SEED ECOLOGY V

seeds in the web of life

BOOK OF ABSTRACTS

Caeté, Brazil
21-25 August 2016


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Seed Ecology V Conference

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Caeté, Brazil
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Caeté 2016

Preface

Dear delegates,

The fifth edition of the Seed Ecology Meeting (International Society for Seed Science Meeting on Seeds and the Environment) will be held from 21 to 25 August 2016 in Caeté, Brazil. We are delighted and honored with the opportunity to host the event for the first time in South America. We warmly welcome you and hope we have a wonderful week. People from Minas Gerais are famous for their hospitality and we are pleased to host all of you. The Seed Ecology V will be a unique opportunity for seed ecologists to present their findings, exchange ideas, create partnerships, meet friends and last but not least, have a lot of fun. We hope that you enjoy the Seed Ecology V, and that you are able to fully take advantage of the opportunities that this meeting provides you with. Enjoy our atmosphere, our beautiful landscape, the field trips and the company of friends who are coming from all over the world for this special week. We do want Seed Ecology V to be a great meeting and an unforgettable experience.

Welcome to Brazil.

Fernando Silveira and Queila Garcia
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Message from the ISSS

Dear delegates of Seed Ecology V,

On behalf of the President of the International Society for Seed Science, Prof Françoise Corbineau, as well as the Executive Committee, it is my great pleasure to welcome you all to the Fifth ISSS Meeting on Seed Ecology in this wonderful historic region of Brazil. The meeting brings together scientists concerned with the behaviour of seeds in the field. The seed is an important element of the plant's life cycle, and is very sensitive to the environment. That the climate is changing on a global scale is no longer an opinion but a downright fact. It is therefore our great concern and duty to make our knowledge available to contribute to models that predict climate-induced changes of plant life on our planet. With this knowledge we may be able to take timely measures to adapt agriculture and food security. Therefore, I heartily agree with the theme of this meeting: "Seeds in the Web of Life". Let's take this opportunity to interact and collaborate among seed ecologists and seed scientists from other disciplines to be prepared for the future. At the same time, enjoy the beautiful nature surrounding the congress venue!

Henk W.M. Hilhorst
President-Elect of ISSS

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Programme

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Oral Presentations

ORAL SESSION 1 | Monday . 9h30 - 12h

Keynote Presentation: Seed bank dynamics: what we know now and some future challenges

Prof. Peter Poschlod
University of Regensburg, Germany
(peter.poschlod@ur.de)

Aspects on soil seed bank persistence are studied in many respects – first, how to classify seed bank persistence, second on environmental parameters affecting seed bank persistence, third on soil seed longevity of rare and threatened species of the central European flora and finally how a persistent seedbank may tell us something about the land use history and how it may be used for the restoration of certain plant communities.

Do dormancy-breaking temperature thresholds change with aging of seeds in the soil seed bank?

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In fire-prone ecosystems, germination studies of physically dormant seeds are usually done by focusing on the role of fire-related heat as a dormancy-breaking cue, but using only fresh seeds. In natural environments, persistent seed banks play a significant role in post-fire recruitment via seed germination. Seeds held within soil seed banks are likely to experience seasonal temperature fluctuations, physiological changes and physical deterioration when compared to fresh seeds, which could change the way seeds respond to dormancy-breaking cues over time. Previous research has also shown that for some species, the dormancy of fresh seeds is not broken by heat treatments representing soil temperatures that typically occur during fire, leading to the assumption that very high temperatures (> 80°C) are needed to break dormancy of fresh seeds. Therefore, we suggested that a sequence of processes, and/or time, may change the dormancy-breaking requirements of physically dormant seeds. We tested the germination of seeds, both buried in the field and under laboratory storage conditions, for four physically dormant native Fabaceae species from fire-prone south-eastern Australia; *Acacia linifolia*, *Bossiaea heterophylla*, *Viminaria juncea* and *Aotus ericoides*. Replicate samples were retrieved after 6 and 18 months to test germination responses after heating at temperatures

ranging from 40 to 100 °C. Field burial caused an increase in germination response over time, effectively reducing the dormancy-breaking temperature thresholds required for fresh seeds. Germination response of laboratory stored seeds indicated that storage time alone was the driver of change for some species, but that other contributing factors drove changes under field conditions.

Soil seed bank dynamics along a degradation gradient in Songnen saline-alkaline grassland, northeastern China

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The stage of vegetation succession is an important factor affecting the characteristics of soil seed banks. In the Songnen saline-alkaline grassland, Northeastern China, the original dominant grass was *Leymus chinensis* but the disturbed landscape now comprises secondary succession communities of *L. chinensis*, *Puccinellia chinampoensis*, *Chloris virgata*, and *Suaeda salsa*, and includes largely bare patches. Seasonal changes of the soil seed bank, seed production and dispersal dynamics along degradation successional communities were investigated. Along the degradation successional gradients, seed density and species richness in soil seed banks differed greatly. Also, significant seasonal changes were observed within each plant community, except for the climax community of *L. chinensis* where the soil seed bank showed the highest species richness of 7-16, but a low Sørensen similarity of 0.22-0.37. In the communities of *P. chinampoensis*, *C. virgata*, *S. salsa*, the highest seed density of the soil seed bank were 62166, 38556 and 31932 seeds/m2, respectively. In bare patches, there were a number of seeds in the soil seed bank and some seedlings also appeared in the aboveground vegetation demonstrating the existence of persistent soil seed bank in these sites. The *L. chinensis* seeds appeared only in the *L. chinensis* community proving that the soil seed bank was not likely to be the driving factor for the restoration of *L. chinensis* grassland. Acknowledgements: this work was financed by the National Natural Science Foundation (41371260, 41271522), the National Basic Research Program (2015CB150802), the Program of Science and Technology development of Jilin province (20140204050SF).

Clima change and the soil seed bank of secondary forests in the region of Manaus – Simulation of a temperature increase

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Climate change is a threat, especially to the Amazon rainforest, as the greatest warming-up is expected in this region, with an estimated temperature increase from 4 to 8 °C until the years 2071 to 2100. Deforestation will even worsen the situation. With the depletion of mature forests, the soil seed bank is the major source for the establishment of a secondary forest with pioneer species. This study

simulated different temperature regimes on the germination success of seeds from the soil of secondary forests in the region of Manaus. Soil samples, with 3 cm depth, were collected in six secondary forests with different histories. The samples were homogenized and germination and seedling development were assessed during four months, maintaining the soil in the dark or with a 12h photoperiod. The following six temperature conditions were tested with 30 subsamples each; (i) constant temperature of 25 °C and 12:12h alternating temperatures of 20:30 °C, considered as controls (ii) simulation of a temperature rise of 5 °C with 30 °C constant and 25:35 °C alternating temperatures (iii) simulation of a 10 °C temperature rise with 35°C constant and 30:40 °C alternating temperatures. As expected for pioneer species, germination was higher in the light and with alternating temperatures than with constant temperatures. The highest seedling density occurred under the control (20:30 °C) and with an increase of 5 °C (25:35 °C); at 30:40 °C, germination was drastically reduced. None of the alternating temperatures could overcome the necessity of light for germination. With the increase in temperature, mortality after germination increased. In general, woody plants were more sensitive to temperature rise than herbs. However, some species-specific sensitivities were detectable. The results indicate that regeneration of the vegetation by the soil seed bank may be significantly affected by global warming-up.

Seed banks reflect the past and foretell the future: The case of grassland patches within an urban matrix in South Africa

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Grasslands are threatened in South Africa, with many patches being highly transformed, whilst others occur within an urban/suburban matrix. Fragmented patches within the eThekwini Municipal Area, in South Africa, represent a conservation priority but are often inappropriately managed based on the fact that their disturbance status and natural regenerative potential are poorly understood. This motivated the present study which compared floristic composition and structure between seed bank and standing vegetation in eight subtropical grassland patches exposed to varying disturbance regimes (viz., undisturbed, intermediate and disturbed). Floristic surveys conducted at each site, involved year round quadrat sampling with 80% sampling effort. Additionally, transect sampling was performed monthly for a year at each site. The seed bank composition of each site was determined by removing germinable soil seed bank samples after the two main flowering events at each site and recording the resulting germinants. The seed bank flora represented only ±10% of the standing vegetation species in all three disturbance categories, with the Sørenson similarity index ranging from 12 – 18% across disturbance categories, as opposed to the 40 – 50% reported for grasslands in southern African and elsewhere. The effects of disturbance were evident across intermediate and disturbed sites, with the latter containing fewer species in the standing and seed bank vegetation than the intermediate and undisturbed sites.

Alien taxa that occurred frequently in the standing and seed bank vegetation at disturbed sites also occurred in the seed banks of intermediate and undisturbed sites. This suggests that the undisturbed sites may be prone to alien plant invasion in the event of disturbance. Two of the three disturbed sites clustered together, while the remaining sites grouped together in a UPGMA cluster analysis; these results may be based on differences in site history and burning regime. Seed bank health and hence, regenerative potential may be poor at many of these sites, particularly those that have been disturbed, necessitating species reintroduction and in some cases habitat restoration.

Contributions of aerial and soil seed banks to maintaining populations of a dune annual in an unpredictable dune ecosystem

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Forming aerial and soil seed banks in a species at the same time is a mechanism for population maintenance in unpredictable environments. Eolian activity greatly affects growth and regeneration of plants in the sand dune system. However, we know little about the difference in the contributions of these two seed banks to population dynamics in sand dunes. In this study, seed release, germination, seedling emergence and survival of a desert annual, *Agriophyllum squarrosum*, inhabiting Ordos Sandland in China, were investigated to explore the contributions of the two seed banks to population maintenance. We found: (1) the size of the aerial seed bank was higher than that of soil seed bank throughout the growing season; (2) seed release was positively related with wind velocity; (3) compared with the soil seed bank, seed germination from the aerial seed bank was lower in low temperature (5/15 °C) but higher in light; (4) seedling emergence from the soil seed bank was earlier than that from the aerial seed bank; (5) early-emerged (15 April – 15 May) seedlings died due to frost, but seedlings that emerged during the following months survived to successfully reproduce. Our study suggests that a bet-hedging strategy for the two seed banks enable *A. squarrosum* populations to successfully cope with the unpredictable desert environment. Acknowledgements: National Natural Science Foundation of China (31370705).

ORAL SESSION 2 | Monday . 14h - 17h30

Keynote Presentation: Evolutionary aspects of dormancy at the whole-seed/embryo level: many unanswered questions

Prof. Carol Baskin
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Beginning with Nikolaeva's seed dormancy classification system in the 1960's, our understanding of the evolution of seed dormancy has increased greatly; however, many unanswered questions remain. My talk will focus on some of the questions that need to be answered to fully understand the evolutionary relationships of the kinds of seed dormancy. Although the original hierarchical seed dormancy classification system was recently expanded, it is still incomplete, lacking, for example, how seed dormancy of palms, mycoheterotrophs and holoparasites with undifferentiated embryos and some marine angiosperms fits into the system. How many additions need to be made to the list of families with embryos that grow (inside the seed) before germination is complete? This is an especially important question for monocots and in particular those with a capitate embryo. *Amborella*, the most basal extant angiosperm, has a rudimentary embryo, but such an embryo is not known in seeds of extant or fossil gymnosperms. What is the origin of the rudimentary embryo? Did some yet-to-be-discovered ancient gymnosperm have a rudimentary embryo, or is this an "invention" of the angiosperms? Physiological dormancy (PD) occurs in all 13 kinds of embryos. Thus, did PD evolve in the basal kind of embryo? What is the basal kind of embryo – rudimentary or linear underdeveloped? Why is there more diversity in embryo morphology in angiosperms than in gymnosperms? Is Martin's 70-year-old family tree of seed phylogeny correct? Finally, when did PD evolve, and why is it the most common kind of dormancy on earth?

Fire cues trigger germination and stimulate seedling growth in grass species from Brazilian savannas

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Although fire cues (high temperatures and smoke) are known to influence seed germination in several species across fire-prone environments, their effect on seed germination of Brazilian savanna (Cerrado) species is poorly understood. We exposed grass seeds of eight species from Cerrado to heat shock (80°C and 110°C for

5 min) and/or smoke water, and then set them to germinate in light or dark, at either summer (28ºC/18ºC) or winter (27ºC/14ºC) temperature regimes in an incubator. In addition, we evaluated the effects of smoke water on seedling root and shoot growth for four of the species. Smoke interacted with the dark treatment to increase germination from 28% (control) to 93% in *Aristida recurvata*, and also increased seed germination in *Aristida riparia*. Smoke had no effect on germination of either of these species in the light. Heat shock alone also promoted seed germination in *A. recurvata*. For *Digitaria lehmanniana*, smoke interacted with heat shock to improve germination from 5% to 16%. In contrast, the fire cue treatments did not have any effect on the seed germination of the remaining five species. Smoke water stimulated root growth for *A. riparia*, *A. recurvata* and *Ctenium cirrhosum* but had no effect on their shoot growth. *Aristida* species have an active awn system which facilitates seed burial into the soil. The strong promotive effect of smoke on *Aristida* germination in dark conditions suggests that these species are fire adapted, with a germination flush and seedling growth both stimulated by fire. The species that showed no response to fire cues may either have adapted via alternative strategies or require different concentrations of smoke or levels of heat. This study is among the first to show that smoke can promote seed germination and positively affect seedling growth for species from Brazilian savannas.

Do fungi release the mechanical dormancy conferred by the seed coverings of *Lepidium didymum*?

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Millennia of co-evolution has made mutualistic relationships between plants and fungi common place in nature. Nutrient exchange, contributions to defence against pathogens and herbivores are just some of the ways in which these relationships are typified. We present a novel example of how plants have evolved alongside with the rich fungal environment that is soil. We present evidence of an interaction between soil fungi and the fruits of *Lepidium didymum* (Brassicaceae). We demonstrate fungal-mediated erosion of the pericarp tissues in a process guided by plant tissue architecture. The *L. didymum* pericarp acts as a mechanical barrier to delay germination, but it does not restrict water uptake or gas exchange. We discovered that the lignified pericarp is colonised by soil fungi, which play a key role in germination timing. Puncture-force measurements demonstrate that the pericarp is selectively weakened by the fungi at the micropylar end to allow penetration of the radicle. We identified a specific anatomical region of less lignified cells within the endocarp, representing a preformed breaking zone which is degraded by fungal hyphae. As a consequence, the fungal colonisation of fruits leads to a much faster onset and higher maximum germination as it effectively breaks this pericarp-imposed dormancy.

Little effect of daily temperature fluctuation on physical dormancy breaking in legume species from *Cerrado* and forest

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In species with physical dormancy (PY), differences of daily fluctuations in temperature have been argued to disrupt seed coat structures, thus allowing imbibition. We aimed to evaluate the role of temperature fluctuation in breaking PY in 18 legumes from *Cerrado* and forest. Temperature fluctuation was applied in shrubs from open savannas (n=9), and trees from savanna woodlands (n=3), and forest (n=6) under laboratory conditions during 90 days. Experiments simulated a range of temperatures recorded in *Cerrado* open sites at Central Brazil, varying from 18 to 55°C. Four independent chambers were used as replicates, with 25 seeds per replicate (except for *Erythrina speciosa*, *Peltophorum dubium* and *Mimosa oligosperma*, with 10 seed/species), and a control treatment, kept in room temperature. Seeds were then set to germinate under optimal conditions and germination was scored for one month, with viability tests of non-germinated seeds performed by the end of the trials. All study species showed no significant increase in germination after temperature fluctuations. *Peltophorum dubium* (forest) showed a decrease in viability, and six other species showed lower germination when compared to Control, irrespectively of being from *Cerrado* or forest. One of those six species, *Copaifera langsdorffii*, which occurs in both environments, had both germination and viability reduced in treatments of temperature fluctuation. The other five reduced only germination, keeping the same viability of the control. Thus, daily temperature fluctuation may inhibit germination in comparison to room temperature (control). Fluctuating temperatures had no effect in germination or viability in *Senegalia polyphylla*, a species from both savanna woodlands and forest with permeable seed coat. Overall, most of the tested species kept viability in comparison to the control after the 90 days of experiment, and thus, daily temperature fluctuation alone is not the factor breaking the physical dormancy of these species.

Warmer maternal environment during seed production reduces seedling performance in a physically dormant species

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The dynamics surrounding seeds are key to population persistence in fire-prone ecosystems. To fully understand how populations may persist, and in particular to predict the impacts of changing climatic conditions, we need to develop a clearer picture of the ecological consequences of variation in germination and seedling recruitment. In this study, I investigated the effects of increased maternal environment temperature on subsequent seed offspring and seedling vigour. Ten *Bossiaea heterophylla* (Fabaceae) plants from a single population were grown from

seed to maturity in a common garden over a two year period. Upon the onset of flowering, the group was divided between control conditions or a warmed greenhouse approximating a 4°C mean temperature increase and maintained until seed dehiscence. Germinated seeds from each maternal environment group were then sown and seedling survival and growth measured for 3 weeks, followed by a drought stress treatment. Seed weight and seedling performance were compared between the two groups. While no differences were found for seed weight, seedling performance differed considerably. Seeds developed under warmed conditions producing slower growing seedlings with less resilience to drought, reflecting similar findings of seed vigour loss reported due to maternal environment warming for agricultural species. These results show that the combination of warmer temperatures during seed development and loss of resilience by seedlings to dry conditions combine to limit potential recruitment success under future conditions.

The role of pericarp on germination of heterocarpic *Bidens*

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Diaspore heteromorphism, or heterocarpy, is a recurrent reproductive strategy in Asteraceae species. The dicarpy is frequntly found among the *Bidens* species: one type is fewer in number, less dispersive and more germination delayed than the other. To understand how the germination delay proceeds, we focused on the pericarp anatomy and chemical composition (HPLC/MS) of eight *Bidens* species. We categorize the heterocarpic species by their morpho-physiological features in: (1) dicarpic [*B. alba*(L.) DC.; *B. aristosa* (Michx.) Britton; *B. bipinnata* L.; *B. pilosa* L.; *B. subalternans* DC.; *B. frondosa* L.] and (2) polycarpic (*B. gardneri* Baker), also one monocarpic species (*Bidens* sp.). The cypsela cross sections displayed some structural difference among the types, but it is not regarded as a germination barrier effect. The mesocarp, the developed layer, presented similar layer numbers, cell compositions and cell wall structures. On the other hand, the chemical composition of the pericarp types varied for *B. alba*, *B. aristosa*, *B. bipinnata*, *B. pilosa* and *B. subalternans*, the dicarpic species. To them the amine type compounds (sphingamine) were identified as relevant secondary compounds for the central cypselae, whereas flavonols (quercetin and kaempferol) and esculetin were relevant for the peripheral cypselae were detected. The relation betweeen the seed germination behavior and pericarp composition leads us to assume that there is a chemical inhibitor in the pericarp peripheral cypsela. However the exact compound and the way of action still not clear. To sum, we did not find strong anatomical features acting as physical constraint difference among cypsela types in *Bidens*. But the chemical composition variance indicates that the dicarpic germination difference may occurs via chemical inhibition (CNPq GD proc. 47810/2010-8, CNPq PQ proc. 306498/2012-0, PRP-USP).

Predicting the future germination performace of *Myracrodruon urundeuva* (Fr. All.) using thermal time and hydrotime model approaches

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Thermal time and hydrotime models evaluate seed germination across a range of temperatures and osmotic potentials and can be used to predict the effect of climate on seed germination. In this study, we used these models to quantify the thermal and hydro germination behaviour of *Myracrodruon urundeuva*, an endangered dry forest species, and to predict the effect of projected climate change scenarios on its germination performance and seedling development. Seeds of *M. urundeuva* were collected at different years (2010-2013) from the Brazilian biome *Caatinga* (W 040°07'13" S 8°36'55) characterised by a semi-arid hot climate and with some shallow salinized soils. Seeds were germinated across a range of temperatures (5 to 40 °C) and osmotic potentials (0 to -0.8MPa) created using polyethylene glycol (PEG) and NaCl. After 7 and 14 days from sowing, normal seedlings were accounted. Germination data were applied to thermal time and hydrotime models using repeated Probit analysis. Although air temperature might be higher than 34 °C until 2055 in a high CO_2 emission scenario, this may not inhibit seeds germination, which showed optimum temperature around 35 °C and maximum temperature higher than 40 °C. The minimum osmotic threshold for germination was lower in PEG (< -0.6MPa) than in NaCl (> -0.41 MPa), indicating NaCl toxicity in these seeds. This might compromise seed germination in future climates for the *Caatinga* biome since the annual rainfall is predicted to reduce by 20%, increasing the extent of soil salinization. Seedlings failed to develop at temperatures higher than 35 °C and osmotic potential lower than -0.4MPa (PEG solutions) and -0.36MPa (NaCl solutions). Although *M. urundeuva* seeds are likely to germinate in more pessimistic future scenarios, seedling recruitment might not happen in driest and hottest regions of Brazil, such as *Caatinga*. In those conditions, *M. urundeuva* natural regeneration, biodiversity and distribution throughout Brazil and may be compromised.

Towards a mechanistic understand of fire-driven recruitment in species with physiological dormancy: the role of heat shock, smoke, seasonal temperatures and seed age

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Dormancy and germination requirements determine the timing and magnitude of seedling emergence, with important consequences for seedling survival and growth. Physiological dormancy is the most widespread form of dormancy in flowering plants

yet the seed ecology of species with this dormancy type is poorly understood in fire-prone ecosystems. The role of seasonal temperatures as germination cues in these habitats is often overlooked due to a focus on direct fire cues such as heat shock and smoke, and little is known about the combined effects of multiple fire-related cues and environmental cues as these are seldom assessed in combination. We aimed to improve understanding of the germination requirements of physiologically dormant species in fire-prone floras by investigating germination responses across members of the Rutaceae from south eastern Australia. We quantified the individual and combined effects of heat shock, smoke, and seasonal temperatures on the germination of seven species of *Boronia* using fresh and buried seeds over a 2-year period. Dormancy was high at dispersal but declined significantly in buried seeds. Dormancy loss was unidirectional in some species while others exhibited seasonally-driven dormancy cycling. Germination syndromes were extremely variable but correlated with broad patterns in seed morphology and phylogenetic relationships between species. The rate and magnitude of germination responses were heavily influenced by seasonal temperatures and the duration of burial in the soil seed bank. Both heat shock and smoke promoted germination, and interacted in complex ways that could not be reliably predicted from the effect of application of single cues. We identify mechanisms by which the season of fire occurrence is predicted to significantly impact both the timing and magnitude of seedling emergence in natural populations. This has important implications for current fire management practices, and for population persistence under climate change where the historical fire season is predicted to widen.

Do seeds advance its development with respect to the fruit ripening? Preliminary results

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Many plants attract seed dispersers and indicate the presence of ripe fleshy fruits with coloration changes. If seed maturation is simultaneous with the visual signs for frugivorous, a portion of seeds can be removed before being ready for dispersal. Here we tested the visual signal delay hypothesis, which implies that to achieve a greater reproductive success of the plant, seed development must precede the visual signal of the fruit (to avoid the dispersal of unviable seeds). We evaluated this hypothesis with fruits of 4 tropical species (*Chamaedorea linearis*, *Chamaedorea pinnatifrons*, *Oreopanax* cf. *microcephalus*, *Eugenia victoriana*), evaluating if the development of mature and immature seeds is similar. We tested electrical conductivity on seeds, as an approach to evaluate the germination potential along development. We found that seed conductivity of *C. linearis* and *C. pinnatifrons* decreases with fruit ripening but the conductivity of *C. linearis* showed minor differences between the intermediate and mature stages. The conductivity of *O.* cf. *microcephalus* and *E. victoriana* showed no relationship with fruit ripening and showed similar values for all maturation stages. These results suggests that the seeds may have similar germination probabilities regardless of their state of maturation and therefore have a similar germination potential. These results support the delay hypothesis;

nevertheless, it is necessary to carry out germination and tetrazolium tests to determine if the electrical conductivity is a reliable indicator of the seed's viability of these species.

Identifying key drivers of dormancy in species with hard woody indehiscent endocarps using *Persoonia longifolia* as a representative species.

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Germination of species with hard woody endocarps has often proven difficult with several iconic species from the southern jarrah forests of Western Australia being symptomatic of similar-seeded species elsewhere around the world. Whilst physical seed dormancy has been eliminated for many of these species, the mechanisms involved in dormancy break have yet to be clearly identified. *Persoonia longifolia* is one such species from southern Western Australia, whose reproductive unit includes a hard woody indehiscent endocarp. *Persoonia longifolia* has been studied for well over a decade with only limited germination success until quite recently. Long term germination trials directed by phenology and in situ burial experiments have revealed that both warm and cold stratification are required in order to promote germination. Wet/dry trials showed that the best germination occurred when transient warm and wet conditions were experienced during the generally dry summer months followed by cold and wet conditions in winter prior to germination in early spring. These conditions are reflective of the conditions within the Mediterranean environment in which this species occurs. We suggest that warm stratification acts as a means of weakening the endocarp, and in particularly loosening the lid along the predetermined fracture line and that cold stratification operates at a physiological level within the embryo itself.

ORAL SESSION 3 | Tuesday . 9h - 12h

Keynote Presentation: Importance of seed ecology to restore tropical grasslands

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In ecological restoration, the lack of information regarding the ecology and the biology of the target species hinders numerous restoration actions, especially in tropical ecosystems. In South America or Africa, several degraded areas failed to be restored, sometimes despite a large seed input. Several hypotheses are possible to explain these failures among which a possible germination issue. Successful restoration is often limited by the lack of information on how to reintroduce propagules, as well as the biology and ecology of these propagules; the establishment of target species requires knowledge of their germination behavior. The restoration of some communities depends on the availability of viable seeds and non-dormant seeds; it also depends on suitable condition to germinate: some species germinating only under particular conditions. Through examples in South America and Africa, we will highlight the crucial link between seed ecology and ecological restoration.

Ecological importance of seed coat mucilage in key stages in the life history of *Artemisia sphaerocephala*

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Artemisia sphaerocephala Kraschen. (Asteraceae) is a desert shrub inhabiting moving and semi-stable sand dunes in northern China. Up to 35% of seed dry mass of this species is mucilage. In recent years, we have reported that seed mucilage of *A. sphaerocephala* plays key roles in the adaption of this shrub to the desert environment. In seed germination, the germination percentage of mucilaginous achenes was significantly higher than that of demucilaged achenes in osmotically- and saline-stressful conditions, indicating that mucilage can improve seed germination in adverse environments. During dew deposition in the desert, mucilage helps seeds to absorb more water and to carry water for longer time, thereby aiding DNA repair of achene cells. In seedling establishment, mucilage improves seedling emergence and reducing seedling mortality under drought conditions. In addition, degradation of seed mucilage by soil microflora promotes early seedling growth in barren sand dunes. In seed dispersal, hydrated mucilage reduces seed removal by ants and thus anchors seeds of desert species in the vicinity of mother plants. Therefore, seed mucilage appears to be an important functional trait that provides many ecological benefits in key stages in the life history of desert plants in the desert environment.
Acknowledgements: National Natural Science Foundation of China (31470476).

Linking intraspecific seed mass variability to fitness along an elevational gradient: a test with *Baccharis aliena*

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Given that larger seeds are able to cope with adverse or competitive environments, a larger seed size is usually related to a greater plant fitness. Accordingly, seeds are expected to become larger at higher elevations to overcome the harsher environmental conditions that prevail at higher altitudes. However, plant fitness also depends directly on the number of seeds produced, and variability in both seed size and number should be considered to understand how elevation may modulate plant fitness. Here we addressed how individual seed mass, total seed number per plant and germinability change along an elevation gradient in *Baccharis aliena*, and analysed changes in multiplicative fitness to address how individual seed mass relates to fitness. To do so, we tagged 10 female plants of *B. aliena* in populations located at 900, 1200, 1600 and 2000 m asl along the Sierras Grandes hills, Cordoba province, Argentina. At flowering, we registered the complete number of inflorescences produced by each plant. At fruiting, we collected three inflorescences from each focal plant and registered the number of viable seeds/ inflorescence, individual seed mass and germinability. Multiplicative fitness was obtained as: total number of inflorescences per plant*mean number of seeds per inflorescence*average seed germinability. Individual seed mass and germinability showed an U-shape relationship with elevation, and therefore seeds from 900 and 2000 m asl had the largest seeds and highest germination values. Total seed number per plant increased with elevation but multiplicative fitness was similar along the gradient. A seed size-number trade-off showed that *B. aliena* is able to offset for a lower seed number with larger seeds. Overall, our result do not support the hypothesis that harsher enviromental conditions associated with an increasing elevation should increase plant fitness by producing larger seeds in this species.

Recolonisation strategies developed by pioneer plants of New Caledonia through their seeds and implications for restoration of ecological continuum on ultramafic soils

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New Caledonia has the important mission to reconcile its exceptional biodiversity with the rapid development of human activities. One of the most important threats is habitat fragmentation especially due to mining exploration. Over the past 40 years, revegetation has been developed to reduce such impacts but ecological restoration concept capability and concepts have only been developed in the past 15 years. It involves knowledge of ecological succession and the study of seed

of pioneer species appears essential. In this context, a large synthesis on what is already known regarding seed ecology has been carried out into plants species occurring both on the Goro plateau and the Koniambo massif in New Caledonia. A database was constructed containing more than 8000 values on life-traits of all the species. This database presents data dealing with 41 life-traits such as the reproductive type, the adult height, the type of fruit, the size and weight of seeds, the dispersion type, the germination and dormancy types. An analysis of all these data allowed us to highlight two overriding ecological strategies integrating several life traits that allow pioneer plants to withstand and adapt to ultramafic constraints. The first brings together the fruit lignified character, the seed coat thinness, the low weight of the seeds, their wind dispersal, the large size of the embryo and their non dormancy character. The second brings significant thickness of the integument, the heavy weight of the seed, the pulpy fruit character bounds to dispersal by zoochorie, the occurrence of physical and/or physiological dormancy(ies) allowing a great persistence in the soil seed bank. The coexistence of these two strategies, among others, within the New Caledonia "mining maquis" is essential for is sustainability. These results finally also enabled us to propose strategies for the establishment of ecological continuums in these two areas.

Seed size as a determinant of stress tolerance and plant-plant interactions in a semiarid grassland

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It is well known that seed size determines the competitive ability of seedlings, but its effect on facilitative plant-plant interactions is poorly understood. Large-seeded species are better competitors than small-seeded ones, and they also withstand more stress. Many facilitative interactions occur because neighbors ameliorate stress, so large-seeded, stress-tolerant species are likely to depend less on facilitation than small-seeded species that may require amelioration. Using ten semiarid grassland species differing in seed size, we asked (1) Are large-seeded species more tolerant to hydric stress? (2) Do small-seeded species experience stronger competitive and facilitative effects from their neighbors than large-seeded ones? (3) Does stress tolerance determine the relationship between seed size and facilitation? We measured germination, survival and growth in a natural hydric stress gradient. For each performance measure we obtained stress tolerance indices that were summarized through PCA into a single measure T of stress tolerance. In a second field experiment we placed seeds of the ten species in patches differing in the density of four different associated species and measured germination, survival and growth. Through non-linear regressions of these performance measurements on the density of associated species we estimated interaction coefficients β. As expected, T increased with seed size. Also, the variance in β diminished with seed size, indicating that small-seeded species are strongly outcompeted by some neighboring species and intensely facilitated by others, while large-seeded species experience mild interactions. The relationship between T and β was more complex: as expected, in small-seeded species facilitation diminished with T, but in large seeded

plants the relationship was reversed. Our results have important implications for the study of facilitation, community organization, and the tolerance-competition trade-off theory.

Inter-specific variability in germination and early survival of savanna trees in response to environmental variation

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There is a growing concern on the effects of climate and biotic changes on savannas and tropical grasslands. However, the lack of empirical comparative studies on how plant community composition might change under environmental variation constrains predictive models and conservation management in savannas. Here we evaluate how variable is establishment (germination and early seedling survival) of 12 common savanna tree species under different environmental conditions, and how differences in species' seed characteristics contribute to explain such inter-specific variation. A completely crossed field-experiment evaluated the influence of moisture availability (regulated by water addition and sunlight exposition) and grass presence on tree establishment. The effect of grass, light and water supply on germination and on early survival differed among species. Seed characteristics explained part of this variation. Under low moisture conditions, while the probability of establishment increased with a higher seed biomass, nitrogen and potassium seed concentration, it was reduced by a higher phosphorus seed concentration. Tree species responses to environmental variation vary during the early recruitment phases, seed traits being important to explain such variability. Consequently, considering inter-specific variation when studying vegetation dynamics can improve our ability to predict impacts of environment changes on savanna structure.

Comparative germination of conespecific pairs of two contrasting Brazilian savannas

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Savannas cover large areas in the Brazilian territory, but may be represented by two main continuous areas separated by the Amazon rainforest: The *Cerrado* savannas, located in the Central Plateau of Brazil, and the Rio Branco savannas, located in Northern Brazil, in the Roraima State. These savannas have been subjected to distinct conditions of temperature, rainfall, seasonality, soil and fire frequency. For example, Rio Branco savannas usually occur in sandy soils and present higher maximum temperatures and fire frequencies than *Cerrado* savannas, thus suggesting that at soil scale seeds may be subjected to more intense levels of stress than seeds present in the soils of *Cerrado* savannas. Considering these differences, the aim of this study

was to investigate, under laboratory conditions, the effects of desiccation, water deficit, heat shock and high temperatures on the germination percentage of two very common tree species of these savannas (*Bowdichia virgilioides* and *Curatella americana*). Seeds were collected at both sites, from ten adult individuals of each species. We found that, for both species, seeds from populations occurring in the Rio Branco savannas are more tolerant to desiccation, water deficit and heat shock than seeds from populations occurring in *Cerrado* savannas. Furthermore, seeds collected from populations occurring in Roraima germinated in a wider temperature range than those collected in Central Brazil. These results show that seeds from savannas subjected to more stressful conditions present higher tolerance to stress factors, such as extreme temperatures and water deficit. Considering our results, we conclude that the predicted climatic changes might be more harmful to seeds of populations occurring in the Central Plateau savannas than those of populations occurring in Northern savannas, with distinct consequences for dynamics and resilience of tree populations occurring at different sites in the Brazilian territory.

Is germination of alpine species modeled by habitat provenience?

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Alpine environments are characterized by rich and diverse habitats, resulting in many plant species along with their many adaptation mechanisms. Seed germination has shown to play a crucial role in the regeneration and maintenance of such plant communities, though it has been difficult to identify a typical behaviour for "alpine germination". The diverse germination and dormancy responses across alpine species may arise from the vast species diversity and many ecological niches of these environments, resulting in different adaptation strategies to ensure seedling emergence and survival. To this understanding, a habitat-specific approach may help to better understand recruitments patterns across alpine species. To test this, seeds of 53 species from alpine grasslands belonging to Habitat 6230 and 6170 (Natura 2000 classification) were exposed to different temperature treatments in a controlled laboratory (i.e., 15/5ºC and 25/15ºC, 12-h daily photoperiod after 0 and 3 months of cold-wet stratification, or with gibberellic acid). Seed germination varied across all factors considered here (i.e., species, incubation temp., habitat and treatment). In particular, germination increased increasing the incubation temperature and the stratification period, and was higher for the species inhabiting the siliceous habitat. Despite finding no difference in dormancy types, species from the siliceous habitat (6230) showed a lower degree of physiological dormancy, indicating the evolution of regenerative strategies related with this habitat. Furthermore, species-specific behaviours were identified using an objective clustering approach for grouping the species into optimal germination niches. These niches indicate different germination strategies that elicit germination during the entire year, with cold stratification not always being enough of a factor to release dormancy. The different habitat-related patterns for dormancy and germination shown here may have important implications for alpine grassland management and restoration, and for a better understanding of the impact of climate change on regeneration success in this sensitive environment.

Multiple trait analysis of seed germination and life history

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Nitrate has been described to stimulate germination, acting as gap detection mechanism. Canopy gaps also have stronger temperature fluctuations. To understand the interaction between temperature and nitrate in Arabidopsis thaliana, germination responses were characterized using 14 accessions. Observations for plant traits were collected during simultaneous plant growth in a climate chamber to produce seeds. Final germination and germination rate differed widely between the accessions. At higher temperatures nitrate increased final germination but also reduced germination speed. The first component in a PCoA explained 62% of the variance, and was associated with the base temperature. A strong association was observed between high base temperature and nitrate-reduced germination rate at high temperatures but not at the optimum germination temperature. Similarly, accessions with early time-to-flowering showed this nitrate-reduced germination rate at high temperatures, while the germination rate in water at high temperatures was stimulated more strongly for early but not late time-to-flowering accessions. A high base temperature was also associated with early time-to-flowering, a low number of flowering branches, small leaf size and low annual precipitation. Moreover, early time-to-flowering was associated with low fecundity and low sensitivity to osmotic stress of final germination. These data suggest that the effect of nitrate on germination not only interacts with temperature, but is also associated with other life history traits, dependent on the precipitation at the geographical origin of the accession. Nitrate appeared to trigger a higher risk strategy by increasing the final germination at high temperatures, while at the same time reducing this germination risk for the populations with high base temperature and early flowering by reducing the germination rate. To test this hypothesis, germination of Plantago species from a range of environments are studied in the EU-funded NASSTEC project.

ORAL SESSION 4 | Tuesday . 14h - 17h

Keynote Presentation: Adaptation of Seed Germination to Climate, Habitat and life-cycle

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Germination timing is regulated by both seed morphological and seed physiological adaptations varying in function of life cycle strategy, habitat and local climate conditions. The relative importance of morphological and physiological adaptations varies along different taxonomic levels. At the population level, adaptation of germination timing to local climate conditions results in subtle intraspecific variation in germination requirements. Physiological dormancy broken by cold stratification in *Geranium robertianum* is lower in populations growing in regions with mild winters, while seeds of *Daucus carota* in germinate faster in drier regions. At the species level, physiological adaptation of species specific seed germination can be associated with morphological adaptations. Hypotheses concerning the factors driving evolution of germination characteristics can be tested using phylogenetic comparative methods. Apiaceae species with larger relative embryo length at dispersal in general germinate faster, which is highly beneficial in dry habitats and for species with short life-cycles. The Amaranthaceae are known to have some of the fastest germinating seeds, a characteristic that is related to the stressful habitats the species grow in and their life-cycle strategy. The expression of physiological mechanisms cueing germination timing strongly depend on seed morphological traits conserved at the family level, such as an underdeveloped embryo and a water-impermeable seed coat. These morphological traits can be more beneficial in specific habitat conditions resulting in phylogenetic clustering of taxa in these habitats.

Seed germination in cleistogamous species: theoretical considerations and a literature survey of experimental results

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A cleistogamous species consists of individuals that produce both chasmogamous (open, CH) and cleistogamous (permanently closed, CL) flowers, which facilitates a mixed mating system. In contrast to what one might expect, CL (obligately selfed) seeds and the plants derived from them can be more fit than CH (potentially outcrossed) seeds and the plants they give rise to. Our aim was first to review some current thinking on the theoretical aspects of mixed mating and cleistogamy and then to determine, via a literature review, if data on the germination stage of the plant life cycle are in concert with the theory that in cleistogamous species production of CL is advantageous over that of CH. Based on germination (or

seedling emergence) of CH vs. CL seeds in 26 species in 11 families of monocots and eudicots, CL seeds germinated better in 107 and equally well as in 62 of 248 case studies as CH seeds (68.1%). We conclude that our study lends support to the theory that production of CL seeds by cleistogamous species is advantageous over that of CH seeds. Retention of CH by CL species may be due to the need to prevent total selfing (s=1.0) and thus total inbreeding depression (δ), which theory predicts would decrease reproductive success.

The role of climatic stability on the evolution of seed dormancy: a test in *campo rupestre*, a biodiversity hotspot

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Models of costs and benefits of dormancy (D) predict that the evolutionary stable strategy in long-term stable environments is for nondormancy (ND), but this prediction remains to be tested empirically. We reviewed seed traits of the climatically- and geologically-stable, nutrient-impoverished *campo rupestre* grasslands to test the hypothesis that ND is favoured over D in seeds of species in this vegetation. We examined the relative importance of life-history traits and phylogeny in driving D and assessed seed viability at the community level. Germination and viability data were retrieved from 67 publications, and ND/D was determined for 168 species in 25 angiosperm families. We also obtained the percentage of embryoless, viable and dormant seeds for 83 populations. Frequencies of species with D and ND seeds were compared with global databases of dormancy distribution. The majority of *campo rupestre* taxa (62.5%) had ND seeds, and the ND/D ratio is the highest for any vegetation type on Earth. Dormancy was unrelated to other species life-history traits, suggesting that contemporary factors are poor predictors of D. We found significant correlations between dormancy and phylogeny. Dormancy diversity was highly skewed toward the root of the phylogenetic tree, and there was a strong phylogenetic signal in the data, suggesting a major role for phylogeny in determining the evolution of D vs. ND and seed viability. Quantitative analysis of the data also revealed that at least half of the seeds produced by 46% of the surveyed populations were embryoless and/or otherwise nonviable. Our results support the view that long-term climatic and geological stability favour ND. Seed viability data show that *campo rupestre* has a markedly low investment in regeneration from seeds, highlighting the need for specific *in situ* and *ex situ* conservation strategies to avoid loss of biodiversity (Financial support: CAPES and FAPEMIG).

Temperature but not moisture response of germination shows phylogenetic 3 constraints while both interact with seed mass and life span

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Understanding how plant traits interact with climate to determine plant niches is decisive for predicting their reaction to changing climate. While life span and seed size are known to modify the importance of germination timing. Germination traits such as base temperature and base water potential directly translate climatic conditions into germination timing, impacting performance in later life stages. 2. Despite a potentially strong link it is not yet known how base temperature, base water, seed mass, life span and climate are related. 3. We therefore wanted to test the relations of base temperature, base water potential for germination to seed size and life span while controlling for bioclimatic regions, and to quantify evolutionary signal in both germination traits and seed size. 4. Here, we analysed the relations in a worldwide data set on germination traits of temperature and moisture, seed sizes and life spans as well as climate type of 240 seed plants belonging to 49 families. We tested for phylogenetic signal in germination traits and seed size using Pagel's λ. 5. Both germination temperature and moisture are negatively related with seed size. Annual plants show a seed size-base water potential relation and perennials a temperature seed-mass relation. Pagel's λ highlighted the slow evolution of base temperature for germination, comparable to seed mass while base water potential revealed to be labile. Synthesis: In future, base water potential and seed mass should be used jointly when moisture niches of plants are to be predicted. Life span, seed size and base temperature should be taken into account while analysing thermal limits of species distributions.

Altitudinal and climatic associations of seed dormancy and flowering traits evidence adaptation of annual life cycle timing in Arabidopsis thaliana

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The temporal control or timing of the life cycle of annual plants is presumed to provide adaptive strategies to escape harsh environments for survival and reproduction. This is mainly determined by the timing of germination, which is controlled by the level of seed dormancy, and of flowering initiation. However, the environmental factors driving the evolution of plant life cycles remain largely unknown. To address this question we have analysed nine quantitative life history traits, in a native regional collection of 300 wild accessions of *Arabidopsis thaliana*. Seed dormancy and flowering time were negatively correlated, indicating that these

traits have coevolved. In addition, environmental-phenotypic analyses detected strong altitudinal and climatic clines for most life history traits. Overall, accessions showing life cycles with early flowering, small seeds, high seed dormancy and slow germination rate were associated with locations exposed to high temperature, low summer precipitation and high radiation. Furthermore, we analysed the expression level of the positive regulator of seed dormancy DELAY OF GERMINATION 1 (DOG1), finding similar but weaker altitudinal and climatic patterns than seed dormancy. Therefore, DOG1 regulatory mutations are likely to provide a quantitative molecular mechanism for the adaptation of *A. thaliana* life cycle to altitude and climate.

Longing for the dark: ecology and phylogeny of the photoinhibition of seed germination

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Light conditions provide important information about the optimal time and place for seedling establishment. In this context, photoinhibition of seed germination, defined as the partial or complete suppression (or retardation) of germination under white light (daylight) conditions, has been interpreted as a physiological adaptation to avoid germination at or near the soil surface. It is the first time that, based on all available published literature, an all inclusive, fully quantitative analysis is conducted on the photoinhibition of germination in seed plants. Hence, we reviewed the literature for 426 taxa in 28 orders and 69 families and placed our analyses within a phylogenetic comparative framework. Ancestral state reconstructions indicate that photoinhibition mostly evolved in modern clades becoming frequent in monocots, which mostly diversified and invaded open (often dry) seasonal habitats. Interestingly, photoinhibition is associated with specific morphological and ecological plant and seed traits, allowing for adaptive considerations regarding plant life histories and natural environment. Most taxa have dark-coloured seeds, and logistic regressions predict a higher occurrence of photoinhibition in relatively small plants with seeds neither very small nor very large (mostly with mass between 0.1 to 100 mg) that preferably germinate at cool temperatures (~15°C). Overall, we confirm that seed germination photoinhibition is strongly associated with open, disturbed and dry habitats (including coastal sandy ones) but, interestingly, it is also shared by species from humid climatic regions suggesting a degree of phylogenetic inertia, especially within monocots. Moreover, an intriguing implication of this adaptation is the formation of a third seed bank type, apart from the well established, canopy and soil seed banks: the soil-surface seed bank. Based on ancestral reconstructions, we argue that photoinhibition became more frequent mainly in mid-latitude seasonal climates and in coincidence of palaeoclimatic events related to the Neogenic orogenesis, leading to the expansion of open habitats and the establishment of modern deserts.

Predicting patterns of seed germination in Western Australian *Eucalyptus* L'Her. (Myrtaceae) under global warming

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Seed germination is crucial for persistence in species that rely on seeds for post-disturbance regeneration, and is linked to local environmental conditions. Small increases in temperature during the growing season may threaten populations of some species by altering germination timing and success, further impacting on population dynamics, community composition and species' geographic ranges. Climate forecasts for the Mediterranean-climate ecosystem of southern Western Australia predict temperature increases of up to 6.5°C by 2070, coupled with a 5-60% decline in rainfall and an increase in bushfire risk. *Eucalyptus* (Myrtaceae) is the dominant tree flora in the region. It is a genus with high commercial value as well as of great ecological importance with many species cultivated worldwide for timber, oil, biofuels and ornamental purposes. Using a temperature gradient plate, germination temperature thresholds for 22 endemic species were assessed across a range of constant and fluctuating temperatures. The observed data were subsequently modelled against forecasts of warming for the region that incorporated mean monthly minimum and maximum temperatures for each seed source site. Most species attained high germination levels under a broad range of constant and fluctuating temperatures, often wider and higher than those forecast for 2070. The models tended to predict a longer mean time to germination compared to the observed data. Some inland species were predicted to suffer germination declines, but it would appear that the majority of the study species will be able to maintain high germination levels into the future. However, germination cannot proceed without adequate moisture and forecasts for rainfall declines may render seed highly vulnerable to desiccation in the future. Mean temperatures for optimal germination across the study species were not related to latitude of source populations. Understanding species ability to tolerate new temperature regimes is essential for effective conservation management and ecosystem restoration.

Hedging your bets: Understanding the dimorphic diaspore syndrome of *Aethionema arabicum*

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The dispersal of seeds and fruits is an essential step in a plants life cycle. An adaptive mechanism for plants to successfully propagate and survive in harsh environments or unfavourable conditions is the production of heteromorphic dispersal units. The annual *Aethionema arabicum* (Brassicaceae) exhibits fruit and seed (diaspore) dimorphism. It has the ability to produce two very distinctive fruit types (large dehiscent and small indehiscent) on the same infructescence with two very different

seed types (mucilaginous and non-mucilaginous). The aim of the SeedAdapt consortium (www.seedadapt.eu) is to use a comparative approach to understand the dimorphic diaspore syndrome with its distinct adaptations to provide a dormancy bet-hedging strategy. The dimorphism is associated with several distinct anatomical, physiological and biomechanical differences between the two fruit and seed morphs while the fruit ratios (dehiscent/indehiscent) change in response to environmental conditions. We propose that *Ae. arabicum* is an ideal model system to unravel the molecular control of heteromorphism and phenotypic plasticity. Thus enabling investigation into the regulatory basis of fruit, seed, and seedling trait diversity, contributing to a field of major importance in ecology, physiology, seed industry and crop breeding.

ORAL SESSION 5 | Thursday . 9h - 12h

Keynote Presentation: The relative role of birds and ants in seed dispersal and plant regeneration

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Up to ca. 90% and 65% of trees from tropical forests and savannas have birds and mammals as seed dispersers. However, careful investigations that track the fate of seeds are indicating subtle subsequent steps of dispersal (diplochory) after seeds reach the ground. These subsequent interactions may change not only the spatial distribution of seeds, but also the likelihood of recruitment. In this presentation I will show results from study cases investigating in detail the seed dispersal of plants from the Brazilian *Cerrado*, a tropical savanna. Birds are indeed primary seed dispersers from these plants and remove 20% to 50% of plant individual crop sizes from plant canopy. However, many fruits/seeds are dropped beneath the parental plants by birds while feeding. Selective exclusion experiments indicated that fallen diaspores are promptly removed by several species of ants. Ants also collect seeds from bird droppings away from parental plants. For some trees and/or years ants can be even more effective quantitative dispersers than birds. Birds can disperse seeds much farther away than ants, while ants redistribute the seed shadow at short distances to the ant nests. Seedlings are more common and have higher one-year survival near ant nests than in controls away. Although fruits and seeds of most *Cerrado* plants have no trait indicative of seed dispersal by ants (i.e. myrmecochory), ants play a role in the regeneration of the species investigated. Seed dispersal by birds would increase the chances of escape from the mortality-prone zone near the parental plant and colonization of new sites, while ants are more important in short-scale processes such as directed-dispersal to the ant nests.

Effects of the seed density of three species on the seed removal by ants of the genus *Pheidole*

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In ants, seed density affects the formation of organized trails and the individual ant's decision to forage. However, little is known about how the density of seeds of different species in a patch affects the behavior of ants. We analyze how seed density affects removal by ants of the genus *Pheidole* using seeds of three species that differ in the degree of preference by these ants. We developed a mathematical model where the number of seeds removed is the product of the number of ants A foraging in an area times the probability P that an ant removes a seed. The model was parameterized with field data on the number of seeds removed in patches

that differed in the seed density of the three species, either alone or mixed. The probability of trail formation increased with seed density, but the number of seeds required to form trails was smaller for the most preferred seeds. P differed across species and also increased with density, indicating that ants prefer to forage in resource-rich patches. However, P was unaffected by the presence of other species in the patch, suggesting that ants have a search image. Thus, from the viewpoint of any given focal species, the number of seeds removed was only affected by the neighboring, associated species trough changes in A resulting from trail formation. If the density of the focal species is high enough to induce trail formation, the associated species had no effect. However, associated species could induce trails even when the density of the focal species was low, augmenting the removal rate of its seeds. Therefore, the density of a single species has a great effect on the seed removal by ants, but the interaction with seeds of other species also affects removal especially at low or intermediate densities.

Is seed dispersal by avian frugivores a broad-scale determinant of bird-dispersed tree diversity?

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The role of biotic interactions in governing species distributions at broad spatial scales is intensely debated. In this study, we tested the effect of frugivorous bird diversity on bird-dispersed tree diversity across southern Africa to investigate whether seed dispersal mode affects tree diversity patterns. We classified all southern African trees according to their dispersal modes, namely bird-, mammal- and wind-dispersed. Similarly, all birds were classified according to their frugivory preference as obligate frugivores, partial frugivores, opportunistic fruit-eaters and non-fruit-eaters. Species richness maps were generated for each of the above-mentioned tree and bird guilds. Mantel tests were used to test for spatial correlations between bird-dispersed trees and obligate frugivores, partial frugivores, opportunistic fruit-esters and non-fruit-eaters. We expected to find strong correlations between bird-dispersed trees and obligate and partial frugivores as bird-dispersed trees are directly dependent on these frugivores to facilitate their spread. Conversely, we expected weak correlations between bird-dispersed trees and opportunistic and non-fruit-eaters. Similarly, we tested the spatial correlations between non-bird-dispersed trees and all frugivore guilds, expecting to find weak correlations. We mapped the regional hotspots of each frugivore guild and each tree dispersal mode and investigated the spatial congruence patterns of bird and tree species hotspots. We expected higher hotspot overlap for bird-dispersed trees and obligate and partial frugivores than for obligate and partial frugivores and non-bird-dispersed trees. Contrary to expectation, Mantel tests indicated high correlations between all frugivore guilds and all dispersal modes, with frugivores not showing a higher correlation with bird-dispersed trees than the other combinations of frugivore guilds and tree dispersal

guilds. Additionally, there was little spatial overlap between the hotspots of any of the avian feeding guilds and tree dispersal guilds trees. Our findings suggest that the diversity of frugivorous birds has little effect on the diversity patterns of bird-dispersed trees at broad spatial scales.

The wind dispersal of polymorphic plant species *Zygophyllum xanthoxylum* with winged diaspores

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What the differences in dispersal among different morphological diaspores of polymorphic plant species are remains unclear. We used *Zygophyllum xanthoxylum*, a plant species with five types of winged-diaspore including two-winged (disc-like), three-winged (y-like, T-like, and Y-like type), and four-winged type to deterimine the distance of primary dispersal under different height and wind velocity, and the threshold velocity of secondary dispersal of the diaspores under the ground surfaces as brick, sand, loam soil, and gravel in wind tunnel. The disc-like and y-like seeds had a further dispersal distance in the primary dispersal, and a higher threshold velocity in secondary dispersal than T-like, Y-like, and four-winged types did on the same type of ground surface. The wind speed and the height of seed release were two important factors, accounting for 41.1 and 24.8% ($p<0.01$), while wing loading, shape index and settlement-velocity for 9.0% ($P < 0.01$), 1.4% ($P < 0.01$) and 0.9% (not significant) of the total contribution for the primary dispersal distance, respectively. A significant positive correlation between primary dispersal distance and threshold velocity of secondary dispersal occurred in brick and sand. However, there was no significant correlation between primary and secondary dispersal in loam soil and gravel. There was a trade-off, unrelated with the roughness of ground surface, between the primary and the secondary dispersal when the value of wind speed multiplied by the height of seed release was less than 4.8 $m^2 s^{-1}$ in primary dispersal. Our results indicate that (1) the wind speed has the biggest influence on primary dispersal, (2) different ground surface characteristics result in different relationships between the threshold of wind velocity of secondary dispersal and diaspore traits, and (3) the trade-off between the primary and the secondary dispersal can only occur under some specific circumstances.

Seed dispersal and habitat filtering determine recruitment patterns of tropical tree species

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Seed deposition patterns and the spatial distribution of mortality, especially among seeds and seedlings, determine where new individuals recruit within a plant population. Both the Janzen-Connell and Hubbell's recruitment models state that

mortality is high near parent plants. According to the first model, this results in a decrease in population aggregation through ontogeny, and in spatial dissociation between seedlings and adults. Conversely, Hubbell predicts that these ontogenetic stages remain associated due to a numerical effect caused by high seed density near the parents. We used Spatial Analysis by Distance IndicEs (SADIE) techniques to determine the spatial patterns and relationships of seeds, seedlings and adults of three bird-dispersed tree species at two 1-ha plots of the Atlantic Rainforest in SE Brazil. Aggregation is commonly observed in tropical populations and seems to be linked to seed dispersal. Therefore, we expect all ontogenetic stages to be aggregated and spatially associated, thus supporting Hubbell's model. Seeds were randomly distributed in most cases; seedlings were always aggregated, and adults were aggregated in half the cases. As an overall pattern, seeds and seedlings were spatially associated to adults, while seeds and seedlings were associated in only few cases. Our results indicate that seeds are randomly scattered around adults and originate clumps of seedlings, which are located near the parents. Because seedlings recruit close to adults and are likely to conserve population aggregation through ontogeny, this study supports Hubbell's model, as expected. Nevertheless, it is noteworthy that recruitment takes place near adults even though seeds and seedlings are not spatially associated. This suggests that environmental filtering in fine spatial scales may also be playing an important role in determining where new plants recruit. Multiple ecological processes that shape the distribution of individuals within a community are likely to explain the high biodiversity of tropical forests.

Why are we missing seed removal by crickets in tropical forest?

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Disentangle the effects of multiple agents is a challenge for seed dispersal ecologists and essentially depends on our natural history knowledge of whom and how the seeds are removed. In tropics, invertebrates act mainly as secondary dispersers of vertebrates' dispersed diaspores. Ants and crickets are abundant in tropical forest and known as consumers of fallen fruits and seeds in the forest floor. Here, we comparatively investigated seed removal by ants and crickets and their role as seed dispersers of four Marantaceae species in Central Amazonia. Marantaceae' species are mainly myrmechocores and ornithochores with diaspores bearing lipid-rich arils. For each plant species we performed seed removal experiments in 9 plots (100 m x 5 m) and in two periods: diurnal and nocturnal, with 2 hours of continuous observation each. Removal events were counted and the removal distance measured. Removal was performed by 17 ant and 6 cricket species. Ants counted for 56.6% (n=77) of removals, and crickets 43.4% (n=59), indicating that seed removal by crickets on the forest floor is as common as by ants. Seed predation just occurred once by crickets, generally crickets consumed only the aril of arillate seeds. Crickets removed more seeds at night compared to ants. On average, ants removed seeds for longer distances; however crickets tended to disperse larger seeds farther. Ants tend to accumulate seeds around nests while crickets have a

scatter dispersal pattern. Invertebrates such as ants and crickets act at local scales (< 5 m) and their seed removal distances, even if apparently small, represent enough escape from under parent´s canopy for herbs that are mostly around 1m high. Our results show that crickets can be as important as ants for the dispersal of arillate seeds species. Crickets may have a complementary role on the dispersal process of both vertebrate-dispersed' and ant-dispersed' species.

How far do Neotropical primates disperse seeds?

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Seed dispersal effectiveness (SDE), the contribution of dispersers to plant population growth, consists of quantitative and qualitative components. SDE is determined by number of seeds removed and seed survival through each stage of dispersal from treatment in mouth and gut to deposition and germination sites. Fitness effect of seed deposition depends on distance from seed source, but the factors determining seed dispersal distance remain largely unknown. Here, we hypothesize that the distance traveled from a parent before being defecated is consequence of how long the seed is retained in disperser's gut, how rapidly the disperser moves per unit time and how twisted the travel path of the disperser is relative to the straight-line distance moved away from the feeding plant. Our analyses were done with Neotropical primates, which play a key role in tropical forests due to their large body size and home ranges, and high consumption of large fruits. We obtained data from 15 primate species dispersing up to 112 plant species in 26 published studies, and ran multiple regression analyses and model selection to determine which factors affect seed dispersal distances. Primates carry from 40% to 92% of ingested seeds to distances greater than 100m and are able to disperse them up to 1,540m away from mother plant. Our analyses show that daily path length, gut transit time, and home range size explained 70% of variation in average seed dispersal distance. We provide an intuitive and powerful method to estimate dispersal service, using only three general and readily-observed measures; we argue that primates act as efficient seed dispersers in Neotropics. Together with previous knowledge on seed germination after passage through primate's gut, we show that they provide high dispersal quality via beneficial seed treatment in the gut and predictable transport of seeds well away from parent tree crowns. (Financial support: CAPES and FAPEMIG)

Fruiting phenology and seed dormancy in a *Cerrado* savanna community

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Seed dispersal around the onset of the rainy season and dormancy are alternative strategies to control germination time and success in seasonal ecosystems. We aimed to investigate the proportion of dormant species according to both dispersal season and dispersal syndrome in a *Cerrado* savanna under seasonal climate. Furthermore, we intended to determine whether dormancy class is related to dispersal season and syndrome. We collected seeds from 33 species (15 families) from a *Cerrado* community in southeastern Brazil. The species were classified into dispersal syndromes: zoochory, anemochory and autochory; dispersal seasons were divided into rainy, late-rainy, dry and late-dry; and dormancy classes: morphological (MD), morphophysiological (MPD), physiological (PD), physical (PY) and physiophysical (PDPY). Half of the species showed no dormancy (54.5%), followed by PD (21.2%), PY (15.2%), MPD (6.1%), MD (3%) and no PDPY. Dispersal season and syndrome were related, where wind-dispersed species were fruiting exclusively during the dry season, auto-dispersed species in the late-rainy and dry seasons, and animal-dispersed species in all seasons. The proportion of dormant species and dormancy classes varied with dispersal season and syndrome. Most autochorous species were dormant (80%, exclusively PY), followed by zoochorous (48%, all except PY) and anemochorous species (14%, exclusively PY). Regarding dispersal season, 80% of species dispersing in the late-rainy season showed dormancy, where most dormancy classes were found (MPD, PD and PY). However, only 23% of species dispersing during the dry season were dormant (all PY). Our study showed that germination in this *Cerrado* was controlled by both dormancy and dispersal season. Nevertheless, the proportion of dormant species was highest in the late-rainy season, which offers the most favorable conditions for germination, but not for seedling establishment, likely favoring the evolution of dormancy. Therefore, species dispersing seeds in the late-rainy season tend to be dormant, while species dispersing in the dry season are not, regardless of their dispersal syndrome.

Seed-size selection in relation to seed predation: the effects of seed size, relative frequency, and total density

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Seed predation is a selective force that can affect natural selection on seed size when predators cause differential mortality of seeds in relation to their size. Optimal foraging theory predicts that larger seeds should be preferred due to a maximization of energy over effort, but if there is phenotypic variation in seed size, seeds can also be selected in a frequency dependent manner. It is often assumed that predator

selection for larger seeds results in a selective conflict with plant's post-germination stages where usually seed size is under positive directional selection. Less attention has been given to the idea that granivores could show a switching behavior when faced with the choice of differently sized seeds that vary in relative frequencies. In this paper we ask whether a desert ant population and a community of heteromyid rodents select *Dithyrea californica* seeds in relation to their size and frequency of sizes, and whether background seed density affects granivore selectivity for seed size. We set two preference experiments where we offered *D. californica* seeds that varied in size, frequency of sizes, and density of seeds to a population of the harvester ant *Pogonomyrmex rugosus* and to a community of heteromyid rodents of the Sonoran Desert. We found that ants had preferences for larger seeds when frequency and density were held constant. Contrarily, rodents had equal preferences for large and small seeds despite variation in seed frequency and density. Rodents showed anti-apostatic selection regardless of background density while ants showed pro-apostatic selection only at low density. These results suggest that granivores in the Sonoran Desert influence seed-size selection differently. Selection will be conflicted with post-germination stages when rodents encounter large seeds at low relative frequency and ants encounter large seeds at high relative frequency and low density.

ORAL SESSION 6 | Thursday . 14h - 17h

Keynote Presentation: Environmental control of dormancy in weed seed banks: predicting temporal patterns of weed emergence

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Understanding seed dormancy sufficiently to predict temporal patterns of seedling emergence from soil seed-banks has long been a goal to both seed ecologists and agronomists. On one hand, timing of emergence can have critical consequences for plant fitness and population dynamics. Therefore, forecasting temporal patterns of emergence under different climatic scenarios is relevant for understanding how weed populations will respond to future climate change. On the other hand, because plants are more vulnerable in the seedling stage, the possibility of predicting seedling emergence patterns is instrumental for improving the efficacy of weed control methods. In order to predict dormancy changes of buried seeds, and consequently temporal patterns of emergence, we should: 1-have a clear notion of which and how environmental factors affect the dormancy level of the seed-bank, 2-quantify the effect of those factors on seed-bank dormancy level and 3-include the developed quantitative relationships into a coherent modeling framework. In this work, I present an attempt to conceptualize the effect of the environment in the seed-bank dormancy level, distinguishing between factors that modulate dormancy level of buried seeds (as for example soil temperature) and those that usually terminates dormancy (as for example light and alternating temperatures). Based on this conceptual framework I show approaches that can be used to establish functional relationship between dormancy level regulating factors and changes in the dormancy status of the seed-bank. Finally, I present examples of how these approaches can be included into a coherent modelling framework to forecast temporal patterns of weed emergence under different environmental scenarios.

Germination niche of herbaceous species in the deciduous forest vegetation zone in eastern North America

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In the deciduous (nemoral) forest vegetation zone of eastern North America, herbaceous plant species behave as summer annuals (SA), winter annuals (WA), monocarpic perennials (MP) or polycarpic perennials (PP), and we ask if their germination niches vary with regard to temperature. To help answer this question, 540 sets of germination phenology data for 347 species (SA, 63; WA, 81; MP, 27; PP,

176) in 59 families were analyzed. These data were from studies in which fresh seeds collected in the region were sown on soil (wet in autumn, winter and spring and wet/dry in summer) in a non-temperature-controlled greenhouse and monitored weekly. When all data for a life cycle type are considered, mean temperature during the week of first germination and the week with the highest germination percentage were significantly higher for WA than for MP, PP or SA. However, mean temperature during the week for final germination was significantly lower for WA than for MP, PP or SA. For-spring germinating species, temperature during the week of first germination for SA did not differ significantly from that for PP but was higher than for MP; PP and MP did not differ. Mean temperature for the week with highest germination percentage and during the week of final germination was significantly higher for SA than for PP or MP; PP and MP did not differ. For autumn-germinating species, temperature during the weeks of first, highest or final germination did not differ significantly for WA, MP and PP. Thus, temperature germination niche overall was wider for SA than for spring-germinating MP and PP, but it was the same for WA and autumn-germinating MP and PP.

An unexplored side of sexual reproduction: thermal ranges of pollen germination, seed dormancy and germination drive species distribution

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Although plant distribution patterns are well documented, our understanding of the ecophysiological mechanisms that control the geographical ranges of plant species remains poor. While much attention has been previously paid to the 'vegetative' part of plant life-cycle (e.g. the sensitivity of the shoot), recent findings in pollen and seed ecology highlight how little we actually know about the role of reproductive traits in controlling species distribution. Using the data on the temperature requirements for pollen germination (PG) and tube growth (PTG), seed dormancy and seed germination along a temperature gradient for plant species originating from contrasting climatic conditions, we tested whether thermal range of these traits is related to the species distribution ranges, in this case along a temperature gradient. First, we found that minimum temperature for both pollen germination and pollen tube growth was positively strongly correlated with temperature conditions at our collections sites (r^2=0.25, p=0.01 and r^2=0.46, p<0.001, respectively). Second, the number of species with non-dormant and non-deep physiological dormant seeds decreased with increasing low-temperature stress (e.g. winter duration, frequency and magnitude of frost events). Third, initial temperature of seed germination was also a good predictor of species occurrence along the elevational gradient (r^2=0.57, p<0.001), however, the nature of this relationship was positive. Our findings suggest that the strong relationship between the studied reproductive traits and habitat temperatures is an important contributor to the climatic restriction of plant species distributions. We argue that improved knowledge of theses thermal precursors to successful sexual reproduction could, from a functional perspective, enhance our

understanding of species distributions along climatic gradients and our ability to predict how anthropogenic climate change might affect plant community composition.

Germination ecology of Mediterranean winter annuals: implications for their use as cover crops in sustainable olive orchards

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Native cover crops have the potential to provide ecosystem services such as erosion and pest control. They can also increase the sustainability of woody crops, particularly in southern Spain, where 30% of land use is olive orchards managed with bare soil. Within a research program to develop native cover crops, we analyzed the germination response of 19 native taxa with physiological (PD) or physical (PY) dormancy. We tested their behavior as winter annuals and their suitability as cover crops to fit within the management cycles of olive farming. We measured total germination, germination rate and TB, TO, and TC of fresh seeds from natural populations across 10 temperature treatments, from 5C°-35C°, constant and alternate. We repeated a second round of germination experiments with the same seed populations following nine months of dry after-ripening (DAR), using one alternating temperature of 20C°/10C°. Fresh seeds of Poaceae germinated from 15% to 100% with highest germination at warmer temperatures. The overall high germination response of the fresh and stored Poaceae seeds indicate that these species do not have high levels of PD and can be sown and established in any season under irrigation. Among the 13 forb taxa, germination ranged from 0-100% and results were mixed in response to temperature. Among 9 taxa with PD, the TO was at warmer temperatures for 4 taxa, at cooler temperatures for 2 taxa and there was no pattern of temperature effect for 3 taxa. DAR improved total germination, indicating a dormancy-breaking effect on PD. Despite being generally classified as winter annual species, the populations in our study had a variety of germination responses across treatments. An important consideration for successfully establishing these native cover crops is to match the sowing date with the specific temperature and DAR requirements for optimal germination of each taxon.

Can nitrogen addition increase salt tolerance of alfalfa and *Leymus chinensis* at germination and early seedling stages?

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Salinization has become more and more serious all over the world. In the meanwhile, atmospheric nitrogen deposition and agricultural nitrogen addition have increased. If nitrogen addition can increase salt tolerance of plants remain elusive. Alfalfa and *Leymus chinensis* are the most important Legume and grass species in China. They are usually used for establishing monoculture artificial grassland or legume-grass mixtures. If the two species inhibit each other at emergence stage is not clear. We conducted an experiment to answer the two questions. Seeds of alfalfa and *Leymus chinensis* were solely or collectively germinated in 0, 100, 200 mM NaCl solutions added with 0, 20, or 40 mM NH_4NO_3. Germinated was recorded for 20 days and radicle length and seedling height were measured. The Na^+ and K^+ content, as well as the nitrogen content of the seedlings were also measured. The results showed that germination and seedling growth of the two species were not affected by mixed or individual sowing. Low nitrogen addition significantly increased germination percentage and seedling height of *Leymus chinensis* under salt, compared to the no nitrogen control. It has no significant influence on germination and seedling height of alfalfa. However, nitrogen addition decreased the radicle length of both species. The nitrogen content of *Leymus chinensis* seedlings in nitrogen addition treatments increased compared to the control. The Na^+ content of *Leymus chinensis* seedlings in low nitrogen addition treatment decreased compared to the control. The results indicated that nitrogen can enter seeds, which inhibited Na^+ absorption and increased salt tolerance of *Leymus chinensis* seeds. Alfalfa can fix nitrogen, so it is not sensitive to nitrogen addition.

Climate changes modulating Zn-toxicity to *Dimorphandra wilsonii* Rizz seed germination: effects of temperature

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The effects of temperature changes on Zn toxicity to seed germination of the threatened Brazilian species *Dimorphandra wilsonii* were evaluated. Seeds submitted to increased Zn doses (0, 75, 150 and 200 mg l^{-1}) were germinated under different temperatures (25, 30 and 35 ºC). Deleterious effects of Zn on seed germination were only observed at 30 and 35 ºC. Under both 30 and 35 ºC, seed germinating under Zn presence showed increased respiration rates and hydrogen peroxide (H_2O_2) concentrations. The activation of enzymatic antioxidants assured seed germination

in seeds exposed to Zn. Ascorbate peroxidase (APX) was seen to have a central role in H_2O_2-scavenging in seeds exposed to Zn under the highest temperature studied. Increased APX activity allowed germination, while its decrease was followed by decreasing germination in Zn-treated seeds germinating under 35 ºC. Under a scenario of climate changes, it is urgent to avoid increasing Zn concentrations in natural habitats to do not threat conservation efforts of this endangered plant species. (Financial support: CAPES, CNPq and FAPEMIG)

Seed permeability variation in legumes from a fire-prone ecosystem: going further than dormancy classifications

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Several species have impermeable seed coats, showing physical dormancy (PY). However, there is some percentage of seeds in the population that are permeable and which will promptly germinate when water is available. We believe that this could be a good strategy to spread germination, even if the factor that breaks dormancy is absence in a particular year. We have been studying PY in legume species from *Cerrado*, where fire is an important ecological factor. *Cerrado* is composed by a mosaic of physiognomies, from the more open savannas (more frequent fires) to forests (absence of fire). We hypothesize that legume species show variation in percentage of permeable/impermeable seeds in their populations and that proportion may vary annually and according to fire history. We collected seeds from legume species (shrubs and trees) in different physiognomies of *Cerrado*. We also collected seeds from two *Mimosa* species in areas with different fire histories (>5 and 2 years of fire exclusion) and from one species, *Mimosa leiocephala*, we collected seeds from the same population from 2013-2015. To the permeability tests, we selected 100 undamaged seeds, weighed and soaked in water for 24, 48 and 72h. We weighed at these periods and considered seeds to be permeable when they increased in 20% of initial weight. Only two of the study species showed <10% of permeable seeds (*Peltophorum dubium*, *Harpalyce brasiliana*). The percentage of permeable seeds in the other species varied from 14-96%, and this variation was independently of growth form and habitat. Moreover, seed permeability varied according to fire history (from 7 to 65% in *Mimosa pteridifolia*) and year of collection (from 4 to 22% in *M. leiocephala*). Therefore, we suggest that percentage of permeable seeds within the population should be considered as a trait, and not only a dichotomous permeable/impermeable species classification.

Smoke originated from different plants has various germination responses

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Whether smoke produced from different plant materials has different compounds that in turn stimulate different germination responses remains inconclusive. We compared effects of smoke solutions and separated active fractions from alfalfa (*Medicago sativa*), prairie hay (*Festuca hallii*), and wheat straw (*Triticum aestivum*) on germination of four species from Fescue Prairie. Salad Bowl lettuce (*Lactuca sativa*) was used as a quick bioassay to trace the active compounds in smoke solutions. Column chromatography and High Performance Liquid Chromatography (HPLC) were used to separate and identify active compounds in smoke solutions. Tested seeds were primed for 24 h at room temperature in darkness using serial dilutions of smoke solutions and separated active fractions, as well as karrikinolide (KAR1). After priming, seeds were dried at room temperature in darkness for 7 d and subsequently incubated at 10/0°C or 25/15°C in 12h light /12h dark or 24 h darkness for 49 d. KAR1 was in the smoke made from prairie hay, and wheat straw, but was not present in alfalfa smoke. Priming in KAR1 solutions increased germination of three native species. Concentrated smoke solutions made from alfalfa has neutral and positive effects on seed germination of *Artemisia frigida* and *Coynza canadensis*, respectively. Concentrated smoke solutions made from prairie hay and wheat straw decreased germination of both species. Our results indicate that KAR1 is not universally present in smoke and has the potential in favouring seed regeneration of native species in Fescue Prairie. Possible unidentified active compounds are involved in smoke produced from alfalfa.

Poster Session

Removal of artificial diaspores in degraded and pristine areas of *campo rupestre*

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Granivore invertebrates and vertebrates have important effects on seed fate. The removal or predation of diaspores during post-dispersal phase can affect plant community dynamics and natural regeneration processes. The *campo rupestre* vegetation presents little resilience to soil removal, but the mechanisms that this major disturbances affect the ecological processes involved in ecosystem's ability to recover is still unexplored. The aim of this study was to test the hypothesis that seed predation could be an important factor limiting natural plant recolonization in *campo rupestre*. We performed a factorial experiment involving assessment of artificial diaspore removal in three paired disturbed and pristine sites, and in vertebrate-excluded and control paired stations. We made artificial diaspores containing sugar and fat, with attractive aroma and color. In each area, we placed six stations with vertebrate's exclusion cages and six control stations open structures with 10 artificial diaspores in each one, totaling 720 artificial diaspores that were evaluated for removal or attack marks after 48 hours of exposure. Contrary to our expectations, we found that diaspore removal was reduced by more than two fold in disturbed sites compared to pristine sites. An average of 85% of artificial diaspores were removed or attacked in pristine sites, and 35% in disturbed sites. Our results also suggest that invertebrates comprised the group that contributed most to seed removal. However, also contrary to our expectations, removal by vertebrates was less affected in disturbed sites, where invertebrate activity seemed to be significantly reduced. Our study suggests that post-dispersal removal of diaspores could be greatly reduced in disturbed sites. On the other hand, seed removal and predation, even at lower rates compared to the pristines sites, is still occurring and could negatively affect vegetation regeneration, especially if seed rain in those disturbed patches are also negatively affected. (Finantial support: CAPES and FAPEMIG)

Inter-specific variability in germination and early survival of savanna trees in response to environmental variation

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There is a growing concern on the effects of climate and biotic changes on savannas and tropical grasslands. However, the lack of empirical comparative studies on how plant community composition might change under environmental variation constrains predictive models and conservation management in savannas. Here we evaluate how variable is establishment (germination and early seedling survival) of 12 common savanna tree species under different environmental conditions, and how differences in species' seed characteristics contribute to explain such inter-specific variation. A completely crossed field-experiment evaluated the influence of moisture availability (regulated by water addition and sunlight exposition) and grass presence on tree establishment. The effect of grass, light and water supply on germination and on early survival differed among species. Seed characteristics explained part of this variation. Under low moisture conditions, while the probability of establishment increased with a higher seed biomass, nitrogen and potassium seed concentration, it was reduced by a higher phosphorus seed concentration. Tree species responses to environmental variation vary during the early recruitment phases, seed traits being important to explain such variability. Consequently, considering inter-specific variation when studying vegetation dynamics can improve our ability to predict impacts of environment changes on savanna structure.

A quantitative analysis of the dependency on temperature of the entrance of *Polygonum aviculare* (L.) seeds into secondary dormancy

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In seeds of many summer annuals low temperatures under moist conditions provoke dormancy release while high temperatures induce secondary dormancy. These temperature-dependent changes in seed dormancy level are related to changes in the thermal range permissive for seed germination through variations in the minimum or lower-limit temperature (Tl) allowing germination. Although numerous studies have been conducted to characterize the effect of temperature on dormancy release, there is less information on how temperature regulates induction into secondary dormancy. The aim of this work was to: (1) characterize the role of temperature on dormancy induction in *Polygonum aviculare* seeds and (2) evaluate the effect of previous stratification temperature on the subsequent dynamics of induction into secondary dormancy. To achieve these objectives seeds of *P. aviculare* were stratified at 1.6, 5 and 10°C until achieving a minimum dormancy, and then were induced into secondary dormancy by further storage at

10, 15, 20, 25 and 30°C. At different times during storage seeds were exhumed and germinated at 10 and 15°C. Based on obtained germination time course-curves we quantified changes in the thermal range permissive for seed germination through variations in the mean lower limit temperature for seed germination (Tl(50)) using a mathematical simulation germination model. We found that induction into secondary dormancy in *P. aviculare* seeds can be assessed quantitatively through changes in Tl(50). The dependency on temperature of the induction into secondary dormancy could be described formally through: i) the identification of a threshold temperature for secondary dormancy to be induced (7.9°C); ii) the development of a Dormancy Induction Thermal Time Index (DItt); iii) the establishment of a bi-linear and positive relationship between Tl(50) and the accumulation of DItt. Additionally, we found that the induction rate into secondary dormancy was affected by the stratification temperature at which the seeds were exposed during dormancy loss.

Environmental maternal effects on temperature-dependent dormancy release in *Polygonum aviculare* buried seeds

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For many species, timing and extent of seedling emergence are strictly related to the dormancy state of the seed-bank. As several weed seed populations show dormancy, the possibility of predicting their emergence in the field depends largely on our knowledge of seed dormancy dynamics in relation to environmental factors. Although post-shedding regulation of dormancy has been widely studied and modeled, there is scarce information related to maternal effects on seed-banks dormancy behavior and almost no attempt to include these effects on predictive models of seedling emergence. In this work, we studied the effects of (i) flowering-time (which define seed-development and maturation environment), (ii) photoperiod during seed-development and maturation, and (iii) dispersal-time, on dormancy release of *Polygonum aviculare* seeds. To study the influence of (i), we carried out plantings under field conditions in contrasting dates. To study (ii), plants were grown under natural and extended (+4hs) photoperiod conditions. Finally, to analyze (iii), we performed successive harvests of mature seeds. Collected seeds (from experiments i, ii and iii) were buried in pots and stored at 1.6, 5 and 9.8°C. At different times during storage, seeds were exhumed and germination was tested at 10, 15, 20 and 25ºC. Based on obtained germination time-course curves, we established changes in the permissive thermal range for seed germination through variations in the limit temperatures using a mathematical germination model. We found that dormancy release and, hence, germination patterns were significantly affected by seed maturation conditions. An increase in dormancy loss rate related to a faster decrease of the lower limit temperature for germination with delay in planting date was observed. Maternal photoperiod conditions could explain, at least partially, these differences. Mathematical models for dormancy loss which include the effect of maternal environment were developed and simulations of emergence patterns in the field were performed.

Year of production affects level of dormancy in macaw palm (*Acrocomia aculeata*) seeds

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Macaw palm (*Acrocomia aculeata*) is a species broadly distributed in tropical America, which seeds show primary dormancy. In this work, we studied seeds produced in two consecutive years (2013 and 2014) from a macaw palm population. 2013 had around 40% more precipitation than 2014 during macaw palm seed development and maturation time. We aimed to evaluate the effect of year of production on germinability and oxidative signaling during germination process of macaw palm seeds. For germination experiment, besides control, the following overcoming dormancy treatments were performed: +GA3 (seeds were immersed in GA3 solution for 48h after imbibition) and –operculum (operculum removal after imbibition). The germination experiment was evaluated during 60 days. Embryos of control, +GA3 and –operculum from recently recovered (0 days), 2 and 7 days after overcoming treatments were evaluated in relation to hydrogen peroxide (H2O2) levels. Seeds produced in 2013 showed higher germinability than those from 2014 in all treatments (control, +GA3 and –operculum). In seeds from 2013, H2O2 levels on treated ones, +GA3 and –operculum that showed 23 and 78% of germination, respectively, were higher than in control ones (2% of germination) two days after treatments imposition. In seeds from 2014, the levels of H2O2 were higher in embryos from –operculum (40% of germination) in relation those from +GA3 (less than 2% of germinability) two days after treatments imposition. We suggest that year of production had an effect on dormancy level of macaw palm seeds and indicated that H2O2 acts as signaling molecule in germinative process of this species. (Financial support: FAPEMIG)

Now, later or never….? Investigating the seed germination phenology of Andean species

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Seeds are one of the most important means by which plants can migrate and change their distribution. Most research on seeds and seedlings of alpine plants has focused on the optimal conditions for germination and the prevalence of dormancy in alpine environments. Lacking in the literature is information on seed germination phenology, that is when and under which conditions seeds of alpine plants germinate in the field. Here we investigate the different patterns of seed germination phenology among seeds of Andean species, and look for the potential drivers of these different strategies (e.g environmental conditions). We selected 40 seed collection sites along an elevation gradient equally distributed on the Eastern and Western slopes of the Mocho-Choshuenco Volcano in the South of Chile. At each site, we placed ibuttons dataloggers to measure plant temperature

and duration of snow cover. We recorded the plant flowering phenology in each plot and collected seeds of 30 species (16 families). We are exposing the seeds to temperatures that mimic the seasonal changes in soil temperature measured in the field and scoring germination every 3 days. Here we show preliminary results of the study, the different patterns of germination found so far and the influence of the environment (temperature and snow duration) on these patterns. We believe that seed germination phenology might be influenced by the environment in which seeds are produced as well as the post dispersal conditions seeds are exposed to. We hope our results can give indications on how warming and early snowmelt in alpine areas will affect seed germination phenology and seedling recruitment.

Submergence of recalcitrant seeds of *Eugenia stipitata* McVaugh: ecology supporting seed technology

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Eugenia stipitata is a small tree occurring in regular flooded areas close to large rivers the Amazon region. Its large berries have great economic potential and contain several recalcitrant seeds. This study tested the possibility of seed survival under water for short term seed storage. Two heights of water column were tested. (i) seed were submerged in water in a plastic containers and a water column of 6 cm was established with perforations, and (ii) seeds were submerged in glass containers with a height of 26 cm. A hose maintained an approximately water flow of 0.01 L seg-1 throughout the test. The seeds of both lots were maintained under these conditions for up to one year and germination was assessed periodically. With a subsample, we removed both, shoot and root of the germinated seeds and observed the regenerative ability, as these damages may occur in nature by currents, animal consumption or by handling of the seeds during storage. Metabolic activity of the seed tissue was assessed with tetrazolium staining. The seeds survived for at least one year under submersion and stared to germinate after two months under water, regardless of the water column´s height. A reduction in germination speed was noted during the first 30 days of submersion. The seeds are able to produce a second normal seedling, even after complete removal of the first root and shoot. *E. stipitata* is adapted to flooded areas, as the seeds can tolerate submersion and germinate under flooded and non-flooded conditions. The seedlings are extremely tolerant to mechanical stress. These characteristics will allow seed storage of these recalcitrant seeds under water for at least one year.

The role of seed rain in a tropical dry forest succession

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A major limitation for the recovery of tropical vegetation through secondary succesion is insufficient propagule availability. In successional forests with reduced seed banks and where plants possess a limited resprouting ability, such as old fields, taxonomic enrichment of the plant community seems to be largely mediated by the arrival in the seed rain of species that have not yet established in the site (allochtonous component). Successional structural and compositional changes may affect seed rain attributes (species composition, abundance and richness) through differentially attracting seed dispersers and obstructing the movement of wind through the canopy. The aim of this study was to examine the role of seed rain as an enriching mechanism during a tropical dry forest succesion in southern Mexico. To this end, seed rain attributes were assessed by means of seed tramping in a successional chronosequence encompassing a wide range of fallow ages (0-43 yr), plus a mature forest stand. A total of 144 seed traps were set up and inspected monthly during one year. In total, 28,542 seeds were tallied and assigned to 221 species, based on a local seed catalogue. The three most abundant taxa in the seed rain were the early successional species *Mimosa tenuiflora*, *Urochloa fusca* and *Aeschynomene compacta*. Seed rain richness and density varied along the successional gradient; at early stages diaspores of Asteraceae and Poaceae prevailed, whereas seeds of late successional species like *Bursera simaruba* were only recorded in the seed rain observed at older fallows. Tree species such as *Cochlospermum vitifolium*, *Machaerium biovulatum*, *Astianthus viminalis* and *Beaucarnea recurvata* were recorded in the seed rain despite their absence in the established vegetation. Our results show changes in seed rain composition during succession and demonstrate the considerable enriching potential of seed rain by contributing new species to the community assembly process.

Tegument thickness of seeds contributes to increasing water retention in Brazilian savanna

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In the *Cerrado* Biome, species must overcome some abiotic filters, such as seasonality and high temperatures, in order to germinate and establish. Thus, tegument thickness can be an important trait. Some authors consider it as a multifunctional trait, since it protects the inner parts of the seeds against shocks and microorganisms, regulates the speed of imbibition, gas exchange and germination. In this study, we

investigated if tegument thickness is also related with internal humidity maintenance and the viability of seeds in drier environments. Therefore, we classify the seeds in thick (*Hymenaea strignocarpa* and *Copaifera langsdorfii*) and thin (*Anadenanthera colubrina* and *Handroanthus serratifolius*). We tested four treatments, using ten replicas with six seeds each, as follows: no dehydration, thin/dehydrated, thick/ scarified/dehydrated, thick/not scarified/ dehydrated. We measured the initial water content and during dehydration in 12 hours periods, until 72 hours. After the treatments were applied, we put the seeds to germinate and measured the germination rate and the index of germination speed (IGS). Seeds with thicker and scarified tegument lost more humidity, had higher germination rates and IGS (5,08 + 0,13; 78%; 0,71 + 0,22, respectively) than not scarified seeds (6,15 + 0,35; 30%; 0,18 + 0,09, respectively). Seeds with thin tegument lost more humidity and had lower germination rates and IGS (4,19 + 1,88; 21%; 0,95 + 1,25, respectively), but no difference was observed between dehydrated and no dehydrated. These results indicate that tegument thickness is a trait related with imbibition speed and inner humidity maintenance; therefore, seeds with thicker integument can tolerate drier environments better than those with thin tegument.

Differential effects of glyphosate and Roundup on *Dimorphandra wilsonii* Rizz seed germination

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The use of glyphosate-based herbicides in agriculture has greatly increased over the past few years. In the Brazilian *Cerrado*, glyphosate-formulations have been widespread and uncontrolled used, which has threatened the population of endangered species *Dimorphandra wilsonii*. Therefore, we investigated the toxicity of increased doses (0, 5, 25 and 50 µg l-1) of glyphosate and one of its formulation, Roundup®, on seed germination of *D. wilsonii*. Both compounds drastically decreased seed germination but Roundup deleterious effects were greater than glyphosate. Moreover, while total seed germination was decreased as glyphosate-doses increased, the deleterious effects of Roundup was not significantly different, regardless the studied dose. Reduced germination in seeds exposed to glyphosate or Roundup was related to their inducing decreases in seed respiration rates (RCO2) and not to oxidative stress through hydrogen peroxide accumulation. Our results indicate that by interfering in the respiration, glyphosate and Roundup induce decreases in this energetic metabolism, disrupting seed germination. Moreover, the toxicity of Roundup was greater than of the glyphosate due to its greater alteration of respiration. In this context, our results point out the importance, to avoid or to regulate the use of glyphosate-based herbicides in natural habitats of *D. wilsonni*, as the herbicide is toxic to seed germination and therefore, may threat conservation efforts. (Financial support: FAPEMIG, CNPq, CAPES)

Light and temperature requirements for seed germination of six *Xyris* (Xyridaceae) species from Serra do Cipó, Minas Gerais

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Light and temperature are the main abiotic factors influencing seed germination. Xyridaceae family has five genders, being *Xyris* the largest in number of species. This family is very representative in the rupestrian fields of the Espinhaço Mountain in Brazil. Our objective was to evaluate the effects of light and temperature in the germination of six *Xyris* species, which occurs at the rupestrian fields of Serra do Cipó. Seeds of *Xyris asperula*, *X. longiscapa*, *X. seubertii*, *X. subsetigera*, *X. trachyphylla* and *X. pilosa* were characterized by size and dry mass. Seeds were sown under different continuous light (12h photoperiod or continuous dark) and temperature (10, 15, 20, 25, 30, 35 and 40 ºC) conditions. Moreover, for *X. asperula*, *X. subsetigera* and *X. longiscapa*, alternating temperatures (15/30 and 20/30 ºC, with dark period coinciding with lower temperature) was investigated. Seeds were small (below 0.8 mm of length and 0.31 of width) and dry mass varied between 0.4 and 0.1 µg seed-1. No germination was detected under dark conditions, indicating positive photoblastic behavior of seeds. All species germinated in a wide temperature range (15-30 ºC), except for *X. longiscapa* which germinated only at 20 ºC. Temperature of 10 and 40ºC inhibited seed germination. The optimum temperature for germination varied among the species: *X. asperula* (20/30, 25-30 ºC, >68%), *X. longiscapa* (20 ºC, 46%), *X. seubertii* (20-25 ºC, 69%), *X. subsetigera* (20/30, 25 ºC, >52%), *X. trachyphylla* (25-30 ºC, 95%) and *X. pilosa* (25 ºC, 91%). Germination speed indexes were higher under temperatures ranging from 20 to 30 ºC. We conclude that all studied species have absolute light requirement for germination. This characteristic associated with the reduced seed size can contribute for persistent seed bank formation in this species. (Financial support: CNPq and FAPEMIG)

Size of the embryo and cell growth control establish different degrees of seed dormancy in palm trees

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There is little information about the factors that determine differences in the intensity of dormancy between species of palm trees. The aim of this study was to compare anatomical and physiological aspects of dormant seeds and seeds submitted to a method of dormancy breaking in two species of palm trees with different levels of dormancy. *Attalea vitrivir* and *Butia capitata* seeds were evaluated for endogenous levels of ABA and GAs in cotyledon petiole and operculum, force required for the displacement of the operculum, activity of the endo-β-mannanase enzyme and cell elongation in the embryonic axis and ligule. Analyses were carried out in dry and imbibed seeds and after incubation for 2, 5 and 10 days (intact or

without operculum). The germination of intact seeds of *A. vitrivir* and *B. capitata* was 68% and 3%, respectively, and the removal of the operculum stimulated the percentage and speed of germination, reaching more than 90% in the two species. Reducing ABA and increased GAs, after incubation, coincided with the elongation of the embryonic cells in both species. However, no evidence that the hormonal balance is involved in the activation of endo-β-mannanase or weakening of the operculum was found. The cells of the embryos of both species have approximately the same lengths, but as the embryo of *A. vitrivir* has twice the number of cells the *B. capitata*, a small individual elongation provided embryo growth necessary for the displacement of the operculum, resulting in lower degree of dormancy of the species. Our results suggest that the difference in the intensity of dormancy between species is related to the size of the embryo and cell growth control. (Financial support: FAPEMIG)

Can experimental light conditions alter the thermal time for germination of bromeliad seeds?

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Vriesea bituminosa, *V. friburgensis* and *V. pardalina* species exhibit aphotoblastic seeds that germinate in temperatures ranging from 15 to 35°C. This study analyzed the interaction between light and temperature requirements for germination of these three bromeliads seeds collected after different times in 2000 and 2015. Seeds were set to germinate under constant temperatures of 15, 20, 25, 30 and 35°C at three light conditions: daily photoperiod (12h); constant white light; and darkness. A thermal time (θ) approach was then applied to the germination (g) results and the seed responses were modeled. Linear regression was used to express probit(g) as a function of both θ and log θ to determine the sub-optimal and supra-optimal temperature for each seed lot and the best model evaluated on the basis of the r2 values. Both the base temperature (Tb) and maximum temperature (Tm) for germination were similar among species independent of the harvest time and experimental light conditions. The thermal time requirements for 50 % of germination (θ50), in turn, decreased in seeds put to germinate under constant light. The different experimental conditions of light can change thermal time parameters and make arbitrary forecasts. (Financial support CAPES, CNPq and FAPEMIG)

Accelerated ageing and subsequent imbibition affect seed viability and the efficiency of antioxidant system in macaw palm seeds

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Accelerated ageing is an accurate indicator of seed vigor and storability, helping the understanding of cellular and biochemical deterioration that occur during seed ageing. The present study was carried out to elucidate the mechanisms of ageing in macaw palm embryos. Seeds were artificially aged during 4, 8 and 12 days at 45ºC and 100% relative humidity. After ageing, seeds were tested for viability (tetrazolium), electrical conductivity, lipid peroxidation (MDA) and hydrogen peroxide (H_2O_2) content. Part of the aged seeds was imbibed for 8 days to determine the hydrogen peroxide content and the activity of antioxidant system enzymes (superoxide dismutase, catalase and glutathione reductase). Ageing reduced the embryo viability from 8 days of treatment and increased malondialdehyde content (MDA) and solute leakage. Hence, membrane permeability correlated with both loss of viability and lipid peroxidation. After imbibition, H_2O_2 content significantly increased along with superoxide dismutase activity. Catalase activity was significantly higher than control in embryos aged from 8 days, and glutathione reductase activity did not change. Our results suggest that macaw palm seed deterioration during accelerated ageing is closely related to lipid peroxidation, and that enzymatic antioxidant system is not completely efficient in reducing reactive oxygen species after imbibition, a critical phase to germination. Moreover, accelerated ageing test can be used as a reliable model to understand the mechanisms involved in palm seeds deterioration. (Financial support: CNPq and FAPEMIG)

Germination behaviour of seeds of Chilean columnar cacti across temperature gradient

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Germination behaviour across temperature might be related with recruitment chances in a climate changing scenario. Seeds of four columnar cacti, *Echinopsis atacamensis*, *E. chiloensis*, *E. litoralis* and *E. skottsbergii*, were sown in a thermogradient plate to evaluate germination responses to temperature. A gradient between 6.4 to 33.9^{0}C of constant temperatures was used. Three replicates of forty seeds were sown on 1% agar in Petri dishes. Germination in percentage and rate were determined in each experiment. Germination rate were used to determinate optimal temperature and to obtain cardinal temperatures, including basal, maximum and optimal plateau. Results showed that seeds were able to germinate in a wide range of temperatures. Ranges were similar among species, germination was concentrated

between 10 and 30°C. Germination rate showed slightly differences among species, being *E. atacamensis* the species that showed the narrowest plateau between 23 and 27°C of maximum germination rate. Populations of *E. atacamensis* showed also the northern and maximum altitude geographical distribution. *E litoralis* showed the lowest germination in temperature under 15°C, probably because of a coastal distribution. *E. skottsbergii*, despite it is also a coastal species, showed ability to germinate high and fast in a wide range of temperatures, even in a wider range than *E. chiloensis*, though its geographic distribution is much narrower than *E. chiloensis*. The ability to germinate in wider ranges of temperatures might indicate that these species might be able to face at least changing temperature regimes as result of climate change.

Spatial and temporal presence of grasslands maintain local weed diversity thanks to spatio-temporal dispersal process

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In frequently disturbed environments, plant community assembly mainly results from spatial dispersal and temporal dispersal through seed bank. Here, we propose to quantify the relative contributions of temporal and spatial dispersal on weed species assembly in farmlands. Weeds are mostly annual plants that rely exclusively on seeds for perpetuation, the latter presenting various level of longevity and dispersal capacity according to the species. In farmland, arable fields surrounded by landscape with high proportion of grasslands harbor high level of weed diversity revealing important dispersal flux. Similarly, the presence of grasslands in the past history (i.e crop succession) of the field promotes actual weed community diversity thanks to temporal dispersion through the seed bank. Therefore, grasslands favor weed diversity both by being present in the surrounding landscape and in the crop succession. However whether the effect of grasslands is higher in space or time remains unknown mainly because their presence in space and time are generally correlated. We tested the effect of the presence of grasslands (percentage and distance in space vs time) by analyzing weed diversity in winter wheat fields in the LTER 'Zone Atelier Plaine et Val de Sèvre' (France; www.za.plainevalsevre.cnrs.fr). We selected fields so that the presence of grasslands were not correlated in space and time. We then calculated weed taxonomic and functional diversity using Hill's numbers. Selected traits for functional analysis were seed mass, seed form, seed lipid content, plant height and dormancy levels since they are known to be involved in plant spatio-temporal dispersal. Preliminary results suggest a higher impact of grassland in time than in space on weed diversity. Weed seeds traits diversity may give interesting insights about weed species assembly processes.

Can seed germination explain the spatial distribution of *Leucaena leucocephala* (Fabaceae) in worldwide?

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Leucaena leucocephala (Lam.) Wit. (Fabaceae) is an alien and invasive species in several Brazilian ecosystems whose seeds show physical dormancy. This species is knowing to occur in regions of the world with different conditions climate as: North America – USA (temperate continental – Cfa); Central and South America – Mexico (tropical wet and dry – Aw); oceanic islands of the Atlantic and Caribbean, Hawaii, Ecuador, Brazil (tropical – Cwa, Cwb); North and South Africa; Europe – Italy (warm Mediterranean – Csa); Southwest and Southeast Asia – Western India, Indonesia, Malasya, Papua New Guinea, Thailand; Japan Islands – Ogasawara (Bonin) (humid subtropical – Cfa); and Australia (dry arid – BWh and marine west coast – Cfb). Although it is widely distributed, still do not known what environmental factor is responsible for promoting the loss of seed physical dormancy. The hypothesis is that fluctuations in temperature in the soil can increase the chance of forming the water gap and thus promote dormancy loss. The study aimed to identify the best temperature regime able to relieve the physical dormancy of *Leucaena* seeds. Samples of 25 seeds inside nylon bags were buried in the sand during six months and submitted to the following temperature regimes simulating the climates types: cold season (0 – 15°C), dry and wet; warm season (25 – 40°C), dry and wet. The germination percentage of seeds from all simulations did not exceed 25%, except for the warm Mediterranean (Csa) simulation, that reached 62%. The results indicated that only a large change in temperature regimes combined with dry/wet moisture transition can relieve seed dormancy of *L. leucocephala*, causing the water gap to open and allowing germination to occur. However, seed germination does not explain its wide geographic distribution. (Acknowledgments: FAPEMIG).

Avian seed dispersal of *Miconia irwinii* (Melastomataceae) in a rupestrian grassland site, southeastern Brazil

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Seed dispersal mutualisms play a central role in the maintenance of biodiversity in tropical ecosystems. *Miconia* is one of the largest genera among tropical angiosperms and their fruits are widely consumed by animals, especially by birds that are known to be the main seed dispersers. *Miconia irwinii* is an endemic species of Brazilian rupestrian grasslands, but its role as food source in these harsh ecosystems remains poorly understood. Our aim was to evaluated the role of birds as potential seed dispersers of *M. irwinii* and determine the possible factors that

affect visitation rates and variation in seed dispersal effectiveness. We selected 15 individuals and characterized plant size, fruit crop and availability of fruiting conspecifics in a 25 radius. To evaluate the feeding behavior of avian frugivores on *M. Irwinii*, we conducted 240 hours of focal observations, 16 hours for each plant. We recorded 235 visits by nine bird species that acted as legitimate dispersers ingesting entire seeds while feeding on fruits. The Plain-crested *Elaenia* was the most frequent disperser, responsible for 35% of visits and 40% of seeds dispersed. The second most important dispersers was the Cinnamon Tanager, responsible for 20% of visits and seeds dispersed. The Rufous-collared Sparrow was the third most frequent species responsible for 25% of visits, but only 8% of seeds were dispersed. Although, in some occasion, it can actually ingest entire fruits with seeds, in most visits this bird just bite pieces of fleshy pulp or drop fruits on the ground. The visitation rate to individual plants was positively correlated to plant size, fruit crop size and number of fruiting conspecifics in the neighborhood. These results indicate that avian frugivores can track fruit availability at plant and local scales, increasing their foraging activity that translates in higher rates of seed dispersal in resource rich patches. (Financial Support: CAPES, CNPq and FAPEMIG)

Seed dormancy cycles in four tropical *Xyris* (Xyridaceae) species

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Seed dormancy cycles prevent germination during unfavorable periods for seedling establishment, being an important mechanism in species inhabiting seasonal environments. Xyridaceae family have wide distribution and high level of endemism in the Brazilian rockfields. Our objective is to verify the existence of seasonal dormancy cycles in four perennial *Xyris* species occurring in Brazilian rockfields. Seeds of four species (*X. trachyphylla*, *X. subsetigera*, *X. longiscapa* and *X. asperula*) were placed in bags and buried at 5cm below the soil surface in September (Spring season) in the Serra do Cipó National Park, where the species occur naturally. Every two months during 18 months, the seeds were exhumed and germination was assessed at 15, 20, 25 and 30 °C (for *X. asperula* also at 35 ºC) under 12h photoperiod. The temperature and soil moisture data were obtained by sensors buried in the same place the seeds, connected to a data-logger. All species showed dormancy cycles (except *X. longiscapa* seeds at 25 and 30 ºC that germinate at low percentages). The secondary dormancy is acquired during the rainy summer and overcame during the subsequent dry season (autumn/winter). This mechanism prevent that germination occurs at the end of the rainy season, avoiding the death of seedlings in the subsequent dry and unfavorable season. The soil temperature range was low (below 10 °C) compared to thermal amplitude found in temperate regions. This suggests an important role of soil moisture (which presents large variations) and not only of temperature in the acquisition and overcome the secondary dormancy. Germinability after 14 months of burial was similar to the initial, demonstrating the ability of the species to form a persistent seed bank. We conclude that the seeds of all studied species form a persistent seed bank and exhibit seasonal cycles of dormancy. (Financial support: CAPES and FAPEMIG)

Seed germination ecology in *Trapa natans*, a widely distributed freshwater macrophyte

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Species with extensive geographical distribution, such as aquatic plants, tend to have a broad regeneration niche including germination strategy suited to avoid the main risks of habitats they occupy. *Trapa natans* L. (water caltrop) is one of the global species occupying an extremely wide yet discontinuous native range across temperate Europe, Asia and Africa: the species has also been introduced to North America and Australia, where it naturalised and reported invasive. It is an extremely important food crop in China and India for its nutritious nuts. At local range, it colonises nutrient-rich shallow areas of lakes, ponds and slow-moving streams and rivers forming a dense mats of floating vegetation. Despite its wide distribution and cultivation value, seed ecology of water caltrop remains poorly investigated. The present study is an attempt to fill this gap. Fresh mature seeds were cold stratified for 0-12 weeks then germinated along a wide range of environmental (temperature, light, oxygen) gradients, and evaluated for its tolerance to desiccation and extreme low temperatures. First, we found out that fresh mature seeds of *T. natans* were physiologically dormant (PD), require at least 9 weeks of cold moist stratification to overcome PD. Second, the non-dormant seeds germinate at wide range of temperature from alternating 14/10°C to 33/10°C and constant 22°C in complete darkness and 14/10h light/dark regime with and without hypoxia conditions. Third, non-dormant seeds were sensitive to desiccation, even failed to tolerate a brief spell of drying at high humidity conditions, but tolerated low temperature down to -14°C. Our findings suggest that the wide seed germination niche could explain the broad distribution of this species at local and global scales.

Functional traits and seed establishment of forest species by direct sowing for restoration of degraded areas

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Functional traits are associated with the strategies of establishment of forest species and restoration by direct sowing depends on the proper selection of species capable of overcoming the environmental filters that constraint seed emergency. We investigated the functional traits related to development (successional group, growth rate, biological fixation of N_2), autecology (leaf shedding, dispersion syndrome, seed size and dormancy and species distribution) and ecological functionality (facilitation, fertilization, fauna attraction) of 32 forest species. These

traits were analyzed based on field emergence of seeds with and without treatments using biological stimulators and polymers. Fast growth rates of adults associated with the ecological group of the pioneers were the traits related to seed emergency. Only four species (*Mabea fistulifera*, *Peltophorum dubium*, *Mimosa bimucronata*, and *Anadenanthera colubrina*) represented 78.4% of total emergency. However, the use of polymers and stimulators favored the emergence of non-pioneer species without biological nitrogen fixation capacity, regardless of the presence of dormancy and seed size. Whereas the choice of species depends on its performance to trigger relevant ecological processes, direct sowing with pioneer species and rapid development promote a facilitation process providing shade conditions and supporting the successional process necessary for the establishment of others species by sowing direct.

Evaluating the use of camera traps in the canopy to examine frugivore visits to *Oreopanax echinops* (Araliaceae) in the highlands of Guatemala

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Studies that examine frugivore assemblages have traditionally relied on focal tree observations. However, this method presents disadvantages in that few trees can be monitored simultaneously and not for periods of 24 hours per day. We deployed camera traps in the canopy of *Oreopanax echinops*, a vulnerable cloud forest tree species of Mesoamerica to identify the frugivores that visit this species and evaluate the effectiveness of this method. Eight camera traps were used to monitor eight trees. To reach the canopy, we used the single rope technique. Cameras were programmed to be active 24 h daily. Trees were monitored during the peak fruiting months (27 March–22 April 2012 and 13 December 2012–7 April 2013). We detected 12 frugivore–omnivore species (nine birds and three mammals). We recorded two nocturnal species (*Potos flavus* and an unidentified rodent) and two threatened bird species (*Oreophasis derbianus* and *Penelopina nigra*). Visitation rates by time of day were not equal and the number of independent events were correlated to sampling effort. Our study suggests that camera trapping in the canopy can be a valuable tool to examine frugivore assemblages, as well as their visitation rates and activity patterns, especially for cryptic and nocturnal species that may not be detected in a traditional focal tree observation. Our results also suggest that O. echinops may provide an important foraging resource for the vertebrate community of our study area. Our method was limited in that we could not determine fruit consumption with certainty for all detection events, quantify fruit consumption, or collect information on fruit handling per visit. This can be overcome by monitoring or experimentally manipulating fruit availability or by combining camera trapping and focal tree observations.

Changes in sensitivity to dormancy break and longevity in two populations of physically dormant seeds of *Senna multijuga*

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Senna multijuga is a widely distributed tree species in Brazil and produces physically dormant seeds which present seasonal germination. Therefore, the objectives of this study were to verify changes in sensitivity to dormancy break and the longevity of seeds in the soil seed bank. The length, width and thickness of 50 seeds from each population were measured using digital calipers. To determine seed mass, 50 seeds were weighed using a precision scale. Forty five nylon bags containing 100 seeds (population 1 and 2) were buried in soil at a depth of 5 cm. Five bags were exhumed at two-month intervals for 18 months and five replications of 25 non-imbibed seeds each were placed in Petri dishes on moist germination paper and incubated in light at 25, 35 and 30/20 ºC. Germinated seeds were counted for 30 days at three-day intervals. After incubation the remaining seeds were manually scarified with aid of sandpaper to assess viability. Soil temperature and rainfall were recorded continuously. Population 1 has larger seeds than population 2. Germination increased mainly at 35 ºC throughout the year for both populations, with a slight increase at the other temperatures. The majority of seeds does not break dormancy until the beginning of the spring in the next year, but increase their sensitivity at higher temperatures. These physically dormant seeds form a transient soil seed bank and increase their sensitivity to dormancy break in the late autumn/early winter. Population 2 has higher proportion of dormant seeds than population 1, and it may be related to the small size of those seeds. (Financial support: CAPES and FAPEMIG)

Germination behaviour of seeds of the vulnerable cactus *Browningia candelaris* (Meyen) Britton & Rose, across a temperature gradient

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Germination responses to temperature might give clues about establishment possibilities of species in a climate changing scenario. Seeds of the columnar cactus *Browningia candelaris* were sown onto a two-way thermogradient plate to evaluate germination responses to temperature. A gradient between 5.8 and 36.3^{0}C was established from front to back during the light phase and from left to right during dark phase, giving a combination of 169 temperatures which considered both alternating and constant temperatures. Germination percentage and rate

were determined and seedling emergence was evaluated. Germination rates were used to obtain cardinal temperatures of germination (base, ceiling (maximum) and optimum temperatures). Results showed that B. candelaris seeds are able to germinate across a wide range of temperatures. Under constant temperatures, germination occurred mainly from 17 at 28^{0}C. A wider range was observed under alternating temperatures, producing germination between 17^{0}C and 31^{0}C during the light phase and between 6^{0}C and 28^{0}C during the dark phase. Cardinal temperatures supported these observations, with the base temperature 11.04°C at constant temperatures, but 8.53°C under alternating temperatures. Extreme temperatures obtained low or no germination. The highest reached was 68 % of germination and 56 % of seedling emergence, which was observed at two thermal conditions, 21-24°C/14-21°C day/night and also with colder nights of 21-26°C/6-9°C. The germination behaviour might be related with two probable windows of seedling establishment in natural habitats, one from unusual but possible rains related to ENSO events and also summer rain events from altiplanic storms.

Acquisition and overcome of secondary dormancy in *Syngonanthus verticillatus* (Eriocaulaceae) seeds

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Syngonanthus verticillatus (Eriocaulaceae) is an herbaceous and perennial species, typical of the rockfields (Campos Rupestres) in southeastern Brazil. This species produces small seeds, dispersed in a non-dormant state. However, the seeds acquire secondary dormancy and present annual dormancy cycles, which follows the seasonality of the occurrence's region. Seed dormancy is acquired during the rainy season and overcome during the dry season, allowing germination at the beginning of the next rainy season. In order to demonstrate the required time to change dormancy status in seeds, we determined: (1) the minimum humidity exposuring time required for seed dormancy acquisition in *S. verticillatus* and (2) the minimum exposure to dry condition required to overcome seed dormancy;. Seeds were buried in moist substrate at 25 °C for 15, 30, 45 and 60 days to induce dormancy. To overcome dormancy, dormant seeds (from the moist substrate treatment) were buried and kept in a dry substrate for 60, 90, 120, 150 and 180 days at 25 °C. At each sampling time, seeds were exhumed and subjected to germination tests at 15, 20, 25 and 30 °C under 12h photoperiod. Our results shown that dormancy was acquired progressively from 15 days (conditional dormancy), reaching absolute dormancy after 60 days in moist substrate, with most evident response in high temperatures (25 and 30 °C). The period of 120 days in dry substrate was not enough to overcome dormancy (after 60 days in wet substrate), but the dormancy was overcome after 180 days under this condition. We conclude that the dormancy acquisition in moist substrate occurs faster than overcome dormancy in dry substrate, showing that *S. verticillatus* seeds are finely adjusted to the seasonality of the occurrence area of the species. (Financial support: CNPq and FAPEMIG)

Morphology and ecophysiology of *Swartzia langsdorffii* Raddi. seeds

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Swartzia langsdorffii Raddi. is a native tree from Atlantic Rain Forest and semi deciduous forest in southeast region of Brazil. This species has large orange fruits, lignified, with abundant resin secretion, high water content and late dehiscence. Each fruit has approximately three large, rounded and brownish seeds, surrounded by a yellow aril, and both of them present high water content after dispersal. Although recalcitrant, seeds are dispersed in the dry season, August, the month with the lowest rainfall of the year in Lavras, Minas Gerais province. Thus, the aims of this work were to evaluate the morphophysiological and anatomical traits that allow seed viability maintenance after dispersal and to identify the true contribution of *S. langsdorffii* pericarp to seed survival and germination. Pores were found distributed in the seed coat and also a great amount of stomata in the hypocotyl-axis protoderm. These structures are probably related to gas exchange between seed and surrounding structures. Phenolic compounds were also observed in this area and probably are responsible for seed protection against decomposers and abiotic stresses. Seeds remain viable in the soil for up to seven months without significant reduction in water content, even despite the low rainfall and relative humidity of soil before the beginning of the rainy season. Additionally, it was possible to verify that seeds do not lose water even when not protected by pericarp and aril, probably due to its shape, size, litter relative humidity and to cutin thickening found in the protoderm cell walls. Seeds inside pericarp or surrounded by the aril presented higher water content and germination percentage, evidencing that these structures are not responsible for restriction of water loss but to allow higher seed water content and being the main responsible for *S. langsforffii* seeds survival and germination after dispersal.

Improving seed viability in storage of species from different alpine grasslands

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Long term seed conservation of alpine plants is thought to be problematic, though the diversity of seed longevity responses highlighted so far do not allow to identify consistent behaviours across alpine species. In this regard, because of the strong pre and post dispersal environmental effect on seed longevity, the possibility that

species response to this trait may be related with habitat provenience cannot be ruled out. Therefore, further experiments are needed to improve the longevity of alpine seeds in storage and to investigate possible patterns across alpine habitats. Here, the life spans of 40 alpine species representing related species from alpine grasslands belonging to Habitat 6230 and 6170 (Natura 2000 classification) were compared. Moreover, the effectiveness of some priming treatments to re-establish the viability loss during storage was investigated on 10 species. Seeds were exposed to controlled ageing test (CAT, at 45°C and 60% RH) and regularly sampled for germination testing. The time taken for viability to fall to 50 % was determined using probit analysis, recording radicle and cotyledon emergence separately. To investigate the effect of osmopriming on seed longevity, 15d-aged seeds of 10 species were osmoprimed at 0, -2.5 and -10.0 MPa for 48 hours in dark at 25oC and then returned to CAT. Seed viability declined, as the period of experimental storage increased, with a significant variation across species. Moreover, in some species radicle emergence was not a reliable indicator of seed viability, while more accurate results were obtained including also the cotyledons emergence. Primed seeds (all treatments) improved the survival/longevity of six species, with -10 MPa providing the greatest rejuvenating effect on aged seeds. Outcome of this study may have important implications to maintain high quality ex situ seed collections of alpine species.

How much do seed banks contribute to species coexistence?

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Seed banks are thought to play an important role in species coexistence through storage effect. For these to occur, species must buffer their populations against unfavourable years, differ in their response to climate variation, and the effect of competition must be high in favourable years. Seeds could contribute to the storage effect if germination responses to environmental variation differ across species or if seed banks buffer the competition effects during an unfavourable year. In this study we aim to determine how can seed banks buffer the competition effects in a semiarid grassland in Southern Mexico. We studied the 24 most abundant species of the grassland, 10 of which were annuals. To describe the seed banks, we buried 600 seeds of each study species at 3 cm depth. We recovered 200 seeds of each species after 6 and 18 months. To assess viability, seeds were placed in petri dishes with agar at 1% and then on moist filter paper with ethephon at 0.01 M. We propose a new method to relate seed bank longevity and competition using models of population dynamics. Species differed in their germination responses, in seed longevity and seed bank size. Four species had transient seed banks and they correspond to perennial grasses. However, the species with the largest seed bank sizes were also perennial species, but with some dormancy mechanism. Our analysis indicates that few species coexist by storage effects. For those which do, larger seed banks are essential to avoid competition and prevent low population growth rates in unfavourable years.

The ecological role of dew in assisting seed germination of the annual desert plant species in a desert environment, northwestern China

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It is important to understand the effects of dew events on non-mucilaginous seed germination of annual desert plant species during dry seasons, which is critical to maintaining long-term soil seed banks in a harsh desert environment. We hypothesize that dew deposition also assists in the non-mucilaginous seed germination of annual desert species. A common field dew treatment experiment was conducted in the Linze Inland River Basin Research Station to investigate the effects of dew deposition on the seed germination of four annual species, including *Agriophyllum squarrosum*, *Corispermum mongolicum*, *Bassia dasyphylla* and *Halogeton arachnoideus*. The results showed that the presence of dew significantly increased seed germination percentages and decreased the nonviable seed percentages of *B. dasyphylla* and *H. arachnoideus*, whereas there was no such trend for the seeds of *C. mongolicum* and *A. squarrosum*. The ecological effects of dew on the seed germination and viability of the annual desert plants were species specific. Although dew wetting is insufficient to cause seed germination, it may help in priming the seeds.

Fire-related cues in germination of *Vellozia* species

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Fire is one of the most important factors affecting plant communities in *Cerrado*, but less is understood about the regeneration strategies and fire-related germination cues. To better understand the response to fire of a common family in *Cerrado*, the Velloziaceae, we exposed ten species of *Vellozia* from different regions from Brazil to heat shock and smoke treatments. We hypothesized that germination would be increased by the smoke treatments and also that seeds would resist to the exposure to high temperatures. We exposed seeds (5 replicates/species with 20 seeds) to 60°, 100° and 200°C for 1 minute (heat shock); and smoke aqueous solutions 1:1 concentration for 24 hs. Results showed a significant increase in germination for three species in response to smoke treatment: *Vellozia albiflora* (Southeastern Brazil, from 44% to 71%), *Vellozia goiasensis* (North Brazil, 45.8% to 59.4%) and *Vellozia seubertiana* (North Brazil, from 63% to 80). All species resisted to the exposure to temperatures of 100°C, and at least half of them resisted to 200°C, except for *V. lilacina*, *V. compacta* (Southeastern Brazil), *V. albiflora*, *V.* sp (Central Brazil), and *V. goiasensis* (North Brazil), which showed a decrease in germination at this temperature. Thus, all *Vellozia* species showed to have fire-resistant seeds, an important trait in fire-prone ecosystems and moreover, three of the study species had their germination enhanced by smoke.


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