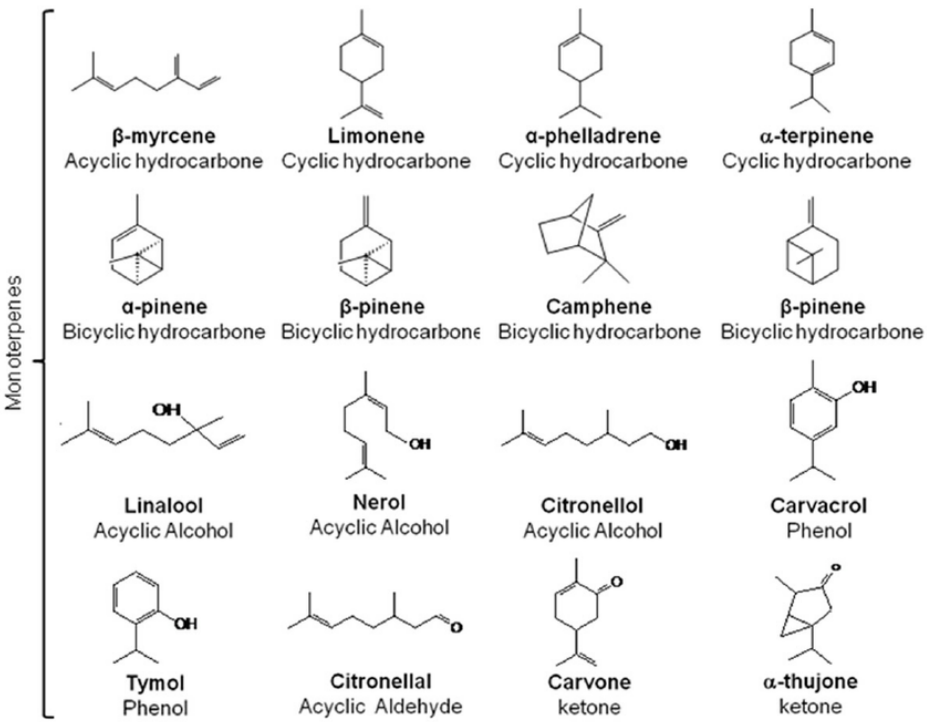
Exogenous Terpenes in Agriculture: Can External Application Improve Crop Performance?

Terpenes are among the most diverse and abundant secondary metabolites produced by plants. While these compounds are well known for their roles in plant defense and stress responses, recent research has explored whether applying terpenes externally to plants can provide practical benefits in commercial agriculture. This post examines the current scientific understanding of exogenous terpene applications through both foliar sprays and root zone treatments.



Models for a collection of commonly found monoterpenes

What Are Terpenes and Why Do Plants

Produce Them?

Terpenes represent the largest class of plant secondary metabolites, with approximately 55,000 known members across the plant kingdom (1). Plants synthesize these compounds through the methylerythritol phosphate pathway in plastids and the mevalonate pathway in the cytosol. The resulting molecules range from simple monoterpenes containing 10 carbon atoms to complex diterpenes with 20 carbons and beyond.

The primary ecological function of terpenes involves plant protection. These volatile organic compounds help plants defend against pathogens and herbivores, attract beneficial insects and pollinators, and provide protection against environmental stresses such as heat and drought (2). Given these natural protective functions, researchers have investigated whether externally applied terpenes might confer similar benefits to crops.

Foliar Application of Monoterpenes

The most comprehensive study on foliar terpene application comes from research on tomato plants under water deficit stress. When a mixture of nine monoterpenes was applied as a foliar spray at concentrations ranging from 1.25 to 5 mM, the treated plants showed significant improvements in oxidative stress management (3).

The foliar-applied monoterpenes were readily absorbed by tomato leaves, increasing total foliar monoterpene content by up to 2.5-fold compared to untreated controls. Most importantly, the treatment substantially decreased hydrogen peroxide accumulation and lipid peroxidation in plants exposed to drought stress. At the optimal concentration of 1.25 mM, plants showed a 50% reduction in oxidative damage compared to controls, though this protective effect did not extend to preventing photosynthetic decline (3).

The mechanism appears to involve direct quenching of reactive oxygen species by the terpenes themselves. Interestingly, higher concentrations of 2.5 and 5 mM increased activity of antioxidant enzymes like superoxide dismutase and ascorbate peroxidase, but also induced some oxidative stress, suggesting a threshold effect where lower concentrations may be more beneficial than higher ones.

Monoterpene Concentration	H_2O_2 Reduction (%)	Lipid Peroxidation Reduction (%)	Enzyme Activity Change
1.25 mM	~50%	~45%	No change
2.5 mM	~35%	~30%	Increased
5.0 mM	~25%	~20%	Increased

Root Zone Applications and Belowground Signaling

While foliar applications have shown promise for stress mitigation, root zone applications of terpenes have been explored primarily for pest management through biological control. The sesquiterpene E-β-caryophyllene serves as a particularly well-studied example of how terpenes function in the rhizosphere.

When maize roots are damaged by western corn rootworm larvae, they naturally emit E-β-caryophyllene, which attracts entomopathogenic nematodes that parasitize and kill the pest insects (4). Field experiments demonstrated that when synthetic E-β-caryophyllene was applied to soil near maize varieties that do not naturally produce this signal, adult beetle emergence decreased by more than 50%, demonstrating the practical potential of this approach.

The effectiveness of soil-applied E-β-caryophyllene depends heavily on soil properties. Research has shown that this sesquiterpene diffuses primarily through the gaseous phase of soil rather than the aqueous phase. In clay soils at 10% water content, diffusion was significantly limited, but increasing moisture to 20% substantially improved signal propagation in clay loam and sandy loam soils (5).

In controlled field trials, maize plants engineered to constitutively emit E-β-caryophyllene and treated with entomopathogenic nematodes suffered 60% less root damage and had significantly fewer adult beetles emerge compared to non-emitting lines (6). This demonstrates that strategic application of specific terpenes to the root zone can enhance biological control efficacy.

Disease Resistance Through Diterpene Application

Diterpenes have shown particularly strong antimicrobial properties when applied to plants. Two labdane-type diterpenes isolated from tobacco, sclareol and cis-abienol, were tested as exogenous treatments on tobacco, tomato, and Arabidopsis plants. These compounds effectively inhibited bacterial wilt diseases, with microarray analysis revealing that they activated genes encoding components of plant immune responses, including MAP kinase cascades and defense-related biosynthetic pathways (1).

In maize, the diterpene epoxydolabranol demonstrated simultaneous effectiveness against two major fungal pathogens, Fusarium graminearum and Fusarium verticillioides. The diterpene momilactone B showed allelopathic properties, completely inhibiting germination of several weed species at concentrations of 4 to 20 ppm when applied to soil (1).

Terpene Type	Application Method	Target Organism	Effective Concentration

Monoterpenes (mixed)	Foliar spray	Drought stress	1.25 mM
E-β-caryophyllene	Soil drench	Root pests	200-20,000 ng
Sclareol/cis-abienol	Root application	Bacterial wilt	Not specified
Momilactone B	Soil application	Weeds	4-20 ppm

Practical Considerations for Application

Several factors influence the effectiveness of exogenous terpene applications. For foliar treatments, the physiochemical properties of individual terpenes significantly affect uptake and translocation. Compounds like α-terpinene and terpinolene show greater solubility and cellular accumulation compared to more volatile molecules like α-pinene and limonene (3).

Timing and application frequency also matter. Foliar sprays applied twice daily showed better results than single applications, suggesting that maintaining adequate concentrations on leaf surfaces requires repeated treatments. For soil applications, the water content and texture of the growing medium critically influence how well terpene signals diffuse through the root zone.

Cost remains a significant consideration. Production of terpenes for agricultural use requires either chemical synthesis or bio-production in heterologous hosts. For structurally complex terpenes, chemical synthesis may be economically prohibitive, making microbial production platforms like engineered Escherichia coli or Saccharomyces cerevisiae more practical options (7).

Limitations and Future Directions

Current research reveals important limitations. While exogenous monoterpenes effectively reduced oxidative stress in tomato plants, they did not prevent the photosynthetic decline associated with stomatal closure during drought. This suggests that terpene applications may be most useful as supplementary treatments rather than standalone solutions for stress management (3).

The dose-response relationship appears complex, with higher concentrations sometimes producing counterproductive effects. In the tomato study, 5 mM monoterpene applications induced oxidative stress while attempting to protect against it, highlighting the importance of careful concentration optimization for each crop and application method.

Much of the existing research has been conducted under controlled laboratory or greenhouse conditions. Large-scale field trials examining the agronomic and economic viability of exogenous terpene applications remain limited. Questions about the persistence of applied terpenes under field conditions, their environmental fate, and potential non-target effects require further investigation.

Conclusions

Exogenous terpene applications represent an emerging area of agricultural research with demonstrated benefits in specific scenarios. Foliar monoterpene sprays can mitigate oxidative stress from drought at appropriate concentrations. Soil-applied sesquiterpenes like E-β-caryophyllene enhance biological pest control by attracting beneficial nematodes. Diterpenes show promise as antimicrobial agents when applied to roots.

However, practical adoption requires further development.

Growers interested in this technology should recognize that terpene applications are most likely to succeed as part of integrated management strategies rather than as standalone interventions. The variable responses across different terpene types, concentrations, and application methods mean that each crop system will require careful optimization.

As production costs decrease and application protocols become more refined, exogenous terpenes may find their place in the grower's toolkit, particularly for organic production systems seeking alternatives to synthetic pesticides. Until then, this remains a promising but still developing technology that warrants continued research attention.