Plant Physiology and Biochemistry 74 (2014) 133–140

Contents lists available at ScienceDirect

Plant Physiology and Biochemistry

journal homepage: www.elsevier.com/locate/plaphy

Research article

Microbe associated molecular patterns from rhizosphere bacteria trigger germination and *Papaver somniferum* metabolism under greenhouse conditions

A. Bonilla [b,1], A.L.F. Sarria [a,b,1], E. Algar [b], F.J. Muñoz Ledesma [c], B. Ramos Solano [b,*], J.B. Fernandes [a], F.J. Gutierrez Mañero [b]

[a] Universidade Federal de São Carlos, Laboratório de Produtos Naturais, Departamento de Química, São Carlos, SP 13.565-905, Brazil
[b] Faculty of Pharmacy, San Pablo CEU University, PO Box 67, Boadilla del Monte, 28668 Madrid, Spain
[c] ALCALIBER I+D+i, S.L.U. Ctra, Carmona-El Viso del Alcor, km. 18, 41410 Carmona, Sevilla, Spain

ARTICLE INFO

Article history:
Received 2 August 2013
Accepted 11 November 2013
Available online 19 November 2013

Keywords:
Biotic elicitation
Germination
Morphinanes
PGPR
Systemic induction
MAMPs

ABSTRACT

Ten PGPR from different backgrounds were assayed on *Papaver somniferum* var. Madrigal to evaluate their potential as biotic elicitors to increase alkaloid content under the rationale that some microbe associated molecular patterns (MAMPs) are able to trigger plant metabolism. First, the 10 strains and their culture media at two different concentrations were tested for their ability to trigger seed germination. Then, the best three strains were tested for their ability to increase seedling growth and alkaloid levels under greenhouse conditions. Only three strains and their culture media enhanced germination. Then, germination enhancing capacity of these best three strains, N5.18 *Stenotrophomonas maltophilia*, Aur9 *Chryseobacterium balustinum* and N21.4 *Pseudomonas fluorescens* was evaluated in soil. Finally, the three strains were applied on seedlings at two time points, by soil drench or by foliar spray. Photosynthesis was measured, plant height was recorded, capsules were weighted and alkaloids analyzed by HPLC. Only N5.18 delivered by foliar spray significantly increased plant height coupled to an increase in total alkaloids and a significant increase in opium poppy straw dry weight; these increases were supported by a better photosynthetic efficiency. The relative contents of morphine, thebaine, codeine and oripavine were affected by this treatment causing a significant increase in morphine coupled to a decrease in thebaine, demonstrating the effectivity of MAMPs from N5.18 in this plant species. Considering the increase in capsule biomass and alkaloids together with the acceleration of germination, strain N5.18 appears as a good candidate to elicit plant metabolism and consequently, to increase productivity of *Papaver somniferum*.

1. Introduction

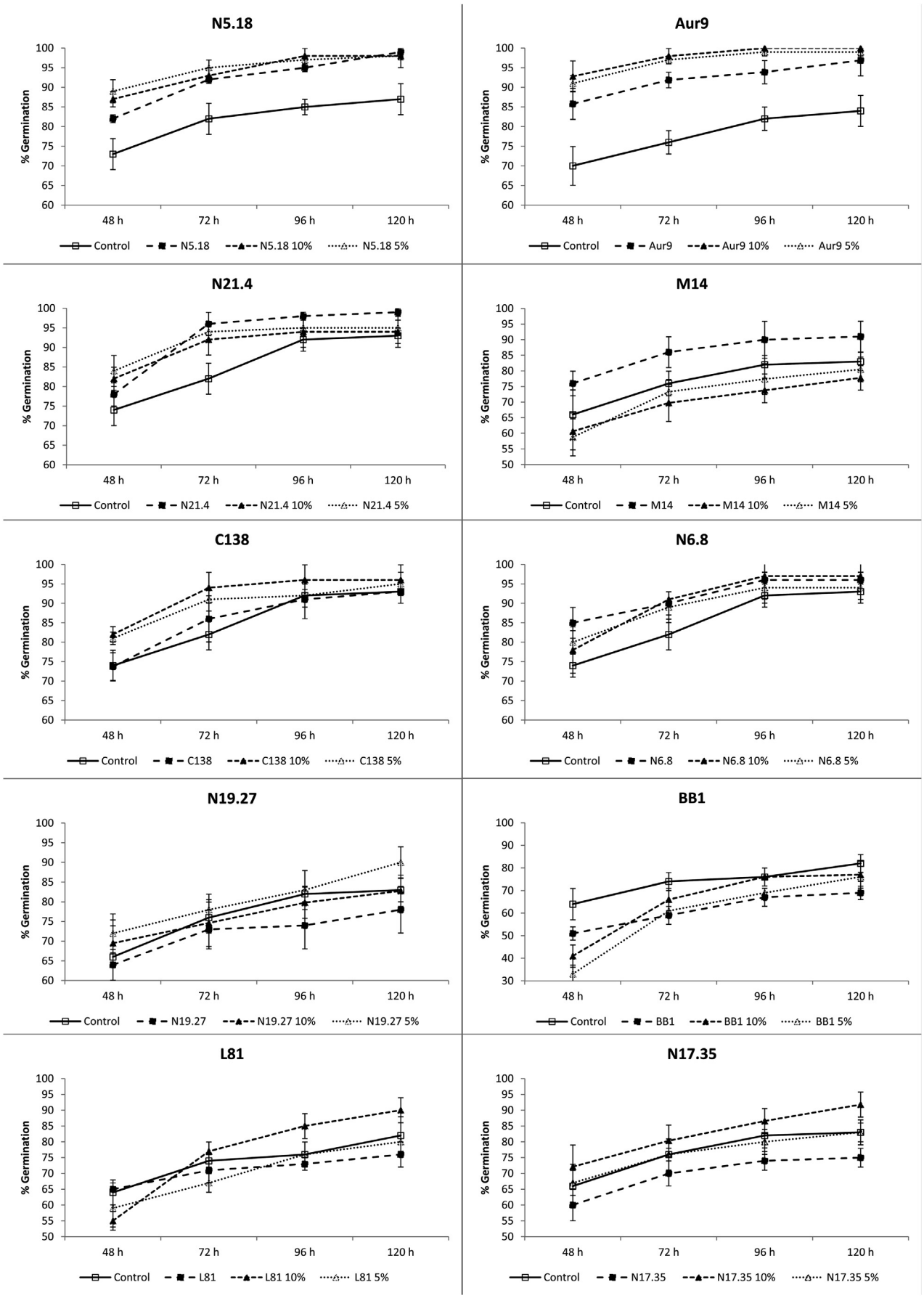
Opium poppy, *Papaver somniferum*, is the most important source of morphinane alkaloids exploited by the pharmaceutical industry as analgesics, antitussives and anti-spasmodic (Liscombe and Facchini, 2008). Despite the many efforts made to obtain alkaloid production in cell cultures, today field production is the option. In Spain, cropping surface devoted to this crop is over 9.500 ha mostly located in southern and central Spain (Montes-Borrego et al., 2011).

However, due to the inducible nature of secondary metabolism, alkaloid levels change according to environmental conditions (Facchini, 2001; Bourgaud et al., 2001; Szabo et al., 2008), and therefore, yield is highly compromised due to different factors. This lack of reproducibility may be overcome by the means of elicitation (Poulev et al., 2003; Algar et al., 2012), that is triggering plant's metabolism with a molecule, the elicitor, that can be of different nature (Radman et al., 2003). So far, elicitors have been grouped into two distinct blocks: abiotic factors (light intensity, temperature, chemicals) (Srivastava and Sharma, 1990; Bennett et al., 2004; Kim et al., 2005) and biotic factors (pathogenic bacteria, beneficial bacteria, fungi and insects) (Alves et al., 2004; Alcantara et al., 2005; Ramos-Solano et al., 2008).

Biotic elicitation with Plant Growth Promoting Rhizobacteria (PGPR) is proposed as a useful strategy to improve biomass production and to trigger secondary metabolism at the same time (Zhang et al., 2004; Ramos-Solano et al., 2010). Upon recognition of the non-pathogenic biotic agent, a series of metabolic changes are

* Corresponding author. Tel.: +34 372 64 11; fax: +34 91 351 04 96.
E-mail address: bramsol@ceu.es (B. Ramos Solano).
[1] These authors contributed equally to this work.

0981-9428/$ – see front matter © 2013 Elsevier Masson SAS. All rights reserved.
http://dx.doi.org/10.1016/j.plaphy.2013.11.012


N5.18
% Germination
48 h
72 h
96 h
120 h
Control
N5.18
N5.18 10%
N5.18 5%
Aur9
Aur9
Aur9 10%
Aur9 5%
N21.4
N21.4
N21.4 10%
N21.4 5%
M14
M14
M14 10%
M14 5%
C138
C138
C138 10%
C138 5%
N6.8
N6.8
N6.8 10%
N6.8 5%
N19.27
N19.27
N19.27 10%
N19.27 5%
BB1
BB1
BB1 10%
BB1 5%
L81
L81
L81 10%
L81 5%
N17.35
N17.35
N17.35 10%
N17.35 5%