



RESISTANCE MANAGEMENT STRATEGIES FOR THE COLORADO POTATO BEETLE (*LEPTINOTARSA DECEMLINEATA*) IN POTATO PRODUCTION

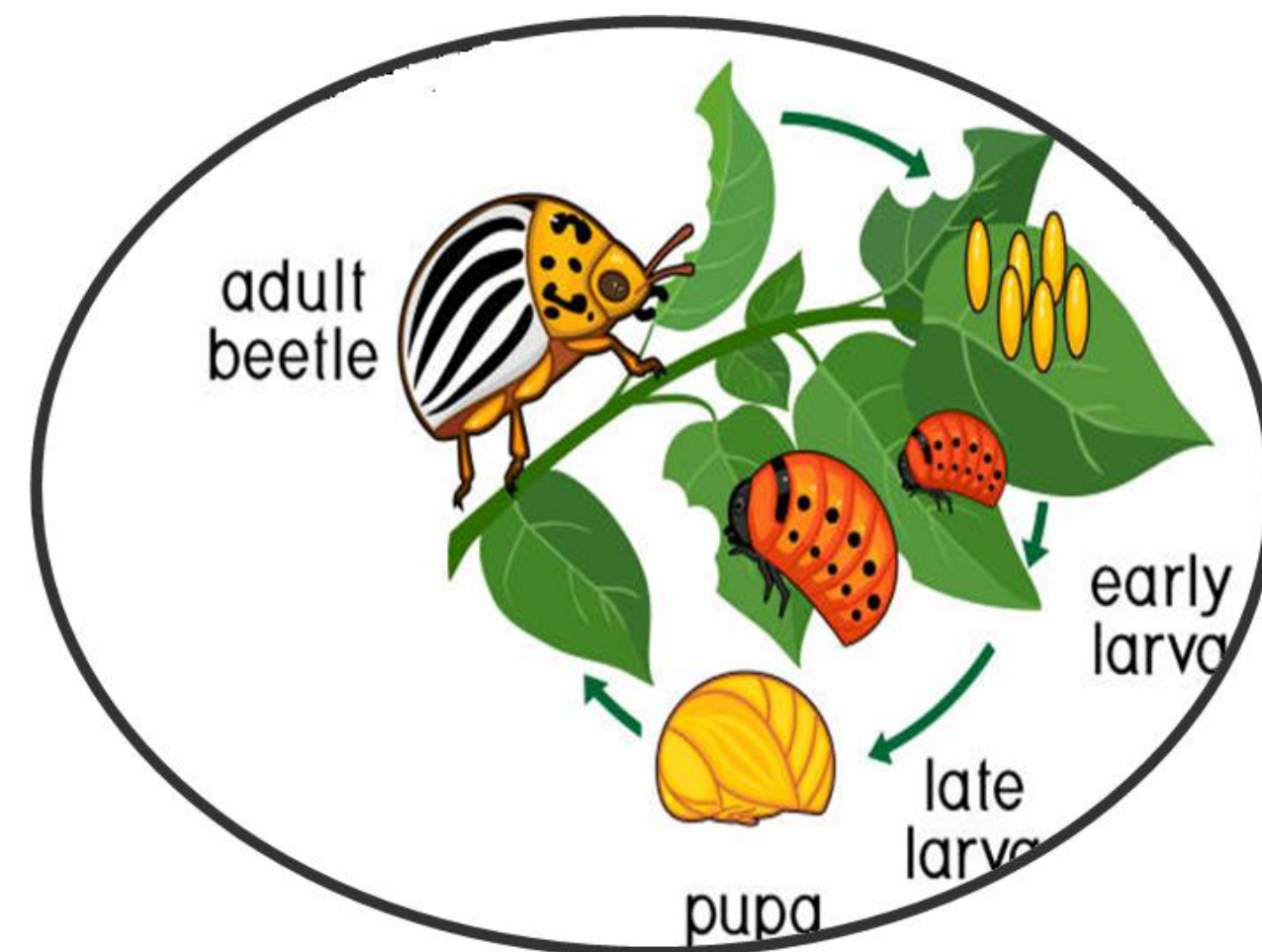
Biljana Kovacevik, Sasa Mitrev, Emilija Arsov, Dusan Spasov, Biljana Atanasova, Marija Taskova Kukutanov, Natalija Markova Ruzdik
 Faculty of Agriculture, Goce Delcev University, Stip, Goce Delcev Str. No. 89, PO box 201, Stip 2000, Republic of North Macedonia
 Contact author: biljana.kovacevik@ugd.edu.mk

Abstract

The Colorado potato beetle (*Leptinotarsa decemlineata*) is one of the most destructive pest of potato crops, known for its remarkable ability to rapidly develop resistance to insecticides, particularly neonicotinoids such as acetamiprid. This paper focuses on resistance management strategies through an integrated approach that combines chemical and non-chemical control measures. Special emphasis is given on the rotation of insecticides with different modes of action (IRAC groups) in order to reduce selection pressure on pest populations. Recommended rotation programs include active substances from IRAC 1B, IRAC 3, IRAC 4, IRAC 5, IRAC 6, and IRAC 28 groups, such as lambda-cyhalothrin, emamectin benzoate, chlorantraniliprole, etc. Furthermore, control efficacy is significantly improved when treatments are applied during early larval stages (I–II), when the insects are most susceptible. Integrated pest management (IPM), including mechanical control, crop rotation, biological agents such as *Bacillus thuringiensis*, and regular population monitoring, plays a key role in sustainable pest control. Adherence to recommended application rates and treatment only when the economic threshold is exceeded further reduces the risk of resistance development. Combining these strategies ensures effective and long-term control of the Colorado potato beetle, while minimizing environmental impact and preserving insecticide efficacy.

Introduction

The Colorado potato beetle (CPB), has been a major pest in potato production, with insecticides playing a crucial role in its management. These systemic insecticides, introduced in the mid-1990s, offered highly effective control of *L. decemlineata* and other pests, and were initially praised for their versatility and minimal environmental impact. Neonicotinoids, which can be applied in multiple ways, including as seed treatments, foliar sprays, and soil applications, provide long-lasting control and reduce the need for broader-spectrum chemicals. However, the widespread and repeated use of these insecticides has led to insecticide resistance, threatening the sustainability of these compounds. As resistance to neonicotinoids becomes more prevalent, there is an increasing need for alternative pest management strategies, including the integration of newer insecticides with different modes of action. This shift presents a challenge for growers accustomed to the broad-spectrum control provided by neonicotinoids, highlighting the importance of diversifying pest management approaches to protect both crops and the long-term effectiveness of insecticides.



Colorado Beetle Life Cycle

- A female of CPB can produce around 500 eggs. The larvae pass through four developmental stages (instars).
- Fully developed larvae burrow into the soil and pupate.
- After 5–10 days, new adults emerge and resume feeding, potentially starting the cycle again.
- Depending on environmental conditions, especially temperature, the entire life cycle can be completed in as little as one month, allowing for one to three generations per year.



Host range

CPB belongs to the family Chrysomelidae (leaf beetles), and it is a major pest primarily associated with plants in the Solanaceae family. Its most important hosts are cultivated crops such as potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), and eggplant (*Solanum melongena*). Among these, CPB shows a strong preference for potato, which is considered its principal host. However, it can also feed and develop on a range of wild and weedy Solanaceous species, including *S. rostratum*, *S. carolinense* (horse nettle), *S. dulcamara* (bittersweet nightshade), and *S. sarrachoides*. These alternative hosts can support beetle populations, especially when cultivated crops are not available.

Effective management strategies

An effective management program for CPB should be based on IPM, correct timing, and strict rotation of insecticide modes of action (IRAC groups). The key principle is to target the early larvae (L1–L2) stage, which is the most susceptible stage and avoid repeated use of the same chemical group within the same season. Monitoring should begin early in the season when overwintered adults appear and egg masses are present on potato leaves. Control measures should be applied shortly after egg hatch, when most larvae are in the L1–L2 stage. This is the most effective window because larvae are actively feeding and are highly susceptible to insecticides. For the first application, IRAC Group 28 (diamides such as chlorantraniliprole or cyantraniliprole) is often the most effective option, providing rapid cessation of feeding and strong residual activity. Alternatively, IRAC Group 5 (spinosyns) can be used as a highly effective larval control tool. If additional treatments are required, rotation is essential. IRAC Group 6 (avermectins) can be used against young larvae, while IRAC Group 1B (organophosphates) may provide fast knockdown where resistance is not high. During mid and late season, second and third generations should be managed using different IRAC groups than those used earlier. IRAC Group 4 (neonicotinoids) may still be effective in some areas, but resistance is widespread, especially in adults. IRAC Group 3 (pyrethroids) generally has the highest resistance levels and should only be used with caution, mainly for early larvae if local susceptibility exists. Resistance management is critical. The same IRAC group should never be applied consecutively, and diamides (IRAC 28) should be limited to one application per generation. Chemical control should be combined with crop rotation, destruction of volunteer host plants, and field monitoring to reduce population pressure.

Table 1. MoA groups of insecticides and active ingredients to control CPB

Chemical group	Active ingredient	Mode of action	Effectiveness	Resistance rate
Avermectines (IRAC 6)	Abamectin emamectin benzoate	Binds to chloride channels in nerve and muscle cells, causing paralysis, loss of feeding, and death	young larvae (L1–L3). Lower effectiveness on the late larval stage and adults	Low to moderate
Diamides (IRAC 28)	Chlorantraniliprole Cyantraniliprole	Act on Ryanodine receptors (RyR) in muscle cells, causing paralysis	L1–L2 actively feeding early larval stage. Lower effectiveness on the late larval stage and adults	Low to moderate
Neonikotinoides (IRAC 4)	Acetamiprid sulfoxaflor	Act on nicotinic acetylcholine receptors (nAChRs) causing paralysis and death	Early and late generation	Widespread resistance exists globally
Organophosphates (IRAC 1B)	Pirimiphos-methyl malathion	Inhibit Acetylcholinesterase (AChE) in the insect nervous system, leading to muscle tremors, paralysis and death	L1–L2 actively feeding early larval stage. Lower effectiveness on the late larval stage and adults	Widespread resistance exists globally
Pyrethroides (IRAC 3)	lambda-cyhalothrin	Act on Voltage-gated sodium channels in insect nerve cells causing tremors, "Knockdown" paralysis and death	L1–L2 actively feeding early larval stage. Lower effectiveness on the late larval stage and adults	Strong, well-documented resistance
Spinosins (IRAC 5)	Spinosad	Act on Nicotinic acetylcholine receptors (nAChRs) (different binding site than neonicotinoids) leading to uncontrolled muscle contractions, tremors and paralysis	L1–L2 actively feeding early larval stage. Lower effectiveness on the late larval stage and adults	Moderate
Biological insecticide (IRAC 11)	<i>Bacillus thuringiensis</i>	Produce Cry toxins that bind to receptors in the insect gut creating pores in the gut lining and cause the insect to stop feeding and die	L1–L2 actively feeding early larval stage. Lower effectiveness on the late larval stage and adults	Low to moderate