RELATIONSHIP BETWEEN PLANT TRAITS AND RESISTANCE TO BURIAL BY MARLY SEDIMENT

Burylo M.[1] *– Rey F.*[2] *– Dutoit T.*[3]

[1] Cemagref, Mountain Ecosystems research unit, 2 rue de la papeterie, BP 76, 38402 Saint Martin d'Hères Cedex, France, melanie.burylo@cemagref.fr
[2] Cemagref, Mountain Ecosystems research unit, Grenoble, France
[3] Biological engineering department, Avignon University, France

Abstract: In marly lands of the French Southern Alps, harsh soil erosion results in sediment movements during intensive rainfall events. Plants can be subjected to sediment burial in their early stages of development and their protective function may be reduced. In a context of land restoration, it is important to know species resistance to environmental disturbances and to be able to predict it, in particular from plant traits (height, biomass, sugar and starch accumulation). However, few studies on woody species tolerance to burial by sediment have been carried out. Seedlings of five woody species were buried in marly sediment at three different depths in a pot experiment for 8 weeks: no burial (control), partial burial (50% stem height) and complete burial (100% stem height). Height over time, biomass and survival rates were measured to assess species resistance to burial. The results show that among the five species, only one (*Acer campestre*) survived complete burial. All plants survived partial burial, but there were significant differences in height and biomass between buried plants and controls, and significant differences between species responses. Three different responses to disturbance were identified: negative (*Hippophae rhamnoides*, *Ononis fruticosa*), neutral (*Robinia pseudo acacia*, *Pinus nigra*) and positive (*Acer campestre*). The results finally suggest that species resistance to burial by marly sediment is related to sugar accumulation in plant stems.

Keywords: response traits, burial, erosion, marls, sediment

Introduction

In the marly ravines of the Southern Alps, the land is subjected to significant hydric erosion. During intensive rainfall events, large quantities of sediment are transported and may bury plants. Burial substantially alters soil conditions, increasing soil humidity, reducing temperature in the root zone, increasing soil compaction and lowering the concentration of oxygen surrounding the roots, which can result in root asphyxiation (Baldwin and Maun, 1983; Maun, 1998).

Plant responses to burial by sand has been widely studied. Maun (1998) showed that plants can adopt three types of response: negative, neutral, and positive. In addition, the response of tolerant species to burial by sand is well known today, resulting for example in stimulation of plant growth (Zhang and Maun, 1992; Maun *et al.*, 1996) and their physiological activity (Disraeli, 1984; Shi *et al*., 2004; Perumal and Maun, 2006) and adventitious root formation (Langlois *et* al, 2001; Dech and Maun, 2006).

However, the response of species to burial by fine sediments still requires more precise study (Kent *et al.*, 2001). In addition, in a context of land restoration of marly ravines, one of the major concerns is to be able to use simple variables to predict whether the vegetation spontaneously taking hold after human intervention will withstand the environmental conditions, here burial. Several authors have hypothesized a relation between plant response and the amount of energy stored in the plant's storage organs. However, to our knowledge, no study has tested this.

The objective of this study was therefore to 1/ study the response of different species to marly sediment burial and 2/ relate plant resistance to plant traits.

Materials and methods

Five dominant woody species in the natural vegetation were sampled: three tree species, *Acer campestre*, *Robinia pseudo acacia* and *Pinus nigra*, and two shrubs, *Hippophae rhamnoïdes* and *Ononis fruticosa*. After germination in a growth chamber, seedlings were cultivated for 5 weeks in an open garden in pots (15x18 cm) filled with marly soil. Three burial treatments were applied: no burial (control), partial burial (50% stem height) and complete burial (100% stem height). At the time of burial, sugar and starch contents were measured in plant stems and roots.
Height and plant survival were measured every 2 weeks. After 8 weeks, fresh biomass of above and below-ground organs were measured and the log response ratio (lnRR) was calculated as the logarithm of the ratio of control plants' biomass and buried plants' biomass.
Repeated ANOVA (ANOVAR) and ANOVA measures were used to test for differences in height, lnRR and sugar and starch content (Statistica version 7.1 for Windows, Statsoft 1984).

Results and discussion

Only one species survived total burial (100%), *A. campestre*, with 40% seedlings surviving at 6 weeks. However, all species tolerated partial burial well since seedling emergence varied between 90% and 100%.
The ANOVAR (Table 1) results indicated an increase in height over time for control individuals and buried individuals (a significant effect of the time variable). However, burial only had an effect on *H. rhamnoïdes*, whose individual plants presented slowed growth compared to control individuals (significant after 6 weeks).

Table 1: Species response to burial – Height growth (ANOVAR). F values and significant levels of time, burial and timexburial. ns: nonsignificant, *$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$

	Acer	*Robinia*	*Pinus*	*Hippophae*	*Ononis*
Time	20.4 ***	9.56 ***	4.53 **	72.4 ***	56.85 ***
Burial (50% plant height)	0.002 ns	0.12 ns	1.22 ns	5.42 *	0.89 ns
Time x burial	0.3 ns	0.12 ns	0.92 ns	5.65 ***	0.93 ns

The ANOVA results show that there are significant lnRR differences between the species ($F = 8.97$, $p<<0.001$ for the root biomass lnRR; $F = 6.15$, $p<<0.001$ for above-ground organ biomass lnRR – Figure 1). For above-ground organ biomass, *H. rhamnoïdes* and *O. fruticosa* presented slowed biomass production. *R. pseudo acacia* and *P. nigra* showed no particular response to burial, whereas *A. campestre* showed a trend toward stimulation of biomass production. As for below-ground biomass, four species slowed their root biomass production. *A. campestre* remained neutral to burial.

The results identified a gradient of resistance to burial characterized by three types of response:
a. slowing of activity and reduction of growth (*H. rhamnoides* and *O. fruticosa*)
b. species that were neutral to burial (*R. pseudo acacia* and *P. nigra*)

c. species that were highly resistant, even stimulated by burial (*A. campestre*).

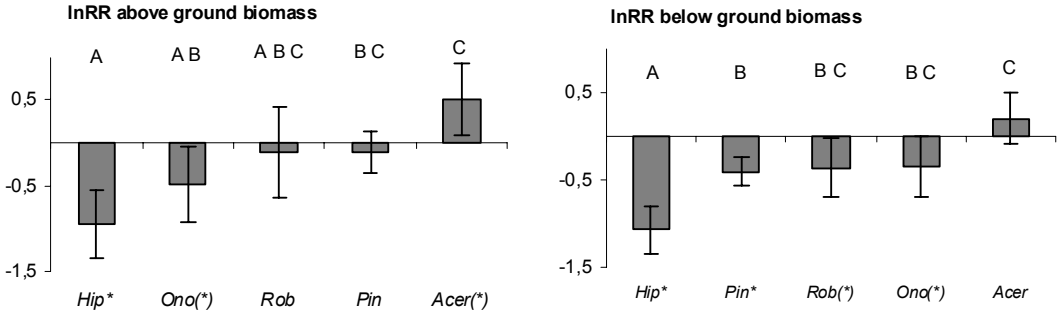

Figure 1: Species response to burial – Fresh biomass production (ANOVA). Differences with zero: * $p<0.05$; (*) $p<0.1$.

The ANOVA analysis of sugar and starch contents in stems and roots revealed no significant differences between the species (Table 2). However, we noted that the gradient of sugar concentration mirrored the gradient of resistance to burial, showing that the species that were the least resistant to burial presented the lowest concentrations, and. *A. campestre*, identified as the most resistant species, had the highest concentrations.

Generally speaking, the five species tested tolerated partial burial well but did not survive total burial (except *A. campestre*). The sediment heights applied (a mean 3.8 cm and 7.2 cm for partial and total burial, respectively) correspond to the heights of sediment that can accumulate in the field (Rey, 2005). These results confirm that burial, depending on height, can cause substantial mortality in plant communities developing on eroded land. In addition, the results indicate increasing mortality with rising sediment height for all species. Other authors have also obtained mortality results leading to the same conclusion (Brown, 1984; Langlois *et al.*, 2001; Shi *et al.*, 2004; Dech and Maun, 2006). However, this study showed that species can respond differently to burial by marly sediments.
Furthermore, the results identified three different responses to burial (growth slowed, unchanged, or accelerated by burial), manifested by differences in biomass, height growth, and survival rate. These results correspond to the conceptual model proposed by Maun (1998) on species response to burial in sand. Our study therefore seems to indicate that this model could also be valid for analyzing the response of woody species to sediment burial.
This experiment was conducted on the scale of individual plants cultivated in pots. However, within a plant community, interactions between species can modify their response (Owen *et al.*, 2004). Moreover, clonality phenomena can also be decisive in the resistance of plants to burial (Maun, 1998). Indeed, clonal species can either

colonize new areas through vegetative reproduction or they can feed the buried parts until their emergence above the sediments through clonal integration (Yu *et al.*, 2002).

Conclusions

The results of this study showed differences in resistance to burial between species in the first stages of plant colonization after restoration. Within a context of land restoration of marly ravines, one of the major objectives is to be able to predict whether vegetation establishing spontaneously after human intervention will resist the environmental conditions, here burial by sediment. Sugar and starch contents of plant stems at the time of disturbance could explain the differences in the responses observed.

Acknowledgements

The authors wish to thank Sophie Labonne and Damien Lemoine for their technical assistance during data collection, measurements, and data analysis.

References pt 10

Baldwin KA, Maun MA (1983). Microenvironment of Lake Huron sand dunes. Canadian Journal of Botany,61: 241-255.

Brown JF (1997). Effects of experimental burial on survival, growth and resource allocation of three species of dune plants. Journal of Ecology,85: 151-158.

Dech JP, Maun MA (2006). Adventitious root production and plastic resource allocation to biomass determine burial tolerance in woody plants from central Canadian coastal dunes. Annals of Botany,98: 1095-1105.

Disraeli DJ (1984). The effect of sand deposits on the growth and morphology of Ammophila breviligulata. Journal of Ecology,72: 145-154.

Kent M, Owen NM, Dale P, Newnham RM, Giles TM (2001). Studies of vegetation burial: a focus for biogeography and biogeomorphology? Progress in Physical Geography,25: 455-482.

Langlois E, Bonis A, Bouzillé JB (2001). The response of Puccinellia maritima to burial: a key to understanding its role in salt-marsh dynamics? Journal of Vegetation Science,12: 289-297.

Maun MA (1998). Adaptations of plants to burial in coastal sans dunes. Canadian Journal of Botany,76: 713-738.

Maun MA, Elberling H, D'Ulisse A (1996). The effects of burial by sand on survival and growth of Pitcher's thistle (Cirsium pitcheri) along Lake Huron. Journal of Coastal Conservation,2: 3-12.

Owen NW, Kent M, Dale PM (2004). Plant species and community responses to sand burial on the machair of the Outer Hebrides, Scotland. Journal of Vegetation Science,15: 669-678.

Perumal VJ, Maun MA (2006). Ecophysiological response of dune species to experimental burial under field and control conditions. Plant Ecology,184: 89-104.

Rey F (2005). Efficacité des ouvrages de génie biologique pour le piégeage des sédiments dans des ravines incisées dans des marnes (Alpes du Sud, France). Géomorphologie: relief, processus, environnement, 1 : 21-30.

Shi L, Zhang ZJ, Zhang CY, Zhang JZ (2004). Effects of burial on survival, growth, gas exchange and biomass allocation of Ulmus pumila seedlings in the Hunshandak sandland, China. Annals of Botany,94: 553-560.

Yu F, Chen Y, Dong M (2001). Clonal integration enhances survival and performance of Potentilla anserina, suffering from partial sand burial on Ordos plateau, China. Evolutionary Ecology,15: 303-318.

Zhang J, Maun MA (1992). Effects of burial in sand on the growth and reproduction of Cakile edentula. Ecography,15: 296-302.