Investigating the Behaviour of Nucleic Acid-Based Nanoparticles in Plants for Next-Generation Crop Protection

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Background & Rationale

Climate change, pesticide resistance, and increasing restrictions on synthetic pesticides are pushing crop protection toward safe, biodegradable and precision solutions.

Nucleic acid-based nanoparticles (NANPs) built from DNA/RNA nanostructures can protect and deliver RNA biocontrols across plant barriers while remaining non-toxic and biocompatible.

Objective

Engineer stimuli-responsive NANPs to deliver dsRNA, siRNA or artificial miRNAs with protected foliar application, triggered intracellular release and systemic, durable silencing of pest and pathogen genes.

NANP Design Features

- Layered DNA origami shields protect RNA from UV, nucleases and wash-off.
- Leaf-surface adhesion peptides improve retention and uptake after spraying.
- pH-sensitive linkers keep NANPs stable on leaf surfaces but trigger disassembly inside slightly alkaline plant cells (pH 7.2–7.8).
- DNA origami backbone provides immune-priming motifs (salicylic acid/jasmonic acid pathways) without host genome modification.

Main Research Findings

- Single low-dose foliar application (<5 μg RNA per plant) achieved strong, long-lasting silencing.
- Systemic and transgenerational effects were observed in treated crop systems.
- DNA origami backbone contributed immune priming (SA/JA pathways) alongside RNAi activity.

Triggered Delivery Pathway

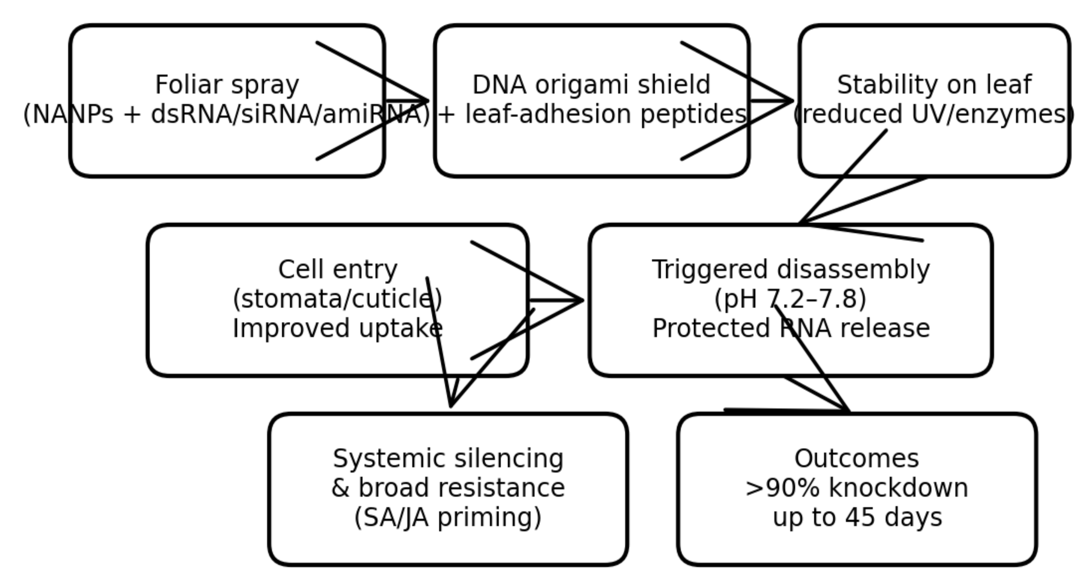

Figure 1. Adhesion and protection on leaf surface, cellular entry, pH-triggered disassembly and systemic outcomes.

Experimental Scope

Crops: tomato, soybean and maize.

Targets: acetyl-CoA carboxylase (aphids), β-glucuronidase (Pseudomonas syringae), and coat protein (potyviruses).

Trigger: disassembly in plant cell pH 7.2–7.8 for protected RNA release.

Comparison of Delivery Platforms

Platform	Stability (after spray)	Plant uptake	Reported outcome
Naked RNA	Low	Low	Short activity
Clay-based RNA	Mod.	Mod.	Mod. efficacy
Liposome RNA	Mod.	High	High efficacy
Stimuli-responsive NANPs	High	High	>90% knockdown; up to 45 days

Table 1. Comparative performance summary.

Key Results

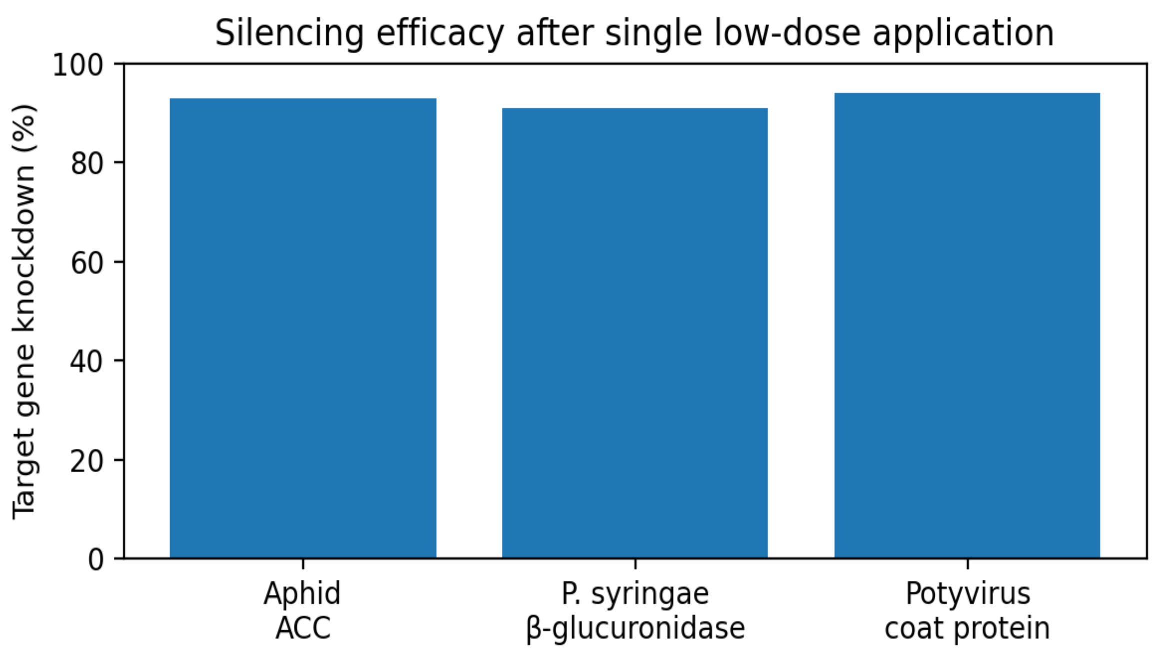

Figure 2. Knockdown for insect, bacterial and viral targets after a single low-dose spray.

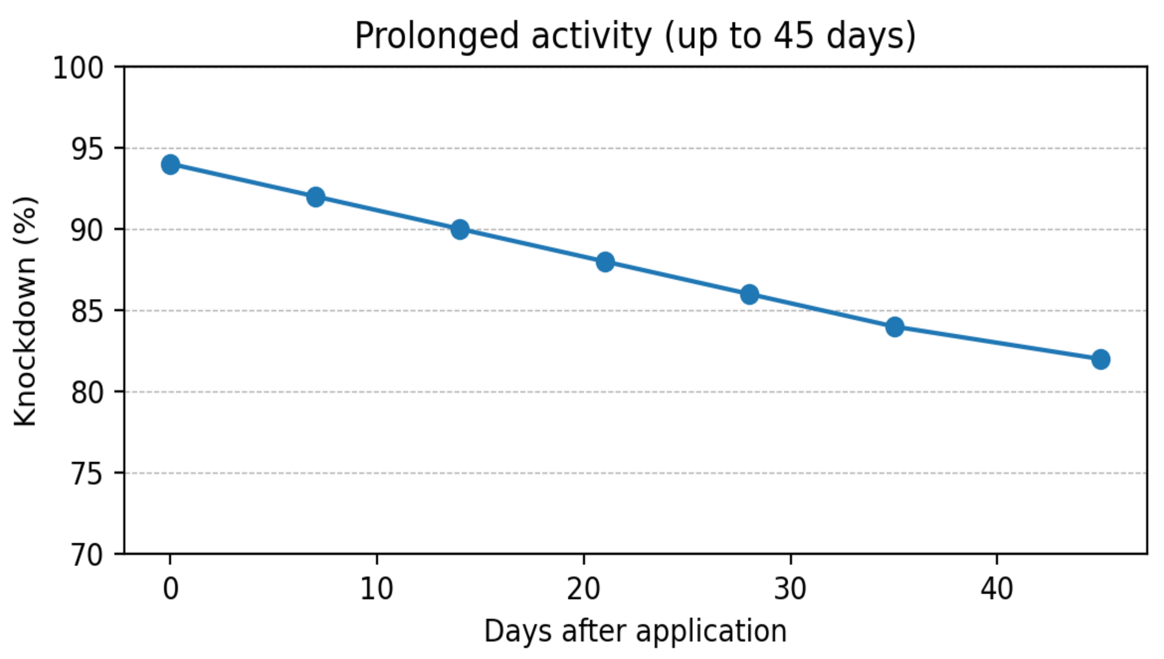

Figure 3. Prolonged activity up to 45 days (illustrated from reported persistence).

Safety & Environmental Fate

- Non-target assays (honeybees, ladybugs and soil nematodes) showed negligible off-target effects.
- Environmental fate studies indicated rapid biodegradation within 72 hours, reducing persistence risks.
- Approach enables RNA-based protection without genetic modification of the crop genome.

Conclusion

Stimuli-responsive nucleic acid nanoparticles combine protected foliar delivery, pH-triggered intracellular RNA release, systemic silencing and immune priming. The platform is biodegradable and offers a practical alternative to chemical pesticides for precision IPM.

Keywords

Plant protection; nucleic acid nanoparticles; RNAi; gene knockdown; integrated pest management; food security.