

A Comprehensive Manual on Organic Pest Management and Biogeochemical Interventions in the Berlin-Brandenburg Agricultural Region

Introduction: The Agronomic Framework of Berlin-Brandenburg

The architectural design of a sustainable, high-yielding crop rotation and organic pest management system must be inextricably linked to the localized climatic boundaries and pedological realities of the target geography. The Berlin and wider Brandenburg region presents a highly specific, moderately challenging agronomic environment¹. Situated within USDA Hardiness Zone 7b, the region experiences average annual extreme minimum temperatures ranging between -15°C and -12.2°C ¹. The operational growing season is strictly dictated by absolute frost dates. Historical meteorological data indicates that the last spring air frost (0°C) typically occurs around May 8, while the first autumn air frost arrives near September 22, delineating a reliable frost-free window of approximately 137 days¹. The agricultural window expands to up to 206 days when observing specific hard ground frost intensities (-2°C), allowing for the extended cultivation of cold-hardy cultivars¹.

However, the defining limitation of the Brandenburg agricultural landscape is its pedology. The region is dominated by Pleistocene-derived glacial sands and sandy loams (Arenosols), frequently exhibiting critically low agricultural yield indices, commonly rated between 25 and 40 Bodenpunkte¹. These coarse-textured soils are characterized by an abundance of macropores, which ensures excellent aeration but simultaneously results in an exceptionally low Available Water Capacity (AWC)¹. Consequently, these soils are highly susceptible to acute drought stress during the summer months and suffer from severe vulnerability to the downward leaching of water-soluble macronutrients¹. Compounding this physical limitation is the long-term decline in localized groundwater recharge, which has dropped significantly by up to 40% since 1980 due to shifting precipitation patterns, increased evapotranspiration, and changes in atmospheric solar radiation transmittance¹.

In such a fragile environment, conventional agricultural models—which rely heavily on synthetic fertilizers and broad-spectrum pesticides—rapidly degrade soil organic carbon (SOC), disrupt the delicate soil microbiome, and exacerbate drought vulnerability¹. Consequently, the implementation of systemic organic pest management is an absolute agronomic necessity. This manual exhaustively details the integration of chemical ecology, specifically via companion planting and "push-pull" strategies, alongside the precise formulation of biochemical

interventions, such as natural insecticidal soaps, to establish a closed-loop, highly resilient phytosanitary defense matrix.

Geo-Climatic Parameter	Metric / Occurrence	Agronomic Implication
Hardiness Zone	USDA Zone 7b	Limits overwintering survival of certain pests; dictates cover crop selection. ¹
Air Frost ($0^{\circ}C$)	May 8 (Last Spring) – Sept 22 (First Autumn)	Defines the primary 137-day window for frost-sensitive cash crops. ¹
Hard Ground Frost ($-2^{\circ}C$)	April 5 (Last Spring) – Oct 28 (First Autumn)	Defines the extended 206-day window for cold-hardy brassicas and root vegetables. ¹
Soil Typology	Glacial Sands / Arenosols (25–40 Bodenpunkte)	High drainage, low AWC; rapid leaching of nutrients; susceptible to structural collapse. ¹
Groundwater Recharge	-40% decline since 1980	Necessitates profound drought-resilience strategies and moisture-conserving mulch layers. ¹

Institutional and Regulatory Infrastructure

The deployment of natural substances in organic agriculture within Berlin and Brandenburg is strictly governed by European Union regulations, primarily the EG-Öko-Basisverordnung (Regulation (EU) 2018/848), and is overseen by domestic regulatory bodies³. The Federal Office of Consumer Protection and Food Safety (BVL), operating in tandem with the Julius Kühn-Institut (JKI) and the Pflanzenschutzamt Berlin, dictates the legal framework for phytosanitary interventions³.

The JKI, specifically the Institute for Epidemiology and Pathogen Diagnostics based in Braunschweig and Quedlinburg, conducts extensive research into the biology and ecology of harmful organisms affecting crops in the region, operating regional testing stations to evaluate biological control efficacy⁷. Furthermore, the Pflanzenschutzamt Berlin maintains continuous surveillance for quarantine pests, issuing alerts and managing intercepted invasive species⁶. Recent monitoring by these agencies has highlighted the expanding threat of the Japanese

beetle (*Popillia japonica*) and the Asian longhorned beetle (*Anoplophora glabripennis*) within the region, necessitating localized quarantine measures and mass-trapping protocols using pheromone lures¹⁰.

Under Regulation (EU) 2018/848 and its implementing acts (e.g., Regulation (EU) 2021/1165), agronomists must strictly differentiate between "Basic Substances" (Grundstoffe) and fully registered organic plant protection products³. Basic substances are materials derived from food or common natural products that possess a secondary phytosanitary use but are not primarily marketed as pesticides¹². For instance, *Equisetum arvense* (Field Horsetail) extract and *Salix* spp. (Willow bark) extract are legally approved as basic substances for fungicidal applications to bolster plant resistance against *Oidium* and *Peronospora*¹³. Conversely, highly potent botanicals, such as Azadirachtin extracted from the Neem tree, require rigorous formal registration¹⁶. The BVL strictly monitors the distribution of these compounds, authorizing products like NeemAzal-T/S specifically against aphids acting as virus vectors and specific free-feeding larvae¹⁸. It is vital to note that broad-spectrum historical botanicals, such as Rotenone, are strictly prohibited in Germany due to their extreme toxicity to fish and their lack of selectivity³.

Regulatory Classification	Description	Typical Examples	Regulatory Body
Basic Substances (Grundstoffe)	Naturally occurring materials, often food-grade, with secondary plant protection benefits.	<i>Equisetum arvense</i> extract, <i>Salix</i> spp. extract, Fructose. ¹³	Approved under EU 1107/2009; Managed by BVL. ¹²
Registered Bio-Pesticides	Extracted botanical or microbial compounds requiring rigorous toxicological and efficacy testing.	Azadirachtin (NeemAzal-T/S), Potassium salts of fatty acids, Spinosad. ¹⁶	BVL authorization required. ³
Prohibited Botanicals	Historical natural toxins banned due to excessive ecotoxicity or lack of selectivity.	Rotenone, Nicotine. ³	Banned across the EU. ³

Chemical Ecology and Habitat Management: The

"Push-Pull" Paradigm

The manipulation of volatile organic compounds (VOCs) and the spatial arrangement of host and non-host plants form the foundation of habitat management in organic agriculture²². The "push-pull" strategy leverages ecological pleiotropy, a phenomenon where specific plant emissions simultaneously repel target herbivores (the "push") and attract them toward highly apparent, sacrificial trap crops (the "pull"), while concurrently recruiting natural parasitic and predatory enemies to the main crop²³.

This methodology capitalizes on the concept of host plant apparency. Apparency is not an intrinsic property of a single plant but a highly context-dependent variable shaped by the surrounding botanical matrix²⁴. By strategically intercropping species that emit disruptive semiochemicals, agronomists can effectively camouflage primary cash crops, rendering them "chemically unapparent" to host-seeking pests²⁴. The success of a push-pull system relies on redesigning the chemical landscape, altering the spatial dynamics of the field, and optimizing the Land Equivalent Ratio (LER), which measures the yield advantage of intercropping compared to monoculture²⁴.

***Daucus carota* and *Allium cepa*: Intercropping for Umbelliferae Protection**

The cultivation of carrots (*Daucus carota*) in the sandy soils of Berlin is frequently jeopardized by the carrot rust fly (*Psila rosae*), an oligophagous pest whose larvae burrow into the taproot, causing catastrophic aesthetic and structural damage²⁷. The female *P. rosae* utilizes olfactory cues to locate suitable host plants; however, this host-seeking behavior can be profoundly disrupted by the integration of *Allium cepa* (onion) or other aromatic plants such as coriander (*Coriandrum sativum*) and summer savory (*Satureja hortensis*)²⁹.

Empirical trials demonstrate that intercropping carrots with onions significantly reduces the incidence of *P. rosae* damage²⁹. The biochemical mechanism underpinning this protection is driven by the emission of sulfur-containing volatile organic compounds, predominantly diallyl disulfide (DADS) and dipropyl disulfide, exuded by the *Allium* species³¹. DADS acts as a potent masking agent and repellent; it disrupts the host-plant location signals utilized by *P. rosae*, rendering the carrot chemically invisible to the pest³¹. Similar volatile-mediated protection has been observed in lettuce (*Lactuca sativa*) cultivation, where continuous intercropping with *Allium cepa* successfully repels the thread caterpillar (*Agrotis ipsilon*), a major lepidopteran pest³⁵. Beyond pest repellency, DADS exerts profound, concentration-dependent physiological effects on the root architecture of neighboring crops. At low concentrations (0.04 to 1.45 mM), DADS significantly stimulates mitotic activity within the root meristem of adjacent plants, increasing both root hair length and density³². This localized biostimulation improves the carrot's ability to forage for limited moisture in the sandy Brandenburg Arenosols¹. However, high concentrations of DADS (between 6.20 mM and 20.67 mM) inhibit root expansion, causing a sharp decrease in the ratio of cell length to diameter³². This biphasic, dose-dependent response highlights the critical need for precise spatial distancing in companion planting³². To optimize the Land Equivalent Ratio (LER) and prevent allelopathic suppression while maintaining pest confusion,

companion plants must typically be positioned within a specific effective radius, generally one to three feet from the target crop²⁶.

Dead-End Trap Cropping: The *Barbarea vulgaris* Model

While basic push-pull systems rely on spatial diversion, advanced organic systems utilize "dead-end" trap crops to actively decimate pest populations³⁹. *Barbarea vulgaris* (winter cress), a wild crucifer, represents a highly sophisticated model for managing devastating brassica pests, specifically the diamondback moth (*Plutella xylostella*) and flea beetles (*Phyllotreta nemorum* and *Phyllotreta undulata*)³⁹.

Flea beetles are a primary threat to young cabbage and radish seedlings in the Berlin region, typically emerging in June and causing extensive "shot-hole" damage to the cotyledons and early true leaves⁴⁴. The last generation overwinters in the soil, initiating a new lifecycle the following spring⁴⁴. While traditional organic management relies on ultra-fine horticultural nets (mesh size < 1mm) and the application of rock dust (Gesteinsmehl) or algal lime (Algenkalk) to mechanically deter feeding, the integration of *Barbarea vulgaris* provides active biological eradication⁴⁴.

Barbarea vulgaris exists in two morphologically and biochemically distinct chemotypes: the pest-susceptible P-type (characterized by pubescent leaves) and the pest-resistant G-type (characterized by glabrous leaves)⁴⁷. The G-type is unique among Brassicaceae because it synthesizes high concentrations of triterpenoid saponins—specifically 3-O-cellobiosyl-hederagenin (hederagenin cellobioside) and 3-O-cellobiosyl-oleanolic acid⁴⁰. Simultaneously, *B. vulgaris* produces glucosinolates, predominantly the aromatic (S)-2-hydroxy-2-phenylethylglucosinolate (glucobarbarin)⁴². Glucosinolates are universally utilized by specialist crucifer pests as host-recognition markers and oviposition stimulants³⁹. The biosynthesis of these compounds involves complex enzymatic pathways regulated by endogenous thioglucosidases (myrosinases), creating a pre-formed phytoanticipin defense system⁴². Consequently, female diamondback moths and flea beetles are highly attracted to the chemical profile of *B. vulgaris*, preferentially laying their eggs on its young leaves due to the high glucosinolate concentrations³⁹. However, upon hatching, the larvae consume the foliage and ingest the lethal triterpenoid saponins. The saponins act as severe feeding deterrents and cellular toxins, leading to near-total larval mortality³⁹. This phenomenon represents an evolutionary mismatch or "mistake" by the insect⁴⁰. By planting G-type *Barbarea vulgaris* on the periphery of cabbage plots, the pest population is drawn away from the cash crop and subsequently eradicated, breaking the reproductive cycle without the application of external bio-insecticides⁴⁰.

***Nepeta cataria* and Behavioral Manipulation**

For solanaceous crops, particularly potatoes (*Solanum tuberosum*), the Colorado potato beetle (*Leptinotarsa decemlineata*) remains a paramount threat in Brandenburg⁵¹. Over-reliance on a limited number of botanical insecticides can lead to resistance, making habitat manipulation crucial⁵³. To mitigate this pest, *Nepeta cataria* (catnip), a member of the Lamiaceae family, can be deployed as an intercrop²⁰. The essential oil of *N. cataria* is dominated by nepetalactone, an

iridoid monoterpenoid that accounts for up to 80.4% of the plant's volatile emissions⁵⁴. Nepetalactone functions as a highly potent repellent and antifeedant against both adult and larval stages of *L. decemlineata*²⁰. The molecular structure of nepetalactone interacts directly with the olfactory receptor neurons within the basiconic sensilla of various insect pests, causing profound spatial disorientation⁵⁷. Furthermore, volatile emissions from *N. cataria* recruit predatory insects, serving a dual function within the push-pull framework²⁵. Cultivating *N. cataria* within potato tramlines or as a border crop creates a localized zone of olfactory interference, drastically reducing the colonization rate of the potato beetle and mitigating the need for intensive biological spraying⁵⁶.

Subterranean Allelopathy: *Tagetes* spp. and Nematode Suppression

Phytosanitary management must extend below the soil surface, particularly in the sandy Arenosols of Berlin where plant-parasitic nematodes, such as the root-knot nematode (*Meloidogyne incognita*) and the root-lesion nematode (*Pratylenchus penetrans*), thrive and inflict severe damage to root crops⁶¹. The integration of Marigolds (*Tagetes patula* and *Tagetes erecta*) as rotational cover crops or intercrops provides unparalleled subterranean nematode control⁶¹.

The roots of *Tagetes* species exude alpha-terthienyl (α -T), a highly bioactive, sulfur-containing heterocyclic compound based on a five-membered thiophene ring⁶¹. Alpha-terthienyl operates as a potent phototoxic allelochemical. Once ingested or absorbed through the nematode's hypodermis, and particularly upon exposure to near-ultraviolet light (or activation via root

peroxidases in the absence of light within the soil matrix), α -T acts as a generator of highly destructive reactive oxygen species (ROS), including singlet oxygen and superoxide anion radicals⁶¹.

These ROS induce catastrophic oxidative stress within the nematode⁶⁶. While nematodes attempt to detoxify these radicals via the upregulation of the SKN-1 transcription factor—which triggers Phase II detoxification enzymes, superoxide dismutases (SOD), and catalases (CTL) to

convert superoxide radicals into benign oxygen and water—the oxidative burst generated by α -T rapidly overwhelms these biochemical defenses⁶⁶. This cascade leads to cellular apoptosis, disrupting key metabolic enzymes like cholinesterase, and causing 100% mortality in juvenile nematodes at concentrations as low as 33 ppb⁶¹. By cultivating *Tagetes* in alternating rows with root vegetables or utilizing it as a preceding green manure, agronomists can biochemically sanitize the soil profile without resorting to prohibited chemical fumigants⁶¹. Furthermore, intercropping *Tagetes* has been shown to increase the density of nematode-trapping fungi and beneficial endophytic bacteria in the rhizosphere, compounding the suppressive effect⁶¹.

The Formulation and Biogeochemistry of Natural Insecticidal Soaps

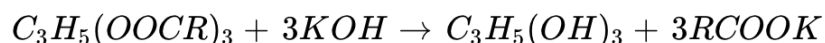
When companion planting and preventative measures prove insufficient to halt an acute infestation of soft-bodied arthropods (e.g., aphids, whiteflies, spider mites, and thrips), the

application of natural insecticidal soaps becomes the primary curative intervention in organic agriculture⁶⁷. However, the efficacy and safety of these sprays depend entirely on strict adherence to stoichiometric chemistry and an understanding of lipid-membrane interactions⁷⁰.

The Saponification Reaction and Stoichiometry

True insecticidal soaps are exclusively the potassium salts of fatty acids⁷². They are synthesized via the saponification of triglycerides (derived from plant oils or animal fats) using a strong alkali, specifically potassium hydroxide (KOH)⁷⁰. Unlike sodium hydroxide (NaOH), which produces hard, solid bar soaps, the larger atomic radius of the potassium ion disrupts the crystalline packing of the fatty acid chains, resulting in a soft, highly water-soluble paste perfectly suited for foliar dilution⁷⁴.

The general stoichiometric equation for the alkaline hydrolysis (saponification) of a triglyceride is⁷⁷:



This reaction yields one molecule of glycerol and three molecules of the potassium carboxylate salt (the active insecticidal soap)⁷⁷. To formulate a highly effective agricultural soap without residual phytotoxic alkali, the exact Saponification Value (SV) of the chosen lipid must be utilized⁷⁹. The SV is defined as the milligrams of KOH required to completely saponify one gram of fat, mathematically expressed as⁷⁷:

$$SV = \frac{(V_b - V_s) \times N \times 56.1}{W}$$

(Where V_b and V_s are the titration volumes of the blank and sample, N is the normality of the acid, 56.1 is the molecular weight of KOH, and W is the sample weight).⁷⁷.

Because the SV is inversely proportional to the average molecular weight of the fatty acids, oils rich in short-chain fatty acids (e.g., coconut oil, which is heavily saturated with lauric acid) exhibit a high SV (248–265 mg KOH/g), whereas oils dominated by long-chain fatty acids (e.g., olive oil, rich in oleic acid) possess a lower SV (187–196 mg KOH/g)⁸¹. When executing a saponification protocol, practitioners must account for the purity of the technical-grade KOH, which is typically 90% pure; the calculated KOH requirement must be divided by 0.90 to ensure complete hydrolysis without leaving unreacted, greasy lipids that could smother plant stomata⁸².

Phytotoxicity and Optimal Chain Length Selection

The selection of the base oil is the most critical variable in formulating an insecticidal soap, as the carbon chain length directly dictates both insecticidal efficacy and plant phytotoxicity²¹.

Short-chain fatty acids (those containing 9 carbon atoms or fewer, such as octanoic or nonanoic acid) are highly phytotoxic; they destroy the cuticular waxes of plant leaves and rapidly induce

severe foliar necrosis²¹. In contrast, long-chain fatty acids containing between 10 and 18 carbon atoms (C10-C18)—particularly oleic acid (C18:1), lauric acid (C12:0), and ricinoleic acid (C18:1-OH)—exhibit maximum insecticidal properties while remaining benign to plant tissues at appropriate concentrations²¹.

For optimal agricultural formulation, a blend of olive oil (yielding potassium oleate) and a smaller percentage of coconut oil (yielding potassium laurate) is ideal⁸⁵. The saponification process requires precise thermal regulation, typically executing the reaction at 50°C to 80°C until the mixture achieves a translucent, homogenous state⁸⁸. The completion of the reaction and the neutralization of the alkali are confirmed via pH testing; the soap solution is titrated with phenolphthalein. A clear, pale pink solution indicates an optimal pH range of 8.5 to 9.5⁸⁹. A dark pink hue denotes excessive caustic alkali, which will inevitably cause severe chemical burns to plant foliage⁹⁰.

Once successfully saponified, the soap paste is diluted to a strict concentration of 1% to 2% active ingredient in water²¹. Formulations exceeding a 2% concentration drastically elevate the risk of phytotoxicity, particularly during periods of intense solar radiation or drought stress, both of which are common in the Brandenburg summer²¹.

Modes of Action and Application Mechanics

Insecticidal soaps operate purely via direct contact; they lack systemic translocation and provide absolutely no residual activity once the aqueous carrier evaporates⁶⁸. Consequently, comprehensive foliar coverage, particularly on the abaxial (lower) leaf surfaces where pests congregate, is mandatory⁶⁸.

Upon contact, the amphiphilic properties of the potassium fatty acid salts facilitate multiple lethal mechanisms against soft-bodied arthropods:

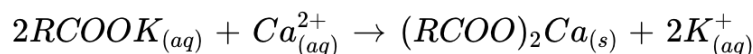
1. **Cuticular Disruption:** The lipophilic tail of the soap molecule acts as a solvent, dissolving the protective epicuticular wax layer of the insect. This drastically increases transpirational water loss and induces rapid, fatal desiccation³⁹.
2. **Cellular Cytolysis:** The soap penetrates the tracheal system and intersegmental membranes, physically disrupting the phospholipid bilayers of the insect's cell membranes. This causes profound osmotic failure, cellular leakage, and rapid necrosis⁶⁸.
3. **Asphyxiation:** The aqueous soap solution readily enters the spiracles, occluding the tracheal network and triggering lethal asphyxiation⁶⁹.

Because efficacy is dependent on the soap remaining in a liquid state for as long as possible to facilitate cuticular penetration, applications in Berlin must be timed for early morning or late evening to prevent rapid volatilization induced by high midday temperatures⁶⁸. Furthermore, sublethal exposures to potassium soap can induce a hormetic response in certain pests. For instance, studies on the bean weevil (*Acanthoscelides obtectus*) reveal a biphasic behavioral response: potassium soap acts as an attractant at sublethal concentrations (LC25) but as a potent repellent at high concentrations (LC90)⁹⁵. This dictates that sub-optimal dilution rates can inadvertently attract pests rather than eradicate them.

Addressing Hard Water Antagonism

A significant operational challenge in the Berlin-Brandenburg region is the inherent hardness of

the municipal and well water, which contains high concentrations of divalent cations, particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}). When potassium salts of fatty acids are diluted in hard water, an immediate ion-exchange reaction occurs:



This reaction yields insoluble calcium and magnesium carboxylates, commonly observed as "soap scum"⁶⁸. This precipitation catastrophically depletes the active concentration of the insecticidal soap in the aqueous phase, rendering the spray biologically inert and leaving unaesthetic, phytotoxic chalky residues on the crop foliage⁶⁸.

To circumvent this chemical antagonism, the formulation must be buffered using advanced organic chelating agents. The addition of fully neutralized potassium citrate serves this function perfectly⁹⁶. Potassium citrate possesses a high binding affinity for free calcium and magnesium ions, effectively sequestering them into soluble chelate complexes and preventing them from reacting with the fatty acid chains⁹⁶. The incorporation of potassium citrate not only preserves the insecticidal efficacy of the soap but also acts as an active descaling agent, helping to clean the stomata of the plant and reverse hard water staining⁹⁶.

Active Ingredient	Synthesis Reagents	Target Pests	Primary Mode of Action	Limitations / Hazards
Potassium Oleate / Laurate	Olive/Coconut Oil + KOH + H\$_{2}\$O	Aphids, Whiteflies, Thrips, Spider Mites	Cytolysis, Wax Disruption, Asphyxiation ⁶⁸	Zero residual activity; phytotoxic at >2%; inactivated by hard water. ²¹
Potassium Citrate	Citric Acid + KOH	N/A (Adjuvant)	Chelates Ca^{2+} and Mg^{2+} [cite: 96, 97]	Required only in hard-water regions to prevent soap precipitation. ⁹⁷

Synergistic Integration: Neem Oil Emulsification

To overcome the lack of residual activity inherent to potassium soaps, agronomists frequently integrate cold-pressed Neem oil (*Azadirachta indica*), creating a synergistic bio-insecticide⁹⁹. Neem oil contains azadirachtin, a highly complex tetranortriterpenoid that acts as a potent ecdysone antagonist⁵³. Unlike soap, which kills on contact, azadirachtin is absorbed translaminarily into the plant tissue. When an insect ingests it, it disrupts the endocrine system,

completely halting the molting process (ecdysis) and suppressing feeding behavior, leading to eventual death within 4 to 5 days⁵³.

Because Neem oil is highly hydrophobic and prone to rapid thermal and ultraviolet degradation, formulating a stable, bio-available spray requires advanced emulsification⁹⁹. The potassium insecticidal soap acts as a highly effective primary emulsifier⁸⁷. By matching the Hydrophilic-Lipophilic Balance (HLB) of the surfactant to the Neem oil—optimizing for an HLB value of approximately 10—a stable, monodisperse nanoemulsion (particle size ~200 nm) can be generated⁹⁵. The use of rotor-stator pre-emulsification followed by high-pressure homogenization yields a colloiddally stable suspension⁹⁹. This nanoemulsification vastly increases the droplet surface area, improving foliar adhesion, enhancing cuticular penetration, and shielding the fragile azadirachtin molecules from premature photodegradation under the intense Brandenburg summer sun⁹⁹. Other essential oils, such as spike lavender (*Lavandula latifolia*), have also demonstrated high efficacy when emulsified, acting as potent fumigants and contact toxins against invasive pests like the spotted wing drosophila (*Drosophila suzukii*)¹⁰³.

Ecotoxicological Impacts on *Apis mellifera* and *Bombus terrestris*

While often marketed as universally safe, insecticidal soaps and essential oils demand extreme caution regarding their impact on non-target, beneficial pollinators, specifically the honeybee (*Apis mellifera*) and the bumblebee (*Bombus terrestris*). While dried soap residues pose minimal threats, direct contact with wet soap spray is highly lethal, as it readily penetrates the insect's spiracles⁶⁷. Furthermore, sub-lethal ingestion of concentrated potassium salts via contaminated nectar sources severely disrupts the delicate osmoregulatory balance of the bee's hemolymph¹⁰⁴.

Bees possess highly specific dietary requirements for sterols and fatty acids to synthesize phospholipids, generate cell membranes, and fuel de novo lipogenesis¹⁰⁵. The ingestion of foreign, concentrated potassium carboxylates can overwhelm their metabolic pathways and downregulate foraging activity due to the unpalatability of high-mineral solutions¹⁰⁴.

Furthermore, the indiscriminate application of agrochemicals, including certain adjuvants and surfactants, has been shown to alter the delicate gut microbiota of bees, reducing the populations of lactic acid bacteria (LAB) that naturally help detoxify xenobiotics¹⁰⁷.

While organic interventions are exponentially safer than systemic synthetic pesticides like neonicotinoids—which cause catastrophic mitochondrial dysfunction, rapid depolarization of neuronal mitochondria, and altered gene expression in *B. terrestris*—they are not entirely without ecological consequence¹⁰⁹. Therefore, to strictly protect pollinator populations, insecticidal soaps must never be applied to crops currently in bloom or during active foraging hours; applications must be restricted to twilight⁶⁷.

Advanced Microbial Biopesticides and Targeted Eradication

When habitat manipulation and contact soaps are insufficient, targeted microbial biopesticides are deployed to manage severe outbreaks without harming the beneficial predator populations established by the push-pull systems.

- ***Bacillus thuringiensis* var. *kurstaki* (B.t.k.):** Utilized specifically against free-feeding Lepidopteran larvae, such as the cabbage white butterfly (*Pieris brassicae*) and the box tree moth (*Cydalima perspectalis*)¹⁰¹. The bacterium must be ingested by the caterpillar, whereupon its alkaline-activated Cry toxins perforate the insect's midgut epithelium, causing fatal septicemia¹⁰¹. This pathogen is highly host-specific and remains completely harmless to mammals, birds, and crucial natural enemies like *Cotesia glomerata*, a parasitoid wasp of the cabbage white butterfly¹⁰¹.
- ***Bacillus thuringiensis* var. *tenebrionis* (B.t.t.):** Commercially available as Novodor FC, this specific strain is highly toxic to the larvae (L1-L4 stages) of the Colorado potato beetle (*Leptinotarsa decemlineata*)⁵³. Under the BVL framework, it frequently receives emergency 120-day authorizations (Notfallzulassungen) during severe summer outbreaks. It is applied at 5.0 Liters/ha when temperatures exceed 22°C, a threshold where Neem-based products begin to lose efficacy due to thermal degradation¹⁷.
- **Entomopathogenic Nematodes:** To combat soil-dwelling larval stages, specifically the maggots of the cabbage root fly (*Delia radicum*) and the carrot rust fly (*Psila rosae*), the application of *Steinernema feltiae* or *Heterorhabditis bacteriophora* nematodes is highly effective¹¹⁶. These microscopic worms actively seek out host larvae in the soil matrix, penetrate their natural openings, and release symbiotic bacteria that liquefy the host from the inside, providing unparalleled biological control precisely where foliar sprays cannot reach¹¹⁶.

Systemic Integration: The 5-Year Biogeochemical Rotation

To fully realize the efficacy of these interventions within the limiting Arenosols of the Berlin-Brandenburg region, they must be embedded within a rigorous 5-year crop rotation that balances nitrogen fixation, humus generation, and strict phytopathological breaks¹. The temporal sequencing of botanical families is dictated primarily by the biological life cycles of devastating soil-borne pathogens, specifically *Plasmodiophora brassicae* (Clubroot) and *Rhizoctonia solani* (Black Scurf)¹.

1. **Year 1: Deep Rooting & Fixation (Blue Lupin + Rye/Vetch Cover):** Initiates with *Lupinus angustifolius*, driving deep taproots through the compacted sand to retrieve leached phosphorus while fixing up to 180 kg N/ha biologically¹.
2. **Year 2: First Heavy Feeder Phase (Cabbage + *Barbarea vulgaris*):** Cabbage utilizes the massive nitrogen reserves. *Barbarea vulgaris* G-type is planted on the margins as a lethal trap crop for diamondback moths and flea beetles⁴². In the event of an outbreak, B.t.k. is applied¹⁰¹. Strict phytosanitary gaps are maintained to starve *Plasmodiophora brassicae* resting spores¹.
3. **Year 3: Moderate Feeder (Carrots intercropped with Onions):** Carrots are sown interspersed with *Allium cepa* at precise spatial intervals to maximize the Land Equivalent Ratio (LER). The emission of DADS creates a chemical shield against the carrot rust fly (*Psila rosae*)²⁶. *Steinernema feltiae* is applied to the soil early in the season to

preemptively destroy overwintering pupae¹¹⁷.

4. **Year 4: Second Heavy Feeder Phase (Potatoes + *Nepeta cataria*):** Potatoes are grown alongside *Nepeta cataria* to repel *Leptinotarsa decemlineata* via nepetalactone emissions¹¹⁹. Should climatic conditions heavily favor the beetle, emergency applications of *B.t.t.* (Novodor FC) or a NeemAzal-T/S nanoemulsion are executed⁵³. Biochar and vermicompost are incorporated to suppress *Rhizoctonia solani*¹.
5. **Year 5: Scavenger and Soil Sterilization Phase (Winter Rye + *Tagetes*):** Rye scavenges remaining nutrients, preventing groundwater leaching¹. Post-harvest, *Tagetes* is sown as a summer catch crop. Its deep root exudation of alpha-terthienyl utilizes solar radiation to generate a lethal ROS burst, biochemically sanitizing the soil matrix of *Meloidogyne* nematodes prior to the return to Year 1⁶¹.

Works cited

1. 24 Berlin Crop Rotation Schedule.pdf
2. (PDF) Evidence that organic farming promotes pest control, https://www.researchgate.net/publication/326424626_Evidence_that_organic_farming_promotes_pest_control
3. Ökologischer Landbau: Pflanzenschutzmittel - Wissensportale, <https://wissen.julius-kuehn.de/oekologischerlandbau/pflanzenschutz-staerkungsmittel/pflanzenschutzmittel>
4. EGTOP Annex II Draft/Final Report - Sinab, https://www.sinab.it/sites/default/files/egtop-report-feed-vi-and-petfood-i_en.pdf
5. Frequently asked questions ON ORGANIC RULES, https://poljoprivreda.gov.hr/UserDocsImages/dokumenti/poljoprivreda/ekoloska/organic-rules-faqs_en.pdf
6. Pflanzengesundheitskontrolle - Berlin.de, <https://www.berlin.de/pflanzenschutzamt/pflanzengesundheit/>
7. Epidemiologie und Pathogendiagnostik - JKI, <https://www.julius-kuehn.de/ep>
8. Versuchsstellen - ILU e.V., <https://www.ilu-ev.de/koordinierungsstelle/versuchsstellen/>
9. Plant Protection in Field Crops and Grassland - JKI, <https://www.julius-kuehn.de/en/a>
10. Auftretensmeldungen - pflanzengesundheit.julius-kuehn.de, <https://pflanzengesundheit.julius-kuehn.de/schaedlinge--auftretensmeldungen.html>
11. authorising certain products and substances for use in organic, [https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=PI_COM:Ares\(2021\)2131426&rid=4](https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=PI_COM:Ares(2021)2131426&rid=4)
12. EN Annex I ACTIVE SUBSTANCES CONTAINED IN PLANT, https://eur-lex.europa.eu/resource.html?uri=cellar:37dc6843-e70b-11eb-93a8-01aa75ed71a1.0023.02/DOC_2&format=PDF
13. Richtlinie - ECOVIN Bundesverband Ökologischer Weinbau, <https://www.ecovin.de/richtlinie/>

14. Ökologischer Weinbau 2020 - Oberlahn Winzer,
<http://www.oberlahn-winzer.de/pdf/oko-weinbau-broschure.pdf>
15. Oekologischer Weinbau 2026 - Regierungspräsidium Darmstadt,
https://rp-darmstadt.hessen.de/sites/rp-darmstadt.hessen.de/files/2026-05/rs-broschuere-oeko-2026_2.pdf
16. Neem-Forschung in Deutschland: Wissen für die Praxis - Niem-Handel,
<https://niem-handel.de/en/usefull-information/all-about-neem/neem-in-der-forschung/>
17. Pflanzenschutzmittel im Ökolandbau,
https://static.dw.com/downloads/52215106/kuehne_Pflanzenschutzmittel.pdf
18. Zulassungen für Notfallsituationen (letzte Änderung - BVL.bund.de,
https://www.bvl.bund.de/DE/Arbeitsbereiche/04_Pflanzenschutzmittel/01_Aufgaben/02_ZulassungPSM/01_ZugelPSM/02_Notfallzulassungen/psm_ZugelPSM_notfallzulassungen_node.html?thema=Zulassungen+f%C3%BCr+Notfallsituationen+%28letzte+%C3%84nderung%3A+8.+September+2026%29
19. NeemAzal - T/S - Agryco, https://www.agryco.de/de_DE/neemazal-t-s/p513474
20. Plant-Derived Pesticides as an Alternative to Pest Management and,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC8400533/>
21. Insecticidal soap - Wikipedia, https://en.wikipedia.org/wiki/Insecticidal_soap
22. Editing Plant Volatile Isoeugenol for Integrated Aphid Management,
<https://pubs.acs.org/doi/10.1021/acs.jafc.5c04008>
23. (PDF) Beyond 'push-pull': unraveling the ecological pleiotropy of,
https://www.researchgate.net/publication/383495318_Beyond_'push-pull'_unraveling_the_ecological_pleiotropy_of_plant_volatile_organic_compounds_for_sustainable_crop_pest_management
24. Host Plant Apparency and Push–Pull Strategies: A Unified ... - MDPI,
<https://www.mdpi.com/2075-4450/17/6/543>
25. Exploiting phytochemicals for developing a 'push–pull' crop ... - Ovid,
<https://www.ovid.com/journals/jebot/fulltext/10.1093/jxb/erq229~exploiting-phytochemicals-for-developing-a-pushpull-crop>
26. The effect of intercropping on yielding of root vegetables of,
https://www.researchgate.net/publication/282678203_The_effect_of_intercropping_on_yielding_of_root_vegetables_of_Apiaceae_family
27. Principles of Weed Science Third - DOKUMEN.PUB,
<https://dokumen.pub/principles-of-weed-science-third.html>
28. Organic Fruit and Vegetables from the Tropics - UNCTAD,
https://unctad.org/system/files/official-document/ditccom20032_en.pdf
29. Effect of Intercropping carrot (*Daucus carota* L.) with two aromatic,
https://www.researchgate.net/publication/296688155_Effect_of_Intercropping_carrot_Daucus_carota_L_with_two_aromatic_plants_coriander_Coriandrum_sativum_L_and_summer_savory_Satureja_hortensis_L_on_the_population_density_of_select_carrot_pests
30. Effect of intercropping carrot (*Daucus carota* L.) with french marigold,
https://www.researchgate.net/publication/271265027_Effect_of_intercropping_carrot_Daucus_carota_L_with_french_marigold_Tagetes_patula_nana_L_and_pot_m

[arigold_Calendula_officinalis_L_on_the_occurrence_of_some_pests_and_quality_of_carrot_yield](#)

31. Testing Garlic (*Allium sativum*) Intercropped with Tomato (*Solanum*,
https://www.researchgate.net/publication/378610552_Testing_Garlic_Allium_sativum_Intercropped_with_Tomato_Solanum_lycopersicum_In_the_Control_of_Aphids
32. The Garlic Allelochemical Diallyl Disulfide Affects Tomato Root,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC4977361/>
33. Changed host plant volatile emissions induced by chemical,
https://www.researchgate.net/publication/266388929_Changed_host_plant_volatile_emissions_induced_by_chemical_interaction_between_unattacked_plants_reduce_aphid_plant_acceptance_with_intermorph_variation
34. Volatile mediated suppression of *Pythium violae* ... - WUR eDepot,
<https://edepot.wur.nl/705339>
35. (PDF) Intercropping of lettuce and onion controls caterpillar thread,
https://www.researchgate.net/publication/309421720_Intercropping_of_lettuce_and_onion_controls_caterpillar_thread_Agrotis_ipsilon_major_insect_pest_of_lettuce
36. Research Advances in Allelopathy of Volatile Organic Compounds,
<https://www.mdpi.com/2311-7524/7/9/278>
37. Efficacy of three *Tagetes* species for the suppression of lepidopteran,
<https://www.frontiersin.org/journals/agronomy/articles/10.3389/fagro.2025.1670233/full>
38. Companion Planting Vegetables: Boost Your Yield - Holland Kertészeti,
<https://www.hollandkerteszeti.hu/en/blogs/my-garden-blog/companion-planting-vegetables>
39. Role of Saponins in Plant Defense Against Specialist Herbivores,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC6600540/>
40. Insect Attraction versus Plant Defense: Young Leaves High in ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC3994119/>
41. GARTENZEIT - Kwizda Agro Haus & Garten,
https://www.kwizda-garten.at/AGRO_MICRO/kwizda-garten.at/09_downloads/KWIZDA-0336_Gartenzeit_Magazin.pdf
42. Aromatic Glucosinolate Biosynthesis Pathway in *Barbarea vulgaris*,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC4744896/>
43. Identification of Defense Compounds in *Barbarea vulgaris* against,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC2785962/>
44. Erdflöhe bekämpfen gegen Löcher an Radieschen und Rucola,
<https://www.freisinger-gartenblog.de/lebensraum-garten/erdfloeh-loecher-radieschen-rucola-asiasalat/>
45. Kohlschädlinge effektiv bekämpfen: Gartentipps für Hobbygärtner,
<https://samen.de/blog/kohlschaedlinge-effektiv-bekaempfen-gartentipps-fuer-hobbygaertner.html>
46. Rapserdfloh (*Psylliodes chrysocephala*) - Ökolandbau.de,
<https://www.oekolandbau.de/bio-in-der-praxis/oekologische-landwirtschaft/oekolog>

- [ischer-pflanzenbau/oekologischer-pflanzenschutz/pflanzendoktor/schaderreger/sc](#)
[haderreger-im-ackerbau/rapserdfloh-psyliodes-chrysocephala/](#)
47. Expression patterns, molecular markers and genetic diversity ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC4487577/>
 48. A high-density genetic map and QTL mapping of leaf traits ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC6518621/>
 49. Resistance in the Plant, *Barbarea vulgaris*, and Counter-Adaptations,
https://www.researchgate.net/publication/41533012_Resistance_in_the_Plant_Bar_barea_vulgaris_and_Counter-Adaptations_in_Flea_Beetles_Mediated_by_Saponi_ns
 50. *Barbarea vulgaris* Glucosinolate Phenotypes Differentially Affect,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC2239252/>
 51. Biologische Zentralanstalt Berlin Sitz Kleinmachnow,
<https://sdei.senckenberg.de/media/openaccess/02637.pdf>
 52. Tagungsband Entomologentagung - ResearchGate,
https://www.researchgate.net/profile/Roland-Muehlethaler/publication/264326540_Entomologentagung_vom_21-24_Marz_2011_in_Berlin_Abstracts/links/5416d93d0cf2fa878ad42efd/Entomologentagung-vom-21-24-Maerz-2011-in-Berlin-Abstracts.pdf
 53. ISIP- Kartoffelkäfer - Bio-aus-BW,
https://bio-aus-bw.de/Lde/Startseite/Artikel+_Interviews/isip-kartoffelkaefer
 54. Full article: Botanical insecticide as simple extractives for pest control,
<https://www.tandfonline.com/doi/full/10.1080/23312025.2017.1404274>
 55. Allelopathic Properties of Lamiaceae Species - PMC - NIH,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC9182988/>
 56. The Use of Push-Pull Strategies in Integrated Pest Management,
https://www.researchgate.net/publication/6823225_The_Use_of_Push-Pull_Strategies_in_Integrated_Pest_Management
 57. Parnapimarol and Nepetaparnone from *Nepeta parnassica*,
https://www.researchgate.net/publication/5460082_Parnapimarol_and_Nepetaparnone_from_Nepeta_parnassica
 58. Taxonomy, Ontogenesis, Biochemical Composition, and Biological,
<https://impactfactor.org/PDF/IJPQA/12/IJPQA.Vol12.Issue2.Article6.pdf>
 59. Bioactive Volatiles From Push-Pull Companion Crops Repel Fall,
<https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2022.883020/full>
 60. CHAPTER 11 - Stephen Tvedten,
http://www.stephentvedten.com/11_Basic_Control_Overview.pdf
 61. Alpha-terthienyl (A novel marigold derivative): An overview on,
<https://horizonpublishing.com/index.php/PST/article/view/8256>
 62. (PDF) Plant parasitic nematode management using antagonistic,
https://www.researchgate.net/publication/383609832_Plant_parasitic_nematode_management_using_antagonistic_plants_as_a_potential_substitute_to_hazardous_chemical_control_-_a_review
 63. Antifungal activity of *Tagetes patula* extracts on some,

- https://www.researchgate.net/publication/8252106_Antifungal_activity_of_Tagetes_patula_extracts_on_some_phytopathogenic_fungi_Ultrastructural_evidence_on_Pythium_ultimum
64. Nematicidal actions of the marigold exudate α -terthienyl, <https://www.semanticscholar.org/paper/Nematicidal-actions-of-the-marigold-exudate-Hamaguchi-Sato/90bf0583b10f204154ddd4a00fde394dcbddf989>
 65. Naturally occurring thiophenes: isolation, purification, structural, https://www.researchgate.net/publication/273896029_Naturally_occurring_thiophenes_isolation_purification_structural_elucidation_and_evaluation_of_bioactivities
 66. Nematicidal actions of the marigold exudate α -terthienyl - PMC - NIH, <https://pmc.ncbi.nlm.nih.gov/articles/PMC6504006/>
 67. How to Make Insecticidal Soap | BBC Gardeners World Magazine, <https://www.gardenersworld.com/how-to/maintain-the-garden/insecticidal-soap/>
 68. How do insecticidal soaps work? - Home Garden Education Office, <https://homegarden.cahnr.uconn.edu/factsheets/insecticidal-soaps/>
 69. Insecticidal Soaps - LSU AgCenter, <https://www.lsuagcenter.com/~media/system/d/6/0/f/d60f319b064cade1f3330913f83bdbab/alternative%20pest%20control%203%20-%20insecticidal%20soaps.pdf.pdf>
 70. (PDF) Saponification Process and Soap Chemistry - ResearchGate, https://www.researchgate.net/publication/383539877_Saponification_Process_and_Soap_Chemistry
 71. Insecticidal Soap (Potassium Salts of Fatty Acids) - ColtivoBio, <https://www.coltivobio.com/en/insecticidal-soap-uses-and-mode-of-action/>
 72. Organic Insecticidal Soap Recipes | Houzz Forum, <https://www.houzz.com/discussions/1543957/organic-insecticidal-soap-recipes>
 73. NOSB Spring 2025 Meeting Documents - Regulations.gov, <https://downloads.regulations.gov/AMS-NOP-24-0081-0057/content.pdf>
 74. Liquid Soap with KOH: Paste, Dilution and Clarity | SoapIndex, <https://soapindex.com/guides/liquid-soap-making-koh>
 75. Comparative Evaluation of Some Physicochemical Properties on, https://www.scirp.org/html/99064_99064.htm
 76. Potash in Soap Making: Benefits, Uses, and Chemical Properties, <https://elchemy.com/blogs/chemical-market/potash-in-soap-making-benefits-uses-and-chemical-properties>
 77. The Saponification Value of Edible Oils - Nutioils, <https://nutioils.com/documents/white-paper-saponification-value-edible-oils-2025.pdf>
 78. DETERMINATION OF SAPONIFICATION VALUE, <https://repository.seafdec.org/bitstream/handle/20.500.12066/6053/C-6.pdf?sequence=1&isAllowed=y>
 79. Laboratory Saponification Value Determination - Blog, <https://blog.yeswelab.fr/en/cosmetic-plants/laboratory-saponification-index/>
 80. What are SAP Values in Soap Making? | TheSoapery, <https://www.thesoapery.co.uk/blogs/news/saponification-values>

81. Saponification Value Calculator,
<https://calcuick.com/calculator/saponification-value-calculator/>
82. Saponification Value Calculator - GetZenQuery,
<https://www.getzenquery.com/tools/saponification-value-calculator/>
83. Saponification Chart - From Nature With Love,
<https://www.fromnaturewithlove.com/resources/sapon.asp>
84. Potassium Hydroxide Soap Making: Liquid Soap & KOH Guide,
<https://www.sinolookchem.com/info/potassium-hydroxide-in-soap-making-liquid-soa-103526291.html>
85. Fundamentals of Using Soaps as Insecticides | Extension Entomology,
<https://blogs.k-state.edu/kansasbugs/2020/06/12/fundamentals-of-using-soaps-as-insecticides/>
86. Why That Homemade Insecticidal Soap Might Kill Your Garden,
<https://www.iamcountryside.com/soapmaking/homemade-insecticidal-soap-kills-gardens/>
87. Repellant formulation and method - Google Patents,
<https://patents.google.com/patent/US20220079166A1/en>
88. (PDF) Optimization of Manufacturing liquid Soap Based on Virgin,
https://www.researchgate.net/publication/363327892_Optimization_of_Manufacturing_liquid_Soap_Based_on_Virgin_Coconut_Oil_with_a_Combination_Potassium_Hydroxide_and_Ammonium_Hydroxide
89. (PDF) Preparation and Characterization of Coconut Oil Based Soap,
https://www.researchgate.net/publication/342559927_Preparation_and_Characterization_of_Coconut_Oil_Based_Soap_with_Kaolin_as_Filler
90. Saponification of fat - Green Chemistry in Teaching Labo,
https://web.njit.edu/~mitra/green_chemistry/EXP_4.htm
91. How to pH Test Soap the Right Way & Why It Matters!,
<https://www.modernsoapmaking.com/blog/how-to-ph-test-handmade-soap>
92. Natural Products for Managing Landscape and Garden Pests in,
<https://ask.ifas.ufl.edu/publication/IN197>
93. Agricultural Potassium Soap for Pest Control | BIMCO International,
<https://bimcointernational.com/en/agricultural-potassium-soap-pest-control-bimco/>
94. Potassium salts of fatty acids - UC IPM,
<https://ipm.ucanr.edu/home-and-landscape/pesticide-active-ingredients-database/active-ingredient-details/?uaiKey=50>
95. Concentration-dependent lethal and behavioral effects of potassium,
https://www.researchgate.net/publication/405718128_Concentration-dependent_lethal_and_behavioral_effects_of_potassium_soap_on_adult_Acanthoscelides_obtectus_Coleoptera_Chrysomelidae_evidence_for_a_hormetic_response_at_sublethal_exposures
96. US20140174480A1 - Citrate salt bathroom cleaners - Google Patents,
<https://patents.google.com/patent/US20140174480A1/en>
97. Citrate salt bathroom cleaners - WO2014100625A1 - Google Patents,
<https://patents.google.com/patent/WO2014100625A1/en>
98. E 330 CITRIC ACID ANHYDRATE - Ataman Chemical,

- https://www.atamanchemicals.com/e-330-citric-acid-anhydrate_u33175/
99. Photostabilizers for Azadirachtin-A (A Neem-Based Pesticide),
https://www.researchgate.net/publication/10665017_Photostabilizers_for_Azadirachtin-A_A_Neem-Based_Pesticide
 100. neem oil nanoemulsion: Topics by Science.gov,
<https://www.science.gov/topicpages/n/neem+oil+nanoemulsion>
 101. Warum kein Neemöl verwenden? 7 Gründe gegen den Hype,
<https://silberkraft.com/blogs/neemol/warum-kein-neemol-verwenden-7-grunde-gegen-den-hype>
 102. Emulsion stability and residue evaluation of natural fungicide from,
https://www.researchgate.net/publication/328815943_Emulsion_stability_and_residue_evaluation_of_natural_fungicide_from_neem_and_eugenol_oil_in_300_EC_formulation
 103. Insecticidal and oviposition deterrent effects of essential oils and,
https://www.researchgate.net/publication/281580916_Insecticidal_and_oviposition_deterrent_effects_of_essential_oils_and_their_constituents_against_the_invasive_pest_Drosophila_suzukii_Matsumura_Diptera_Drosophilidae
 104. Behavioural regulation of mineral salt intake in honeybees - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC9058550/>
 105. Sterol and lipid metabolism in bees - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC10465395/>
 106. Sterol and lipid metabolism in bees - PubMed,
<https://pubmed.ncbi.nlm.nih.gov/37644282/>
 107. Glyphosate-Based Herbicides and Their Potential Impact on ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC12300706/>
 108. Binding and Detoxification of Insecticides by Potentially Probiotic,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC9740702/>
 109. Assessing the acute toxicity of insecticides to the buff-tailed ... - PMC,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC7294345/>
 110. Impacts of neonicotinoids on the bumble bees *Bombus terrestris* and,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC8577289/>
 111. Nutritional resources modulate the responses of three bee species,
<https://pubmed.ncbi.nlm.nih.gov/36368063/>
 112. Jahresbericht 2014 - Bayerische Landesanstalt für Landwirtschaft - LfL,
https://www.lfl.bayern.de/mam/cms07/ips/dateien/lfl_jahresbericht_2014_ips.pdf
 113. Betriebsmittelliste 2021 - Gäa e.V.,
https://www.gaea.de/assets/pdf/Gaea-FibL-Betriebsmittelliste_2021.pdf
 114. The Ecology of Fungal Entomopathogens 9048139651,
<https://dokumen.pub/the-ecology-of-fungal-entomopathogens-9048139651-9789048139651.html>
 115. Berichte aus dem Julius Kühn-Institut,
<https://ojs.openagrar.de/index.php/BerichteJKI/article/view/11181/10151>
 116. *Steinernema feltiae* – Beneficial nematodes for Pest Control - Koppert,
<https://www.koppert.com/crop-protection/biological-pest-control/beneficial-nematodes/steinernema-feltiae/>

117. Biocontrol in Integrated Pest Management in Fruit and Vegetable,
<https://www.mdpi.com/2311-7524/11/5/522>
118. PI Nr. 14: Lauschangriff auf Schädlinge im Getreide: Insekten-Abhör,
<https://www.julius-kuehn.de/pressemitteilungen/pressemeldung/n/pi-nr-14-lauschangriff-auf-schaedlinge-im-getreide-insekten-abhoer-technik-im-getreidesilo-installiert>
119. Unlocking the Potential of Hydrosols: Transforming Essential Oil,
<https://pmc.ncbi.nlm.nih.gov/articles/PMC11477756/>
120. Plant Essential Oil with Biological Activity - MDPI,
https://mdpi-res.com/bookfiles/book/13279/Plant_Essential_Oil_with_Biological_Activity.pdf?v=1788854857
121. Can the introduction of companion plants increase biological control,
https://www.researchgate.net/publication/357888160_Can_the_introduction_of_companion_plants_increase_biological_control_services_of_key_pests_in_organic_squash