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Minireview

Smoke-derived butenolide: Towards understanding its biological effects

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Abstract

The smoke-derived butenolide, 3-methyl-2*H*-furo[2,3-*c*]pyran-2-one, is a simple organic compound that can increase both the level and rate of seed germination, widen the environmental range over which germination can occur and have a positive effect on seedling vigour. Consequently, butenolide has a wide range of potential applications spanning horticulture, weed control and ecological restoration. Here we review the isolation and identification of this compound from plant-derived smoke, its effects on plants and the current state of knowledge on possible mode of action, as well as impacts it may have in the natural environment.

Keywords: Butenolide; Plant growth; Seed germination; Smoke

1. Introduction

1.1. Smoke as a germination cue

The major role of fire as a disturbance factor and driver of ecosystem properties and function is well recognised (Keeley and Fotheringham, 2000). Beyond the effects on biomass and mortality of established plants, the effect on seed germination has also been identified as a mechanism through which the effects of fire are modulated. This is particularly seen in species with seeds that have hard, water-impermeable seed coats (e.g. species of Fabaceae; Keeley and Fotheringham, 2000). In such seeds, heat from the fire 'cracks' the seed coat enabling subsequent water uptake and hence germination. However, not until more recently was it discovered that in addition to heat, smoke or aqueous extracts of smoke could function as germination stimulants in the threatened fynbos species *Audouinia capitata* (De Lange and Boucher, 1990).

Since that landmark discovery, smoke has been shown to stimulate germination of numerous species from a range of fire-prone environments worldwide including Australian kwongan (Roche et al., 1997), Californian chaparral (Keeley and Fotheringham, 1998a), Western Cape fynbos (Brown et al., 2003) and the Mediterranean basin (Crosti et al., 2006). In a survey of 301 South African fynbos species, it was found that 49.8% of species, ranging from annual herbs to geophytes to trees, had a positive germination response to smoke (Brown et al., 2003). However, a smoke germination response is not limited to species from fire-prone environments as smoke stimulates germination in species such as lettuce (Drewes et al., 1995), red rice (Doherty and Cohn, 2000) and wild oats (Adkins and Peters, 2001).

Although the role of smoke in germination and its potential applicability have been previously reviewed (Brown and Van Staden, 1997; Van Staden et al., 2000; Light and Van Staden, 2004), the aim of this paper is to highlight recent findings related to the highly active germination component in smoke, namely, 3-methyl-2*H*-furo[2,3-*c*]pyran-2-one (Fig. 1-1).

1.2. Discovery of the active butenolide in smoke

Following the initial reports on smoke-stimulated seed germination in the early 1990s, various research groups worldwide attempted to isolate and characterize the chemical(s) present in plant-derived smoke responsible for the phenomenal

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