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A REVIEW ON THE COMPARATIVE EFFICACY OF CHEMICAL PESTICIDES AND TRADITIONAL BOTANICAL TREATMENTS FOR THE MANAGEMENT OF *PIERIS BRASSICAE* (LINNAEUS)

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ABSTRACT

Across every nation, *Pieris brassicae* (Linnaeus), which people call the large cabbage white butterfly, acts as a major trouble for farming because *P. brassicae* creates heavy financial damage to vegetable farms. Experts claim that Pieris brassicae remains a top worry for farmers because the pest eats many cruciferous plants. In this study, various research papers were reviewed to examine how synthetic insecticides and plant-derived remedies prevent the spread of *P. brassicae*. These synthetic insecticides, like chlorpyrifos, spinosad, and cypermethrin, were tested alongside natural plant options to see their power. Artificial poisons showed very fast killing power because 80-100% of the insects died in 24-72 hours. It has been observed that plant-derived remedies work more slowly, even though these natural options keep the environment safe from harm. Natural plant-derived remedies reached 50-88% mortality in the tests. Azadirachtin caused the insects to stop eating and changed how the pests grow. High death rates of 70-95% were reached by Bacillus thuringiensis (Bt) when the medicine poisoned the stomach of the larvae. Because the insects are learning to survive the usual artificial poisons, integrated pest management (IPM) must be used. Integrated pest management (IPM) joins chemical and natural ways to fight *Pieris brassicae*. Many people believe that mixing fast-acting artificial poisons for big problems with natural plant-derived remedies for daily protection is the best path for *P. brassicae* management. This report provides suggestions based on facts so that farmers can keep their fields healthy for a long time.

Keywords: *Pieris brassicae*, cabbage butterfly, pesticide efficacy, botanical insecticides, azadirachtin, *Bacillus thuringiensis*

INTRODUCTION

Globally *P. brassicae* is one of the most economically important pests of cruciferous crops. The polyphagous herbivore causes immense damage to the cultivated brassica species, e.g. cabbage (*Brassica oleracea* var. capitata), cauliflower (*B. oleracea* var. botrytis), broccoli, and other species, to such an extent that yield and marketability may decrease considerably (Singh et al., 2003; Khan et al., 2017; Adhikari et al., 2025). The larval stages are highly damaging to cruciferous crops as they consume a large amount of foliage and pollute the produce with frass, which makes the produce out of market (Rangad et al., 2014; Bhandari et al., 2019). Various conventional pesticides have been employed for pest management and have proved to be very effective, giving a prompt knockdown effect on pests and a higher mortality rate. However, the high reliance on conventional pesticides has resulted in serious implications such as insecticide resistance, adverse effects on non-target organisms and the environment, and increasing demand from consumers for pesticide-free production (Ali et al., 2017). Consequently, emphasis is being given to the development of newer and sustainable alternative control methods, such as botanical pesticides and biological control agents. The plant-derived pesticides, such as Neem oil (*Azadirachta indica*) and the microbial biopesticides such as Bt, can serve as potential alternatives or complements to chemical insecticides (Rezaei et al., 2016).

It exhibits lower toxicity to non-target organisms, reduced environmental persistence, and multiple modes of action that may delay resistance development (Subedi et al., 2025). After these treatments often demonstrate slower action and lower immediate efficacy compared to synthetic ones, necessitating careful evaluation of their practical utility in commercial agriculture. The extensive research on individual control methods, comprehensive comparative analyses evaluating the relative efficacy, mechanisms of action, environmental impacts, and practical applications of chemical versus botanical treatments for *P. brassicae* management remains limited. This review sheds light on this knowledge gap by systematically synthesizing evidence from peer-reviewed studies to provide a comprehensive assessment of available control options. The objectives of this review are to: (i) provide a comprehensive comparison of mortality data and efficacy metrics for chemical and botanical treatments, (ii) elucidate the mechanisms of action underlying different control strategies, (iii) assess environmental sustainability and non-target effects, (iv) evaluate resistance risks and management approaches, and (v) develop evidence-based IPM recommendations that optimize pest control while minimizing environmental impacts. This synthesis aims to inform researchers, extension specialists, and growers in making informed decisions regarding *P. brassicae* management strategies that balance efficacy, sustainability, and economic viability.

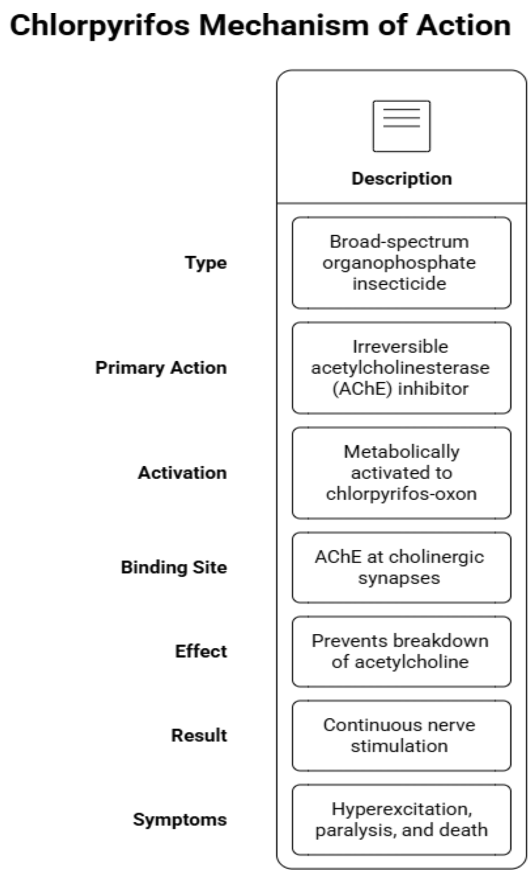
How Chemical Pesticides Work: Mechanisms and Efficacy

It remains the predominant control method in conventional agriculture due to its rapid action, high efficacy, and ease of application. This section will tell the truth behind the major insecticide classes, their mechanisms of action, and comparative efficacy data with reference to *P. brassicae.*

Organophosphates: Chlorpyrifos

Efficacy Against *P. brassicae*

- Demonstrates high toxicity to *P. brassicae* larvae across all instars. Laboratory bioassays have documented mortality rates of 80-100% within 24-72 hours at recommended field rates (Sahak et al., 2010).



- Efficacy varies with larval age, with younger instars showing greater susceptibility.
- Field trials have confirmed effective control at application rates of 0.04-0.05% active ingredient, with residual activity persisting for 7-10 days under field conditions (Khan et al.,

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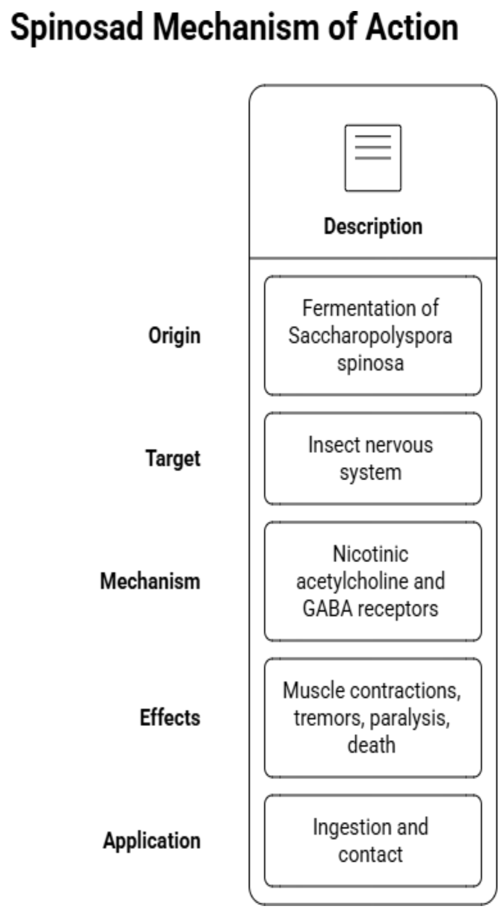
2017).

Spinosyns: Spinosad

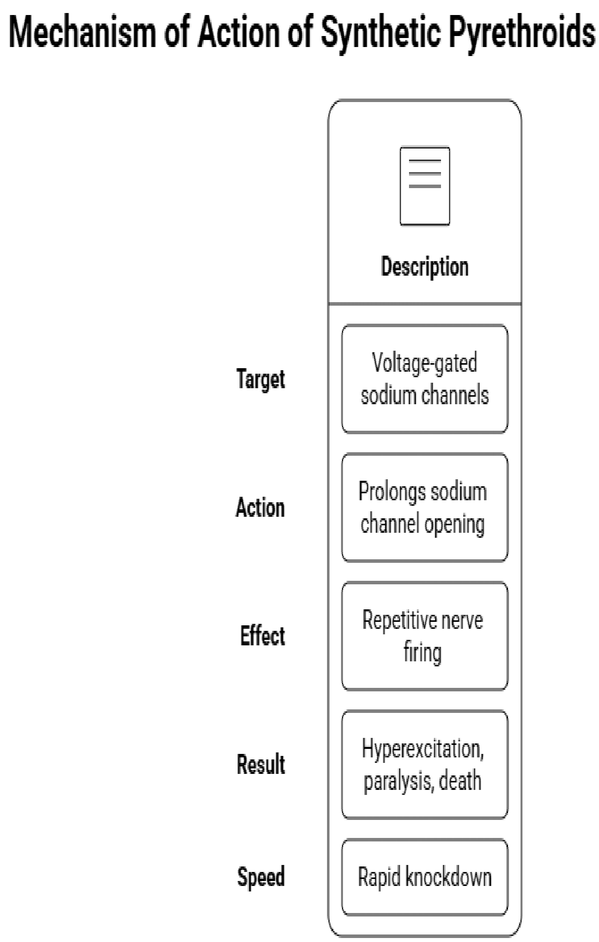


Efficacy Against *P. brassicae*

- Field evaluations reported 85-95% mortality within 48-72 hours at application rates of 0.01-0.015% active ingredient (Al Masum et al., 2025).
- Study found spinosad to be highly effective, with azadirachtin also showing good efficacy but requiring longer exposure periods (Lal et al., 2024).

- Comparative studies have shown that spinosad outperforms many conventional insecticides while maintaining a more favorable environmental profile.
- One synthetic insecticide was reported to be 30.5 times more toxic than spinosad to neonate *P. brassicae* larvae, indicating that newer chemistries may offer even greater efficacy (Bacci et al., 2016).

Pyrethroids: Cypermethrin and Lambda-cyhalothrin



Efficacy Against *P. brassicae*

It has been documented 90-100% mortality within 24-48 hours at recommended concentrations (Braganca et al., 2018).

- Lambda-cyhalothrin, when combined with plant extracts such as cabbage seed oil and *Alhagi maurorum*, showed enhanced insecticidal activity with synergistic effects, allowing for reduced insecticide concentrations while maintaining efficacy (Hajipour et al., 2022).
- Field trials have confirmed effective control with cypermethrin at 0.01-0.015% active ingredient, with residual activity of 5-7 days.
- Pyrethroid efficacy can be reduced under high temperature conditions due to increased metabolic detoxification in insects and faster degradation of the active ingredient (Mir et al., 2026).

Secret behind Traditional Treatment Efficiency

- **Neem-based Formulations**

The most widely studied botanical insecticide is derived from the neem tree (*Azadirachta indica*). The primary active ingredient, azadirachtin, acts as a potent antifeedant, repellent, and insect growth regulator (Hasan & Ansari, 2011). Unlike synthetic toxins that cause rapid death, neem-based treatments often function by disrupting the hormonal balance of the pest, preventing successful molting and pupation. Ali et al. (2017) observed that 7% neem extract significantly reduced the relative growth rate and food consumption of *P. brassicae* larvae. Grišakova et al. (2006) further reported that neem formulations could cause up to 95% mortality in prepupae, highlighting its effectiveness as a long-term population management tool.

- **Microbial Insecticides: *Bacillus thuringiensis***

Bacillus thuringiensis (Bt) is a naturally occurring soil bacterium that produces proteinaceous insecticidal crystals (Cry toxins) during sporulation. When ingested by *P. brassicae* larvae, these crystals are solubilized in the alkaline midgut, where they bind to specific receptors and create pores in the gut lining, leading to septicemia and death. Khan et al. (2016) noted that Bt preparations achieved 100% mortality within six days of treatment. The specificity of Bt makes it an ideal component for IPM programs, as it poses no threat to mammals or most beneficial insects. Research by Rezaei et al. (2016) has also explored the synergistic effects of combining Bt with other botanical extracts like Henna and Neemarin, which enhanced mortality rates against earlier larval stages.

- **Plant Extracts and Essential Oils**

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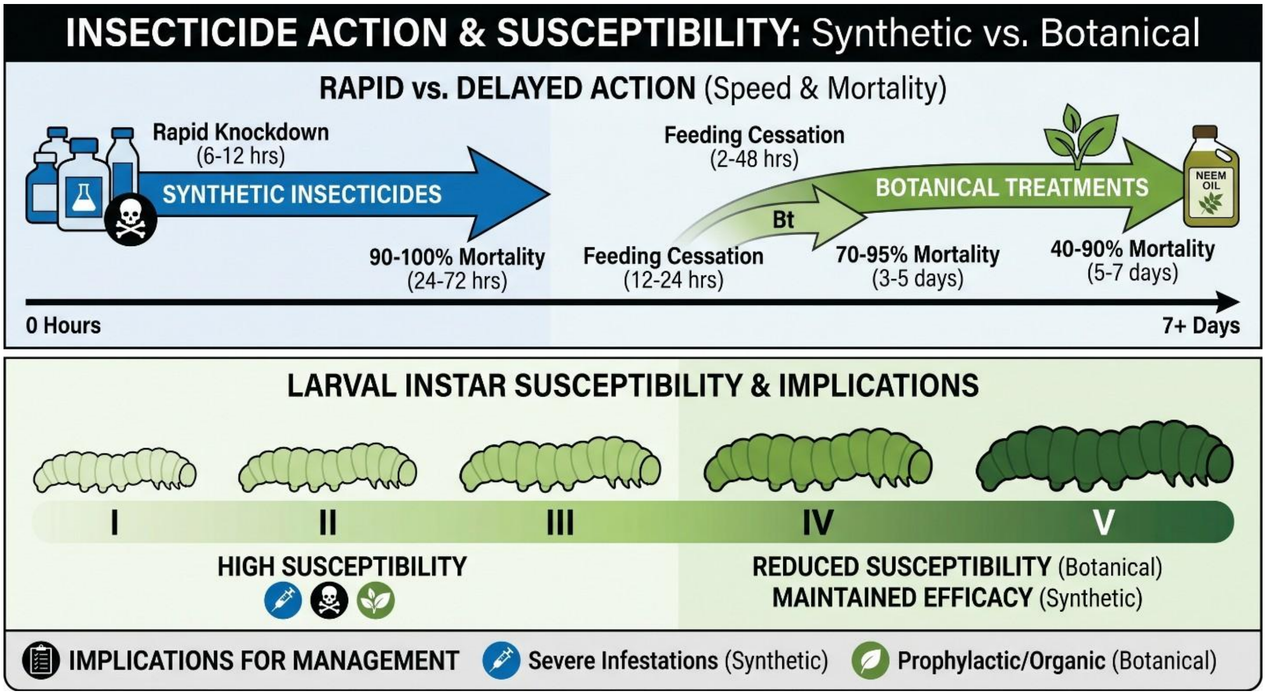
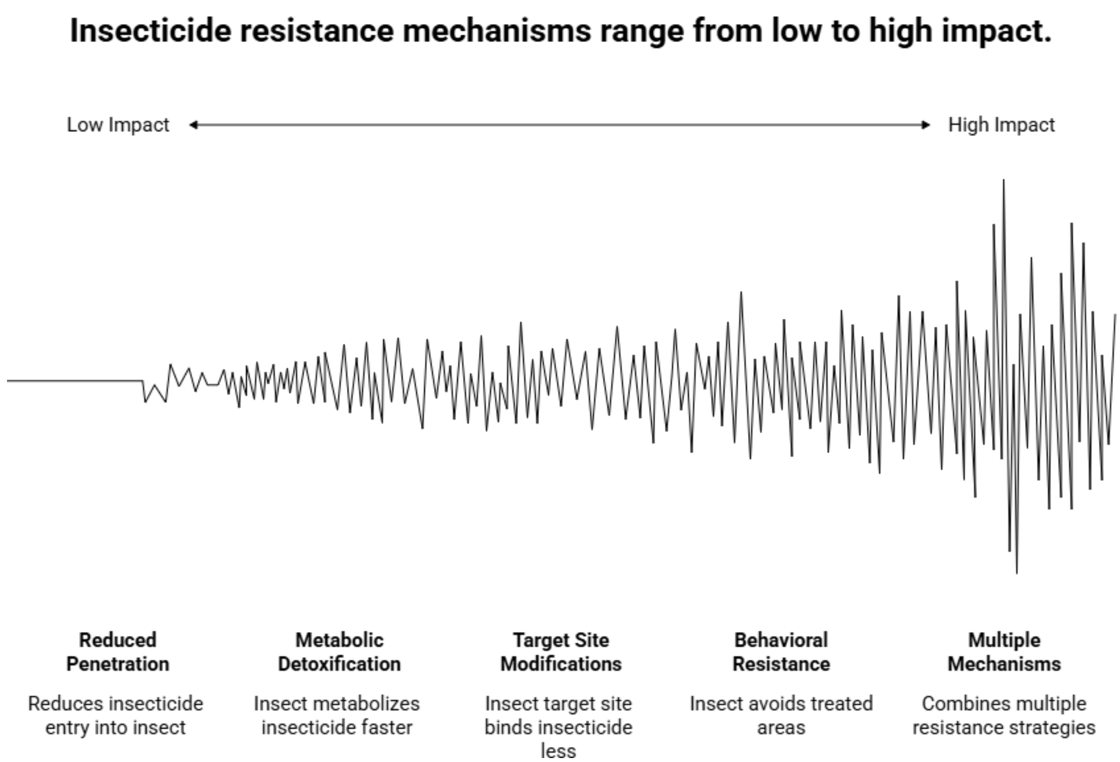
In addition to neem and Bt, numerous other plant extracts have demonstrated insecticidal properties against *P. brassicae*. For instance, extracts from *Zanthoxylum armatum* have shown significant contact and oral toxicity, with LC50 values comparable to some commercial biorationals (Kaleeswaran et al., 2019). Aqueous extracts of *Melia azedarach* have been shown to repel up to 89% of cabbage foliage-feeding larvae (Kibrom et al., 2012). Other promising botanicals include ginger (*Zingiber officinale*) and clove (*Syzygium aromaticum*), which have shown moderate mortality rates and are highly biodegradable (Aminu et al., 2021). The use of essential oils from aromatic plants is also gaining traction as a means of deterring adult oviposition and reducing larval survival (Meenakshi et al., 2023; Pervez et al., 2024).

Comparative analysis of mortality data reveals distinct performance profiles for chemical and botanical treatments against *P. brassicae* (Table 1).

Table 1. Comparative Mortality Rates and Speed of Action for Major Treatment Categories

Treatment Category	Representative Compounds	Mortality Rate (%)	Time to 50% Mortality	Time to Maximum Mortality	Residual Activity
Organophosphates	Chlorpyrifos	80-100	12-24 hours	24-48 hours	7-10 days
Pyrethroids	Cypermethrin, Lambda-cyhalothrin	90-100	6-12 hours	24-48 hours	5-7 days
Spinosyns	Spinosad	85-95	24-36 hours	48-72 hours	5-7 days
Novel Insecticides	Chlorantraniliprole, Indoxacarb	90-100	24-48 hours	48-96 hours	10-14 days
Purified Azadirachtin	Commercial neem products (3-30 mg/mL)	70-90	48-72 hours	5-7 days	1-3 days
Crude Neem Extracts	NSKE, Neem oil (0.5-1.0%)	40-60	72-96 hours	5-7 days	1-3 days
Bacillus thuringiensis	Bt kurstaki, Bt aizawai	70-95	36-48 hours	3-5 days	1-3 days
Plant Essential Oils	Tobacco, *Melia*, *Eucalyptus*	30-70	48-96 hours	5-7 days	1-2 days


INSECTICIDE ACTION & SUSCEPTIBILITY: Synthetic vs. Botanical
RAPID vs. DELAYED ACTION (Speed & Mortality)
Rapid Knockdown
(6-12 hrs)
SYNTHETIC INSECTICIDES
90-100% Mortality
(24-72 hrs)
Feeding Cessation
(2-48 hrs)
BOTANICAL TREATMENTS
NEEM OIL
Bt
Feeding Cessation
(12-24 hrs)
70-95% Mortality
(3-5 days)
40-90% Mortality
(5-7 days)
0 Hours
7+ Days
LARVAL INSTAR SUSCEPTIBILITY & IMPLICATIONS
I
II
III
IV
V
HIGH SUSCEPTIBILITY
REDUCED SUSCEPTIBILITY (Botanical)
MAINTAINED EFFICACY (Synthetic)
IMPLICATIONS FOR MANAGEMENT
Severe Infestations (Synthetic)
Prophylactic/Organic (Botanical)


Insecticide resistance mechanisms range from low to high impact.
Low Impact
High Impact
Reduced Penetration
Reduces insecticide entry into insect
Metabolic Detoxification
Insect metabolizes insecticide faster
Target Site Modifications
Insect target site binds insecticide less
Behavioral Resistance
Insect avoids treated areas
Multiple Mechanisms
Combines multiple resistance strategies

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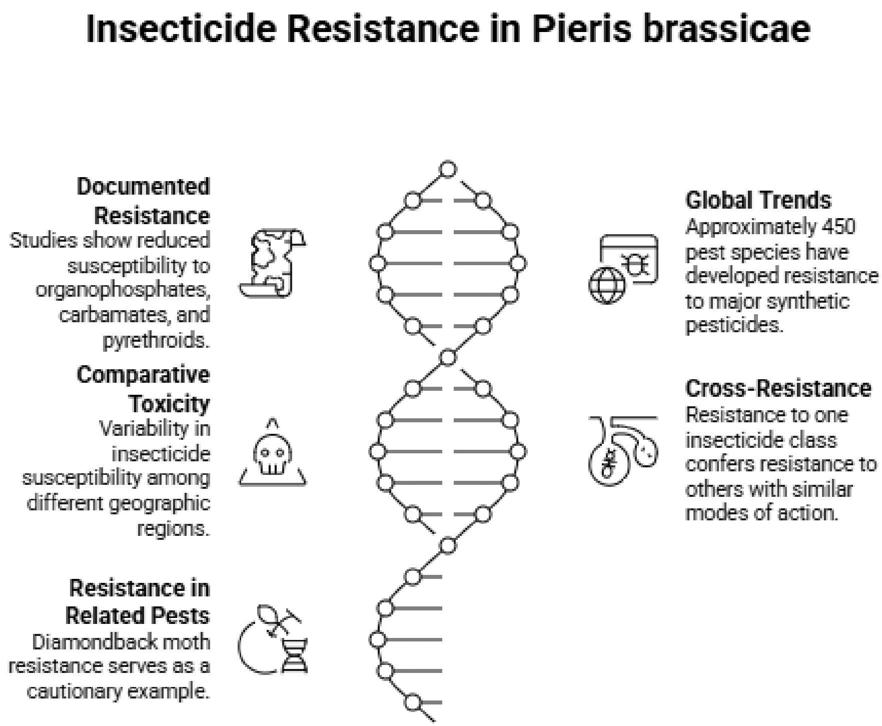

Insecticide Application Timing and Thresholds

	Egg hatch to early instar (I-II)	Mid-instar (II-III)	Late instar (IV-V)
Optimal Timing	Yes	Acceptable	Suboptimal
Botanical Insecticides	Optimal	Acceptable	Reduced efficacy
Synthetic Insecticides	Optimal	High efficacy	Higher doses may be required

Conclusion

A serious global pest of conventional crops, P. brassicae requires effective command regimens that negotiate a balance between profitability, environmental sustainability and safety. Due to their fast action and high efficacy (80–100% mortality rate within 24–72 h), conventional insecticides are reasonable choices for situations requiring rapid pest suppression. But their use is limited by adverse effects, development of resistance, environmental concerns and legal restrictions. Bt and neem/azadirachtin provide relatively potent, healthy alternatives (40 percent– 95% mortality throughout 3–7 days, depending on the item).

Due to multiple actions, little or no threat of harm to desirable insects plus rapid degradation these are especially valuable agents for protecting applications, natural production and integration with organic control.

Despite slower impact, the astringent characteristics of herbal remedies result in helpful crop safety even before full-blown morality is achieved. The comparative study also yields no general findings on the relative desirability of one or another policy of control in any particular scenario. Instead, the best and most sustainable approach is a combination of tactics tailored for specific circumstances. Integrated pest control systems only work, if we can detect pests before they start damaging crops.

Key recommendations for sustainable *P. brassicae* management include:

- ✓ **Implement threshold-based decision making**
- ✓ **Prioritize botanical treatments and selective insecticides**
- ✓ **Target early instar larvae**
- ✓ **Rotate insecticide modes of action**
- ✓ **Conserve natural enemies**
- ✓ **Integrate multiple**
- ✓ **Optimize application timing**

By balancing immediate efficacy needs with long-term sustainability considerations, growers can maintain productive cruciferous crop systems while minimizing environmental impacts and preserving the efficacy of available control tools for future generations.

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