximum temperatures transition through +5 °C.

It is established that the forecast predictors of the phytophage development beginning (1-st stage of the forecast) are maximum air temperatures and photoperiod duration. Time of bud moth caterpillars leaving from wintering places is caused by the accumulation of certain amount of positive temperatures. It is calculated that caterpillars start to leave their wintering places if for each 100 minutes of a light day, on the average, 1 °C warmth comes in April, 1.2–1.5 °C – in March and 2–2.5 °C – in February. So, the earlier (at much shorter light day) the higher maximum air temperatures are necessary for the pest to start development.

The pest caterpillars start leaving their wintering places if at the end of February a light day length is 600 minutes and daily air temperatures reach +15 °C, in the beginning of March (about 650 minutes) – +13 °C, in the beginning of April (about 750 minutes) – +9 °C.

The calculated forecasting equation depicting the interdependence of maximum air temperature, providing the beginning of pest development and photoperiod duration looks like parabola with 97 % level of correlation dependence with an error of determination coefficient 0.8 % and registers as follows:

$$Y = 0.0001097\, x^2 - 0.1896414\, x + 90.6988633,\ D = 0.97 \qquad (1)$$

Using the calculated regression equation, it is possible to define the exact date of bud moth leaving the wintering places, i. e., the optimum time of doing the pest records and sprayings against the phytophage.

It is also established that the duration of currant bud moth caterpillars feeding in buds (2-nd stage of the forecast) is determined by air temperature parameters. For all years of observations depending on developing weather conditions the pest caterpillars,

which have left their wintering places, have been eating the broken buds from 20 to 50 days. The main factors influencing the period of currant moth feeding (Y_1) are average daily temperature (x_1) and the sum of minus air temperatures (x_2) for the feeding period. The equation reflecting quantitative interrelation of the above-mentioned parameters registers as follows:

$Y_1 = 23.88 - 0.422\ x_1 + 0.496\ x^2$, D = 0.70 (2)

The obtained equation allows predicting terms of pest feeding and the beginning of caterpillars leaving for pupation, i. e., time of inter-row hoeing, whenever possible close to bushes for decreasing the pupae number.

The period of currant bud moth development (3-rd stage of forecast) and terms of oviposition by females (4-th stage of forecast) are defined by air temperature indicators and moisture content.

For all the years of observations, depending on weather conditions currant bud moth pupae developed from 12 to 36 days. The main predictors influencing the duration of their development (Y_2) are maximum air temperature (x) and the rainfall sum (x_3) for the period of pupae development. The equation depicting the quantitative interrelation of the above-mentioned indicators registers as follows:

$Y_2 = 65.1 - 2.29\ x + 0.05\ x_3$, D = 0.71 (3)

Using the obtained equation, it is possible to predict terms of pest butterflies flight beginning and, hence, terms of hanging out pheromone-glue traps for the purpose of monitoring phytosanitary condition of black currant plantations and revealing the focuses of its spread.

It is also established that from the beginning of currant bud moth flight up to the start of laying eggs by females can pass from 2 to 12 days, what also depends on prevailing weather conditions. However, in this case the basic defining factor is the minimum air temperature (x_4) and also as in the 3-rd stage, rainfall sum (x_3) for summer period. The quantitative interrelation of the above-named indicators is defined by equation $Y_3 = 17.0 - 1.12\ x_4 + 0.07\ x_3$, D = 0.73 (4), i. e. the higher minimum air temperature and less rainfall, the quicker females start laying eggs.

The basic indicators defining the duration of egg development period (Y_4) and terms of the phytophage larvae leaving for wintering in shelters (Y_5) also are the minimum air temperature (x_4) and rainfall sum (x_4). For all years of inspections the duration of egg development period varied from 8 to 30 days and the duration of hatched from eggs caterpillars before their leaving for wintering in shelters – from 4 to 14 days, what was defined first of all by rainfall sum and minimum air temperatures. The regression equations reflecting the quantitative interrelation of the above-named indicators register as follows:

$Y_4 = 7.3 - 0.44\ x_4 + 0.11\ x_3$, D = 0.67 (5) and

$Y_5 = 4.2 - 0.41\ x_4 + 0.05\ x_3$, D = 0.69 (6).

Thus, based on done researches an algorithm of phenological forecast of 6 stages of currant bud moth development was developed beginning from terms of caterpillar appearance from wintering places up to the beginning of their leaving in shelters. The consecutive use of the calculated equations allows to define beforehand the optimum terms of number records of caterpillars appearing from wintering places, imago flight

dynamics and realization of a complex of chemical (against caterpillars) and agrotechnical (against pupae) measures.

For timely revealing of I. capitella focuses the workers of the Belarussian Institute of Plant Protection together with the employees of the scientific-research laboratory of elementary synthesis of Belarus State University (BSU) carried out the researches on working out the pest synthetic sex pheromone (SSP). For primary evaluation of the pest SSP the workers of the BSU have manufactured 14 experimental samples under the conventional name "Lavabat", differing by the active ingredient content (0.1, 0.2, 1 mg/dispenser) and the dispenser type (black and white rubber tubes, blue sponge, insulin cork). Among all the tested samples the attractiveness in relation to currant bud moth males have shown 8. It is determined that as a dispenser for currant bud moth SSP it is more preferable to use the insulin cork or rubber black tube with a. i. amount 1 mg/dispenser. Using these samples for the period of pest flight 21.05–17.06 has resulted in 11.0–60.6 butterflies caught (Table 1).

Table 1. Attractiveness of SSP experimental samples for currant bud moth (*Lampronia* (*Incurvaria*) *capitella* Cl.), Minsk district, 2007–2008 (currant age 6–7 years)

1 lentelė. Eksperimentinių serbentinės kandies (*Lampronia* (*Incurvaria*) *capitella* Cl.) sintetinio lytinio feromono pavyzdžių patrauklumas, Minsko regionas, 2007–2008 (serbentų amžius 6–7 metai)

Experimental sample Eksperimentinis pavyzdys	Active ingredient content (mg/dispenser) Veikliosios medžiagos kiekis, mg/dalytuvas	Dispenser type Dalytuvo tipas	Butterflies caught during flight period (the average per one trap) Drugiai, pagauti vieno skridimo laikotarpiu, vidutiniškai vienose gaudyklėse
Lavabat T	1	1.5 cm of white rubber tube	10.4
	0.1	1,5 cm baltos guminės žarnelės	1.8
Lavabat D	1		4.0
	0.1		1.2
Lavabat TG	1	Blue sponge circle Mėlynos kempinės ratas	5.0
Lavabat TP	1	Insulin cork	60.6
Lavabat P	0.2	Insulino kamštis	11.0
Lavabat TR	0.2	2 cm of black rubber tube 2 cm juodos guminės žarnelės	11.2

To determine the expediency of conducting the protective measures, besides, timely revealing of the phytophage incidence focuses, its abundance assessments, it is also necessary to have the information concerning host plant cultivar infestation. For this purpose, the infestation studies on 7 black currant cultivars differing by maturation time were carried out in 2003–2004. Bud damage records were done after a full damage during buds advancing.

Table 2. Black currant cultivars damaged by currant bud moth, Samokhvalovichi

2 lentelė. Serbentinės kandies pažeistos juodųjų serbentų veislės, Samokhvalovichi

Cultivar Veislė	Maturation time Sunokimo laikas	Bud damage Pumpurų pažeidimas (%)	
		2003	2004
'Minay Shmyrev'	Mid-early Vidutiniškai ankstyva	26.2	24.2
'Partizanka'	Mid-early Vidutiniškai ankstyva	24.0	18.0
'Katyusha'	Mid-ripening Vidutiniška	10.5	8.2
'Odzebin'	Mid-ripening Vidutiniška	10.3	7.9
'Kantata'	Mid-ripening Vidutiniška	2.7	9.0
'Belorusskaya sladkaya'	Mid-ripening Vidutiniška	1.8	4.0
'Zolushka '	Mid-late Vidutiniškai vėlyva	1.4	2.4
LSL_{05} / R_{05}		11.46	8.13

It is determined that mid-early cultivars were damaged by currant bud moth much stronger than mid-ripening and mid-late. The mid-early ripening cultivars 'Minay Shmyrev' and 'Partizanka' bud damage has reached 18–26 %, what is two and more times higher than the mid-ripening cultivars (Table 2). The least bud damage was noticed in mid-late cultivar 'Zolushka'.

Discussion. World literature analysis concerning the questions of time optimization on carrying out one or another measure in plant protection showed that the similar researches were carried out mainly in the direction of phenological forecasts of agricultural host plant development. In Bulgaria, Slovenia, Japan, USA, Canada different regression models of apple, pear, plum (Hricovsky et al., 1994; Jonaitis, 1994; Kajfez-Bogataj, Bergant, 1998; Morgan, Solomon, 1993), citrus (Ono, Konno, 1999), red currant (Вандова, 2000) development based on the use of quantitative and qualitative characteristics of agrometeorological parameters were worked out. Based on the results of researches, the main forecast predictors are air temperature and rainfall sum. In Russia the investigations are carried out in modeling direction and forecast of the main productive processes of grain, fodder, vegetable and technical crop field agrocoenosises (Бородий, Зубков, 2001; Полуэктов, 2001).

The data show that in all existing models a task of the qualitative relation establishment of the calendar time with the physiological one is solved by similar methods differing by some details. As a leading factor influencing the current speed of the studied object, in the developed models a sum of the effective and average daily air temperature is used. As an additional predictor, authors consider water regime or water-capacity (rainfall sum, relative air humidity and etc.). Nearly all the authors

indicate that the duration of the light period is rather important to the individual object development, however, they consider this parameter as proceeding automatically in a certain location and not taken into account in the developed models. In the researches authors (Koltun, et al., 2003) determined that at initial stages of both the studied phytophage and black currant development, the light period duration as well as air temperature was the main predictor of the developed model of phenological forecast of currant bud moth *Lampronia* (*Incurvaria capitella* Cl.).

Similar researches are done in Poland by Barbara Labanowska (2003), who indicated a close relation of caterpillars leaving the wintering places with daily air temperature and also the possibility of phytophage development beginning in February under air temperatures 10–15 °C and the necessity of carrying out 2–3 sprayings against the pest. Her recommended protective measures are determined basing on field records and observations. The first treatment should be done when the pest leaves the wintering places by pyrethroid group preparations. When the repeated sprayings are necessary against the larvae bitten into buds it is recommended to use contact and systemic preparations. However, in the indicated researches it is not mentioned clearly determined the most optimum time of carrying out the protective measures, what does not allow to provide with efficiency higher than 55–78 % even when such high-toxic synthetic pyrethroids as Decis and Fastac are used. Moreover, carrying out 2–3 treatments against one pest makes protection significantly expensive, increases the energy resources, decreases the profitability of the crop growing and negatively affects the environmental safety.

As a result of our researches a method of instrumental optimum time of spraying against the pest is proposed at the start of *Incurvaria capitella* Cl. caterpillars leaving their wintering places using the regression equation of dependence between maximum air temperature parameters and photoperiod duration.

Conclusions. An algorithm of the pest *Lampronia* (*Incurvaria*) *capitella* Cl., development forecast an opportunity to determine beforehand the optimum time of doing records of caterpillars leaving their wintering places, imago flight dynamics and carrying out a complex of chemical (against caterpillars) and agrotechnical (against pupae) measures in black currant plantations.

For timely revealing of *I. capitella* focuses distribution in black currant plantations the attractiveness and possibility of the phytophage original synthetic sex pheromones is studied. It is determined that as a dispenser for currant bud moth synthetic sex pheromone it is more preferable to use insulin cork or rubber black tube with a. i. amount 1 mg/dispenser.

To determine the expediency of conducting the protective measures the phytophage damage of 7 black currant cultivars is evaluated differing by maturity time. It is determined that mid-early cultivar (‘Minay Shmyrev’, ‘Partisanka’) under conditions of Belarus are damaged by currant bud moth much stronger than the mid and mid-late cultivars. The least pest-damaged cultivar is a mid-late ‘Zolushka’.

Gauta 2009 06 30
Parengta spausdinti 2009 08 15

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Incurvaria capitella Cl. kontroliavimo laiko ir tikslingumo optimizavimas

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Santrauka

Tyrimai atlikti Minsko regiono juodųjų serbentų plantacijose 1994–2008 metais. Tyrimų objektas buvo Baltarusijoje augančios juodųjų serbentų veislės ir serbentinės kandys (*Lampronia* (*Incurvaria*) *capitella* Cl.). Tyrimų tikslas – remiantis fenologinėmis kenkėjų vystymosi prognozėmis, sukurti serbentinių kandžių kontroliavimo sistemą juodųjų serbentų plantacijose. Atsižvelgiant į skirtingą serbentų veislių pažeidimą, buvo panaudotas fitofagų pirminis sintetinis lytinis feromonas. Sukurtas fenologinių serbentinių kandžių vystymosi prognozių algoritmas. Jis suteikė galimybę iš anksto nustatyti optimalų žiemojimo vietas paliekančių vikšrų registravimo laiką, drugių skraidymo dinamiką bei imtis viso komplekso cheminių ir agrotechninių priemonių. Ištirtas pirminių sintetinių fitofago lytinių feromonų patrauklumas. Nustatyta, kad kaip sintetinio lytinio feromono dalytuvą geriausia naudoti insulino kamštį arba juodą guminę žarnelę su 1 mg/dalytuve aktyviosios medžiagos kiekiu. Nustatyta, kad Baltarusijos sąlygomis vidutiniškai ankstyvos veislės (‘Minay Shmyrev’, ‘Partisanka’) serbentinių kandžių pažeidžiamos daug labiau negu vidutinės arba vidutiniškai vėlyvos. Mažiausiai kenkėjų pažeista veislė buvo vidutiniškai vėlyva ‘Zolushka’.

Reikšminiai žodžiai: feromonas, *Incurvaria capitella*, juodieji serbentai, kontroliavimas, patrauklumas, raidos prognozės, veislių pažeidimas.