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# Classical biological control: should we stop or continue?

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**Abstract.** Real contribution of classical biological control (CBC) in the practice of plant protection might be estimated as essential. In Russia, the finest example of a successful CBC agent is *Cryptolaemus montrouzieri* t, which established population was found in Sochi. The population is adapted for development at low temperatures. Speed up of development rate was noted as positively correlated response on natural selection in cold resistant population of *C.montrouzieri*. Natural selection can increase the efficiency of introduced species, as well as the prospects for using these positive changes in their breeding technologies. The pros and cons of using CBC are discussed. Restriction of CBC limits the control of invaders, which spread is promoted by globalization and climate change.

## 1 Introduction

The history of classical biological control (CBC) started in 1880, when the predatory ladybeetle *Rodolia cardinalis* was introduced from Australia to California to control the invasive Australian pest *Icerya purchasi,* which caused huge losses in orange orchards at that time. The extraordinary success of the very first experience of an introduction made scientists realize how easy it could be to control invaders using their natural enemies from the native area of pests. Of course, later there were a lot of not so successful introduction cases; but still, CBC developed and was eventually widely used around the world. About 2500 entomophagous species had been used in the invader suppression programmes by the introduction of their natural enemies. 33% of them were established in the places of introduction, and only 11% were effective against their target pests [1]. But despite such a relatively low efficacy of the introductions, if we take into consideration absolute numbers, there were 574 successful cases of introductions that led to the long-term suppression of pest populations. So the real contribution of CBC in the practice of plant protection might be estimated as essential.

In Russia, the finest example of a successful CBC agent is *Cryptolaemus montrouzieri*, which was introduced in the Sochi region in 1949. Since that time there were several attempts to acclimatize this species, and finally, in 2012, its established population was found [2]. Another CBC agent - *Perillus bioculatus* – was suddenly found in the Krasnodar region more than 40 years after its introduction there in the 1970s. During all that time its population was completely invisible to monitoring. By now, P. bioculatus has already

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settled in the Belgorod region, dispersng across the southern part of Russia [3]. Another unique example of acclimatization is *Serangium parcesetosum*, which was brought to Russia just once in the 1970s and after that single release, this species managed to survive and now its population is well established and significantly suppresses coccids in the Sochi region.

Despite all those positive results in the usage of CBC agents against invasive pests, since 2010, no new entomophagous agents have been introduced because of the potential risk to local insect communities, which could be damaged by new predators or parasitoids. All this environmental concern was triggered by the Convention of Biodiversity, and from the beginning, it seemed reasonable. But the last decade has brought so many problems caused by invasive pests, which has made us reconsider the previous decision concerning the introduction of entomophagous species. CBC has already proved itself as a very effective tool in the suppression or even eradication of invasive species. Without this powerful weapon against invaders, we are entirely helpless facing increasing numbers of new pests yearly or even monthly, especially in greenhouses, spa resorts or organic farms, where pesticide usage is restricted dramatically.

Using local species of entomophagous species to control invaders might be a solution, but obviously, there is almost no chance to find highly specialized natural enemies outside the pest's native area. So we have to use indigenous polyphagous predators, which would be as dangerous for the local entomofauna as the introduction.

Of course, we cannot deny the fact that several former CBC agents are now considered as invaders, potentially dangerous for local communities and biodiversity in general. First of all, there is *Harmonia axyridis* - probably the most famous ladybeetle on the Earth after its legendary conquest of the American continents, South Africa and Europe [4]. But the question about the main cause for *Harmonia*'s invasion is still open. There is an opinion that the reasons would be not only deliberate relocation of *H. axyridis* for biocontrol purposes but also such unstoppable fatal processes as global climate changes, rising world trade, tourism and globalization in general. Indirect evidence of that might be the multiplied cases of independent dispersal of ladybeetles across the globe, including the successful acclimatization of *Coccinella 7-punctata*, *Harmonia 4-punctata* and *Propylea 14-punctata* in North America, long before *H. axyridis* [5]. So it sounds a little bit strange when *H.axyridis* is now blamed for the replacement of *C. 7-punctata*, which is actually an invader too but having arrived in America a little earlier.

Recently the list of analogical cases was fulfilled by one ladybeetle – *Chlitostehus arcuatus* [6]. It was used for plant protection but only inside its native areas, so deliberate introduction cannot cause acclimatization of these predators in new territories. What is the purpose of CBC limitation if we cannot stop the dispersal of entomophagous and pests species as well? Let us face the real situation: biodiversity fluctuates, dominant species replace one another inevitably. Should we sacrifice CBC if we can't control the situation in general?

There's one more reason to continue the introduction of new species. We can use the benefits of natural selection, that's going on in introduced populations. Acclimatization of entomophagous is considered as a possible way of their genetic improvement. Natural selection differs from selective breeding or experimental evolution mainly due to a much bigger size of source population, which increases the probability of success, but usually it takes longer time to get a result [7].

The last decade has brought us several examples of using acclimatized populations for mass rearing and augmentative biocontrol. One of them is Sochi's population of *C. montrouzieri*, which is used successfully in botanical gardens in the North-west of Russia because of its cold resistance. This valuable thermal adaptation seems to be the result of natural selection in the lab population of *C. montrouzieri*, which regularly has been used outdoors for pest control in Sochi for the last 70 years. It is difficult to define when cold resistance emerged in that population, but no later than 2002, because since this time, *C. montrouzieri* has been noted outdoors regularly in huge numbers far from places of its release.

Narrow-directed genetic changes in population driven by artificial selection can be a cause of evolutionary trade-offs when adaptation to adverse conditions leads to a decrease in fitness for other conditions [8]. Natural selection targeting all traits shouldn't have such disadvantages or even induce some positive changes in several traits simultaneosly. To tests this suggestion, we researched cold resistance and fitness in Sochi's populations of *C. montrouzieri*.

## 2 Materials and methods

Adults and pupae of *C. montrouzieri* were collected on the territory of Sochi in September 2011 and reared in lab condition (24ºC, 60%) on eggs of *Sitotroga cerealella* and mealybugs *Planococcus citri* on potato tubers as the substrate for eggs laying. Comparative assessment of survival, developmental rate, and adult weight were carried out on offspring F1 obtained from natural individuals. The weight was tested just after the adult's emerged before feeding. So the beetles had no opportunity to eat or drink anything. It means that the tested weight reflects their size and could be considered as a measure of reproductive potential.

The traits were tested under temperatures 16°C and 24°C, photoperiod 16:8 h light/dark. Larvae were split into 4 groups by 20 individuals, kept in plastic containers (diameter 15 cm, high 5 cm) and fed by *Sitotroga* eggs. As a control, we used a laboratory population from the VIZR collection imported from Egypt in 1933. Statistical processing of the results was performed using the t-student criteria.

## 3 Results and discussion

The survival rate of larvae and pupae in the both populations of *C.montrouzieri* was about 90% at the optimum temperature (24°C). Individuals in the Sochi population completed their development in 25 ± 0.2 days, which is one day faster than in control (26 ± 0.1 days) (Fig. 1A). At low temperature (16 ° C), the survival rate of individuals in the Sochi population was 45 ± 5.6%, which significantly ($p < 0.001$) higher than the control level (26 ± 4.9%). The development rate in the Sochi population was also considerably higher. Beetles completed their development in 90 ± 1.1 days. Control individuals developed about 98 ± 3.3 days (Fig. 1B).

We found no differences in adult weight between two populations at the same temperatures (Fig. 2). Low temperature caused adult weight loss by 10-11% in both populations equally. It means that the Sochi population keeps potentially the same reproductive potential as the lab population under stress conditions.

The obtained result indicates that the Sochi population is adapted for development at low temperatures, which gives it an advantage in late autumn when the temperature drops to 15-17°C. Due to its cold hardiness and high development rate, the Sochi population can complete development until November inclusively, accumulating a significant overwintering reserve of beetles.

Speed up of development rate was noted as positively correlated response on selection in low-humidity resistant population of predatory mite *Phytoseiulus persimilis*, which setteled in Egypt (Kozlova, pers. comm.). So evolutionary changes in natural enemy populations, observed during their acclimatization to new habitats, can be more profound and broader than in narrow-directed selective breeding.

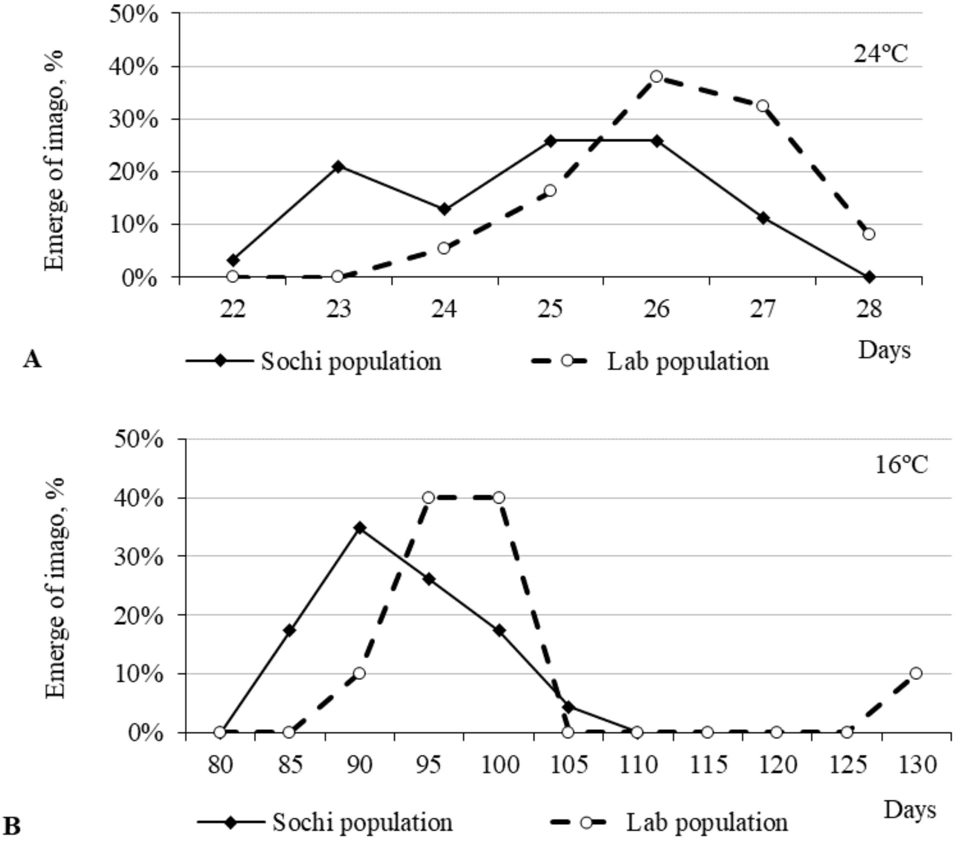

**Fig. 1.** Dynamic of adult emergence at 24ºC (A) and 16ºC (B) in two populations of *Cryptolaemus montrouzieri.*

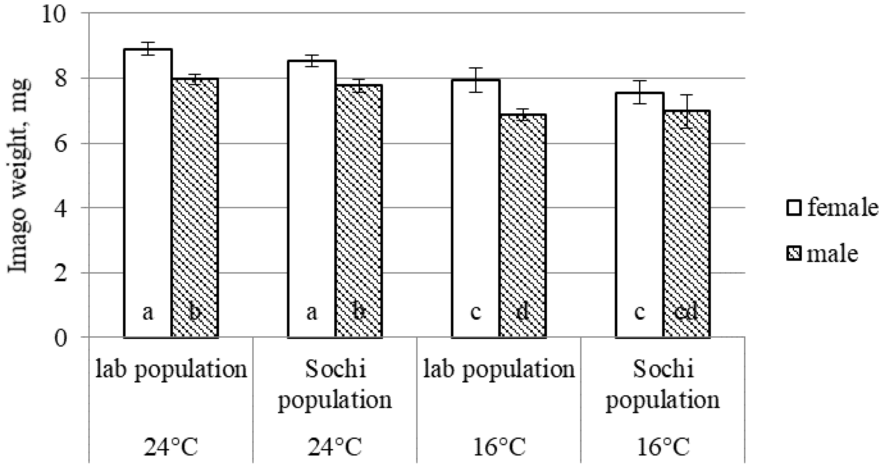

**Fig.2**. Adult weight in two populations of *Cryptolaemus montrouzieri*. The same letters mark the variants that have no statistical differences (p>0.05).

Natural selection can increase the efficiency of introduced species, as well as the prospects for using these positive changes in their breeding technologies. Assuming all the pros and cons of using natural selection, which occurs in CBC, we believe that we shouldn't refuse such a powerful tool in developing a new generation of natural enemies.

The problem is that useful for biocontrol species could be potentially dangerous. Because of that some European countries have banned the use of imported species of natural enemies. As a result, the number of newly tested species decreased dramatically [9]. At the same time, the number of invasive pests increases annually, and this growth is exponential. Restriction of CBC limits the possibilities of biocontrol in the fight against invaders, which uncontrolled spread is promoted by globalization and climate change.

How do we find a win-win solution and avoid the extremes decisions, that we are now observing in Europe? Thanks to the results of CBC gained over the last 150 years, we have a unique opportunity to “have a sneaky peek at the correct answer”. The analysis of life-history strategies of successfully used and relatively safe natural enemies (such *C.montrouzieri* for example) will help identify the combination of traits and environmental factors that have turned some species into our indispensable helpers in pest control, while others - into dangerous invaders.

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