Oecologia (2013) 171:601–603
DOI 10.1007/s00442-013-2621-z

EDITORIAL

Zooming in on plant interactions

Carlos L. Ballaré · Katherine L. Gross · Russell K. Monson

Received: 5 February 2013 / Accepted: 5 February 2013 / Published online: 1 March 2013

Keywords Defense · Herbivory · Mutualism · Microbes

Few areas in plant ecology have experienced the fantastic growth demonstrated by the field of plant interactions with other organisms in recent years. Research in this field has taken rapid advantage of the tools provided by model organisms (particularly *Arabidopsis thaliana*), genetic and genomic approaches, and the improvement of analytical techniques to move the discipline to a completely different level from where it was 10 years ago. Major breakthroughs have been made in the understanding of the mechanisms of plant defenses against herbivores and pathogens, plant interactions with other plants and beneficial microorganisms, such as mycorrhizae and bacterial symbionts, and the modulation of these interactions by biotic and environmental factors.

In recognition of the increased growth of this research focus, *Oecologia* is launching a new editorial office to handle submissions focusing on the functioning of plants in their biotic context. This section of *Oecologia*, led by Prof. Carlos Ballaré, will feature papers dealing with fundamental aspects of the mechanisms of plant interactions with other organisms, including beneficial and pathogenic microorganisms, insects and other animals.

A few examples of the vigorous growth of research areas from which our new editorial section will seek to receive contributions are highlighted below.

Plants interact with their enemies The mechanisms that mediate the activation of plant defenses against herbivorous organisms and pathogens are beginning to be understood at the molecular level, with major breakthroughs involving the identification of the receptors for the two central hormones controlling induced defenses, namely jasmonate (Chini et al. 2007; Thines et al. 2007) and salicylate (Fu et al. 2012). In addition, the interactions between these defense-related hormones and those coordinating other plant functions, such as growth and development, are becoming increasingly well understood (Pieterse et al. 2012). This improved understanding of defense signaling in the context of plant development is shedding light on the mechanisms that regulate plant phenotypic plasticity in the face of tradeoffs that have attracted significant attention among ecologists and evolutionary biologists, such as the growth vs. defense resource allocation “dilemma” (Ballaré 2011). At the same time, knowledge about the types of cues that plants use to obtain information about their biotic context, including light, volatile compounds and soil semiochemicals, has increased significantly (Heil 2010), allowing us a much deeper understanding of biotic interactions in plant communities than the one we had a decade ago.

Plants interact with beneficial microorganisms The role of mycorrhizal fungi in plant nutrient acquisition (Van Der

Communicated by Russell Monson.

C. L. Ballaré (✉)
IFEVA, Consejo Nacional de Investigaciones Científicas y Técnicas, Universidad de Buenos Aires, Ave. San Martín 4453, C1417DSE Buenos Aires, Argentina
e-mail: ballare@ifeva.edu.ar

K. L. Gross
W.K. Kellogg Biological Station, Michigan State University, 3700 East Gull Lake Drive, Hickory Corners, MI 49060, USA
e-mail: kgross@kbs.msu.edu

R. K. Monson
School of Natural Resources and the Environment and Laboratory for Tree Ring Research, University of Arizona, Tucson, AZ 85721, USA
e-mail: russmonson@email.arizona.edu

Heijden et al. 2008) and defense (Hartley and Gange 2009; Herre et al. 2007; Pozo and Azcón-Aguilar 2007) has been documented with an unprecedented level of detail, and the sequencing of the genome of the ectomycorrhizal basidiomycete *Laccaria bicolor* (Martin et al. 2008) represented a milestone in our quest to understand the mechanisms of rhizosphere colonization and symbiosis. Communication chemicals identified in root exudates and known to be involved in plant interactions with parasitic weeds and symbiotic arbuscular mycorrhizal fungi (strigolactones) were recently shown to play a central role in regulating above-ground plant architecture, and were thereby moved to the rank of plant hormones (Gomez-Roldan et al. 2008; Umehara et al. 2008). Thus, work on underground communication between plants and neighboring organisms has contributed key elements to our understanding of basic aspects of plant biology. Studies of plant communication with N-fixing symbionts (Oldroyd and Downie 2008), its regulation by environmental cues (Suzuki et al. 2011), and the consequences for plant defense (Ballhorn et al. 2012), have also produced major advances in our understanding of this important interaction.

Novel approaches to classic questions Innovative approaches using molecular and genetic tools have allowed manipulation of gene expression in non-model organisms, thereby testing the functional significance of putative defense and communication mechanisms in ecologically meaningful scenarios (Gase and Baldwin 2012). Studies on plant responses to biotic stressors have also begun to combine experiments with phyologenetic approaches, allowing ecologists to formulate hypotheses about the evolution of resistance and tolerance traits (Agrawal and Fishbein 2008) and interactions between different mechanisms of plant defense (Thaler et al. 2012). In the same vein, genome-wide expression profiling is beginning to be used to address classic ecological questions (e.g., plant responses to generalist vs. specialists herbivores) (Bidart-Bouzat and Kliebenstein 2011), genome-wide association mapping is being applied to explore natural variation in defense phenotypes (Kloth et al. 2012), and combinations of experimental and genetic approaches in model organisms have recently led to the discovery of epigenetic controls on the expression of the defense phenotype (Luna et al. 2012; Rasmann et al. 2012; Slaughter et al. 2012). These advances have important implications for our understanding of the ecology and evolution of plant interactions with their enemies. A common denominator in the examples above is the use of research approaches that go beyond the boundaries of traditional specialization, allowing synergistic interactions among scientists working in a broad cross-section of disciplines, including molecular biology, ecophysiology, community ecology, and ecosystem science and sustainable agriculture.

Biotic interactions and global change The interactive effects of global change and biotic interactions have also received considerable attention in recent years. Important questions that are beginning to be addressed include, for example, how plant interactions with consumer and beneficial organisms are affected by changes in temperature (Jamieson et al. 2012), elevated atmospheric CO_2 (DeLucia et al. 2012), and other atmospheric pollutants (Blande et al. 2010), and how introduction of novel biotic players may affect ecosystem stability and function (Callaway et al. 2008). Also, from the perspective of agricultural production, emerging questions include how agricultural intensification is disrupting plant defenses (Ballaré et al. 2012), and how we can use our improved understanding of defense mechanisms to "add back" important defense traits that were lost during the process of crop domestication to cultivated plant species (Bleeker et al. 2012).

This new editorial office will interact closely with those focusing on Plant Population and Community Ecology (Prof. Katherine Gross) and Plant Ecophysiology and Ecosystem Processes (Prof. Russell Monson). Papers addressing fundamental questions in the areas of chemical ecology, sensory ecology, and molecular ecology will be particularly welcome. New handling editors, with outstanding credentials and a broad perspective of the discipline, have been appointed to handle manuscripts for this new subject category.

References

Agrawal AA, Fishbein M (2008) Phylogenetic escalation and decline of plant defense strategies. Proc Natl Acad Sci USA 105: 10057–10060

Ballaré CL (2011) Jasmonate-induced defenses: a tale of intelligence, collaborators and rascals. Trends Plant Sci 16:249–257

Ballaré CL, Mazza CA, Austin AT, Pierik R (2012) Canopy light and plant health. Plant Physiol 160:145–155

Ballhorn D, Kautz S, Schädler M (2012) Induced plant defense via volatile production is dependent on rhizobial symbiosis. Oecologia:1–14

Bidart-Bouzat MG, Kliebenstein D (2011) An ecological genomic approach challenging the paradigm of differential plant responses to specialist versus generalist insect herbivores. Oecologia 167: 677–689

Blande JD, Holopainen JK, Li T (2010) Air pollution impedes plant-to-plant communication by volatiles. Ecol Lett 13:1172–1181

Bleeker PM et al (2012) Improved herbivore resistance in cultivated tomato with the sesquiterpene biosynthetic pathway from a wild relative. Proc Natl Acad Sci USA 109:20124–20129

Callaway RM et al (2008) Novel weapons: invasive plant suppresses fungal mutualists in America but not in its native Europe. Ecology 89:1043–1055

Chini A et al (2007) The JAZ family of repressors is the missing link in jasmonate signalling. Nature 448:666–671

DeLucia EH, Nabity PD, Zavala JA, Berenbaum MR (2012) Climate change: resetting plant–insect interactions. Plant Physiol 160:1677–1685

Fu ZQ et al (2012) NPR3 and NPR4 are receptors for the immune signal salicylic acid in plants. Nature 486:228–232

Gase K, Baldwin IT (2012) Transformational tools for next-generation plant ecology: manipulation of gene expression for the functional analysis of genes. Plant Ecol Divers 5:485–490

Gomez-Roldan V, et al (2008) Strigolactone inhibition of shoot branching. Nature 455:189–194

Hartley SE, Gange AC (2009) Impacts of plant symbiotic fungi on insect herbivores: mutualism in a multitrophic context. Annu Rev Entomol 54:323–342

Heil M (2010) Plastic defence expression in plants. Evol Ecol 24:555–569

Herre EA, et al (2007) Ecological implications of anti-pathogen effects of tropical fungal endophytes and mycorrhizae. Ecology 88:550–558

Jamieson MA, Trowbridge AM, Raffa KF, Lindroth RL (2012) Consequences of climate warming and altered precipitation patterns for plant-insect and multitrophic interactions. Plant Physiol 160:1719–1727

Kloth KJ, Thoen MPM, Bouwmeester HJ, Jongsma MA, Dicke M (2012) Association mapping of plant resistance to insects. Trends Plant Sci 17:311–319

Luna E, Bruce TJA, Roberts MR, Flors V, Ton J (2012) Next-generation systemic acquired resistance. Plant Physiol 158:844–853

Martin F, et al (2008) The genome of *Laccaria bicolor* provides insights into mycorrhizal symbiosis. Nature 452:88–92

Oldroyd GED, Downie JA (2008) Coordinating nodule morphogenesis with rhizobial infection in legumes. Annu Rev Plant Biol 59:519–546

Pieterse CMJ, van der Does D, Zamioudis C, Leon-Reyes A, van Wees SCM (2012) Hormonal modulation of plant immunity. Annu Rev Cell Dev Biol 28:489–521

Pozo MJ, Azcón-Aguilar C (2007) Unraveling mycorrhiza-induced resistance. Curr Opin Plant Biol 10:393–398

Rasmann S, et al (2012) Herbivory in the previous generation primes plants for enhanced insect resistance. Plant Physiol 158:854–863

Slaughter A, Daniel X, Flors V, Luna E, Hohn B, Mauch-Mani B (2012) Descendants of primed *Arabidopsis* plants exhibit resistance to biotic stress. Plant Physiol 158:835–843

Suzuki A et al (2011) *Lotus japonicus* nodulation is photomorphogenetically controlled by sensing the red/far red (R/FR) ratio through jasmonic acid (JA) signaling. Proc Natl Acad Sci USA 108:16837–16842

Thaler JS, Humphrey PT, Whiteman NK (2012) Evolution of jasmonate and salicylate signal crosstalk. Trends Plant Sci 17:260–270

Thines B et al (2007) JAZ repressor proteins are targets of the SCF(COI1) complex during jasmonate signalling. Nature 448:661–665

Umehara M et al (2008) Inhibition of shoot branching by new terpenoid plant hormones. Nature 455:195–200

Van Der Heijden MGA, Bardgett RD, Van Straalen NM (2008) The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. Ecol Lett 11:296–310