



**A DISTÂNCIA FILOGENÉTICA DETERMINA O SALDO
DAS INTERAÇÕES ENTRE PLANTAS EM DUNAS
COSTEIRAS?**

**DOES THE PHYLOGENETIC DISTANCE DETERMINE
THE OUTCOME OF PLANT-PLANT INTERACTIONS
ON COASTAL DUNES?**

LUIZA TRUFFI DE OLIVEIRA COSTA

**Diadema, São Paulo, Brasil
Dezembro - 2023**



A DISTÂNCIA FILOGENÉTICA DETERMINA O SALDO DAS INTERAÇÕES ENTRE PLANTAS EM DUNAS COSTEIRAS?

DOES THE PHYLOGENETIC DISTANCE DETERMINE THE OUTCOME OF PLANT-PLANT INTERACTIONS ON COASTAL DUNES?

LUISA TRUFFI DE OLIVEIRA COSTA

Dissertação apresentada ao Programa de Pós-Graduação em Ecologia e Evolução, da Universidade Federal de São Paulo, como parte dos requisitos para obtenção do título de Mestre em Ecologia e Evolução.

ORIENTADOR: CAMILA DE TOLEDO
CASTANHO

Diadema, São Paulo, Brasil
Dezembro - 2023

Dados Internacionais da Catalogação na Publicação (CIP)

Costa, Luisa Truffi de Oliveira

A distância filogenética determina o saldo das interações entre plantas em dunas costeiras? / Luisa Truffi de Oliveira Costa. – – Diadema, 2023.

80 f.

Dissertação (Mestrado em Ecologia e Evolução) - Universidade Federal de São Paulo - Campus Diadema, 2023.

Orientadora: Camila de Toledo Castanho

1. Ecologia filogenética. 2. Facilitação. 3. Competição. 4. Interação entre plantas. 5. Meta-análise. I. Título.

Agradecimentos

Gostaria de agradecer a minha família pelo apoio, incentivo e carinho. Agradeço principalmente por me darem uma criação que priorizou a liberdade, o estímulo à curiosidade e o contato com a natureza. Também gostaria de agradecer meus amigos que me acompanharam durante todo esse processo, sempre me animando e fazendo com que a vida seja mais leve e alegre, me trazendo um senso de pertencimento. Agradeço principalmente a minhas amigas, Ypi, Astral, Mirtilo, Kats, Coral, Bambi, mulheres fortes e maravilhosas que me acolhem com carinho e amor em todas as horas, é um privilégio compartilhar a minha jornada com vocês.

Agradeço a Camila por ter sido uma excelente orientadora, aprendi muito durante todo esse processo e nossas trocas sempre foram permeadas pela confiança, paciência e respeito. Me senti totalmente à vontade desde o início nessa relação e agradeço muito por todo o apoio e incentivo tanto para a execução do projeto, mas também para meu desenvolvimento individual como pesquisadora e pessoa de modo geral. Ao Alê por me abrir portas e acompanhar em projetos paralelos a este, esse incentivo e confiança são muito importantes para mim. Além disso, agradeço a todos meus colegas de laboratório pela cumplicidade, opiniões, companhia, inúmeros cafés e apoio em diferentes projetos.

Agora um agradecimento especial ao Ariel, que nos momentos bons e nos difíceis sempre está disponível e disposto a me apoiar. Sua presença me incentiva e faz com que a vida seja mais leve e alegre e que eu acredite que tudo é possível. Agradeço pela nossa convivência, companheirismo, carinho e amor que são essenciais para mim. Preciso também agradecer às minhas companheiras felinas, Mia e Baby, que passaram mais tempo que qualquer outra criatura, me observando fazer análises no R e escrevendo esta dissertação sempre oferecendo amor e fofura incondicionais.

Agradeço a CAPES pelo financiamento, que possibilitou minha total dedicação a este projeto, e a Unifesp e seus docentes pela estrutura e disciplinas cursadas durante esse período.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

Sumário:

	Resumo geral	3
I.	Contextualização	5
II.	Does the phylogenetic distance determine the outcome of plant-plant interactions on coastal dunes?	9
	Resumo	9
	Abstract	11
	Introduction	13
	Material e Methods	17
	Results	22
	Discussion	29
	Appendix: The effect of environmental stress and phylogenetic distance on the outcome of plant-plant interactions on coastal dunes	32
	Supplementary material	35
III.	Conclusões gerais	69
	Referências	71

Resumo geral

A ecologia filogenética de comunidades busca compreender quais os principais processos ecológicos em uma comunidade a partir da interpretação de padrões filogenéticos da comunidade. Essa abordagem foca principalmente em dois processos: a competição e o filtro ambiental. Assumindo que o conservadorismo de nicho é comum, ou seja, que o nicho de espécies mais próximas na filogenia seja mais similar do que de espécies mais distantes, comunidades com um padrão filogenético agregado são interpretadas como sendo principalmente afetadas pelo filtro ambiental e comunidades com padrão de sobredispersão filogenética como sendo mais afetadas pela competição. O filtro ambiental geraria uma comunidade agregada filogeneticamente porque seria esperado que quando sob o processo de filtro ambiental somente as espécies próximas que compartilham as características necessárias para viver em ambientes severos estariam presentes na comunidade. Por outro lado, a competição geraria uma comunidade sobredispersa filogeneticamente porque seria esperado que espécies próximas na filogenia tivessem maior sobreposição de nicho, levando à exclusão competitiva e em uma comunidade com poucas espécies aparentadas coexistindo. Outros processos ecológicos raramente são considerados em análises de ecologia filogenética. Esse é o caso da facilitação, um processo importante para ecologia vegetal porém pouco explorado pela ecologia filogenética e outras análises ecológicas. A facilitação ocorre quando a performance de uma planta é melhor quando próxima a uma vizinha facilitadora do que quando se desenvolve de forma isolada. A vizinha pode aliviar condições estressantes para plantas menos tolerantes por meio de alterações ambientais como alteração da intensidade solar excessiva, aumento da umidade ou aumento de nutrientes limitantes, por exemplo, pela fixação de nitrogênio. É possível esperar que a facilitação seja mais intensa entre espécies distantes na filogenia por causa da complementaridade de nicho. Até agora existem evidências empíricas e teóricas conflitantes para a utilização da distância filogenética como um proxy para o saldo da interação entre espécies e poucos trabalhos exploram diretamente o efeito da distância sobre o saldo das interações. Entre plantas, o hábito de vida e o estágio ontogenético são reconhecidos como importantes para determinar o saldo das interações. Essas características são, respectivamente, somente parcialmente conservadas e totalmente independentes da filogenia. Isso as torna características interessantes para analisar em conjunto com a distância filogenética. As dunas costeiras são um ambiente severo que pode limitar o desenvolvimento das plantas. Nesse ambiente já foram observadas interações de facilitação e competição, mas ainda carecem explicações sobre quais os principais fatores

que determinam o saldo das interações. Neste trabalho avaliamos o efeito da distância filogenética no saldo das interações entre plantas nas dunas costeiras. Também investigamos se o efeito da distância filogenética é modulado pelo hábito de vida e pelo estágio ontogenético das plantas em interação. Para isso, realizamos uma meta-análise, na qual selecionamos estudos que compararam o desempenho de plantas com plantas vizinhas e plantas isoladas em dunas costeiras do mundo todo. Encontramos que a distância filogenética não afeta o resultado das interações entre plantas (163 observações de 25 estudos), nem a combinação de formas de vida, similaridade de hábitos de vida ou estágio ontogenético modulam o efeito da distância filogenética no saldo das interações. Tanto interações positivas quanto negativas foram observadas para interação entre espécies próximas na filogenia e para espécies distantes. Portanto, contrariamente às nossas expectativas, a distância filogenética não foi relevante na determinação das interações entre plantas nas dunas costeiras, mesmo quando considerando o hábito de vida e o estágio ontogenético. Este resultado apoia algumas críticas à ecologia filogenética, principalmente o uso da distância filogenética para inferir processos ecológicos. E também reforça que determinar o saldo das interações entre espécies é uma tarefa complexa e é necessária cautela ao usar proxies para inferi-lo.

Palavras-chave: Ecologia filogenética, facilitação, competição, interações entre plantas, meta-análise

I. Contextualização

A incorporação de análises filogenéticas em ecologia de comunidades busca integrar a história evolutiva das espécies com padrões de co-ocorrência de espécies no mesmo período temporal em um mesmo local. Em 2002 Webb e colaboradores propuseram uma abordagem que utiliza a análise de padrões filogenéticos de comunidades atuais para inferir os principais processos ecológicos que os teriam gerado. Esse campo se desenvolveu rapidamente sob a premissa de que o conservadorismo de nicho e de traços na filogenia são comuns, ou seja, que espécies com menor distância filogenética entre si teriam nichos e características mais similares que espécies com maior distância filogenética (Webb et al., 2002; Cadotte et al., 2019). Essa abordagem foca na análise de processos como filtro ambiental e a competição. É esperado que, devido à limitação de similaridade, espécies próximas filogeneticamente tenham com maior frequência e intensidade interações de competição. No entanto, após duas décadas da publicação que propôs essa abordagem, existem resultados conflitantes, com algumas evidências que apoiam que a distância filogenética seria um bom preditor para competição (Violle et al., 2011), outras que refutam (Cavander-Bares et al., 2009; Bennett et al., 2013) e existem ainda resultados mistos (Cahill et al., 2008). Essa abordagem já foi alvo de críticas em trabalhos teóricos que questionam suas premissas, principalmente a de que somente a similaridade de nicho já seria um indicador suficiente para determinar a prevalência de interações competitivas e que os processos de filtro ambiental e competição são processos mutuamente exclusivos (Gerhold et al., 2015; Mayfield and Levine, 2010). Além disso, o foco na dicotomia dos processos de filtro ambiental e competição acaba desconsiderando outros processos importantes para comunidades, como a facilitação (Valiente-Banuet & Verdú, 2013; Duarte et al., 2020).

As interações entre plantas, tanto as positivas, facilitação, quanto as negativas, competição, são capazes de influenciar profundamente a estrutura e dinâmica de comunidades vegetais (Brooker et al., 2008). Interações que provoquem impactos negativos nos indicadores de desempenho indicam competição, enquanto interações que provoquem impactos positivos indicam facilitação. A planta alvo está sujeita tanto a efeitos positivos quanto negativos que a vizinha pode provocar simultaneamente e o saldo das interações é utilizado para estimar se existe predomínio de um processo sobre o outro. Quando o desempenho da planta alvo na presença da vizinha é melhor que quando isolada existe o predomínio da facilitação e quando o desempenho da alvo é inferior na presença da vizinha existe o predomínio da competição.

A competição entre pares de espécies de plantas ocorre principalmente pela diminuição na disponibilidade de recursos essenciais como água, nutrientes e espaço (Tilman & Pacala, 1993). A sobreposição de nicho pode levar a uma maior competição porque os recursos limitantes necessários para manutenção das plantas são similares, resultando em uma interação com saldo negativo. A competição pode ainda estar relacionada à interferência no desenvolvimento da planta alvo, como no caso de efeitos alelopáticos produzidos pela planta vizinha (Petrankská & McPherson, 1979). Por outro lado, a facilitação envolve melhora das condições ambientais ou aumento na disponibilidade de recursos limitantes, por exemplo, por meio da diminuição da incidência de radiação solar excessiva, redução de temperatura, aumento da umidade ou da disponibilidade de nutrientes (Azevedo & Morgan, 1974; Callaway, 1995; Nara & Hogetsu, 2004). A facilitação entre plantas pode ainda ocorrer de modo indireto por meio da presença de um terceiro organismo, como nos casos de proteção contra herbívoros, atração de polinizadores ou dispersores de sementes (McAuliffe, 1984; Thomson, 1982; Bergamo et al., 2020; Louthan et al., 2014). Interações positivas devem ser mais frequentes entre plantas com características diferentes, porque características diferentes podem levar à complementaridade funcional devido à menor sobreposição de nichos e uso diferente de recursos (Navarro-Cano et al., 2019; Navarro-Cano et al., 2021). Apesar dos processos de competição e facilitação produzirem efeitos opostos nos indicadores de desempenho das plantas, um mesmo par de plantas pode simultaneamente estar sob a influência desses dois processos (Ludwig et al., 2004). Por exemplo, pode ocorrer a competição por nutrientes e simultaneamente ocorrer uma relação de facilitação associada à condição hídrica do solo.

Apesar de escassos, existem trabalhos que analisam o efeito da distância filogenética sobre o saldo das interações entre plantas. Há evidências de que a distância filogenética pode levar à complementaridade de nicho. Por exemplo, o conteúdo de nitrogênio é conservado filogeneticamente e as plantas facilitadoras que fixam nitrogênio beneficiam espécies relacionadas mais distantes do que espécies estreitamente relacionadas (Montesinos-Navarro et al., 2017). Em comunidades de plantas nos desertos do México, Valiente-Banuet & Verdú (2008) observaram que a probabilidade de uma interação de facilitação entre um vizinho adulto e uma plântula alvo desaparecer à medida que a plântula cresce era inversa à distância filogenética entre as plantas.

As dunas costeiras são um ambiente que tem atraído a atenção como um contexto interessante para investigação de interações entre plantas devido às suas condições abióticas severas ao desenvolvimento vegetal (Castanho et al., 2015a). Condições como a alta

temperatura, salinidade e exposição ao vento, baixa disponibilidade de nutrientes, instabilidade do solo e baixa retenção de água podem limitar o desenvolvimento vegetal (Lane et al., 2008). A presença de plantas vizinhas pode amenizar tais condições para plantas menos tolerantes (Castanho & Prado, 2014). Nesse ambiente, geralmente as plântulas têm melhor desempenho quando estão perto de plantas vizinhas adultas do que quando crescem sozinhas, sugerindo que o processo de facilitação é importante nestas comunidades (Castanho et al., 2015b; Shumway 2000). Por outro lado, também há evidências de competição entre plantas vizinhas em dunas costeiras arenosas (Cheplick, 2005; Armas & Pugnaire, 2009). A ocorrência tanto de interações positivas quanto negativas torna este ambiente um excelente modelo para explorar como o contexto em que as interações ocorrem afeta o saldo das interações entre as plantas. O efeito da distância filogenética nas interações das plantas neste ecossistema permanece pouco explorado (mas ver Zhang et al., 2016) e a interação entre o efeito da distância filogenética com o efeito do hábito de vida e do estágio ontogenético nas interações das plantas, até onde sabemos, nunca foi explorado neste ecossistema.

Neste trabalho avaliamos o efeito da distância filogenética no saldo das interações entre plantas em dunas costeiras. Para isso realizamos uma meta-análise, que permite uma síntese quantitativa do conhecimento atual sobre as interações das plantas neste ambiente. Previmos que plantas com relações filogenéticas próximas teriam interações negativas com mais frequência e plantas com relações filogenéticas distantes teriam interações neutras ou positivas com mais frequência. Também exploramos se o hábito de vida e o estágio ontogenético das plantas em interação modulam o efeito da distância filogenética no saldo das interações das plantas. Essas são características reconhecidas como importantes para determinação do saldo da interação entre plantas e são, respectivamente, parcialmente e completamente independentes da filogenia, tornando interessante a análise de como essas características poderiam afetar o efeito da distância filogenética sobre o saldo das interações. Para o hábito de vida, previmos que o efeito da distância filogenética seria mais forte para plantas com o mesmo hábito de vida do que para plantas com formas de vida diferentes. Isso porque a distância filogenética poderia informar sobre a sobreposição de nicho de plantas com formas de vida similares e melhor prever o saldo da interação, enquanto para plantas com diferentes formas de vida a diferença no hábito de vida poderia já ser informativa para determinação do saldo. Para o estágio ontogenético previmos que as interações negativas seriam mais frequentes entre adultos do que entre um adulto e uma plântula, mas que a distância filogenética seria importante para ambos. Isso porque é comum que adultos tenham uma maior capacidade de consumo de recursos comuns que poderia gerar uma interação de

competição entre eles, no entanto é comum nesse ambiente que plântulas sejam menos tolerantes às condições ambientais e tenham uma melhor performance quando próximas a vizinhas adultas que tornam as condições mais amenas.

II. Does the phylogenetic distance determine the outcome of plant-plant interactions on coastal dunes?

Resumo

1. A ecologia filogenética usa padrões filogenéticos para inferir processos ecológicos de comunidades. É esperado que, por causa da sobreposição de nicho, a competição seja mais intensa entre espécies próximas na filogenia. Interações positivas, como a facilitação, raramente é considerado em análises de ecologia filogenética, mas é possível esperar que a facilitação seja mais intensa entre espécies distantes na filogenia por causa da complementaridade de nicho. Até agora existem evidências conflitantes para a utilização da distância filogenética como um proxy para o saldo da interação entre espécies.
2. Entre plantas o hábito de vida e o estágio ontogenético são reconhecidos como importantes para determinar o saldo das interações. Essas características são, respectivamente, somente parcialmente conservadas e totalmente independentes da filogenia. Isso as torna características interessantes para analisar em conjunto com a distância filogenética.
3. As dunas costeiras são um ambiente severo que pode limitar o desenvolvimento das plantas. Nesse ambiente já foram observadas interações de facilitação e competição, mas ainda carecem explicações sobre quais os principais fatores que determinam o saldo das interações. Neste trabalho avaliamos o efeito da distância filogenética no saldo das interações entre plantas nas dunas costeiras. Também investigamos se o efeito da distância filogenética é modulado pelo hábito de vida e pelo estágio ontogenético das plantas em interação. Para isso, realizamos uma meta-análise, na qual selecionamos estudos feitos em dunas costeiras do mundo todo que compararam o desempenho de plantas com plantas vizinhas e plantas isoladas.
4. A distância filogenética não afetou o resultado das interações entre plantas (163 observações de 25 estudos), nem a combinação de formas de vida, similaridade de hábitos de vida ou estágio ontogenético modulam o efeito da distância filogenética no saldo das interações. Portanto, contrariamente às nossas expectativas, estas características não foram relevantes na determinação das interações entre plantas nas dunas costeiras. Este resultado apoia algumas críticas sobre o uso da distância filogenética para inferir processos ecológicos. E também reforça que determinar o

saldo das interações entre espécies é uma tarefa complexa e é necessária cautela ao usar proxies para inferi-lo.

Síntese: A distância filogenética não é um bom preditor para o resultado das interações planta-planta nas dunas costeiras. Mesmo quando se considera o hábito de vida e a combinação do estágio ontogenético das plantas em interação e o estresse ambiental em que as interações ocorrem. Estas descobertas rejeitam a hipótese de que a distância filogenética é um bom proxy para estimar as interações entre espécies.

Palavras-chave: Ecologia filogenética, facilitação, competição, interações entre plantas, meta-análise

Abstract

1. Phylogenetic ecology uses phylogenetic patterns to infer ecological community processes. Competition is expected to be stronger between closely related species because of higher niche overlap. Facilitation is rarely considered in ecological phylogenetic analysis, but it could be expected to be stronger between distantly related species because of niche complementarity. So far there are mixed results as to whether phylogenetic distance is a good proxy for species interactions.
2. Among plants, the growth form and ontogenetic stage are characteristics that have been recognized as good at determining the outcome of plant-plant interactions. These characteristics are, respectively, only partially conserved and completely independent of the phylogenetic relatedness, which makes them interesting to analyze along with the effect of phylogenetic distance.
3. Coastal dunes are a harsh environment for plant development in which both facilitation and competition have been observed but there is limited understanding of which factors determine the outcome of the interactions. We evaluated the effect of phylogenetic distance on the outcome of plant interactions on coastal dunes. We also investigated if the effect of the phylogenetic distance was modulated by the growth form and the ontogenetic stage of the interacting plants. To achieve this we conducted a meta-analysis, in which we selected studies done in coastal dunes that compared the performance of plants with neighbors and isolated plants.
4. We found that phylogenetic distance did not affect the outcome of plant interactions (163 observations, 25 studies), nor did growth form combination, similarity or ontogenetic stage modulate the effect of phylogenetic distance on the interactions outcomes. Therefore, contrary to our expectations these characteristics were not relevant in determining plant-plant interactions in coastal dunes. This result supports some criticism about using phylogenetic distance to infer ecological processes, and also reinforces that determining the outcome of species interactions is a complex task and caution is needed when using proxies to infer it.

Synthesis: The phylogenetic relatedness is not a good predictor for the outcome of plant-plant interactions in coastal dunes. Even when considering the growth form and the ontogenetic stage in combination with the interacting plants and environmental stress in which the interactions occur. These findings reject the hypothesis that phylogenetic distance is a good proxy for species interactions.

Key-words: Phylogenetic ecology, facilitation, competition, plant-plant interactions, meta-analysis

Introduction

Phylogenetic community ecology analyzes community phylogenetic patterns to infer the main processes responsible for structuring communities (Webb et al., 2002). This field has grown under the assumption that closely related species have more similar traits due to phylogenetic conservatism. Therefore, due to limiting ecological similarity, competition is expected to occur more frequently between closely related species (Webb et al., 2002). However in the 20 years after the publication of Webb et al. (2002) there has been mixed results (Cahill et al., 2008) and both evidence to support (Violle et al., 2011) and oppose (Cavander-Bares et al., 2009; Bennett et al., 2013) that phylogenetic distance is a good predictor for competition. Also, there have been theoretical criticisms to the assumptions made in this framework, especially challenging the extent to which only niche similarity translates into more intense competition between individuals and also questioning whether competition and environmental filters are mutually exclusive processes (Gerhold et al., 2015; Mayfield and Levine, 2010). Besides that, work in this field has focused mostly on the dichotomy between competition and environmental filtering, while facilitation between plants is rarely considered in ecological phylogenetic analysis (Valiente-Banuet & Verdú, 2013; Duarte et al., 2020).

Plant-plant interactions, facilitation and competition, are both important factors in the dynamics and structure of plant communities. These two key processes can occur simultaneously in a given pair of interacting individuals and the prevalence of one process over the other is context dependent (Maestre et al., 2003; Brooker et al., 2007). One way of investigating which process is prevalent in a given interaction between a pair of plants is observing the performance of a target plant when developing in isolation and comparing it to its development when near a neighbor plant. Positive interactions are more frequent when the neighboring plants have traits that promote changes in environmental conditions and resources that favor the development of a target plant. Furthermore, positive interactions are more frequent between plants with different traits, because different traits may lead to functional complementarity due to less niche overlapping and different resource use (Navarro-Cano et al., 2019; Navarro-Cano et al., 2020). Therefore, considering that the traits tend to be conserved in the phylogeny of the plants, phylogenetic distance could help understand the variation in the outcome of plant interactions.

Though scarce, there are studies that investigated the influence of phylogenetic distance on the outcome of plant-plant interactions. There is evidence that phylogenetic distance could lead to niche complementarity, for example nitrogen content is phylogenetic

conserved and nurse plants that fix nitrogen benefit more distantly related species than closely related species (Montesinos-Navarro et al., 2017). Previous work in plant communities in the deserts of Mexico by Valiente-Banuet & Verdú (2008) found that the probability of a facilitative interaction between an adult neighbor and a seedling target disappeared as the seedling grew and was inversely determined by the phylogenetic distance between the plants. Furthermore, in a review about restoration experiments it was observed that, for plants with the same growth form, the survival increases when the neighboring plant is more phylogenetically distant to the target plant (Verdú et al., 2012). The authors of this work argue that increasing phylogenetic distance ensures less similarity of phenotypic traits between plants with the same growth form, thus decreasing competition between them (Verdú et al., 2012). Therefore, phylogenetic distance could be a good predictor of the outcome of interactions, capable of estimating differences between niches of plants belonging to the same growth form in a given environment.

Nevertheless, not all characteristics can be inferred through phylogenetic distance; the ontogenetic stage, for example, is completely independent of evolutionary history. And although some characteristics, such as growth form, are usually conserved (Qian & Zhang, 2014), there are examples of families, such as Fabaceae, in which there is a lot of variability (Simon et al., 2009). Both growth form and ontogenetic stage are plant characteristics that are indicators of resource exploitation mode, tolerance to abiotic conditions and the ability to change the surrounding environment. Thus, these characteristics also are niche indicators for plants. Previous investigations point towards the ontogenetic stage being contextually relevant for determination of the outcome of plant interactions. For example, it has been observed in harsh environments, for the same pair of species, that there is a predominance of neutral and negative interactions between adult plants, while adults tend to positively impact seedling performance (Schiffers & Tielbörger, 2006; Armas & Pugnaire, 2009; Urza et al., 2019). This pattern is so often explored in the literature that a specific term for these adult plants that benefit younger plants has been established: nurse plants.

The plant's growth form is also recognized as contextually important for plant interactions, but there is mixed evidence on how plant growth form combination may affect the outcome of plant-plant interactions. In a meta-analysis about restoration herbs had negative effects on themselves and on trees growth and survival, while trees had a positive effect on their own survival, were neutral on growth and had a negative effect on herb growth (Gomez-Aparicio, 2009). There is also evidence that eudicots experience stronger competition with closely related species and monocots experience stronger competition with

more distant related species when all growth forms are analyzed together (Cahill et al., 2008). However, when analyzing the effect of phylogenetic distance only within each group there was no effect for eudicots and monocots had a stronger competition effect with phylogenetically close monocots. This probably happened because eudicots and monocots are distantly related and eudicots can be stronger competitors for light than monocots. Therefore, it is possible to expect some variability in phylogenetic distances within growth form combination groups, which make it an interesting characteristic to investigate along with phylogenetic distance.

Coastal dunes are an environment that has attracted attention as an interesting context for investigation of plant interactions because of its severe abiotic conditions. These conditions are considered limiting to plant development (Castanho et al., 2015a) due to high temperature, salinity and wind exposure, low availability of nutrients, soil instability, and low water retention (Lane et al., 2008). The presence of neighboring plants can mitigate such conditions to sensitive plants (Castanho & Prado, 2014). In this environment, young plants often have better performance when near neighboring plants than when growing alone, suggesting that the facilitation process is relevant in these communities (Castanho et al., 2015b; Shumway, 2000). On the other hand, there is also evidence of competition between neighboring plants in sandy coastal dunes (Cheplick, 2005, Armas & Pugnaire 2009). The occurrence of both positive and negative interactions makes this environment an excellent model to explore how contextual factors affect the outcome of plant interactions. The effect of phylogenetic distance on the plant interactions in this ecosystem remains mostly unexplored (but see Zhang et al., 2016) and the interaction between the effect of phylogenetic distance with the effect of growth form and ontogenetic stage on plant interactions, as far as we are aware, has never been explored in this ecosystem.

In this study we evaluated the effect of phylogenetic distance on the outcome of plant interactions in coastal dunes. To achieve this we conducted a meta-analysis, which allows for a quantitative synthesis, on plant interactions in this environment. We predicted that plants with close phylogenetic relationships would have negative interactions more frequently and plants with distant phylogenetic relationships would more frequently have neutral or positive interactions (Figure 1). We also explored whether the growth form and ontogenetic stage of the interacting plants modulate the effect of the phylogenetic distance on plant interactions, as these characteristics are, respectively, only partially conserved and completely independent of the phylogenetic distance. For the growth form we predicted that the effect of the phylogenetic distance would be stronger for plants with the same growth form than for plants

with different growth forms (Figure 2). For the ontogenetic stage we predicted that negative interactions would be more frequent between adults than between an adult and a seedling, but that the phylogenetic distance would be important for both, with closely related plants having more negative interactions than distantly related plants (Figure 3).

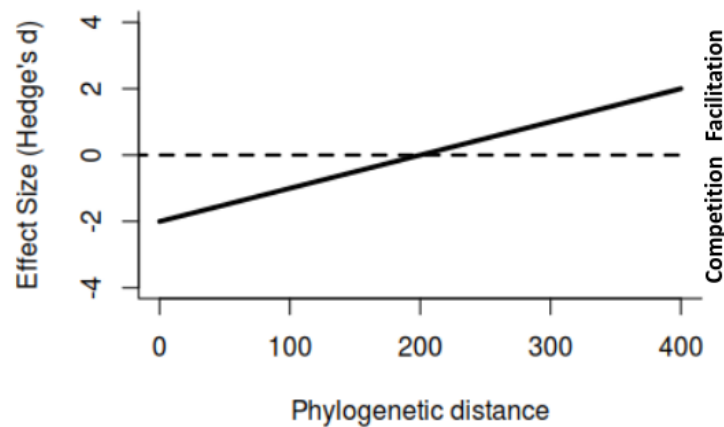


Figure 1. The expected effect of the phylogenetic distance on the outcome of plant-plant interactions on coastal dunes. Positive values of effect size are associated with the prevalence of facilitation and negative values of effect size are associated with prevalence of competition. Dots represent expected effect size of each outcome and the line represents the expected mean effect size.

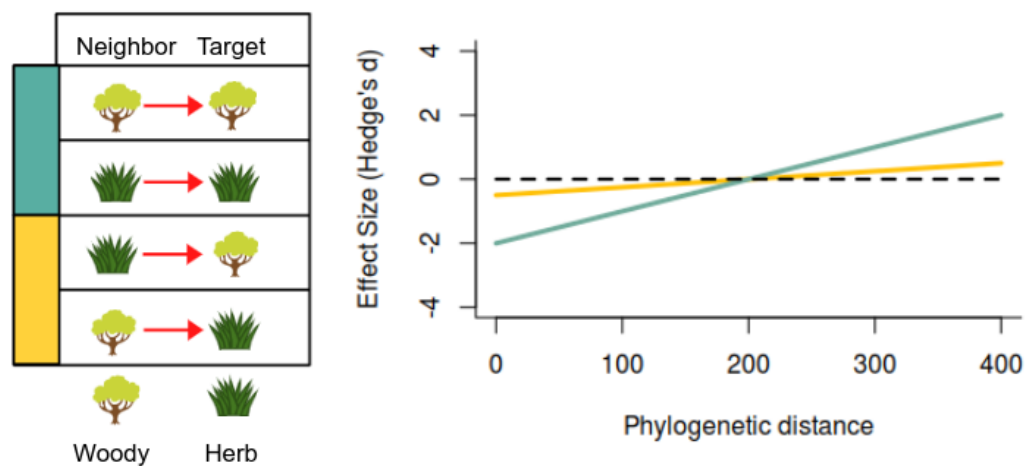


Figure 2. Prediction of the effect of the phylogenetic distance and growth form on the outcome of plant-plant interactions on coastal dunes. Positive values of effect size are associated with the prevalence of facilitation and negative values of effect size are associated with prevalence of competition. Blue represents the interaction between plants with the same growth form and yellow the interaction between plants with different growth forms. Dots represent expected effect size of each outcome and the line represents the expected mean effect size.

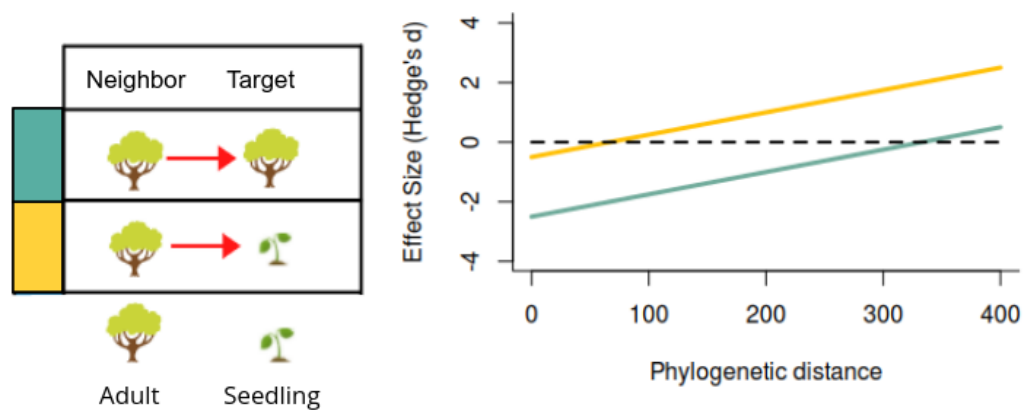


Figure 3. Prediction of the effect of the phylogenetic distance and ontogenetic stage on the outcome of plant-plant interactions on coastal dunes. Positive values of effect size are associated with the prevalence of facilitation and negative values of effect size are associated with prevalence of competition. Blue represents the interaction between adult plants and yellow the interaction between an adult neighbor with a seedling target. Dots represent expected effect size of each outcome and the line represents the expected mean effect size.

Methods

Data collection

To perform our meta-analysis we conducted a survey of the published studies about plant interactions in coastal sand dunes. The literature was queried by using ISI Web of Science and Scopus in November 30, 2022 with the following key terms: (("dune*" OR "restinga" OR "sand* coastal plain" OR "coastal vegetation" OR "coastal ecosystem") AND ("facilitation" OR "positive interaction*" OR "positive effect*" OR "facilitative" OR "competitive" OR "competition" OR "negative interaction*" OR "negative effect*" OR "plant* interaction*" OR "nurse* plant*" OR "density-dependenc*" OR "distance-dependenc*" OR "interference" OR "conspecific*" OR "parent* plant*")) AND ("plant*" OR "tree*" OR "shrub*" OR "herb*" OR "seed*" OR "sprout*")). This search led to 1323 publications which were selected through two screening steps. First we screened the articles only by title and abstract according to our first set of inclusion criteria: i) studies about plant interactions, ii) on coastal dunes, iii) with suitable performance indicators, and iv) based on primary data. Then the selected articles in this first stage ($n = 168$) were read and screened by our second set of inclusion criteria: i) had adequate experimental design (experimental design with a treatment group, the target plant performance with only one species of neighbor plant, and a control, target plant performance when isolated), ii) the area

did not have recent perturbation history, iii) plant species were properly identified, iv) had data required to estimate effect sizes, v) was about angiosperms, and vi) had suitable performance indicators. We selected 25 publications, of which we extracted 163 outcomes for our meta-analysis (Figure 4). When there was a different combination of target and neighbor plants, different study areas, different dune physiognomies or different performance indicators in the same article, each different result was registered as a different outcome.

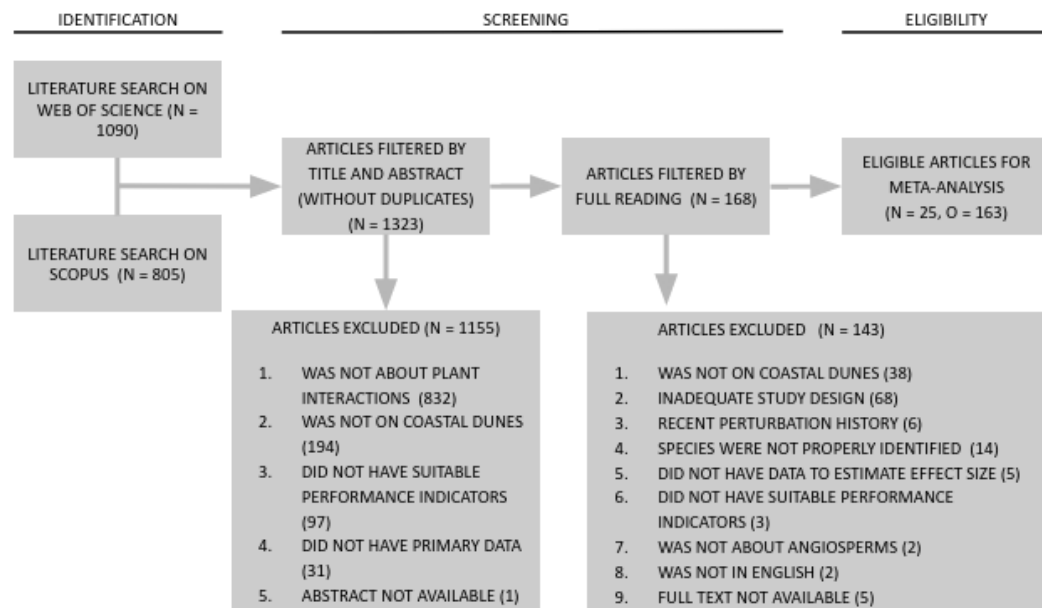


Figure 4. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram flow diagram displaying the number of papers (N) and observations (O) for each step in the process of identification, screening and eligibility.

For all outcomes we extracted data about the study area, experimental design, characteristics of the neighbor and target plant, performance indicator and treatment/control responses (S1) from the articles. One of the characteristics of the neighbor and target plant that we identified was each plant's growth form, which we first registered as literally described by the article. In cases where the article did not identify the growth form of the plants we searched the species description on local herbariums websites to register it. Then we created a second growth form category in which we standardized the growth forms classifying as herb (graminoid and forb) or woody (sub-shrub, shrub and tree). We created an index of growth form combination, in which we registered the neighbor and target plant growth form. We also created an index of growth form similarity, defined as either similar, when neighbor and target were from the same growth form, or different, when neighbor and

target plant were not from the same growth form. Another important plant characteristic we extracted from the article was the ontogenetic stage in which the neighbor and target plant were during the study. We first extracted directly from the study how the authors referred to the plant life stage and then we standardized as seeds, seedlings, not seedlings (young or adult plants), several (study does not control for life stage) or not informed. We had to standardize young and adult plants in a single group because, in many cases, the article provided enough information to assume that the plant was not a seedling, but not enough to assume whether the plant was an adult or in a younger stage between seedling and adult. Then we created an index of ontogenetic stage combination, with the neighbor and the target ontogenetic stage. When data were reported in figures in the original studies, we estimated the values for each sample using the Engauge Digitizer (Mitchell et al. 2020). When any data was not reported in the article we contacted the authors to request it.

Phylogenetic Tree and phylogenetic distance

First we standardized all the species names with the botanical nomenclature of the Leipzig catalogue of vascular plants database through the lcvplants R package (Freiberg et al. 2020). To generate the phylogenetic tree we used our standardized species list in the phylomaker function of the R package V.phylomaker2 (Jin & Qian, 2022). V.phylomaker2 uses a dated mega phylogeny with 74,531 species of vascular plants as a structure to create phylogenies (Jin & Qian, 2022). We used scenario three in the phylomaker function to add the species from our list that were not represented in the mega phylogeny provided by V.phylomaker2; in this scenario, species absent are attached to the phylogeny as polytomies at the middle point of the branch length of their genus. With the phylogenetic tree generated by V.phylomaker2 we estimated the phylogenetic distance that separates the neighbor and target plant species from their most recent common ancestor with the R function cophenetic.

Effect sizes and Meta-analytic models

For each outcome extracted from the articles we calculated an effect size to estimate the difference between the control, target plant performance when isolated, compared to the treatment, target plant performance with the neighbor plant. We used Hedge's *g* as the metric of the effect size of the target plant performance. This metric represents the ratio between the difference in mean outcome between the group of target plants with the neighbor and the group of the target plant without neighbors and the standard deviation of outcome among each observation. Hedge's *g* mean and variance are estimated using the mean, standard

deviation and sample size of each outcome (Borenstein et al., 2009). Outcomes that were represented as contingency tables had to have their results calculated as odds ratios (Borenstein et al., 2009), and later we transformed these effect sizes to hedge's g to standardize all effect sizes in one metric. Positive values of hedge's g indicate the target plant performance was better with the neighbor than when isolated, which could be interpreted as facilitation, and negative values indicate that the target plant performance was worse with the neighbor than when isolated, which could be interpreted as competition. All effect sizes were calculated using the function `escalc` of the package `metafor` (Viechtbauer, 2010) in R.

To assess the effect of different factors on the outcome of plant interactions, we used hierarchical models, which permit the specification of nested groups and, therefore, account for the variance between and within studies when assessing the effect of the phylogenetic relationship on the outcome of plant interaction. We ran all models using the `rma.mv` function in the `metafor` package in R (Viechtbauer, 2010). For all models we used as random effects the study identity and outcome identity. We included study identity as a random factor to control dependent effects among effect sizes extracted from the same study. We also included the outcome identity so we could differentiate the variability in the heterogeneity analysis that was due the variability within studies and the variability between studies.

First, we ran an overall model with only the random variable to assess the variation on effect sizes in our dataset and the overall effect of the presence of a neighbor plant in the target plant performance. In our phylogenetic relationship model we first analyzed the effect of phylogenetic distance on the outcome of plant interactions with all our data (all performance indicators). We then tested the effect of the phylogenetic relationship on the outcome of plant interaction for each performance variable independently by running the same model described above with the subset of data for each performance indicator.

To investigate if the growth form combination modulates the effect of the phylogenetic relationship on the outcome of the interactions, we used the combination of neighbor plant growth form and target plant growth form as an explanatory variable interacting with the phylogenetic distance (Table 1). We also tested the effect of growth form similarity with phylogenetic distance on the outcome of plant-plant interaction. In this analysis, we investigated the effect of the similarity of the growth form between the neighbor and target plant. Growth form similarity was defined as similar when both neighbor and target plant were either herbs or woody and as dissimilar when each plant was from a different growth form. To investigate if the ontogenetic stage modulates the effect of the phylogenetic relationship on the outcome of the interactions, we used the combination of

neighbor plant ontogenetic stage and target plant ontogenetic stage (not seedling-not seedling and not seedling-seedling) as an explanatory variable interacting with the phylogenetic distance.

Table 1. Models used in the meta-analysis and the fixed and random variables used in each model.

Model	Explanatory variables	Random variables
Overall model	none	study id and outcome id
Phylogenetic relationship	Phylogenetic distance between neighbor and target plant	study id and outcome id
Phylogenetic relationship (only with data of each performance indicator individually)	Phylogenetic distance between neighbor and target plant	study id and outcome id
Phylogenetic relationship and combination of neighbor and target plant growth forms (woody-woody, herb-herb, woody-herb))	Phylogenetic distance between neighbor and target plant * growth form combination	study id and outcome id
Phylogenetic relationship and growth form similarity (defined as herb or woody)	Phylogenetic distance between neighbor and target plant * growth form similarity index	study id and outcome id
Phylogenetic relationship and ontogenetic stage combination	Phylogenetic distance between neighbor and target plant * ontogenetic stage combination	study id and outcome id

Heterogeneity, publication bias and sensitivity analysis

To assess the heterogeneity of the observed outcomes for each model we calculated the Q-statistic (often called QT) (Borenstein et al., 2009). It represents a test in which the null hypothesis states there is one common effect size for all observations. Therefore, a significant Q test result indicates heterogeneity in the observed outcomes, which is expected when running hierarchical models. As another measure of the heterogeneity we used I^2 statics (Higgins and Thompson, 2002), which varies from 0 to 1 and represents the percentage of variability that is not linked with the sampling variance.

Publication bias refers to a higher likelihood of statistically significant findings being published than non-significant findings, which could impact the robustness of the results. We estimated publication bias in two ways. First through a visual analysis of funnel plots using the precision (inverse of the standard error) and effective sample size. Since this method assumes that data heterogeneity is null, which is not an appropriate assumption in ecological meta-analysis, we just used it as a visual exploratory analysis (Nakagawa et al., 2023). Then we performed a modified version of the Egger's regression appropriate for hierarchical

models (Nakagawa & Santos, 2012). We ran Egger's regressions with the residuals of the hierarchical models as the response variable and the effect size precision as the moderator. If the intercept of the Egger's regression was significantly different from zero, it would be considered as a sign of publication bias (Nakagawa & Santos, 2012).

We assess the sensitivity of our analysis by searching for influential outliers. Influential outliers are extreme values that could change the result of the analysis. We searched for influential outliers for all the analyses, individually, by using two indicators: hat values and standardized residual values. Effect sizes that had both: hat values greater than two times the average hat value of each dataset and standardized residual values exceeding 3.0, were considered influential outliers (Viechtbauer & Cheung, 2010; Hakeck & Schultz, 2015). If any effect size was considered an influential outlier it would be excluded from the analysis and the analysis would be run again without the influential outlier. Then we would assess if that outlier significantly changed the result of the model and if it did the result without the outlier would be the result reported.

Results

Database

Our search terms led to 1323 publications on Web of Science and Scopus. Out of these 1323, 25 articles meet our all research criteria (Figure 4). We extracted 163 outcomes from these 25 articles, of which 43 had survival as the performance indicator, 40 abundance, 53 growth, 13 reproduction, 11 emergence and 3 occurrence. Among the 163, 131 of the outcomes observed were studies about interspecific interactions and 32 were studies about intraspecific interactions. The articles had data collected in 9 countries (59 outcomes in the USA, 34 France, 18 Italy, 15 Spain, 12 Israel, 11 Brazil, 8 Mexico, 4 South Africa, 2 Canada) (Figure 5).

Phylogenetic tree

In our outcomes there were data from 56 species, from 25 families (Figure 6). The minimal phylogenetic distance between a neighbor and target plant was 0 (when the outcomes were about intraspecific interactions) and the maximal phylogenetic distance was 271.52 Myr (S3).

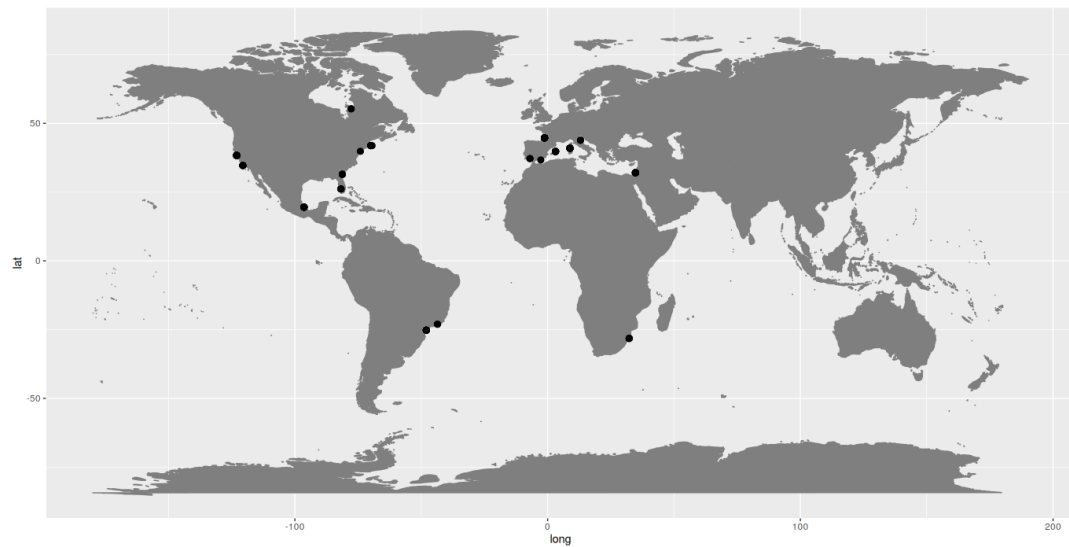


Figure 5. Global distribution of the selected studies research sites. The list of references used can be seen in S1.

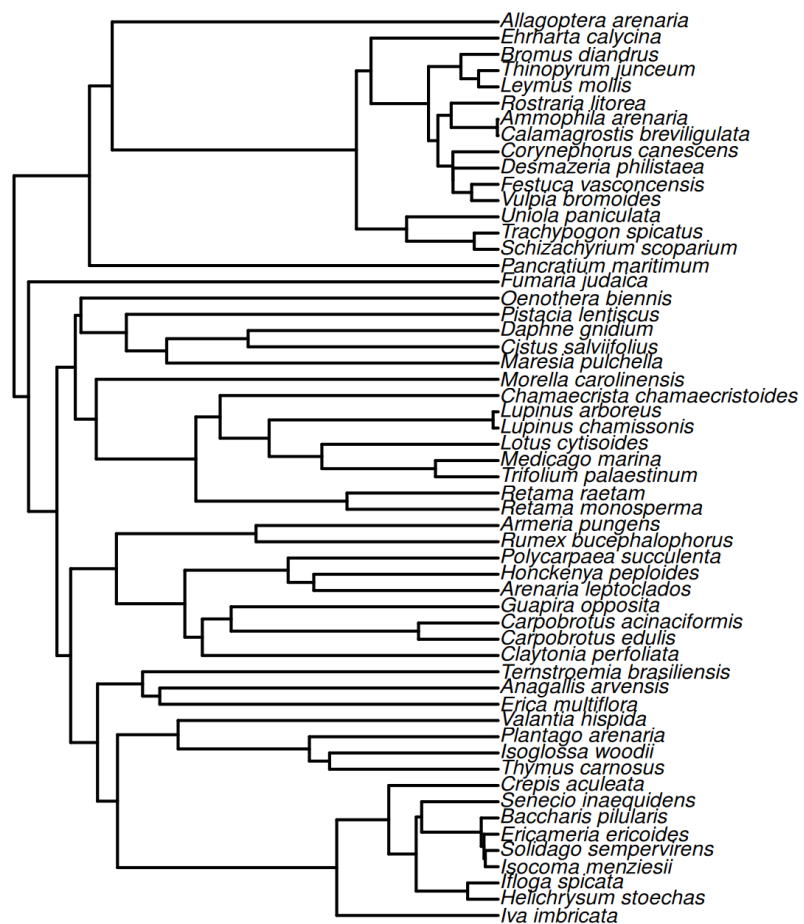


Figure 6. Phylogenetic tree of species present in the meta-analysis.

Factors affecting plant interactions:

Overall model

The overall effect of having a neighbor was neutral to the target plant performance ($p = 0.49$, Figure 7). However, the heterogeneity test was significant indicating that the outcomes do not share a common effect size and that the observed variability could be potentially explained by explanatory variables ($p < 0.0001$).

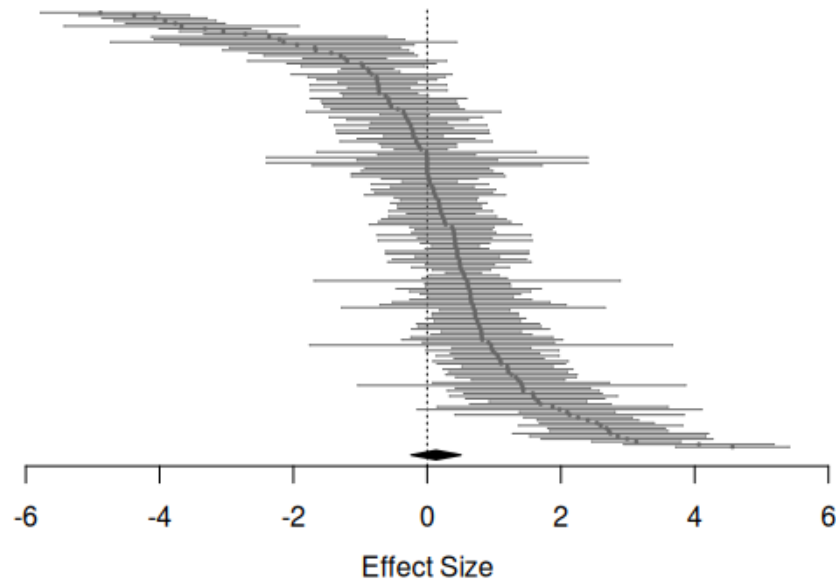


Figure 7. Variation on effect sizes distribution. Ordered forest plot of the effect sizes of the influence of a neighbor plant in the performance of a target plant. Each black dot represents the mean effect size of one outcome and the lines represent the effect size variance of that outcome. The black diamond on the bottom represents the overall mean and 95% confidence interval (CI). Negative effect sizes indicate the target plant had a worse performance in the presence of the neighbor than when isolated and positive effect sizes indicate the target plant had a better performance in the presence of the neighbor than when isolated. This analysis contains 163 outcomes from 25 studies.

Phylogenetic model

The phylogenetic distance between the neighbor and target plant did not affect the outcome of plant interactions when all performance indicators were considered together ($p = 0.92$, Figure 8). The phylogenetic distance also did not affect the outcome of plant interactions when performance indicators (abundance, growth, reproduction and survival) were considered individually ($p = 0.08$, $p = 0.41$, $p = 0.50$, $p = 0.69$, respectively; Figure 9).

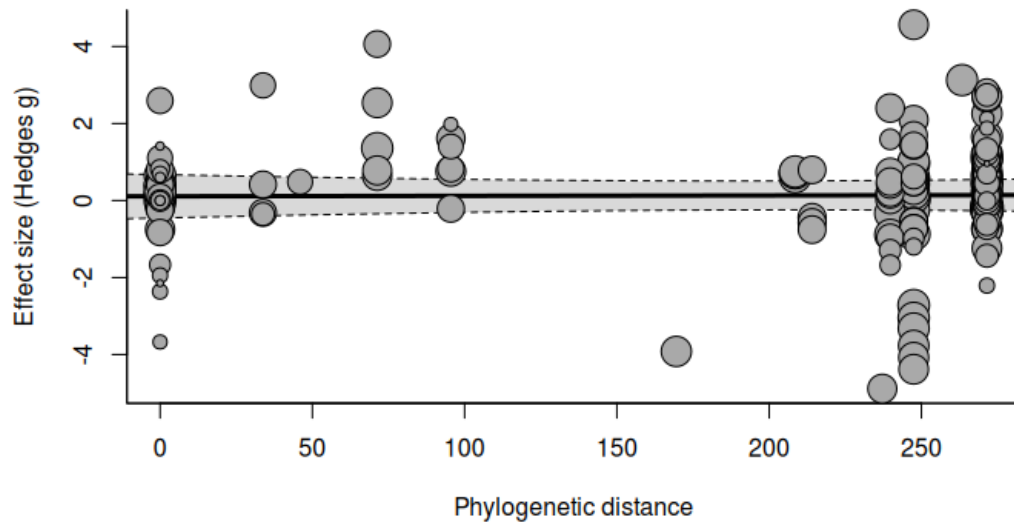


Figure 8. Phylogenetic distance did not affect the outcome of plant interactions ($p = 0.92$). The gray dots represent the effect size of each outcome (163) and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid line and the 95% CI is represented by the gray shaded area and the dotted lines.

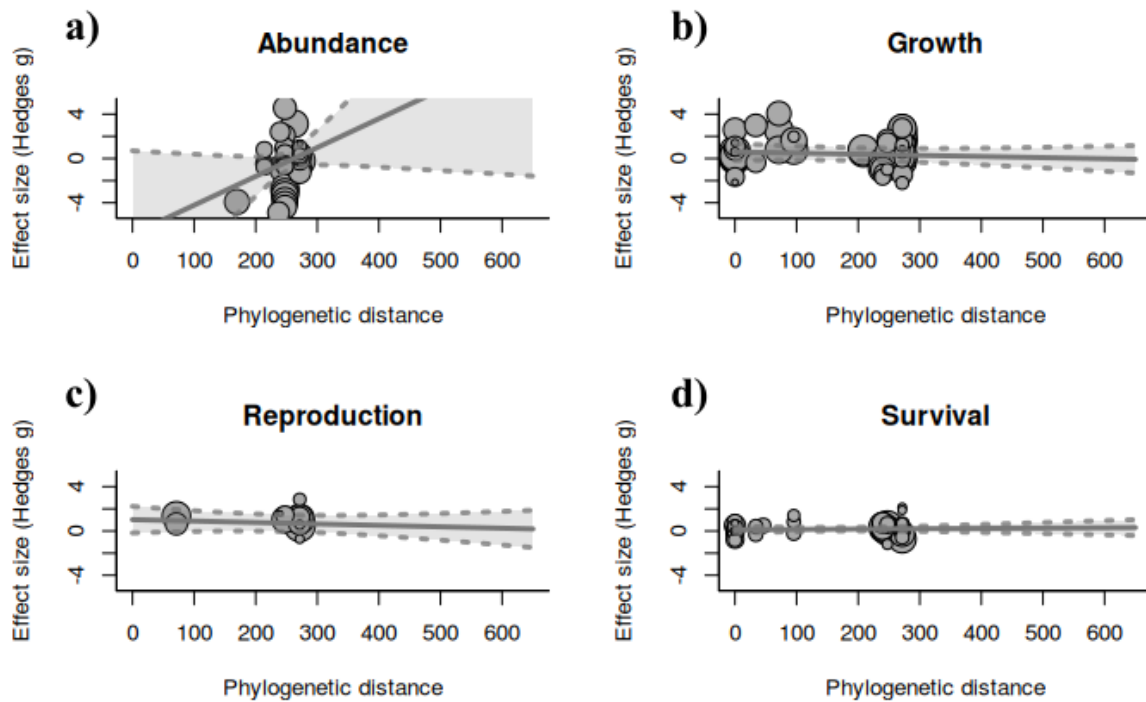


Figure 9. Phylogenetic distance did not affect the outcome of plant interactions when each performance indicator was considered individually a) abundance ($p = 0.08$), b) growth ($p = 0.41$), c) reproduction ($p = 0.50$), d) survival ($p = 0.61$). The gray dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid line and the 95% CI is represented by the gray shaded area and the dotted lines.

Phylogenetic distance and growth form combination

There were 71 outcomes in which the neighbor and target were from different growth forms, being 12 with a woody target and a herb neighbor and 59 with a herb target and a woody neighbor, and 92 that they were from the same growth form, with 53 between herbs and 39 between woody plants. We excluded outcomes about interactions between woody neighbors and herb targets because of the low number of outcomes (12).

The effect of phylogenetic distance and growth form combination on the outcome of plant-plant interaction was not significant ($p = 0.53$, Figure 10). The interactions between plants with the same growth form, either between herbs or between woody plants, and between a woody neighbor and a herb target, all had a neutral outcome ($p = 0.42$, $p = 0.89$, $p = 0.08$) and there was no effect from phylogenetic distance for the interactions of plants with the same growth form ($p = 0.59$, $p = 0.52$). However, the effect from phylogenetic distance for the interactions of a herb target plant and a woody neighbor was nearly significant ($p = 0.06$). This effect has a large confidence interval and this group lacks representation of outcomes of interactions between closely related species. Therefore, it is possible that for the interaction between herbs and woody plants on coastal dunes the phylogenetic distance could be informative about the outcome of the interaction, but unfortunately we lack confidence in this result and would be more confident affirming this if there were more closely related plants in this group in our data set.

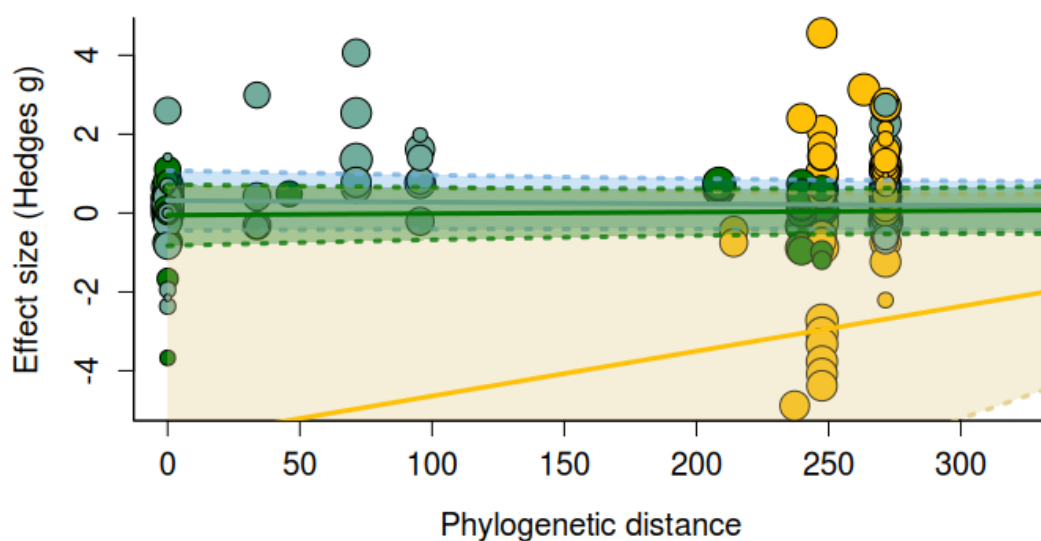


Figure 10. The model of the interaction of phylogenetic distance and growth form combination showed that these factors do not affect the outcome of plant interactions ($p = 0.53$). Blue represents outcomes of

interactions between herbs, green represents outcomes of interactions between woody plants and yellow represents interactions between a woody neighbor and a herb target plant. The dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines.

Phylogenetic distance and growth form similarity

There were 71 outcomes in which the neighbor and target were from different growth forms and 92 that they were from the same growth form. The effect of phylogenetic distance and growth form similarity on the outcome of plant-plant interaction was not significant ($p = 0.55$, Figure 11). Neither the phylogenetic distance ($p = 0.13$), nor interacting with a plant with the same growth form ($p = 0.60$), nor interacting with a plant with a different growth form ($p = 0.15$), nor the modulation of growth form similarity on the effect of phylogenetic distance ($p = 0.13$) influenced the outcomes of plant interaction.

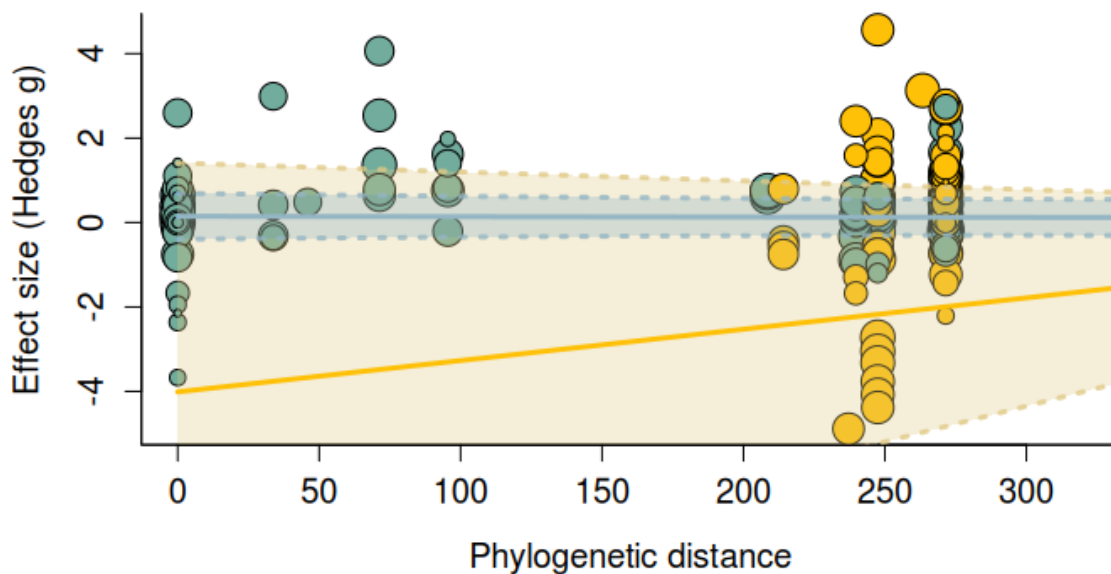


Figure 11. The model of the interaction of phylogenetic distance and growth form similarity showed that these factors do not affect the outcome of plant interactions ($p = 0.55$). Blue represents the group with neighbor and target plant with the same growth form and the yellow represents the group with neighbor and target plant with different growth forms. The dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines. In this model growth forms were defined as herb or woody.

Phylogenetic distance and ontogenetic stage combination

There were 44 outcomes where both the neighbor and the target plant were not seedlings and 36 where the neighbor was not a seedling and the target plant was a seedling. For all the remaining outcomes, the plant ontogenetic stage was either not properly informed by the authors or composed by several different stages. Therefore, we could not analyze these outcomes in the model including plant ontogenetic stage; for this model, we analyzed 80 outcomes from 13 articles.

The effect of phylogenetic distance and ontogenetic stage combination on the outcome of plant-plant interaction was not significant ($p = 0.99$, Figure 12). Neither the phylogenetic distance ($p = 0.73$), nor the ontogenetic stage combination (not seedling - not seedling $p = 0.92$, not seedling - seedling $p = 0.97$), nor the modulation of life stage combination on the effect of phylogenetic distance ($p = 0.87$) influenced the outcomes of plant interaction. The mean outcome of the interaction for both groups was neutral.

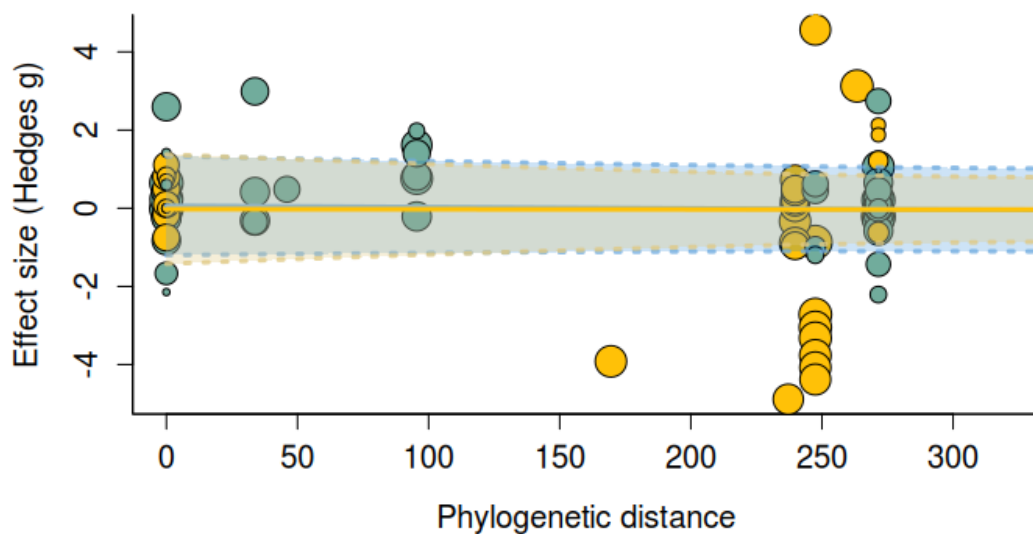


Figure 12. The interaction of phylogenetic distance and ontogenetic stage did not affect the outcome of plant interactions ($p = 0.99$). Blue represents the group in which both neighbor and target plant were not seedlings and the yellow represents the group in which the neighbor was not a seedling and the target plant was a seedling. The dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines.

Heterogeneity, publication bias and sensibility analysis

All models analyzed above had a significant Q, which indicates that we do not have one common effect size for all observations. For all models we also had a high level of heterogeneity, which is considered common in ecology meta-analysis, with $I^2 = 0.92$ for all models, except for the phylogenetic distance and ontogenetic stage combination model that had $I^2 = 0.94$. The high heterogeneity observed in these models indicates that the observed variability could be potentially explained by other explanatory variables not assessed in these analyses and encourages further exploration about what determines the outcome of plant-plant interaction on coastal dunes.

The visual analysis of the funnel plots of all effect sizes did not indicate major gaps of neutral effect sizes of studies with small sample sizes. However, we observed that most articles present in this meta-analysis had at least one outcome with an effect size different than zero, which could be interpreted as a sort of bias of this dataset (S4a, S4b). Nevertheless, according to the modified Egger's regression, there was no sign of publication bias in any of the datasets (S5). No outcomes had values of hat values and standardized residual values above the delimited threshold, therefore, for those criteria no outcome was considered an influential outlier.

However, in the models about growth form combination and growth form similarity, we detected through a visual analysis of the model one outcome as a potential outlier. This outcome had the lowest phylogenetic distance in the group of woody neighbor and herb target and also the lowest phylogenetic distance in the dissimilar growth forms group. To assess the influence of this outcome we excluded it and re-ran the models. Without this outcome the interaction between woody neighbor and herb target was no longer negatively significant and the phylogenetic distance in this group was no longer positively significant, the same pattern was observed in the dissimilar growth form group. Therefore, we assumed that this point was an outlier and excluded it from the growth form combination and growth form similarity analysis and the results presented above are without this outcome (S6a, S6b).

Discussion

Contrary to our expectations, the phylogenetic distance did not affect the outcome of plant interactions independent of growth form similarity and ontogenetic state for interacting plants in coastal dunes. Our results indicate the effect of phylogenetic distance could be relevant only for the interaction between woody neighbors with herb target plants, but there is large uncertainty in this result. Therefore, the effect of the phylogenetic distance, even when

considering growth form and ontogenetic stage, was not as relevant as predicted in determining the outcome of plant-plant interactions in coastal dunes.

Our results contrast with previous research about the reported relevance of phylogenetic distance in determining the outcome of plant interactions (Valiente-Banuet & Verdú, 2008; Verdú & Valiente-Banuet, 2012; Anacker & Strauss, 2016) and to some extent supports evidence found against it (Cavander-Bares et al., 2009; Bennett et al., 2013). We observed that positive interactions and negative interactions occur both between closely and distantly related species, supporting theoretical work that criticized the common assumption in phylogenetic community ecology that competition is stronger between closely related species (Gerhold et al., 2015; Mayfield and Levine, 2010). Phylogenetic distance may not be a good proxy for species interactions because trait similarity may not always be associated with stronger competition (Gerhold et al., 2015). Fitness dissimilarity can also impact the outcome of plant-plant interactions and even be more important than niche differences. If average fitness is conserved in the phylogeny and is more relevant than niche differences to determine the outcome of plant-plant interactions, stronger competition between distantly related species could be expected (Mayfield & Levine, 2010; Godoy et al., 2014). Therefore, trait dissimilarity alone is not enough to make negative interactions less frequent and positive interactions more frequent. So further investigation is needed on how facilitative interactions and niche complementarity are related to specific trait matching rather than just the dissimilarity of traits (Navarro-Cano et al., 2020). Additionally, it could be that the harsh conditions of the coastal dunes often promote intraspecific trait variability, due to phenotypic plasticity, and the individuals on this ecosystem could have traits different from the mean trait of their species (Jung et al., 2010). Therefore, phylogenetic distance used as a proxy of traits in severe ecosystems could perform worse than in more mild conditions. Also, convergent adaptation to specific conditions could cause distant species to perform well when isolated in coastal dunes, diminishing the positive effect of having an adapted neighbor that ameliorates harsh environmental conditions. There is evidence of convergent adaptation to salinity, which is a stressful condition in this environment, even when there is a phylogenetic signal of trait conservatism in the community (Pavoine et al., 2010). All arguments above are non-exclusive and could help explain why phylogenetic distance may not be informative for species interactions outcomes in severe environments.

We found great heterogeneity in our data indicating that the observed variability in the outcomes of plant interaction in this ecosystem could be explained by other factors. Environmental factors could help us better determine the outcomes of plant interactions.

According to the stress gradient hypothesis, the interaction between the same pair of species can have different outcomes depending on the level of stress in the environment in which they occur, with positive interactions being more frequent in more stressful environments (Bertness & Callaway, 1994). This hypothesis has been largely debated with conflicting evidence in different scales, species characteristics and stress indicators (Soliveres et al., 2015). In spite of that, environmental stress still is considered as a relevant factor in determining the outcome of plant-plant interactions. Williams et al. (2021) found that the phylogenetic distance alone was not able to determine the strength of competition. The phylogenetic distance had an effect on the strength of competition only when resource availability was also considered. Also, the effect of the phylogenetic distance on the outcome of plant interactions can vary along altitudinal gradients (Duarte et al., 2020). Including environmental factors that are a proxy for stress levels for plant development may help disentangle the factors affecting the outcome of plant interaction. This may be especially relevant in the coastal dunes system as the harsh conditions may change drastically in a few meters. However, in our study, the phylogenetic distance did not affect the outcome of plant-plant interactions even when environmental factors that are linked to stress were incorporated in the analysis (appendix). Therefore, even when considering the environmental stress the phylogenetic distance was not relevant in determining the outcome of plant-plant interaction on coastal dunes.

In conclusion, we found that the phylogenetic distance did not determine the outcome of plant interactions in coastal dunes, nor did growth form combination or similarity, nor ontogenetic stage combination modulate the effect of phylogenetic distance on these outcomes. Therefore, we conclude that, at least in this ecosystem, phylogenetic distance is not as good a predictor of plant interactions as proposed by Webb et al. (2002). We advise that caution is needed when assuming that phylogenetic patterns are a result of species interactions. However, our conclusions are limited to pairwise interactions, which were the focus in this analysis, and the results for multiple species interacting may be different (Zepeda & Martorell, 2021). Determining the outcome of species interactions is a complex task because it does not depend only on the species characteristics, but also in the fitness, intraspecific variability, environmental conditions and, may also depend on interactions with organisms from other trophic levels.

Appendix

The effect of environmental stress and phylogenetic distance on the outcome of plant-plant interactions on coastal dunes

Environmental conditions can affect the outcome of plant-plant interactions. It is predicted by the Stress Gradient Hypothesis (SGH) that the outcome of plant-plant interactions depends on stress levels in which the interaction occurs (Bertness & Callaway 1994). To explore how environmental stress influences the effect of the phylogenetic distance on plant-plant interactions on coastal dunes, we ran meta-analytic multilevel models of the effect of the phylogenetic distance interacting with two proxies for environmental stress. We used the position on the dune gradient and the global aridity index as indicators of abiotic stress.

On coastal dunes, proximity to the ocean is often considered as a stress indicator, because areas closer to the ocean are more exposed to stressful conditions such as wind, sand burial, and spray salt, and also have higher soil salinity and lower soil fertility than areas further from the ocean (Wilson & Sykes, 1999; Lane et al., 2008; Carboni et al., 2011). We used the position in the dune gradient in relation to the ocean in which the observed interaction occurred as a categorical variable to assess environmental stress. We first extracted from the articles the authors' description of the point in the dune in which the observation was made and then standardized it in four categories: i) front dunes, the area closest to the ocean characterized by the predominance of herbs and harsher environmental conditions; ii) middle dunes, the transition area dominated by herbs and shrubs; iii) back dunes, the farthest area from the ocean, characterized by dominance of woody species and milder environmental conditions; iv) several, when the observations were made in more than one point in the dune gradient. Some articles did not provide enough description about the specific place on the dune gradient where the study was conducted and those observations were excluded.

Another stress condition that varies between the outcomes extracted in your meta-analysis is aridity. Aridity is an environmental measure that combines precipitation, temperature, and/or potential evapo-transpiration, and it quantifies the precipitation availability over atmospheric water demand (Zommer et al., 2008). Aridity can be used to represent environmental severity because water availability is an important abiotic condition to plant development. The presence of a neighbor plant can alleviate the effects of aridity in

some environments and benefit target plants that are less tolerant to this abiotic factor (Maestre et al., 2003, Maestre et al., 2001, Arroyo et al., 2015). To include aridity, we used the global aridity index (GAI) of The Consortium for Spatial Information (CGIAR-CSI). This index combines values of mean annual precipitation and mean annual potential evo-transpiration averaged for the 1950-2000 period, with an approximately 1 km resolution in the equator. We used the geographic coordinates provided by the articles to assess the GAI of each observation. If the geographical coordinates provided by the article were in the ocean, we used satellite images to get a more accurate coordinate. We used this measure as a continuous variable in which higher values of GAI indicate more humid environments.

To assess the effect of environmental stress and phylogenetic distance on the outcome of plant-plant interactions on coastal dunes we used two hierarchical meta-analytic models, one with the position on the dune gradient and the other with global aridity index, both interacting with the phylogenetic distance between interacting plants. We included study and outcome identity as random factors to control dependent effects among effect sizes extracted from the same study. In the dune gradient model we only used observations from the front and middle dune, because there were zero observations from the back dune and only eight observations from several dune points, in a total of 143 observations of 21 articles. For the GAI model we used all the observations selected in the meta-analysis to run these models (163 observations of 25 articles).

We did heterogeneity, publication bias and sensitivity analyses in both models with the same protocols as described in the methods of the main text, through the modified Egger's regression (Nakawaga & Santos 2012) and identifying influential outliers (Viechtbauer & Cheung 2010, Hakeck & Schultz 2015). We also analyzed the residuals of the model with GAI interacting with phylogenetic distance to assess if this model would be better described by a non-linear relationship, and we saw that a linear model was a better fit.

Neither of the models that included environmental stress, as either dune gradient ($p = 0.71$, Figure 1) or GAI ($p = 0.82$, Table 1), explained the variation of plant-plant interaction outcome. The phylogenetic distance ($p = 0.58$; $p = 0.78$) and environmental stress ($p = 0.30$; $p = 0.50$) did not affect the outcome of plant interaction. Also the environmental stress did not modulate the effect of the phylogenetic distance ($p = 0.34$; $p = 0.76$). Both models had high levels of heterogeneity, which is common in ecology meta-analysis. According to the modified Egger's regression there is no evidence for publication bias in the dune gradient and GAI model ($p = 0.93$, $p = 0.58$) and we did not identify any influential outliers.

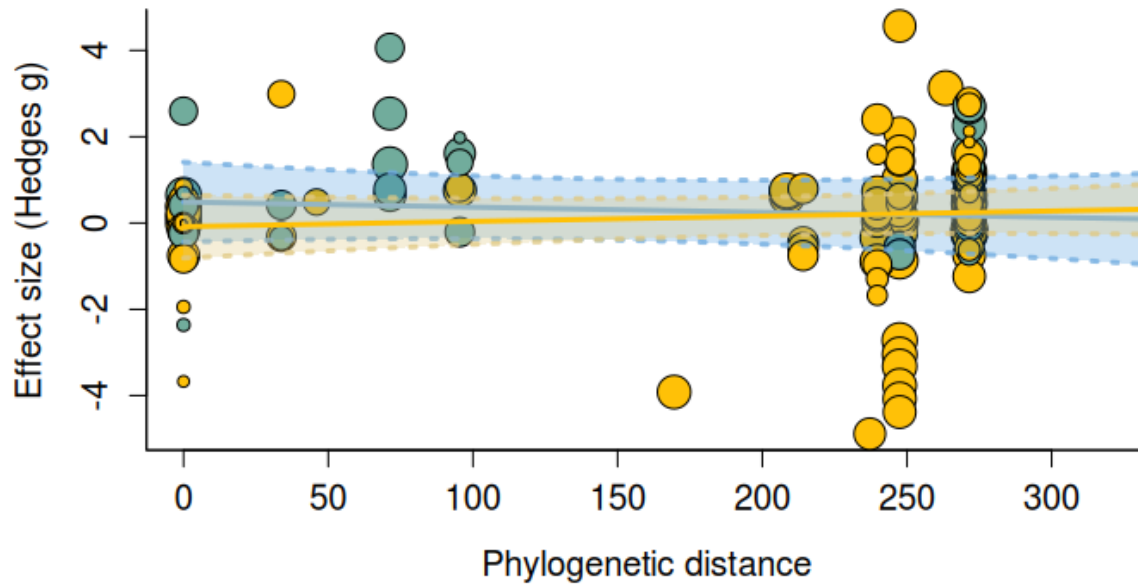


Figure 1. The interaction of phylogenetic distance and position on dune did not affect the outcome of plant interactions ($p = 0.71$). Blue represents the outcomes in which the observation was near the ocean, on the primary dune, considered more stressful for plant development and the yellow represents outcomes in which the observation was on the secondary dune, considered less stressful for plant development. The dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines.

Table 1. Estimate, confidence interval and p-values of each parameter in the model of the effect of phylogenetic distance interacting with GAI on coastal dunes plant interactions.

Parameter	Estimate	95% Confidence interval	p-value
Intercept	-0.39	-1.89, 1.12	0.61
Phylogenetic distance	0.0009	-0.005, 0.007	0.78
GAI	0.72	-1.40, 2.84	0.50
Phylogenetic distance * GAI	-0.0014	-0.01, 0.073	0.76

Overall, we conclude that the phylogenetic distance does not affect the outcome of plant-plant interactions on coastal dunes, even when considering environmental stress variables, such as dune gradient and GAI.

Supplementary material

S1a) Table with data extracted from 163 outcomes from the 25 articles included in the meta-analysis.

study2022	outcome	reference	location2	gradient2	gai	n_sp_LCVP	n_family_LCVP	n_lifeform3	n_lifestage
84	84_10	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_11	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_12	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_15	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_16	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_17	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_01	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_02	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_03	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)

84	84_06	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_07	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_09	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
84	84_20	Shumway_2000	USA	2	1041	Morella carolinensis (Mill.) Small	Myricaceae	woody	not informed (probably adult)
389	389_11	Cusseddu_et_al._ 2016	Italy	2	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several
389	389_09	Cusseddu_et_al._ 2016	Italy	2	344	Carpobrotus acinaciformis (L.) L.Bolus	Aizoaceae	herb	several
389	389_20	Cusseddu_et_al._ 2016	Italy	2	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	adult
8	08_53	DAntonio_1993	USA	2	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several (less seed)
8	08_55	DAntonio_1993	USA	2	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several (less seed)
4	04_01	DAntonio_&_Ma hall_1991	USA	2	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several
4	04_06	DAntonio_&_Ma hall_1991	USA	2	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several
4	04_07	DAntonio_&_Ma hall_1991	USA	2	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several
184	184_28	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Daphne gnidium L.	Thymelaeaceae	woody	not informed (probably adult)

184	184_31	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Daphne gnidium L.	Thymelaeaceae	woody	not informed (probably adult)
184	184_34	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Daphne gnidium L.	Thymelaeaceae	woody	not informed (probably adult)
184	184_37	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Daphne gnidium L.	Thymelaeaceae	woody	not informed (probably adult)
184	184_30	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Erica multiflora L.	Ericaceae	woody	not informed (probably adult)
184	184_33	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Erica multiflora L.	Ericaceae	woody	not informed (probably adult)
184	184_36	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Erica multiflora L.	Ericaceae	woody	not informed (probably adult)
184	184_39	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Erica multiflora L.	Ericaceae	woody	not informed (probably adult)
184	184_29	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Pistacia lentiscus L.	Anacardiaceae	woody	not informed (probably adult)
184	184_32	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Pistacia lentiscus L.	Anacardiaceae	woody	not informed (probably adult)
184	184_35	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Pistacia lentiscus L.	Anacardiaceae	woody	not informed (probably adult)
184	184_38	Rodriguez-Perez_ &_Traveset_2007	Spain	2	462	Pistacia lentiscus L.	Anacardiaceae	woody	not informed (probably adult)

205	205_07	Bonanomi_et_al._2008	Italy	2	667	Medicago marina L.	Fabaceae	woody	not informed
205	205_08	Bonanomi_et_al._2008	Italy	2	667	Medicago marina L.	Fabaceae	woody	not informed
101	101_02	Gagne_&_Houle_2001	Canada	1	1287	Honckenya peploides (L.) Ehrh.	Caryophyllaceae	herb	not informed (probably adult)
101	101_05	Gagne_&_Houle_2001	Canada	1	1287	Honckenya peploides (L.) Ehrh.	Caryophyllaceae	herb	not informed (probably adult)
389	389_16	Cusseddu_et_al._2016	Italy	1	344	Pancratium maritimum L.	Amaryllidaceae	herb	adult
389	389_15	Cusseddu_et_al._2016	Italy	1	344	Lotus cytisoides L.	Fabaceae	herb	adult
261	261_03	Cushman_et_al._2011	USA	1	779	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not informed (probably adult)
261	261_06	Cushman_et_al._2011	USA	1	779	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not informed (probably adult)
261	261_09	Cushman_et_al._2011	USA	1	779	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not informed (probably adult)
261	261_12	Cushman_et_al._2011	USA	1	779	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not informed (probably adult)
261	261_15	Cushman_et_al._2011	USA	1	779	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not informed (probably adult)
261	261_01	Cushman_et_al._2011	USA	1	779	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)

261	261_04	Cushman_et_al._ 2011	USA	1	779	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
261	261_07	Cushman_et_al._ 2011	USA	1	779	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
261	261_10	Cushman_et_al._ 2011	USA	1	779	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
261	261_13	Cushman_et_al._ 2011	USA	1	779	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
232	232_01	Forey_et_al._201 0	France	1	911	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	young
232	232_02	Forey_et_al._201 0	France	1	911	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	young
232	232_15	Forey_et_al._201 0	France	1	911	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	young
232	232_16	Forey_et_al._201 0	France	1	911	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	young
261	261_02	Cushman_et_al._ 2011	USA	1	779	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
261	261_05	Cushman_et_al._ 2011	USA	1	779	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
261	261_08	Cushman_et_al._ 2011	USA	1	779	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
261	261_11	Cushman_et_al._ 2011	USA	1	779	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)

261	261_14	Cushman_et_al._ 2011	USA	1	779	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
125	125_25	Franks_2003	USA	4	704	Uniola paniculata L.	Poaceae	herb	young
125	125_27	Franks_2003	USA	4	815	Uniola paniculata L.	Poaceae	herb	young
125	125_26	Franks_2003	USA	4	704	Iva imbricata Walter	Asteraceae	woody	young
125	125_28	Franks_2003	USA	4	815	Iva imbricata Walter	Asteraceae	woody	young
125	125_33	Franks_2003	USA	4	704	Uniola paniculata L.	Poaceae	herb	young
125	125_35	Franks_2003	USA	4	815	Uniola paniculata L.	Poaceae	herb	young
125	125_34	Franks_2003	USA	4	704	Iva imbricata Walter	Asteraceae	woody	young
125	125_36	Franks_2003	USA	4	815	Iva imbricata Walter	Asteraceae	woody	young
389	389_02	Cusseddu_et_al._ 2016	Italy	1	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several
389	389_01	Cusseddu_et_al._ 2016	Italy	1	344	Lotus cytisoides L.	Fabaceae	herb	several
8	08_51	DAntonio_1993	USA	1	328	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	several (less seed)
232	232_13	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_27	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_11	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_12	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_14	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_25	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
232	232_26	Forey_et_al._201 0	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young

232	232_28	Forey_et_al._2010	France	2	911	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	young
300	300_03	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
300	300_06	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
300	300_01	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
300	300_05	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
300	300_02	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
300	300_04	Le_Bagousse-Pinguet_et_al._2013	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	woody	adult
245	245_02	Cushman_et_al._2010	USA	2	779	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)
245	245_01	Cushman_et_al._2010	USA	2	779	Lupinus chamissonis Eschsch.	Fabaceae	woody	not informed (probably adult)
501	501_01	Magnoli_et_al_2013	USA	2	885	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	not seedling
245	245_06	Cushman_et_al._2010	USA	2	779	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)
245	245_10	Cushman_et_al._2010	USA	2	779	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)
334	334_01	Kleinhesselink_et_al._2014	USA	2	798	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)

334	334_02	Kleinhesselink_et_al._2014	USA	2	798	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)
334	334_03	Kleinhesselink_et_al._2014	USA	2	798	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not informed (probably adult)
245	245_05	Cushman_et_al._2010	USA	2	779	Lupinus chamissonis Eschsch.	Fabaceae	woody	not informed (probably adult)
245	245_09	Cushman_et_al._2010	USA	2	779	Lupinus chamissonis Eschsch.	Fabaceae	woody	not informed (probably adult)
215	215_09	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_10	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_11	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_12	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_14	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_15	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_16	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_17	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_18	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_19	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult

215	215_20	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
215	215_13	Yu_et_al._2009	Israel	2	295	Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	woody	adult
389	389_18	Cusseddu_et_al._ 2016	Italy	2	344	Pancratium maritimum L.	Amaryllidaceae	herb	adult
389	389_08	Cusseddu_et_al._ 2016	Italy	2	344	Lotus cytisoides L.	Fabaceae	herb	several
389	389_17	Cusseddu_et_al._ 2016	Italy	2	344	Lotus cytisoides L.	Fabaceae	herb	adult
389	389_06	Cusseddu_et_al._ 2016	Italy	2	344	Carpobrotus acinaciformis (L.) L.Bolus	Aizoaceae	herb	several
389	389_05	Cusseddu_et_al._ 2016	Italy	2	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several
389	389_07	Cusseddu_et_al._ 2016	Italy	2	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several
389	389_03	Cusseddu_et_al._ 2016	Italy	2	344	Lotus cytisoides L.	Fabaceae	herb	several
389	389_04	Cusseddu_et_al._ 2016	Italy	2	344	Carpobrotus acinaciformis (L.) L.Bolus	Aizoaceae	herb	several
389	389_19	Cusseddu_et_al._ 2016	Italy	2	344	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	adult
126	126_08	Rudgers_&_Maro n_2003	USA	not informed	801	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
126	126_10	Rudgers_&_Maro n_2003	USA	not informed	801	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)
126	126_12	Rudgers_&_Maro n_2003	USA	not informed	801	Ammophila arenaria (L.) Link	Poaceae	herb	not informed (probably adult)

126	126_07	Rudgers_&_Maron_2003	USA	not informed	801	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
126	126_09	Rudgers_&_Maron_2003	USA	not informed	801	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
126	126_11	Rudgers_&_Maron_2003	USA	not informed	801	Baccharis pilularis DC.	Asteraceae	woody	not informed (probably adult)
503	503_01	Tsvuura_et_al_2011	South Africa	not informed	632	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	adult
503	503_02	Tsvuura_et_al_2011	South Africa	not informed	632	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	adult
503	503_03	Tsvuura_et_al_2011	South Africa	not informed	656	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	adult
503	503_04	Tsvuura_et_al_2011	South Africa	not informed	656	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	adult
347	347_03	Paz-Esquivias_et_al_2015	Spain	not informed	299	Retama monosperma (L.) Boiss.	Fabaceae	woody	adult
347	347_05	Paz-Esquivias_et_al_2015	Spain	not informed	299	Retama monosperma (L.) Boiss.	Fabaceae	woody	adult
337	337_01	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
337	337_02	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
337	337_03	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
337	337_04	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
337	337_05	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
337	337_06	Castanho_&_Prado_2014	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult

505	505_01	Castanho_et_al_2015	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
505	505_02	Castanho_et_al_2015	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
505	505_03	Castanho_et_al_2015	Brazil	2	1815	Guapira opposita (Vell.) Reitz	Nyctaginaceae	woody	adult
129	129_04	Martinez_2003	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	adult
129	129_05	Martinez_2003	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	adult
136	136_01	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
136	136_02	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
136	136_04	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
136	136_05	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
136	136_07	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
136	136_08	Martinez_et_al._2004	Mexico	2	634	Chamaecrista chamaecristoides (Collad.) Greene	Fabaceae	woody	not informed (probably adult)
32	32_03	Lee_1995	USA	1	936	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	several (less seed)

416	416_01	Menezes_et_al._2018	Brazil	2	863	Allagoptera arenaria (Gomes) Kuntze	Arecaceae	woody	adult
416	416_02	Menezes_et_al._2018	Brazil	2	863	Allagoptera arenaria (Gomes) Kuntze	Arecaceae	woody	adult
219	219_04	Armas_&_Pugnai_re_2009	Spain	2	159	Pistacia lentiscus L.	Anacardiaceae	woody	adult
232	232_09	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_23	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_07	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_08	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_10	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_21	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_22	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_24	Forey_et_al._2010	France	2	911	Helichrysum stoechas (L.) Moench	Asteraceae	herb	young
232	232_05	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_19	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_03	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_04	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_06	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young

232	232_17	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_18	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young
232	232_20	Forey_et_al._2010	France	1	911	Ammophila arenaria (L.) Link	Poaceae	herb	young

S1b) Table with data extracted from 163 outcomes from the 25 articles included in the meta-analysis (continued).

study2022	t_sp_LCVP	t_family_LCVP	t_lifeform3	t_lifestage3	lifeform2_similarity	lifeform_n_t	lifestage_n_t	performance2
84	Solidago sempervirens L.	Asteraceae	herb	not_seedling	0	w.h	impossible	abundance
84	Solidago sempervirens L.	Asteraceae	herb	not_seedling	0	w.h	impossible	reproduction
84	Solidago sempervirens L.	Asteraceae	herb	seedling	0	w.h	impossible	abundance
84	Solidago sempervirens L.	Asteraceae	herb	not_seedling	0	w.h	impossible	reproduction
84	Solidago sempervirens L.	Asteraceae	herb	not_seedling	0	w.h	impossible	growth_size
84	Solidago sempervirens L.	Asteraceae	herb	seedling	0	w.h	impossible	survival
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
84	Solidago sempervirens L.	Asteraceae	herb	adult	0	w.h	impossible	growth
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	seedling	0	w.h	impossible	abundance
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	not_seedling	0	w.h	impossible	reproduction
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	not_seedling	0	w.h	impossible	growth_size
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	seedling	0	w.h	impossible	survival
84	Calamagrostis breviligulata (Fernald) Saarela	Poaceae	herb	not_seedling	0	w.h	impossible	reproduction
389	Carpobrotus acinaciformis (L.) L.Bolus	Aizoaceae	herb	several	0	w.h	several	abundance
389	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several	0	h.w	several	abundance

389	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	seedling	1	w.w	notseedling_seedlin g	survival
8	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	seedling	1	h.h	several	occurrence
8	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	seedling	1	h.h	several	occurrence
4	Ericameria ericoides (Less.) Nutt. ex Jeps.	Asteraceae	woody	not_seedling	0	h.w	several_adult	growth
4	Isocoma menziesii (Hook. & Arn.) G.L.Nesom	Asteraceae	woody	not_seedling	0	h.w	several_adult	growth
4	Isocoma menziesii (Hook. & Arn.) G.L.Nesom	Asteraceae	woody	not_seedling	0	h.w	several	reproduction
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seedling	1	w.w	impossible	growth_size
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
184	Daphne gnidium L.	Thymelaeaceae	woody	seed	1	w.w	impossible	emergence
205	Rostraria litorea (All.) Holub	Poaceae	herb	several	0	w.h	notinformed_severa l	abundance
205	Rostraria litorea (All.) Holub	Poaceae	herb	not_seedling	0	w.h	notseedling_seedlin g	growth
101	Leymus mollis (Trin.) Pilg.	Poaceae	herb	seedling	1	h.h	impossible	abundance
101	Leymus mollis (Trin.) Pilg.	Poaceae	herb	seedling	1	h.h	impossible	growth
389	Pancratium maritimum L.	Amaryllidaceae	herb	seedling	1	h.h	notseedling_seedlin g	survival

389	Lotus cytisoides L.	Fabaceae	herb	seedling	1	h.h	notseedling_seedling	survival
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	growth
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	growth_size
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	growth_size
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	growth_size
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	1	h.h	impossible	growth_size
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	0	w.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	0	w.h	impossible	growth
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	0	w.h	impossible	growth_size
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	0	w.h	impossible	reproduction
261	Ehrharta calycina Sm.	Poaceae	herb	not_seedling	0	w.h	impossible	growth_size
125	Uniola paniculata L.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
125	Uniola paniculata L.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
125	Uniola paniculata L.	Poaceae	herb	not_seedling	0	w.h	notseedling_notseedling	growth

125	Uniola paniculata L.	Poaceae	herb	not_seedling	0	w.h	notseedling_notseedling	growth
125	Iva imbricata Walter	Asteraceae	woody	not_seedling	0	h.w	notseedling_notseedling	growth
125	Iva imbricata Walter	Asteraceae	woody	not_seedling	0	h.w	notseedling_notseedling	growth
125	Iva imbricata Walter	Asteraceae	woody	not_seedling	1	w.w	notseedling_notseedling	growth
125	Iva imbricata Walter	Asteraceae	woody	not_seedling	1	w.w	notseedling_notseedling	growth
389	Lotus cytisoides L.	Fabaceae	herb	several	0	w.h	several	abundance
389	Armeria pungens (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several	0	h.w	several	abundance
8	Carpobrotus edulis (L.) N.E.Br.	Aizoaceae	herb	seedling	1	h.h	several	occurrence
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
300	Pancratium maritimum L.	Amaryllidaceae	herb	not_seedling	0	w.h	notseedling_notseedling	survival

300	<i>Oenothera biennis</i> L.	Onagraceae	herb	not_seedling	0	w.h	notseedling_notseedling	survival
300	<i>Festuca vasconensis</i> (Markgr.-Dann.) Auquier & Kerguelen	Poaceae	herb	not_seedling	0	w.h	notseedling_notseedling	survival
300	<i>Thinopyrum junceum</i> (L.) Á.Löve	Poaceae	herb	not_seedling	0	w.h	notseedling_notseedling	survival
300	<i>Senecio inaequidens</i> DC.	Asteraceae	woody	not_seedling	1	w.w	notseedling_notseedling	survival
300	<i>Cistus salviifolius</i> L.	Cistaceae	woody	not_seedling	1	w.w	notseedling_notseedling	survival
245	<i>Claytonia perfoliata</i> Donn ex Willd.	Montiaceae	herb	several	0	w.h	impossible	abundance
245	<i>Claytonia perfoliata</i> Donn ex Willd.	Montiaceae	herb	several	0	w.h	impossible	abundance
501	<i>Bromus diandrus</i> Roth	Poaceae	herb	seed	1	h.h	notseedling_seedling	emergence
245	<i>Bromus diandrus</i> Roth	Poaceae	herb	several	0	w.h	impossible	abundance
245	<i>Vulpia bromoides</i> (L.) Gray	Poaceae	herb	several	0	w.h	impossible	abundance
334	<i>Bromus diandrus</i> Roth	Poaceae	herb	not_seedling	0	w.h	impossible	growth
334	<i>Bromus diandrus</i> Roth	Poaceae	herb	not_seedling	0	w.h	impossible	reproduction
334	<i>Bromus diandrus</i> Roth	Poaceae	herb	seedling	0	w.h	impossible	survival
245	<i>Bromus diandrus</i> Roth	Poaceae	herb	several	0	w.h	impossible	abundance
245	<i>Vulpia bromoides</i> (L.) Gray	Poaceae	herb	several	0	w.h	impossible	abundance
215	<i>Maresia pulchella</i> (DC.) O.E.Schulz	Brassicaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Plantago arenaria</i> Waldst. & Kit.	Plantaginaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Polycarpha succulenta</i> (Delile) Mscr.	Caryophyllaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Arenaria leptoclados</i> Boiss.	Caryophyllaceae	herb	seedling	0	w.h	notseedling_seedling	abundance

215	<i>Crepis aculeata</i> (DC.) Boiss.	Asteraceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Rumex bucephalophorus</i> L.	Polygonaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Fumaria judaica</i> Boiss.	Fumariaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Anagallis arvensis</i> L.	Myrsinaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Valantia hispida</i> L.	Rubiaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Trifolium palaestinum</i> Boiss.	Fabaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Ifloga spicata</i> (Forssk.) Sch.Bip.	Asteraceae	herb	seedling	0	w.h	notseedling_seedling	abundance
215	<i>Desmazeria philistaea</i> (Boiss.) H.Scholz	Poaceae	herb	seedling	0	w.h	notseedling_seedling	abundance
389	<i>Pancratium maritimum</i> L.	Amaryllidaceae	herb	seedling	1	h.h	notseedling_seedling	survival
389	<i>Carpobrotus acinaciformis</i> (L.) L.Bolus	Aizoaceae	herb	several	1	h.h	several	abundance
389	<i>Lotus cytisoides</i> L.	Fabaceae	herb	seedling	1	h.h	notseedling_seedling	survival
389	<i>Lotus cytisoides</i> L.	Fabaceae	herb	several	1	h.h	several	abundance
389	<i>Lotus cytisoides</i> L.	Fabaceae	herb	several	0	w.h	several	abundance
389	<i>Carpobrotus acinaciformis</i> (L.) L.Bolus	Aizoaceae	herb	several	0	w.h	several	abundance
389	<i>Armeria pungens</i> (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several	0	h.w	several	abundance
389	<i>Armeria pungens</i> (Link) Hoffmanns. & Link	Plumbaginaceae	woody	several	0	h.w	several	abundance
389	<i>Armeria pungens</i> (Link) Hoffmanns. & Link	Plumbaginaceae	woody	seedling	1	w.w	notseedling_seedling	survival
126	<i>Lupinus arboreus</i> Sims	Fabaceae	woody	seedling	0	h.w	impossible	survival

126	Lupinus arboreus Sims	Fabaceae	woody	seedling	0	h.w	impossible	growth
126	Lupinus arboreus Sims	Fabaceae	woody	seed	0	h.w	impossible	emergence
126	Lupinus arboreus Sims	Fabaceae	woody	seedling	1	w.w	impossible	survival
126	Lupinus arboreus Sims	Fabaceae	woody	seedling	1	w.w	impossible	growth
126	Lupinus arboreus Sims	Fabaceae	woody	seed	1	w.w	impossible	emergence
503	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	seedling	1	w.w	notseedling_seedling	survival
503	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	seedling	1	w.w	notseedling_seedling	growth
503	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	seedling	1	w.w	notseedling_seedling	survival
503	Isoglossa woodii C.B.Clarke	Acanthaceae	woody	seedling	1	w.w	notseedling_seedling	growth
347	Thymus carnosus Boiss.	Lamiaceae	woody	not_seedling	1	w.w	notseedling_notseedling	growth
347	Thymus carnosus Boiss.	Lamiaceae	woody	not_seedling	1	w.w	notseedling_notseedling	survival
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	growth
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	growth
337	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	growth
505	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival

505	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
505	Ternstroemia brasiliensis Cambess.	Ternstroemiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
129	Trachypogon spicatus (L.f.) Kuntze	Poaceae	herb	seedling	0	w.h	notseedling_seedling	survival
129	Schizachyrium scoparium (Michx.) Nash	Poaceae	herb	seedling	0	w.h	notseedling_seedling	survival
136	Trachypogon spicatus (L.f.) Kuntze	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
136	Schizachyrium scoparium (Michx.) Nash	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
136	Trachypogon spicatus (L.f.) Kuntze	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
136	Schizachyrium scoparium (Michx.) Nash	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
136	Trachypogon spicatus (L.f.) Kuntze	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
136	Schizachyrium scoparium (Michx.) Nash	Poaceae	herb	not_seedling	0	w.h	impossible	abundance
32	Solidago sempervirens L.	Asteraceae	herb	not_seedling	1	h.h	several	reproduction
416	Allagoptera arenaria (Gomes) Kuntze	Arecaceae	woody	seed	1	w.w	adult_seed	emergence
416	Allagoptera arenaria (Gomes) Kuntze	Arecaceae	woody	seed	1	w.w	adult_seed	emergence
219	Pistacia lentiscus L.	Anacardiaceae	woody	seedling	1	w.w	notseedling_seedling	survival
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth

232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Helichrysum stoechas (L.) Moench	Asteraceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	growth
232	Thinopyrum junceum (L.) Á.Löve	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Ammophila arenaria (L.) Link	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival
232	Corynephorus canescens (L.) P.Beauv.	Poaceae	herb	not_seedling	1	h.h	notseedling_notseedling	survival

S1c) Table with data extracted from 163 outcomes from the 25 articles included in the meta-analysis (continued).

study2022	MEANc	MEANn	SDc	SDn	Nc	Nn	SE_c	SE_n	sucess_c	sucess_n	fail_c	fail_n	phylo_dist	effectsize	es_variance	e_n
84	2.35	2	1.12	1.7	20	20	0.25	0.38	NA	NA	NA	NA	247.47	-0.24	0.10	40
84	0.25	1.25	0.54	1.25	20	20	0.12	0.28	NA	NA	NA	NA	247.47	01.02	0.11	40
84	0.16	22.1	0.45	31.75	25	25	0.09	6.35	NA	NA	NA	NA	247.47	0.96	0.09	50
84	2340.5	7250.32	1167.8	4486.17	10	10	369.29	1418.65	NA	NA	NA	NA	247.47	1.43	0.26	20
84	5.65	22.07	1.9	12.97	10	10	0.6	4.1	NA	NA	NA	NA	247.47	1.70	0.29	20
84	NA	NA	NA	NA	100	100	NA	NA	21	22	79	78	247.47	0.04	0.04	200
84	12.85	15.8	4.92	3.94	20	20	1.1	0.88	NA	NA	NA	NA	271.52	0.65	0.11	40
84	2.5	3.6	0.57	0.85	8	8	0.2	0.3	NA	NA	NA	NA	247.47	1.44	0.33	16
84	12.68	9.24	29.1	28.05	25	25	5.82	5.61	NA	NA	NA	NA	271.52	-0.12	0.08	50
84	209.2	431.7	82.22	66.41	10	10	26	21	NA	NA	NA	NA	271.52	2.85	0.45	20
84	2	4.34	0.82	1.83	10	10	0.26	0.58	NA	NA	NA	NA	271.52	1.58	0.28	20
84	NA	NA	NA	NA	100	100	NA	NA	12	8	88	92	271.52	-0.27	0.08	200
84	0.2	1.55	0.49	1.48	20	20	0.11	0.33	NA	NA	NA	NA	271.52	1.20	0.12	40
389	29.5	17.5	19.7	7.9	8	8	6.97	2.79	NA	NA	NA	NA	214.11	-0.76	0.27	16
389	6.9	16.4	9.5	12.8	8	8	3.36	4.53	NA	NA	NA	NA	214.11	0.80	0.28	16
389	NA	NA	NA	NA	25	25	NA	NA	21	20	4	5	0	-0.16	0.20	50
8	NA	NA	NA	NA	196	160	NA	NA	61	84	135	76	0	0.54	0.02	352.36
8	NA	NA	NA	NA	47	57	NA	NA	8	0	39	57	0	-1.94	0.79	103.04
4	247	24.1	230.18	59.11	7	8	87	20.9	NA	NA	NA	NA	239.75	-1.29	0.34	14.93
4	-2.6	-47.3	5.03	34.92	7	7	1.9	13.2	NA	NA	NA	NA	239.75	-1.68	0.42	14
4	60	86.3	19.31	10.32	7	7	7.3	3.9	NA	NA	NA	NA	239.75	1.60	0.41	14
184	24.1	25.9	17.44	6.26	20	20	3.9	1.4	NA	NA	NA	NA	0	0.13	0.10	40
184	19.8	23.3	25.94	6.26	20	20	5.8	1.4	NA	NA	NA	NA	0	0.18	0.10	40
184	42.5	50.7	15.65	23.7	20	20	3.5	5.3	NA	NA	NA	NA	0	0.40	0.10	40
184	28	40	31.3	31.75	20	20	7	7.1	NA	NA	NA	NA	0	0.37	0.10	40
184	24.1	26.6	17.44	5.81	20	20	3.9	1.3	NA	NA	NA	NA	247.47	0.19	0.10	40

184	19.8	31.3	25.94	11.63	20	20	5.8	2.6	NA	NA	NA	NA	247.47	0.56	0.10	40
184	42.5	44.4	15.65	29.52	20	20	3.5	6.6	NA	NA	NA	NA	247.47	0.08	0.10	40
184	28	48.7	31.3	35.78	20	20	7	8	NA	NA	NA	NA	247.47	0.60	0.11	40
184	24.1	34	17.44	5.37	20	20	3.9	1.2	NA	NA	NA	NA	208.52	0.75	0.11	40
184	19.8	31.7	25.94	7.6	20	20	5.8	1.7	NA	NA	NA	NA	208.52	0.61	0.11	40
184	42.5	57.4	15.65	24.15	20	20	3.5	5.4	NA	NA	NA	NA	208.52	0.72	0.11	40
184	28	51.1	31.3	31.75	20	20	7	7.1	NA	NA	NA	NA	208.52	0.72	0.11	40
205	87	348	114.3	242.4	12	12	33	70	NA	NA	NA	NA	271.52	1.33	0.21	24
205	0.3	1.65	0.3	1.49	12	12	0.09	0.43	NA	NA	NA	NA	271.52	1.21	0.20	24
101	0.04	0.81	0	2.61	26	26	0	0.51	NA	NA	NA	NA	271.52	0.41	0.08	52
101	18.1	17.5	7.07	5.66	50	50	1	0.8	NA	NA	NA	NA	271.52	-0.09	0.04	100
389	NA	NA	NA	NA	25	25	NA	NA	0	1	25	24	0	0.69	01.01	50
389	NA	NA	NA	NA	25	25	NA	NA	0	0	25	25	0	0	1.45	50
261	3.5	8.1	5.28	7.94	10	10	1.67	2.51	NA	NA	NA	NA	271.52	0.65	0.21	20
261	1.38	1.43	1.04	1.3	10	10	0.34	0.42	NA	NA	NA	NA	271.52	0.04	0.20	20
261	15.5	41.5	11	18.74	20	20	2.46	4.19	NA	NA	NA	NA	271.52	1.66	0.14	40
261	2.3	5.1	2.33	8.27	20	20	0.52	1.85	NA	NA	NA	NA	271.52	0.45	0.10	40
261	4.6	16.7	2.68	6.93	20	20	0.6	1.55	NA	NA	NA	NA	271.52	2.26	0.17	40
261	9.6	17.2	12.05	10.59	10	10	3.81	3.35	NA	NA	NA	NA	71.31	0.64	0.21	20
261	2.33	4.81	3.07	3	10	10	0.96	0.96	NA	NA	NA	NA	71.31	0.78	0.22	20
261	15.5	76.5	11	17.66	20	20	2.46	3.95	NA	NA	NA	NA	71.31	04.06	0.33	40
261	2.3	20.7	2.33	18.6	20	20	0.52	4.16	NA	NA	NA	NA	71.31	1.36	0.13	40
261	4.6	27.1	2.68	11.99	20	20	0.6	2.68	NA	NA	NA	NA	71.31	2.54	0.19	40
232	0.58	1.18	0.81	0.99	15	14	0.21	0.27	NA	NA	NA	NA	0	0.65	0.15	28.97
232	-0.57	1	0.8	0.39	4	3	0.4	0.23	NA	NA	NA	NA	95.48	1.98	1.18	6.86
232	83.4	75	35.03	27.95	6	6	14.3	11.41	NA	NA	NA	NA	0	-0.24	0.34	12
232	24.7	16.67	35.27	35.36	6	6	14.4	14.43	NA	NA	NA	NA	95.48	-0.21	0.36	12
261	1.2	5.7	2.15	4.33	10	10	0.68	1.37	NA	NA	NA	NA	271.52	1.26	0.25	20
261	0.53	2.92	0.51	2.63	10	10	0.17	0.83	NA	NA	NA	NA	271.52	1.21	0.24	20
261	15.5	58.1	11	18.74	20	20	2.46	4.19	NA	NA	NA	NA	271.52	2.72	0.20	40

261	2.3	6.4	2.33	4.74	20	20	0.52	1.06	NA	NA	NA	NA	271.52	01.08	0.12	40
261	4.6	25.4	2.68	10.42	20	20	0.6	2.33	NA	NA	NA	NA	271.52	2.68	0.20	40
125	0.36	2.19	0.17	1.14	2	3	0.12	0.66	NA	NA	NA	NA	0	1.41	1.56	4.8
125	4.73	1.65	1.16	1.1	4	2	0.58	0.78	NA	NA	NA	NA	0	-2.15	1.74	5.33
125	0.36	4.46	0.17	3.42	2	2	0.12	2.42	NA	NA	NA	NA	271.52	0.96	1.91	4
125	4.73	0.69	1.16	1.9	4	5	0.58	0.85	NA	NA	NA	NA	271.52	-2.21	0.91	8.89
125	6.73	6.57	9.15	15.05	2	5	6.47	6.73	NA	NA	NA	NA	271.52	-0.01	0.70	5.71
125	45.6	23.6	12.49	15.56	6	8	5.1	5.5	NA	NA	NA	NA	271.52	-1.43	0.39	13.71
125	6.73	16.8	9.15	9.76	2	2	6.47	6.9	NA	NA	NA	NA	0	0.60	1.36	4
125	45.6	21.9	12.49	13.72	6	6	5.1	5.6	NA	NA	NA	NA	0	-1.67	0.50	12
389	10.8	6.3	8.7	6.4	8	8	3.08	2.26	NA	NA	NA	NA	247.47	-0.56	0.26	16
389	18.7	10.2	14.1	6.6	8	8	4.99	2.33	NA	NA	NA	NA	247.47	-0.73	0.27	16
8	NA	NA	NA	NA	34	90	NA	NA	7	0	27	90	0	-2.36	0.80	98.71
232	1.42	0.98	1.64	1.17	10	9	0.52	0.39	NA	NA	NA	NA	271.52	-0.29	0.21	18.95
232	55.1	50	25.47	31.91	6	6	10.04	13.03	NA	NA	NA	NA	271.52	-0.16	0.33	12
232	-0.62	1.59	0.82	3.46	8	13	0.29	0.96	NA	NA	NA	NA	95.48	0.76	0.22	19.81
232	-1.01	0.55	0.62	0.3	12	10	0.18	0.1	NA	NA	NA	NA	33.79	2.99	0.43	21.82
232	1.5	1.48	1.32	2.86	15	14	0.34	0.77	NA	NA	NA	NA	0	-9	0.14	28.97
232	44.4	72.22	30.86	31.42	6	6	12.6	12.83	NA	NA	NA	NA	95.48	0.82	0.37	12
232	66.7	55.56	33.31	31.43	6	6	13.6	12.83	NA	NA	NA	NA	33.79	-0.32	0.34	12
232	83.6	77.78	24.98	24.85	6	6	10.2	10.14	NA	NA	NA	NA	0	-0.22	0.34	12
300	0.38	0.43	0.37	0.42	7	7	0.14	0.16	NA	NA	NA	NA	271.52	0.12	0.29	14
300	0.23	0.38	0.24	0.37	7	7	0.09	0.14	NA	NA	NA	NA	247.47	0.45	0.30	14
300	0.71	0.71	0.71	0.71	7	7	0.27	0.27	NA	NA	NA	NA	271.52	0	0.29	14
300	0.52	0.86	0.53	0.85	7	7	0.2	0.32	NA	NA	NA	NA	271.52	0.45	0.30	14
300	0.14	0.24	0.13	0.24	7	7	0.05	0.09	NA	NA	NA	NA	45.98	0.48	0.30	14

300	0.14	0.29	0.13	0.29	7	7	0.05	0.11	NA	NA	NA	NA	247.47	0.62	0.30	14
245	6.72	405	12.64	230.25	24	24	2.58	47	NA	NA	NA	NA	239.75	2.40	0.15	48
245	6.72	494	12.64	323.33	24	24	2.58	66	NA	NA	NA	NA	247.47	2.090	0.13	48
501	72.93	53.5	31.35	29.92	20	20	7.01	6.69	NA	NA	NA	NA	271.52	-0.62	0.11	40
245	9.3	12.8	23.03	17.15	24	24	4.7	3.5	NA	NA	NA	NA	271.52	0.17	0.08	48
245	40.7	16.3	39.68	22.54	24	24	8.1	4.6	NA	NA	NA	NA	271.52	-0.74	0.09	48
334	0.48	0.74	0.37	0.35	30	30	0.07	0.06	NA	NA	NA	NA	271.52	0.71	0.07	60
334	11.05	15.82	8.79	8.18	30	30	1.6	1.49	NA	NA	NA	NA	271.52	0.55	0.07	60
334	NA	NA	NA	NA	60	60	NA	NA	57	59	3	1	271.52	0.69	0.50	120
245	9.3	17.4	23.03	17.15	24	24	4.7	3.5	NA	NA	NA	NA	271.52	0.39	0.09	48
245	40.7	2.33	39.68	17.05	24	24	8.1	3.48	NA	NA	NA	NA	271.52	-1.24	0.10	48
215	90.7	0	26	0	40	40	4.11	0	NA	NA	NA	NA	237.16	-4.89	0.21	80
215	154	15.4	44	5.2	40	40	6.96	0.82	NA	NA	NA	NA	247.47	-4.39	0.18	80
215	86.3	8.63	26.7	0	40	40	4.22	0	NA	NA	NA	NA	247.47	-4.07	0.16	80
215	146	41.7	44.7	17.3	40	40	7.07	2.74	NA	NA	NA	NA	247.47	-3.05	0.11	80
215	180	44.5	46	20.6	40	40	7.27	3.26	NA	NA	NA	NA	247.47	-3.77	0.14	80
215	203	24	75	8.5	40	40	11.86	1.34	NA	NA	NA	NA	247.47	-3.32	0.12	80
215	20.8	80	5.2	26	40	40	0.82	4.11	NA	NA	NA	NA	263.36	3.13	0.11	80
215	160	124	39	43	40	40	6.17	6.8	NA	NA	NA	NA	247.47	-0.87	0.05	80
215	0	282	1.5	86.5	40	40	0.24	13.68	NA	NA	NA	NA	247.47	4.57	0.19	80
215	216	11.6	73	3.1	40	40	11.54	0.49	NA	NA	NA	NA	169.53	-3.92	0.15	80
215	231	0	119	0	40	40	18.82	0	NA	NA	NA	NA	247.47	-2.72	0.10	80
215	88.4	79	26.9	57.7	40	40	4.25	9.12	NA	NA	NA	NA	271.51	-0.21	0.05	80
389	NA	NA	NA	NA	25	25	NA	NA	0	0	25	25	0	0	1.50	50
389	16.9	8.3	16.8	13.3	8	8	5.94	4.7	NA	NA	NA	NA	247.47	-0.54	0.26	16
389	NA	NA	NA	NA	25	25	NA	NA	1	1	24	24	0	0	0.77	50
389	6	9.8	5.6	8.9	8	8	1.98	3.15	NA	NA	NA	NA	247.47	0.48	0.26	16
389	17.9	6	20.1	9	8	8	7.11	3.18	NA	NA	NA	NA	247.47	-0.72	0.27	16
389	5.4	0.4	15.2	1	8	8	5.37	0.35	NA	NA	NA	NA	214.10	-0.44	0.26	16
389	10	13.1	12.6	9.6	8	8	4.45	3.39	NA	NA	NA	NA	247.47	0.26	0.25	16

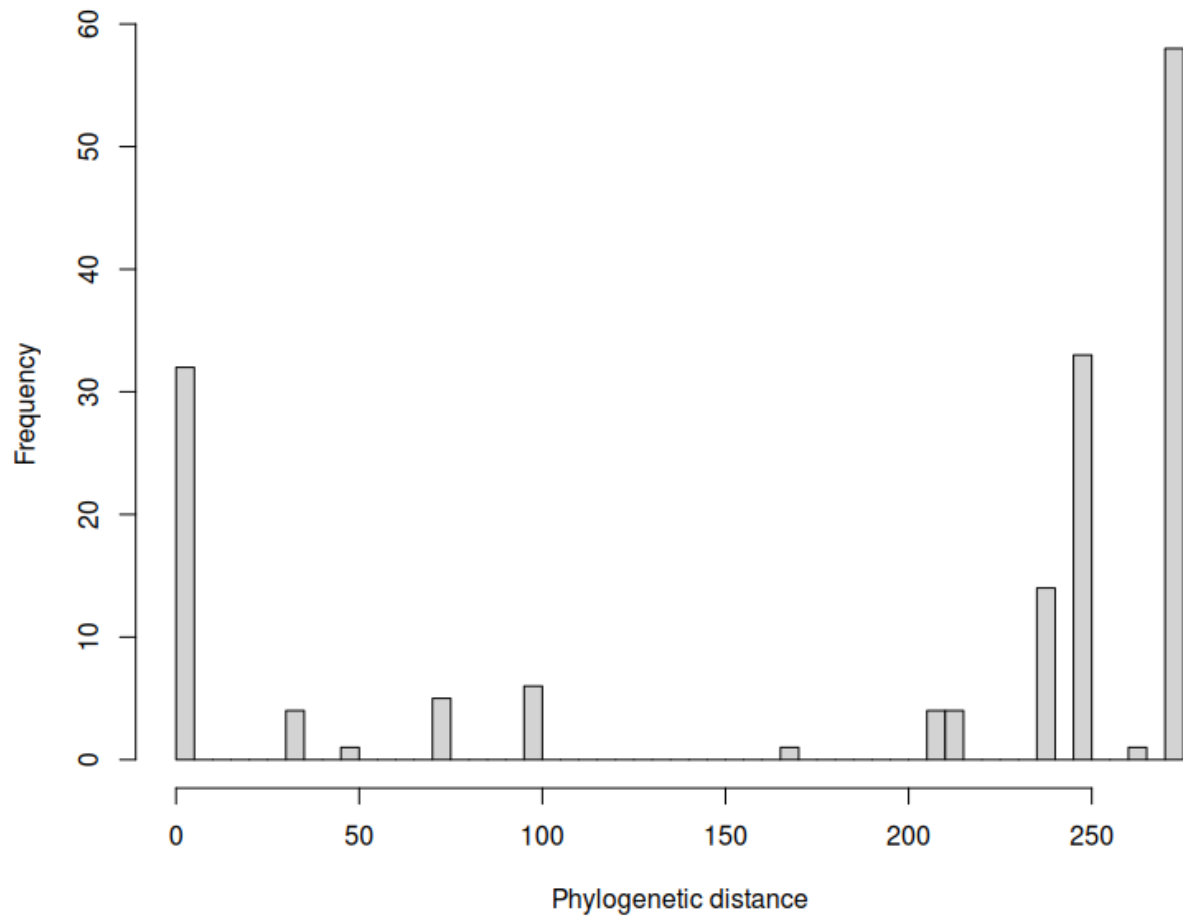
389	15.3	8.7	13.4	7.6	8	8	4.74	2.69	NA	NA	NA	NA	214.10	-0.57	0.26	16
389	NA	NA	NA	NA	25	25	NA	NA	8	3	17	22	0	-0.75	0.21	50
126	NA	NA	NA	NA	100	100	NA	NA	29	11	71	89	271.52	-0.72	0.06	200
126	25.64	37.47	14.17	14.88	37	17	2.33	3.61	NA	NA	NA	NA	271.52	0.81	0.09	46.5 9
126	NA	NA	NA	NA	250	250	NA	NA	10	8	240	242	271.52	-0.14	0.08	500
126	NA	NA	NA	NA	100	100	NA	NA	29	45	71	55	247.47	0.42	0.03	200
126	25.64	32.8	14.17	13.65	37	50	2.33	1.93	NA	NA	NA	NA	247.47	0.51	0.05	85.0 6
126	NA	NA	NA	NA	250	250	NA	NA	10	20	240	230	247.47	0.45	0.06	500
503	60.66	71.65	22.85	19.98	15	15	5.9	5.16	NA	NA	NA	NA	0	0.50	0.14	30
503	1.26	1.36	0.12	0.12	15	15	0.03	0.03	NA	NA	NA	NA	0	0.81	0.15	30
503	1.23	1.25	0.16	0.22	10	10	0.05	0.07	NA	NA	NA	NA	0	0.10	0.20	20
503	1.01	1.16	0.16	0.09	10	10	0.05	0.03	NA	NA	NA	NA	0	1.11	0.24	20
347	0.49	0.18	0.3	0.29	9	6	0.1	0.12	NA	NA	NA	NA	247.47	-0.98	0.32	14.4
347	NA	NA	NA	NA	10	9	NA	NA	9	5	1	4	247.47	-1.20	0.57	18.9 5
337	0.06	0.08	0.11	0.11	15	15	0.03	0.03	NA	NA	NA	NA	239.75	0.18	0.13	30
337	0.31	0.5	0.29	0.21	15	15	0.07	0.05	NA	NA	NA	NA	239.75	0.73	0.14	30
337	0.38	0.39	0.28	0.3	15	15	0.07	0.08	NA	NA	NA	NA	239.75	0.03	0.13	30
337	0.06	-0.03	0.09	0.09	9	12	0.03	0.03	NA	NA	NA	NA	239.75	-0.96	0.22	20.5 7
337	0.04	-0.07	0.11	0.13	46	75	0.02	0.02	NA	NA	NA	NA	239.75	-0.89	0.04	114. 05
337	0.06	-0.3	0.83	1.25	57	59	0.11	0.16	NA	NA	NA	NA	239.75	-0.34	0.03	115. 97
505	0	0.03	0	0.1	30	30	NA	NA	NA	NA	NA	NA	239.75	0.42	0.07	60
505	0.01	0.02	0.03	0.06	30	30	NA	NA	NA	NA	NA	NA	239.75	0.21	0.07	60
505	0.01	0.05	0.03	0.11	30	30	NA	NA	NA	NA	NA	NA	239.75	0.49	0.07	60
129	NA	NA	NA	NA	200	200	NA	NA	0	15	200	185	271.52	2.13	0.76	400
129	NA	NA	NA	NA	200	200	NA	NA	0	10	200	190	271.52	1.88	0.77	400
136	0.25	1.06	0.16	0.98	9	9	0.05	0.33	NA	NA	NA	NA	271.52	1.10	0.26	18

136	0.16	0.21	0.18	0.2	9	9	0.06	0.07	NA	NA	NA	NA	271.52	0.25	0.22	18
136	0.1	1.57	0.13	2.02	9	9	0.04	0.67	NA	NA	NA	NA	271.52	0.98	0.26	18
136	0.15	0.15	0.16	0.17	9	9	0.05	0.06	NA	NA	NA	NA	271.52	0	0.22	18
136	0.17	0.92	0.16	1.09	9	9	0.05	0.36	NA	NA	NA	NA	271.52	0.92	0.25	18
136	0.13	0.15	0.23	0.15	9	9	0.08	0.05	NA	NA	NA	NA	271.52	0.10	0.22	18
32	80.2	40.5	66	39.5	25	25	13.2	7.9	NA	NA	NA	NA	271.52	-0.72	0.09	50
416	0	0	0	0	8	8	0	0	NA	NA	NA	NA	0	0	0.25	16
416	0.5	0.1	0.14	0.04	8	8	0.05	0.01	NA	NA	NA	NA	0	-3.67	0.80	16
219	NA	NA	NA	NA	20	20	NA	NA	2	6	18	14	0	0.82	0.29	40
232	0.42	0.71	1.28	1.08	15	10	0.33	0.34	NA	NA	NA	NA	0	0.23	0.17	24
232	83.6	55.56	24.25	36.85	6	6	9.09	15.05	NA	NA	NA	NA	0	-0.83	0.37	12
232	-0.38	0.67	1.35	0.56	9	13	0.45	0.15	NA	NA	NA	NA	271.52	1.050	0.22	21.2 7
232	-1.35	0.32	0.74	0.34	8	8	0.26	0.12	NA	NA	NA	NA	271.52	2.74	0.56	16
232	0.97	1.31	1.05	2.08	14	12	0.28	0.6	NA	NA	NA	NA	271.52	0.21	0.16	25.8 5
232	50.1	72.22	32.09	29.68	6	6	13.1	12.12	NA	NA	NA	NA	271.52	0.66	0.36	12
232	44.4	44.44	30.86	31.43	6	6	12.6	12.83	NA	NA	NA	NA	271.52	1	0.33	12
232	77.7	66.67	15.92	19.25	6	6	6.5	7.86	NA	NA	NA	NA	271.52	-0.58	0.35	12
232	1.68	1.7	1.72	0.4	5	7	0.77	0.15	NA	NA	NA	NA	271.52	0.02	0.34	11.6 7
232	27.3	38.89	31.35	44.79	6	6	12.8	18.29	NA	NA	NA	NA	271.52	0.28	0.34	12
232	-0.1	1.05	0.74	0.66	7	15	0.28	0.17	NA	NA	NA	NA	95.48	1.61	0.28	19.0 9
232	-1.11	0.38	0.75	0.34	9	12	0.25	0.1	NA	NA	NA	NA	0	2.59	0.39	20.5 7
232	1.51	1.01	1.97	0.58	3	5	1.14	0.26	NA	NA	NA	NA	33.79	-0.35	0.55	7.5
232	41.6	80.56	24.98	26.22	6	6	10.2	10.7	NA	NA	NA	NA	95.48	1.40	0.45	12
232	51.7	63.89	33.8	20.22	6	6	13.8	8.26	NA	NA	NA	NA	0	0.40	0.34	12
232	16.9	27.78	25.23	22.91	6	6	10.3	9.35	NA	NA	NA	NA	33.79	0.42	0.34	12

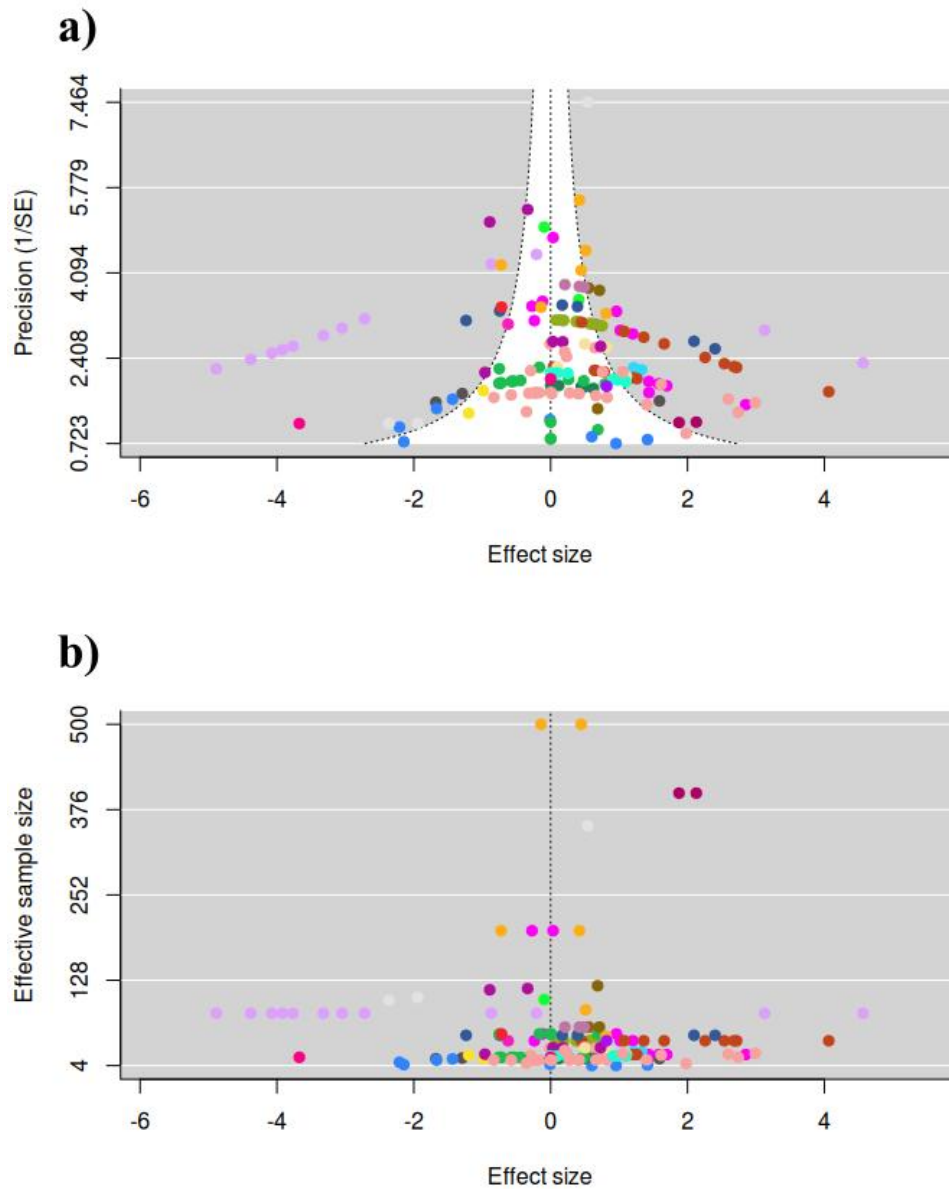
S2. Table with the meta data description of the columns of the table S1.

column name	description
study2022	study number in 2022
outcome	ID for each size effect in each study
reference	article's reference
location2	country where the study was conducted
dd_lat	latitude in decimal degrees calculated by us (to calculate we used coordinates provided by authors and made adjustments in the decimal degrees when necessary, e.g. the point informed by the authors was located on the ocean)
dd_lon	longitude in decimal degrees calculated by us (to calculate we used coordinates provided by authors and made adjustments in the decimal degrees when necessary, e.g. the point informed by the authors was located on the ocean)
gai	global aridity index (when there was more than one coordinate available, we used the intermediary one); "na" when coordinates were not recognized by the site https://www.gps-coordinates.net/
gradient2	part of the dune gradient where the study was conducted (classification as follow: 1 - front/primary/herbaceous dunes/white dune; 2 - middle/semi-stabilized/scrub dunes/open scrub/shrubland/grey dune/transition dune/hind dune/top dunes; 3 - back (except in D'Antonio 1993)/stabilized/forest dunes; 4 - all parts of gradient). If "not informed" or "foredune" in the previous column, we chose one category according to predominant vegetation among neighbors and targets or based on photographs of the area available on Google).
n_sp_LCVP	neighbor species as in the Leipzig Catalogue of Vascular Plants (as in the 'R'-package (lcvplants))
n_lifeform3	broader classification of neighbor life-form. Classification as follow: woody (shrubs and trees), herbs (grass and forbs)
n_lifestage	neighbor lifestage according to the study or supposed by me if it was not clearly informed
t_sp_LCVP	target species as in the Leipzig Catalogue of Vascular Plants (as in the 'R'-package (lcvplants))
t_lifeform3	broader classification of target life-form. Classification as follow: woody (shrubs and trees), herbs (grass and forbs)
t_lifestage3	target life-stage defined as: seed, seedling, not_seedling (if juvenile ou adult), several (if it is a clump of plants and the life-stage is not specified)
performance2	performance estimator classified in broad categories of performance: abundance (includes number of individuals and density), growth, population_growth, growth_size (when the size was used as surrogate for growth), survival, reproduction, diversity (includes richness and diversity index), occurrence and emergence; if it does not apply to this outcome, use "na".
MEANc	mean of performance estimator in control (target without neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
MEANn	mean of performance estimator in treatment (target with neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
SDc	standard deviation of performance estimator in control (target without neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed

SDn	standard deviation of performance estimator in treatment (target with neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
Nc	sampling number in control (target without neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
Nn	sampling number in treatment (target with neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
SE_c	standard error of performance estimator in control (target without neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
SE_n	standard error of performance estimator in treatment (target with neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
sucess_c	number of success in control (target without neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
sucess_n	number of success in treatment (target with neighbor); use "na" if it does not apply to this study; use "not informed" if it does apply to the study but was not informed
fail_c	number of failures in control (target without neighbor); use "na" if it does not apply to this study
fail_n	number of failures in treatment (target with neighbor); use "na" if it does not apply to this study
phylo_dist	phylogenetic distance between the target and neighbor plant
effectsize	effect size as hedge's g
es_variance	variance of the effect size
e_n	effective sampling size



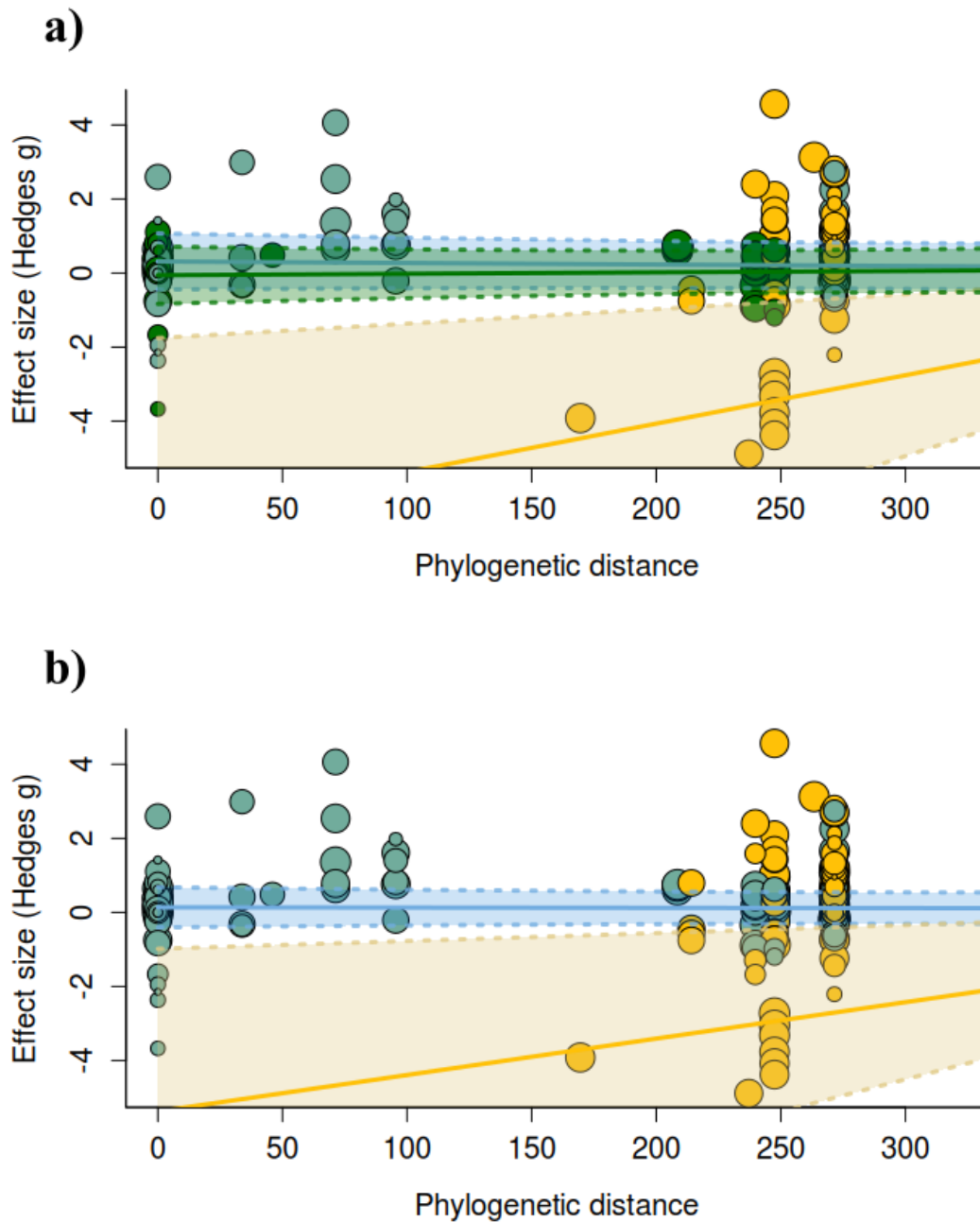
S3. Histogram of the frequencies of phylogenetic distances between neighbor and target plant in our dataset.



S4 a) Precision (inverse of the standard error) and effect size (Hedge's g) funnel plots for all outcomes included in our dataset. Points with the same color are observations from the same study. b) Standard error and effect size (Hedge's g) funnel plots for all outcomes included in our dataset. Points with the same color are observations from the same study.

S5. Table with the results for intercept estimate, standard error and p-values of the Egger's regression that tests for publication bias.

Model	Intercept estimate	Standard error	p-value
Overall model	0.10	0.16	0.51
Phylogenetic distance	0.10	0.16	0.52
Phylogenetic distance (abundance)	-0.94	0.77	0.23
Phylogenetic distance (growth)	0.37	0.25	0.15
Phylogenetic distance (reproduction)	0.66	0.31	0.06
Phylogenetic distance (survival)	-0.06	0.15	0.68
Phylogenetic distance and combination of neighbor and target plant growth forms (woody-woody, herb-herb, woody-herb))	0.17	0.16	0.29
Phylogenetic distance and growth form similarity (defined as herb or woody)	0.15	0.15	0.32
Phylogenetic distance and ontogenetic stage combination	-0.26	0.26	0.33



S6 a) The model of the interaction of phylogenetic distance and growth form combination without excluding the influential outcome showed that these factors do not affect the outcome of plant interactions ($p = 0.17$). Blue represents outcomes of interactions between herbs, green represents outcomes of interactions between woody plants and yellow represents interactions between a woody neighbor and a herb target plant. The dots represent the effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines. There wasn't an effect of the phylogenetic distance ($p = 0.59$), plants with the same growth form (herbs $p = 0.41$, woodys $p = 0.88$), interaction of phylogenetic distance when interacting plants were both woody ($p = 0.52$) on the outcome of plant interactions. However, the interaction between a woody neighbor and a herb target was negative ($p = 0.008$) and the interaction between phylogenetic distance and this combination of growth forms was positive ($p = 0.005$). b) The model of the interaction of phylogenetic distance and growth form similarity without excluding the influential outcome showed that overall these factors do not affect the outcome of plant interactions ($p = 0.14$). Blue represents outcomes of interactions between plants with the same growth form and yellow represents interactions between plants with different growth forms. The dots represent the

effect size of each outcome and its size represents the weight that outcome has on the global mean effect size. The mean effect size is represented by the solid lines and the 95% CI is represented by the shaded areas and the dotted lines. However, there was a positive effect of the phylogenetic distance ($p = 0.01$), a negative effect of growth form dissimilarity ($p = 0.01$) and a negative effect of the interaction of phylogenetic distance with growth form similarity ($p = 0.01$) on the outcome of plant interactions.

III. Conclusões gerais

Não encontramos um efeito da distância filogenética sobre o saldo da interação entre plantas em dunas costeiras, nem observamos a modulação do efeito da distância filogenética pelo estágio ontogenético e o hábito de vida das plantas que estão envolvidas na interação. Portanto, concluímos que a distância filogenética não é um bom preditor para o saldo das interações nesse ecossistema. Em análises complementares consideramos que, segundo a hipótese do gradiente de estresse, o saldo das interações também poderia depender da severidade das condições abióticas. No entanto, o efeito da distância filogenética sobre o saldo das interações não foi significativo mesmo quando consideramos a modulação pela aridez e a proximidade do oceano, separadamente, como proxies de estresse ambiental.

A distância filogenética pode não ser um bom preditor para o saldo das interações porque a similaridade de traços pode nem sempre estar associada a maior intensidade de competição; a diferença de aptidão também é fator importante para determinação do saldo das interações e pode até ser mais importante do que diferenças de nicho (Gerhold et al., 2015). Se a aptidão média for conservada na filogenia e for mais relevante do que diferenças de nicho para determinar o resultado das interações entre plantas, a competição mais forte entre espécies filogeneticamente distantes poderia ser esperada (Mayfield & Levine, 2010, Godoy et al., 2014). Logo, somente a dissimilaridade de traços não é suficiente para tornar interações negativas menos frequentes e as positivas mais frequentes. Portanto, são necessárias investigações sobre como as interações positivas estão relacionadas à combinação específica de traços que poderiam levar à complementaridade de nicho (Navarro-Cano et al. 2020). Além disso, as condições adversas das dunas costeiras podem estar associadas a uma maior variabilidade intraespecífica de traços, devido à plasticidade fenotípica, e os indivíduos neste ecossistema possam ter traços diferentes dos traços médios de suas espécies (Jung et al., 2010). Portanto, o uso da distância filogenética como proxy de traços em ecossistemas severos poderia ter um desempenho pior do que em condições mais amenas. Além disso, a adaptação convergente a condições específicas de dunas costeiras poderia fazer com que espécies distantes tivessem um bom desempenho quando isoladas, diminuindo o efeito positivo de ter um vizinho adaptado que melhorasse as condições ambientais adversas. Há evidências de adaptação convergente à salinidade, que é uma condição estressante neste ambiente, mesmo quando há sinal filogenético positivo na comunidade que indica a conservação dos traços na comunidade (Pavoine et al., 2010). Todos os argumentos acima não são exclusivos e podem ajudar a explicar por que a distância filogenética pode não ser tão informativa para os resultados das interações entre espécies em ambientes severos. Contudo,

como os resultados obtidos neste estudo são restritos a interações entre pares de plantas, é possível que resultados diferentes fossem obtidos caso analisássemos interações entre múltiplas espécies simultaneamente (Zepeda & Martorell, 2021).

Concluimos que é preciso ter cuidado ao interpretar padrões filogenéticos como sendo resultado de interações entre espécies. Determinar os fatores determinantes para o saldo das interações entre espécies é uma tarefa complexa porque não depende apenas das características da espécie, mas também da aptidão, da variabilidade intraespecífica, das condições ambientais e de interações com organismos de outros níveis tróficos.

References:

- Anacker, Brian L., e Sharon Y. Strauss. “Ecological Similarity Is Related to Phylogenetic Distance between Species in a Cross-Niche Field Transplant Experiment”. *Ecology* 97, nº 7 (julho de 2016): 1807–18. <https://doi.org/10.1890/15-1285.1>.
- Armas, Cristina, e Francisco I. Pugnaire. “Ontogenetic Shifts in Interactions of Two Dominant Shrub Species in a Semi-Arid Coastal Sand Dune System”. *Journal of Vegetation Science* 20, nº 3 (2009): 535–46.
- Arroyo, Antonio.I., Pueyo, Yolanda, Saiz, Hugo. and Alados, Concepción .L., Plant–plant interactions as a mechanism structuring plant diversity in a Mediterranean semi-arid ecosystem. *Ecol Evol*, 5: 5305-5317. (2015) <https://doi.org/10.1002/ece3.1770>
- Azevedo, J., e D. L. Morgan. “Fog Precipitation in Coastal California Forests”. *Ecology* 55, nº 5 (1974): 1135–41. <https://doi.org/10.2307/1940364>.
- “Benefit of Shading by Nurse Plant Does Not Change along a Stress Gradient in a Coastal Dune | PLOS ONE”. Acessado 26 de setembro de 2023. <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0105082>.
- Bennett, Jonathan A., Eric G. Lamb, Jocelyn C. Hall, Warren M. Cardinal-McTeague, e James F. Cahill. “Increased Competition Does Not Lead to Increased Phylogenetic Overdispersion in a Native Grassland”. Organizado por Marcel Rejmanek. *Ecology Letters* 16, nº 9 (setembro de 2013): 1168–76. <https://doi.org/10.1111/ele.12153>.
- Bergamo, Pedro Joaquim, Nathália Susin Streher, Marina Wolowski, e Marlies Sazima. “Pollinator-Mediated Facilitation Is Associated with Floral Abundance, Trait Similarity and Enhanced Community-Level Fitness”. *Journal of Ecology* 108, nº 4 (2020): 1334–46. <https://doi.org/10.1111/1365-2745.13348>.
- Bertness, Mark D., e Ragan Callaway. “Positive interactions in communities”. *Trends in Ecology & Evolution* 9, nº 5 (1º de maio de 1994): 191–93. [https://doi.org/10.1016/0169-5347\(94\)90088-4](https://doi.org/10.1016/0169-5347(94)90088-4).
- Brooker, Rob W., Fernando T. Maestre, Ragan M. Callaway, Christopher L. Lortie, Lohengrin A. Cavieres, Georges Kunstler, Pierre Liancourt, et al.. “Facilitation in Plant Communities: The Past, the Present, and the Future”. *Journal of Ecology* 0, nº 0 (6 de setembro de 2007): 070908024102002-??? <https://doi.org/10.1111/j.1365-2745.2007.01295.x>.
- Cadotte, Marc W., Marta Carboni, Xingfeng Si, e Shinichi Tatsumi. “Do Traits and Phylogeny Support Congruent Community Diversity Patterns and Assembly Inferences?” Organizado por David Gibson. *Journal of Ecology* 107, nº 5 (setembro de 2019): 2065–77. <https://doi.org/10.1111/1365-2745.13247>.

Cahill, James F., Steven W. Kembel, Eric G. Lamb, e Paul A. Keddy. “Does Phylogenetic Relatedness Influence the Strength of Competition among Vascular Plants?” *Perspectives in Plant Ecology, Evolution and Systematics* 10, nº 1 (março de 2008): 41–50. <https://doi.org/10.1016/j.ppees.2007.10.001>.

Callaway, Ragan M. “Positive Interactions among Plants”. *The Botanical Review* 61, nº 4 (1º de outubro de 1995): 306–49. <https://doi.org/10.1007/BF02912621>.

Castanho, Camila de Toledo, Christopher J. Lortie, Benjamin Zaitchik, e Paulo Inácio Prado. “A Meta-Analysis of Plant Facilitation in Coastal Dune Systems: Responses, Regions, and Research Gaps”. *PeerJ* 3 (12 de fevereiro de 2015): e768. <https://doi.org/10.7717/peerj.768>.

Castanho, Camila T., Alexandre A. Oliveira, e Paulo Inácio K. L. Prado. “Does Extreme Environmental Severity Promote Plant Facilitation? An Experimental Field Test in a Subtropical Coastal Dune”. *Oecologia* 178, nº 3 (1º de julho de 2015): 855–66. <https://doi.org/10.1007/s00442-015-3285-7>.

Cavender-Bares, Jeannine, Kenneth H. Kozak, Paul V. A. Fine, e Steven W. Kembel. “The Merging of Community Ecology and Phylogenetic Biology”. *Ecology Letters* 12, nº 7 (julho de 2009): 693–715. <https://doi.org/10.1111/j.1461-0248.2009.01314.x>.

Cheplick, Gregory P. “Patterns in the Distribution of American Beachgrass (*Ammophila breviligulata*) and the Density and Reproduction of Annual Plants on a Coastal Beach”. *Plant Ecology* 180, nº 1 (2005): 57–67.

Duarte, Milen, Miguel Verdú, Lohengrin A. Cavieres, e Ramiro O. Bustamante. “Plant–Plant Facilitation Increases with Reduced Phylogenetic Relatedness along an Elevation Gradient”. *Oikos* 130, nº 2 (fevereiro de 2021): 248–59. <https://doi.org/10.1111/oik.07680>.

Freiberg, Martin, Marten Winter, Alessandro Gentile, Alexander Zizka, Alexandra Nora Muellner-Riehl, Alexandra Weigelt, e Christian Wirth. “LCVP, The Leipzig Catalogue of Vascular Plants, a New Taxonomic Reference List for All Known Vascular Plants”. *Scientific Data* 7, nº 1 (26 de novembro de 2020): 416. <https://doi.org/10.1038/s41597-020-00702-z>.

Gerhold, Pille, James F. Cahill, Marten Winter, Igor V. Bartish, e Andreas Prinzing. “Phylogenetic Patterns Are Not Proxies of Community Assembly Mechanisms (They Are Far Better)”. Organizado por Patrick Venail. *Functional Ecology* 29, nº 5 (maio de 2015): 600–614. <https://doi.org/10.1111/1365-2435.12425>.

Godoy, Oscar, Nathan J. B. Kraft, e Jonathan M. Levine. “Phylogenetic Relatedness and the Determinants of Competitive Outcomes”. Organizado por Jerome Chave. *Ecology Letters* 17, nº 7 (julho de 2014): 836–44. <https://doi.org/10.1111/ele.12289>.

Gómez-Aparicio, Lorena. “The Role of Plant Interactions in the Restoration of Degraded Ecosystems: A Meta-Analysis across Life-Forms and Ecosystems”. *Journal of Ecology* 97, nº 6 (2009): 1202–14. <https://doi.org/10.1111/j.1365-2745.2009.01573.x>.

Habeck, Christopher W., e Alexis K. Schultz. “Community-level impacts of white-tailed deer on understorey plants in North American forests: a meta-analysis”. *AoB PLANTS* 7 (1º de janeiro de 2015): plv119. <https://doi.org/10.1093/aobpla/plv119>.

Higgins, Julian P. T., e Simon G. Thompson. “Quantifying Heterogeneity in a Meta-Analysis”. *Statistics in Medicine* 21, nº 11 (2002): 1539–58. <https://doi.org/10.1002/sim.1186>.

Jung, V., Violle, C., Mondy, C., Hoffmann, L. and Muller, S., “Intraspecific variability and trait-based community assembly.” *Journal of Ecology*, 98 (2010): 1134-1140. <https://doi.org/10.1111/j.1365-2745.2010.01687.x>

Jin, Yi, e Hong Qian. “V.PhyloMaker2: An updated and enlarged R package that can generate very large phylogenies for vascular plants”. *Plant Diversity* 44, nº 4 (1º de julho de 2022): 335–39. <https://doi.org/10.1016/j.pld.2022.05.005>.

Lane, C., S. J. Wright, J. Roncal, e J. Maschinski. “Characterizing Environmental Gradients and Their Influence on Vegetation Zonation in a Subtropical Coastal Sand Dune System”. *Journal of Coastal Research* 24, nº sp3 (julho de 2008): 213–24. <https://doi.org/10.2112/07-0853.1>.

Louthan, Allison M., Daniel F. Doak, Jacob R. Goheen, Todd M. Palmer, e Robert M. Pringle. “Mechanisms of plant–plant interactions: concealment from herbivores is more important than abiotic-stress mediation in an African savannah”. *Proceedings of the Royal Society B: Biological Sciences* 281, nº 1780 (7 de abril de 2014): 20132647. <https://doi.org/10.1098/rspb.2013.2647>.

Ludwig, Fulco, Hans de Kroon, Frank Berendse, e Herbert H.T. Prins. “The Influence of Savanna Trees on Nutrient, Water and Light Availability and the Understorey Vegetation”. *Plant Ecology* 170, nº 1 (1º de janeiro de 2004): 93–105. <https://doi.org/10.1023/B:VEGE.0000019023.29636.92>.

Maestre, Fernando. T., Bautista, Susana, Cortina, Jordin. and Bellot, Juan, Potential for using facilitation by grasses to establish shrubs on a semiarid degraded steppe. *Ecological*

Applications, 11: 1641-1655. (2001)
[https://doi.org/10.1890/1051-0761\(2001\)011\[1641:PFUFBG\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2001)011[1641:PFUFBG]2.0.CO;2)

Maestre, Fernando T., Susana Bautista, e Jordi Cortina. “Positive, Negative, and Net Effects in Grass–Shrub Interactions in Mediterranean Semiarid Grasslands”. *Ecology* 84, n° 12 (2003): 3186–97. <https://doi.org/10.1890/02-0635>.

Mayfield, Margaret M., e Jonathan M. Levine. “Opposing Effects of Competitive Exclusion on the Phylogenetic Structure of Communities: Phylogeny and Coexistence”. *Ecology Letters* 13, n° 9 (setembro de 2010): 1085–93. <https://doi.org/10.1111/j.1461-0248.2010.01509.x>.

McAuliffe, Joseph R. “Prey Refugia and the Distributions of Two Sonoran Desert Cacti”. *Oecologia* 65, n° 1 (1° de dezembro de 1984): 82–85. <https://doi.org/10.1007/BF00384466>.

Mitchell, Mark, Baurzhan Muftakhidinov, Tobias Winchen, Alexander Wilms, Bas Van Schaik, Badshah400, Mo-Gul, et al.. “markummitchell/engage-digitizer: Nonrelease”. Zenodo, 12 de julho de 2020. <https://doi.org/10.5281/ZENODO.3941227>.

Montesinos-Navarro, Alicia, Miguel Verdú, José Ignacio Querejeta, e Alfonso Valiente-Banuet. “Nurse Plants Transfer More Nitrogen to Distantly Related Species”. *Ecology* 98, n° 5 (2017): 1300–1310. <https://doi.org/10.1002/ecy.1771>.

Nakagawa, Shinichi, e Eduardo S. A. Santos. “Methodological Issues and Advances in Biological Meta-Analysis”. *Evolutionary Ecology* 26, n° 5 (1° de setembro de 2012): 1253–74. <https://doi.org/10.1007/s10682-012-9555-5>.

Nakagawa, Shinichi, Yefeng Yang, Erin L. Macartney, Rebecca Spake, e Malgorzata Lagisz. “Quantitative evidence synthesis: a practical guide on meta-analysis, meta-regression, and publication bias tests for environmental sciences”. *Environmental Evidence* 12, n° 1 (24 de abril de 2023): 8. <https://doi.org/10.1186/s13750-023-00301-6>.

Nara, Kazuhide, e Taizo Hogetsu. “Ectomycorrhizal Fungi on Established Shrubs Facilitate Subsequent Seedling Establishment of Successional Plant Species”. *Ecology* 85, n° 6 (2004): 1700–1707. <https://doi.org/10.1890/03-0373>.

Navarro-Cano, Jose Antonio, Marta Goberna, Alfonso Valiente-Banuet, e Miguel Verdú. “Phenotypic Structure of Plant Facilitation Networks”. Organizado por Akira Mori. *Ecology Letters* 24, n° 3 (março de 2021): 509–19. <https://doi.org/10.1111/ele.13669>.

Navarro-Cano, Jose Antonio, Marta Goberna, e Miguel Verdú. “Using Plant Functional Distances to Select Species for Restoration of Mining Sites”. *Journal of Applied Ecology* 56, n° 10 (2019): 2353–62. <https://doi.org/10.1111/1365-2664.13453>.

Pavoine, Sandrine, Errol Vela, Sophie Gachet, Gérard de Bélair, e Michael B. Bonsall. “Linking Patterns in Phylogeny, Traits, Abiotic Variables and Space: A Novel Approach to Linking Environmental Filtering and Plant Community Assembly”. *Journal of Ecology* 99, n° 1 (2011): 165–75. <https://doi.org/10.1111/j.1365-2745.2010.01743.x>.

Petranka, James W., e James K. McPherson. “The Role of Rhus Copallina in the Dynamics of the Forest-Prairie Ecotone in North-Central Oklahoma”. *Ecology* 60, n° 5 (1979): 956–65. <https://doi.org/10.2307/1936864>.

Qian, Hong, e Jian Zhang. “Using an Updated Time-Calibrated Family-Level Phylogeny of Seed Plants to Test for Non-Random Patterns of life forms across the Phylogeny”. *Journal of Systematics and Evolution* 52, n° 4 (2014): 423–30. <https://doi.org/10.1111/jse.12086>.

Schiffers, Katja, e Katja Tielbörger. “Ontogenetic Shifts in Interactions among Annual Plants”. *Journal of Ecology* 94, n° 2 (2006): 336–41.

Simon, Marcelo.F.; Grether, Rosaura.; de Queiroz, Luciano.P.; Skema, Cynthia.; Pennington, R.Toby.; Hughes, Colin.E. “Recent Assembly of the Cerrado, a Neotropical Plant Diversity Hotspot, by in Situ Evolution of Adaptations to Fire”. *Proc. Natl. Acad. Sci. USA* (2009), 106, 20359–20364.

Shumway, Scott W. “Facilitative Effects of a Sand Dune Shrub on Species Growing beneath the Shrub Canopy”. *Oecologia* 124, n° 1 (2000): 138–48. <https://doi.org/10.1007/s004420050033>.

Soliveres, Santiago, Christian Smit, e Fernando T. Maestre. “Moving Forward on Facilitation Research: Response to Changing Environments and Effects on the Diversity, Functioning and Evolution of Plant Communities”. *Biological Reviews* 90, n° 1 (2015): 297–313. <https://doi.org/10.1111/brv.12110>.

Thomson, James D. “Patterns of Visitation by Animal Pollinators”. *Oikos* 39, n° 2 (1982): 241–50. <https://doi.org/10.2307/3544491>.

Tilman, D., e S. Pacala. “The maintenance of species richness in plant communities”. *Unknown Journal*, 1º de janeiro de 1993, 13–25.

Urza, Alexandra K., Peter J. Weisberg, Jeanne C. Chambers, e Benjamin W. Sullivan. “Shrub Facilitation of Tree Establishment Varies with Ontogenetic Stage across Environmental Gradients”. *The New Phytologist* 223, n° 4 (setembro de 2019): 1795–1808. <https://doi.org/10.1111/nph.15957>.

Valiente-Banuet, Alfonso, e Miguel Verdú. “Plant Facilitation and Phylogenetics”. *Annual Review of Ecology, Evolution, and Systematics* 44, nº 1 (23 de novembro de 2013): 347–66. <https://doi.org/10.1146/annurev-ecolsys-110512-135855>.

Valiente-Banuet, A. and Verdú, M., Temporal shifts from facilitation to competition occur between closely related taxa. *Journal of Ecology*, 96 (2008): 489-494. <https://doi.org/10.1111/j.1365-2745.2008.01357.x>

Verdú M, Gómez-Aparicio L, Valiente-Banuet A. Phylogenetic relatedness as a tool in restoration ecology: a meta-analysis. *Proc Biol Sci.* 7;279(1734):1761-7. (2012) doi: 10.1098/rspb.2011.2268.

Viechtbauer, Wolfgang. “Conducting Meta-Analyses in R with the Metafor Package”. *Journal of Statistical Software* 36 (5 de agosto de 2010): 1–48. <https://doi.org/10.18637/jss.v036.i03>.

Viechtbauer, Wolfgang, e Mike W.-L. Cheung. “Outlier and Influence Diagnostics for Meta-Analysis”. *Research Synthesis Methods* 1, nº 2 (abril de 2010): 112–25. <https://doi.org/10.1002/jrsm.11>.

Violle, Cyrille, Diana R. Nemergut, Zhichao Pu, e Lin Jiang. “Phylogenetic Limiting Similarity and Competitive Exclusion: Phylogenetic Relatedness and Competition”. *Ecology Letters* 14, nº 8 (agosto de 2011): 782–87. <https://doi.org/10.1111/j.1461-0248.2011.01644.x>.

Webb, Campbell O., David D. Ackerly, Mark A. McPeck, e Michael J. Donoghue. “Phylogenies and Community Ecology”. *Annual Review of Ecology and Systematics* 33, nº 1 (novembro de 2002): 475–505. <https://doi.org/10.1146/annurev.ecolsys.33.010802.150448>.

Williams, Evelyn W., Jacob Zeldin, Wendy R. Semski, Andrew L. Hipp, e Daniel J. Larkin. “Phylogenetic Distance and Resource Availability Mediate Direction and Strength of Plant Interactions in a Competition Experiment”. *Oecologia* 197, nº 2 (1º de outubro de 2021): 459–69. <https://doi.org/10.1007/s00442-021-05024-4>.

Wilson, and Sykes, Is zonation on coastal sand dunes determined primarily by sand burial or by salt spray? A test in New Zealand dunes. *Ecology Letters*, 2: 233-236. (1999), <https://doi.org/10.1046/j.1461-0248.1999.00084.x>

Zepeda, Verónica, e Carlos Martorell. “Effects of Phylogenetic Relatedness on Fluctuation-Dependent and Fluctuation-Independent Coexistence Mechanisms in Multispecies Communities”. *The American Naturalist* 198, nº 1 (julho de 2021): E1–11. <https://doi.org/10.1086/714161>.

Zhang, Liwen, Xiangcheng Mi, e Hongbo Shao. “Phylogenetic Relatedness Influences Plant Interspecific Interactions Across Stress Levels in Coastal Ecosystems: a

Meta-Analysis”. *Estuaries and Coasts* 39 (9 de maio de 2016).
<https://doi.org/10.1007/s12237-016-0104-2>.

Zomer RJ, Trabucco A, Bossio DA, van Straaten O, Verchot LV. Climate Change Mitigation: A Spatial Analysis of Global Land Suitability for Clean Development Mechanism Afforestation and Reforestation. *Agric. Ecosystems and Envir.* 126: 67-80. (2008)
<https://doi.org/10.1016/j.agee.2008.01.014>