

Universidade Federal de São Carlos
Centro de Ciências Biológicas e da Saúde
Programa de Pós-Graduação em Ecologia e Recursos Naturais

Produção de biomassa e necromassa de espécies invasoras e controle mecânico e químico de *Hedychium coronarium* König. (Zingiberaceae) em zonas ripárias neotropicais

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Co-orientadora: Dra. Talita Ariela Sampaio e Silva

Tese Apresentada ao Programa de Pós-Graduação em Ecologia e Recursos Naturais, da Universidade Federal de São Carlos, como parte dos requisitos para obtenção do título de Doutora em Ciências, área de concentração: Ecologia e Recursos Naturais

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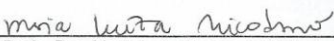
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“Não te deixes destruir...
Ajuntando novas pedras
e construindo novos poemas.

Recrie tua vida, sempre, sempre.
Remove pedras e planta roseiras e faz doces.
Recomeça.

Faz de tua vida mesquinha
um poema.
E viverás no coração dos jovens
e na memória das gerações que hão de vir.

Esta fonte é para uso de todos os sedentos.
Toma a tua parte.
Vem a estas páginas
e não entres seu uso
aos que têm sede.”

– *Cora Coralina*

Dedicatória

Dedico esta tese de doutorado à minha mãe e ao meu pai.

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Resumo Geral

As invasões biológicas são muito comuns. As zonas ripárias estão entre as que sofrem importantes invasões biológicas. O acúmulo de biomassa e necromassa interfere na dinâmica das comunidades de maneira significativa. Considerando a potencial nocividade de espécies invasoras, é interessante que pensemos em formas de controle. Nossos objetivos são verificar se: 1) a produção de biomassa e necromassa de *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora* e *Pennisetum purpureum* estão relacionadas com variáveis climáticas, 2) a produção aérea primária líquida de *H. coronarium*, *U. decumbens*, *M. minutiflora* e *P. purpureum* ao longo do ano, 3) testar o efeito do corte de rametas de *H. coronarium* uma vez e duas vezes por ano no seu crescimento, 4) testar o efeito do arranquio de rizomas de *H. coronarium* uma vez no seu crescimento, 5) testar o efeito no crescimento de *H. coronarium* com injeção em seus rizomas de extrato alcoólico de *Typha domingensis* em duas concentrações (5% e 10%), 6) testar o efeito sobre o crescimento de *H. coronarium* com injeções de glifosato nos seus rizomas e 7) com spray de glifosato nas suas folhas. Nossas hipóteses são 1) a produção de biomassa e de necromassa estarão relacionadas às variáveis climáticas, 2) a produção aérea primária líquida de todas as espécies será alta no ano de estudo e 3) haverá mudança no crescimento de *H. coronarium* com a aplicação dos tratamentos. Coletamos mensalmente biomassa aérea e necromassa das quatro espécies. Para calcular a produção aérea primária líquida, usamos o método de Smalleys. Testamos a normalidade dos dados com o teste de Shapiro-Wilks. A relação entre as variáveis climáticas foi testada com o teste de Spearman. As variáveis não relacionadas entre si foram testadas em modelo linear misto (GLM) na sua relação com as variáveis climáticas. Para selecionar o modelo explicativo mais adequado usamos o teste AKAIKE (AIC), dentro do ambiente R. Para o controle mecânico, estabelecemos três parcelas em cinco áreas subdivididas em quatro sub-parcelas: *i*) controle, *ii*) corte de rametas uma vez por ano, *iii*) corte de rametas duas vezes por ano e *iv*) arranquio de rametas e rizomas. Para o experimento de controle químico, plantamos 5 pedaços de rizoma de 10 cm em aquários de 30 cm x 30 cm x 20 cm com 5 cm de solo adubado. Os aquários foram mantidos em sala com 12 horas de luz e 12 horas de escuro e temperatura controlada de 24+/-2°C. Para testar injeção e spray de glifosato, quatro aquários foram controle e quatro para cada experimento. As injeções foram aplicadas com arma de injeção com 10 mL do produto puro. Após cinco meses, repetimos a injeção e medimos altura e diâmetro na altura do solo mensalmente até três meses depois da última aplicação de injeção. No tratamento com spray, repetimos a aplicação dois e quatro meses depois. Para testar o extrato alcoólico de *Typha domingensis*, três aquários foram controle, três foram usados para cada tratamento: injeção de extrato aéreo em 5% e 10% de concentração, injeção de extrato de rizoma em 5% e 10 % de concentração. Uma vez por mês medimos a altura e o diâmetro na altura do solo de todos os rametas, até três meses depois da aplicação, em todos os tratamentos. Para testar a diferença entre altura e diâmetro nos diferentes tratamentos, usamos modelo linear misto. Todas as análises foram feitas no ambiente R. Usamos a taxa de mortalidade expressa em porcentagem de rametas mortos. As espécies estudadas têm seu funcionamento diretamente relacionado com as variáveis ambientais em questão e podem causar grandes impactos em zona ripária por causa da sua alta produção de biomassa e necromassa ao longo do ano, especialmente *H. coronarium* e *P. purpureum*. Portanto, medidas de controle são de extremo interesse. Os experimentos de controle de *H. coronarium* foram eficientes; o tratamento com injeção de glifosato nos rizomas da planta foi o que obteve o melhor resultado, com taxa de mortalidade de 97,3%. Deve-se

considerar a localidade onde se encontra o *H. coronarium* para que não haja mortalidade de outras espécies quando da aplicação do herbicida.

Palavras-chave: biomassa, necromassa, *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora*, *Pennisetum purpureum*, controle mecânico, controle químico, extrato de *Typha domingensis*.

Abstract

Biological invasions are common. Riparian zones are among those that undergo major biological invasions. The accumulation of biomass and necromass interferes in the dynamics of the plant community in a significant way. Considering the potential harmfulness of invasive species, it is interesting that we think of forms of control. Our objectives are to determine if: 1) biomass and necromass production of *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora* and *Pennisetum purpureum* are related to climatic variables, 2) the net primary aerial production of *H. coronarium*, *U. decumbens*, *M. minutiflora* and *P. purpureum* throughout the year, 3) to test the effect of once and twice-yearly cutting of *H. coronarium* ramets on their growth 4) to test the effect of *H. coronarium* rhizome cutting off once a year, 5) to test the effect on growth of *H. coronarium* with injection in its rhizomes of alcoholic extract of *Typha domingensis* in two concentrations (5% e 10%) and from leaves and rhizome, 6) to test the effect on growth of *H. coronarium* with injections of glyphosate into its rhizomes and 7) with spray of glyphosate on its leaves. Our hypotheses are 1) the production of biomass and necromass will be related to climatic variables, 2) the net primary aerial production of all species will be high in the year of study and 3) there will be effect in the growth of *H. coronarium* with the application of the treatments. For one year we collected monthly aerial biomass and necromass of the four species. To calculate net primary aerial production, we used Smalley's method. We tested the data for normality using Shapiro-Wilks test. Relations among climatic variables were tested with Spearman's test. Variables not related to each other were tested with a mixed linear model (GLM) in its relationship with climate. To select most adequate model of explanation, we used AKAIKE test (AIC), within R environment. For mechanical control we established three plots in five sites subdivided into four sub plots: *i*) control, *ii*) cutting off ramets once a year, *iii*) cutting off ramets twice a year and *iv*) pulling out ramets and rhizomes. For the experiment of chemical control of *H. coronarium* planted five pieces of 10 cm of rhizomes in aquariums of 30 cm x 30 cm x 20 cm with 5 cm of fertilized soil. Aquariums were kept in a room with 12 hours of light and 12 hours of dark and temperature 24 \pm 2°C. To test glyphosate injection and spray, we left four aquariums for control, four for injection and four for spray. Injections were made with 10 mL of the product undiluted. Five months after the first injection, we repeated the procedure. To test glyphosate spray, we repeated the application two months after the first spray, and again after four months. To test *Typha domingensis* alcoholic extract, three aquariums were left for control, three had its ramets injected with leaf alcoholic extract at 5 % and 10 % concentration, three had its ramets injected with rhizome alcoholic extract at 5 % and 10 % concentration. Once a month, we numbered the ramets and measured their diameter on soil level and the total height for all experiments. To test the differences for height and diameter among treatments, we used linear mixed models. All analysis was conducted within the R statistical environment. We also used mortality rates expressed in percentage of dead ramets. The species studied have a direct relationship with the environmental variables in question and cause great impacts on

riparian zone due to its high production of biomass and necromass throughout the year, especially *H. coronarium* and *P. purpureum*. Therefore, control measures are of extreme interest. The control experiments of *H. coronarium* were efficient, treatment with glyphosate injection in the rhizomes of the plant was the one that obtained the best result, with mortality rate of 97,3 %. The locality of *H. coronarium* should be considered so that there is no mortality of other species when applying the herbicide.

Key words: biomass, necromass, *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora*, *Pennisetum purpureum*, mechanical control, chemical control, *Typha domingensis* extract.

1. Introdução geral

1.1. Invasões biológicas

A extensão geográfica de cada espécie é limitada por barreiras, tanto climáticas como geológicas, que não são transponíveis pelos organismos de dada espécie, estabelecendo padrões de evolução diversos em cada área do mundo (Primack e Rodrigues, 2000). A espécie humana modificou este padrão transportando espécies pelo globo, para que os colonizadores sentissem-se em ambiente familiar e para que pudessem caçar; espécies da flora foram introduzidas para ornamentação, agricultura ou pastagem e o transporte acidental também auxiliou na introdução de espécies exóticas em diversas localidades (Primack e Rodrigues 2000, Zenni e Ziller 2011).

As invasões biológicas vêm sendo relatadas há séculos (Davis 2011). Entretanto, apenas em 1958, com o livro *The Ecology of Animal and Plant Invasions*, de Charles Elton, é que se começou a estudar a ecologia das invasões, supondo que comunidades com diversidade maior apresentariam maior resistência às invasões, como resultado da menor oscilação no tamanho de suas populações.

Desde então, inúmeras hipóteses para invasões biológicas foram elaboradas. De acordo com Lonsdale (1999) são três os fatores que influenciam nos processos de invasão: o número de propágulos que chegam ao ambiente invadido (pressão de propágulos), as características da espécie invasora e a suscetibilidade de invasão do ambiente pela espécie exótica, denominada *invasibilidade*. A invasibilidade é, portanto, uma propriedade emergente de um ambiente, sendo o resultado de inúmeros fatores, tais como o clima da região, o regime de distúrbio do ambiente e as habilidades competitivas das espécies nativas (Fridley 2011). A invasibilidade pode ser aferida pela presença (ou ausência) de herbívoros e patógenos, mutualismos e efeitos de facilitação da vegetação residente (Lonsdale 1999).

Neste contexto, a disponibilidade de recursos (água, luz, nutrientes, entre outros) é, portanto, um fator significativo para o sucesso da invasão. Davis e colaboradores (2000) acreditam que a maioria das comunidades de plantas raramente encontra-se em estabilidade em relação à disponibilidade de recursos, devido a flutuações periódicas na oferta de recursos. Assim, a invasão de uma espécie depende do aumento dos recursos, devendo coincidir com a disponibilidade de propágulos invasores. Para estes autores, o aumento de recursos dá-se de duas maneiras: 1) diminuição do seu uso pela vegetação nativa ou 2) o aumento de disponibilidade de recursos pode ser maior do que o aumento do seu uso pela vegetação nativa. Portanto, a teoria da flutuação de recursos disponíveis prevê que uma comunidade de plantas é mais suscetível à invasão sempre que ocorre aumento dos recursos não utilizados disponíveis (Davis et al. 2000).

Por outro lado, maior capacidade de utilizar recursos em períodos de escassez também pode conferir sucesso à invasão. Algumas hipóteses levam a considerar que as plantas invasoras de maior sucesso são aquelas superiores em competição com plantas nativas. Essas invasoras são de maior tamanho, crescem mais rapidamente e respondem de maneira mais vigorosa às flutuações de recursos, ou seja, são mais plásticas em relação à flutuação de recursos (conforme revisado por Simberloff e Rejmánek 2011). Portanto, comunidades com populações que se mantêm abaixo de sua capacidade de suporte devem ser mais suscetíveis a invasões (Fridley 2011).

Ainda no campo da invasibilidade, a existência de competidores/predadores também está ligada ao sucesso da invasão. A hipótese da liberação de inimigos considera que plantas invasoras podem ter maior sucesso em novas regiões por capitalizar a ausência de inimigos naturais e prevê que 1) a nova região não terá inimigos especialistas da espécie exótica, 2) inimigos especializados raramente trocarão de alvo, de espécie nativa para espécie exótica e 3) inimigos generalistas causam maior

impacto em espécies competidoras nativas (Keane e Crawley 2002). Ainda, sabe-se que espécies invasoras que têm relação filogenética maior com espécies nativas causam menores impactos na diversidade e riqueza de espécies nas comunidades que invadem (Strauss et al 2006).

As invasões biológicas são consideradas um dos pontos significativos das mudanças ambientais globais. Isto porque foram reportadas em quase todas as partes do mundo, o que faz com que o fenômeno ocupe a segunda posição nas causas de perda de biodiversidade (Vitousek et al 1997, Simberloff e Rejmanek 2011). Entre os impactos causados por invasões biológicas, podem ser citados alterações no fluxo de energia, alterações na ciclagem de nutrientes e nos atributos do solo, alterações no regime de fogo, construção de novos habitats e exclusão de espécies dominantes (tabela 1) (conforme revisado por Simberloff 2011).

Tabela 1. Alguns exemplos de artigos que discutem processos ecossistêmicos impactados por plantas invasoras.

Processo impactado	Situação específica	Fonte
Mudanças estruturais		Thompson 1991
Ciclagem de nutrientes	Ciclo do nitrogênio	Tyler et al 2007
	Ciclo do fósforo	Turner et al 2008
Regime de distúrbio	Incidência de fogo	Brooks et al 2004
Exclusão de espécies dominantes		Gray et al 1997

Outros impactos causados por invasoras são relativos a produção de biomassa e necromassa de plantas dessas espécies, cujo acúmulo pode interferir de maneira significativa na dinâmica de comunidades vegetais (Violle et al. 2006; Loydi et al. 2014). O acúmulo de biomassa pode diminuir a oferta de luz e de água, prejudicando o crescimento e a reprodução de outras espécies e aumentando a competição entre elas

(Suding and Goldberg 1999; Violle et al. 2006). Na Austrália, o acúmulo de biomassa da invasora *Andropogon gayanus* atua como aporte de material combustível (Setterfield et al. 2013) e este aporte de material combustível por espécies invasoras também pode acontecer em zonas ripárias em períodos de seca (Brooks et al. 2004). No que diz respeito à necromassa, seu acúmulo pode impedir a chegada de luz ao solo, atuando como barreira para o crescimento de espécies, pode produzir substâncias fitotóxicas e pode aumentar o aporte de nutrientes no solo pela sua decomposição, causando o declínio da diversidade de espécies dentro de uma comunidade (Berendse 1999; Foster e Gross 1998).

Zonas ripárias abrigam processos ecológicos próprios, que fornecem importantes serviços ecossistêmicos. Suas espécies vegetais podem apresentar inúmeras adaptações às suas condições ambientais, como raízes adventícias e presença de aerênquima (Naiman e Décamps 1997), sua vegetação atua na ciclagem de nutrientes, de água (Schade et al. 2001) e do solo, as plantas servem de alimento para mamíferos, aves, detritívoros e insetos, entre outros e fornecem abrigo e local para nidificação (Richardson et al. 2007). Ainda, influenciam o clima local, as taxas de fluxo de correntes de água e, por evapotranspiração, controlam o nível de água no solo (Richardson et al. 2007), o que torna o estudo de invasões em zonas ripárias muito relevante. Apesar disso, as zonas ripárias têm alta frequência e abundância de plantas invasoras no mundo todo (Richardson et al. 2007), uma vez que a dispersão de propágulos de espécies invasoras por rios é muito eficiente (Pysek e Prach 1993). Ademais, muitos assentamentos de pessoas estão localizados em beiras de rios, levando a introdução de propágulos de espécies invasoras que podem se estabelecer nesses ecossistemas (Richardson et al. 2007).

No Brasil, muitas plantas invasoras foram trazidas com fins paisagísticos ou como plantas para forrageio de animais. Os registros mais antigos de espécies invasoras datam do século XVIII, relatando o uso de gramíneas africanas para forrageio de animais de corte (Pivello 2011; Zenni e Ziller 2011). Foram contabilizadas até a presente revisão, 117 plantas invasoras diferentes documentadas no Brasil em diferentes ecossistemas: Cerrado, caatinga, mata atlântica, floresta ombrófila densa, floresta tropical semi decídua são alguns exemplos e as zonas ripárias também se encontram entre os que sofrem invasões biológicas importantes (Zenni e Ziller 2011). Entre as espécies que foram trazidas para o país como plantas ornamentais que se tornaram invasoras, estão a herbácea *Impatiens parviflora* (fig. 1), a palmeira *Archontophoenix cunninghamiana* (fig. 2), inúmeras espécies de *Pinus* (fig. 3) e de *Eucalyptus* (fig. 4) para ambientes terrestres, e a macrófita *Eichhornia crassipes* (fig. 5) para ambientes aquáticos (Pivello 2011). Entre as espécies invasoras de maior expressividade no Brasil, estão as gramíneas *Urochloa decumbens*, *Melinis minutiflora* e *Pennisetum pupureum*, trazidas para formação de pasto, e a macrófita *Hedychium coronarium*, que é uma das invasoras que cobre o maior número de fitofisionomias no país (Zenni e Ziller 2011), tendo sido trazida e cultivada para fins ornamentais (Souza e Lorenzi 2005).



Figura 1: invasão de *Impatiens parviflora* na Bélgica. Fonte: Manual of the alien plants of Belgium. In: <http://alienplantsbelgium.be/content/impatiens-parviflora> Acessado em: 14/08/2018



Figura 2: *Archontophoenix cunninghamiana*. Fonte: Global invasive species database. In: <http://www.iucngisd.org/gisd/species.php?sc=1665> Acessado em: 14/08/2018



Figura 3: invasão de *Pinus* sp em campo de altitude da Serra do mar. Fonte: Instituto Hórus. In: http://www.institutohorus.org.br/?modulo=pr_controle_camapua_parana
Acessado em: 14/08/2018



Figura 4: Árvores de *Eucalyptus* sp. Fonte: Revista Agropecuária. In: <http://www.revistaagropecuaria.com.br/2016/03/28/principais-plantas-daninhas-na-cultura-do-eucalipto/> Acessado em: 14/08/2018



Figura 5: *Eichhornia crassipes*. Fonte: Foraging Texas. Merriwether's Guide to Edible Wild Plants of Texas and the Southwest. In: <http://www.foragingtexas.com/2008/10/water-hyacinth.html> Acessado em: 14/08/2018

1.2. Controle

O método mais barato e efetivo de controlar invasões biológicas é a prevenção (Motooka et al 2002). Entretanto, de uma forma geral, a detecção de espécies invasoras ocorre tardiamente (Hobbes e Humphries, 1995). Isso resulta do fato de que as populações de espécies exóticas precisam se estabelecer no novo local, para depois serem capazes de se expandir, isto é, aumentar o seu número de indivíduos (Hobbes e Humphries, 1995; Lockwood et al 2007) (fig. 6). Deste modo, as ações de controle de espécies invasoras são aplicadas quando estas se tornam conspícuas ou quando há um impacto notável sobre as comunidades invadidas, dificultando o controle e a mitigação dos impactos negativos.

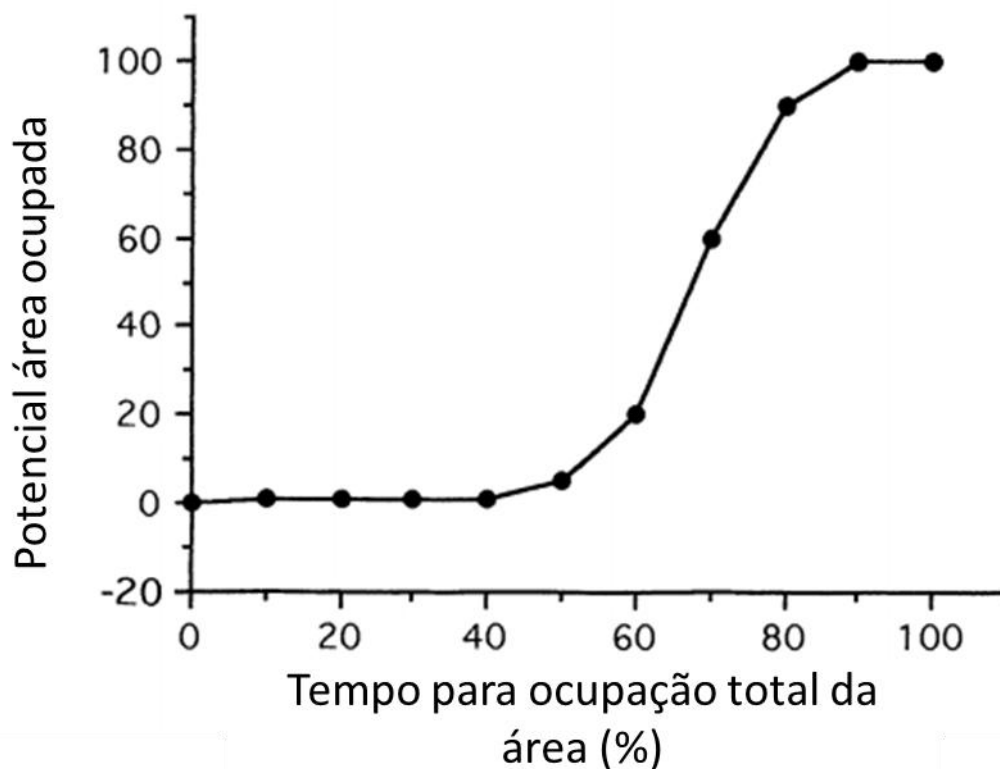


Figura 6: Representação da expansão populacional de uma planta invasora ao longo do tempo. Extraído de Hobbes e Humphries, 1995.

Atualmente, o controle de plantas invasoras pode ser realizado como controle cultural, controle mecânico, controle químico e controle biológico, que podem ser utilizados em combinações (Dechoum e Ziller 2013, Myers e Bazely 2003; Motooka et al 2002). O controle cultural ocorre quando práticas de manejo que modificam agroecossistemas são empregadas, por exemplo, uso de pisoteio de gado para reprimir o brotamento de gramíneas invasoras (Motooka et al 2002).

O controle biológico consiste em introduzir inimigos naturais da espécie invasora em locais onde eles não ocorrem naturalmente, de modo que o agente biológico faça o controle da espécie (Kremer 2005). Um potencial problema da introdução de novas espécies para controle de invasoras é o fato de que aquelas também podem se tornar invasoras, o que faz do uso do controle biológico uma questão ética

(Warner 2016). Mesmo assim, o controle biológico é potencialmente benéfico (Myers e Bazely 2003), tendo sido muito utilizado no Havaí, desde o início do século XX com algum sucesso (Motooka et al 2002). Vem sendo também considerado como ferramenta útil na Nova Zelândia, diminuindo gastos financeiros causados por invasões biológicas (Hayes 2012) e apresentando alto grau de segurança em relação a novas invasões causadas por agentes introduzidos para controle de ervas daninhas (Hayes et al 2013).

O controle mecânico pode ser classificado como específico ou não específico. No controle não específico, um fator do nível ecossistêmico é manipulado para que a espécie alvo diminua em frequência (tais como queimadas, inundações e roçadas generalizadas). No controle específico, por outro lado, apenas a espécie alvo é afetada e este método pode ser realizado arrancando-se ou cortando-se a planta; a técnica deve ser escolhida de acordo com a ecologia da espécie em questão. Tratam-se de técnicas com alto custo e grande trabalho manual (Clewley et al 2012), o que faz com que sejam indicadas quando a invasão for restrita a pequenas áreas, afastando o risco de causar danos para espécies não alvo, no caso de técnica não específica (Myers e Bazely 2003; Motooka et al 2002).

O controle químico é realizado através da aplicação de herbicidas sintéticos, que apresentam diversos mecanismos de funcionamento. Os herbicidas podem ser aplicados por spray aéreo, spray manual ou injeção (Myers e Bazely 2003). A aplicação desses compostos requer cautela, devendo ser considerados a proximidade de plantas não alvo sensíveis, o tamanho da gotícula na aplicação em spray, direção do vento, a altura de aplicação, a volatilidade do herbicida, e altura da planta alvo (Motooka et al 2002), assim como a possibilidade da planta exudar o herbicida pelas suas raízes (Tuffi Santos et al 2005, Kohls et al 2006). Além disso, como o uso dos herbicidas é regulado pelos países, é necessária a consulta de órgãos reguladores antes da sua utilização.

Herbicidas a base de glifosato estão entre os mais utilizados para o controle de herbáceas (Dechoum e Ziller 2013). O glifosato é uma substância solúvel em água, de calda pronta altamente corrosiva (Amarante-Junior et al 2002) que apresenta toxicidade aguda e crônica considerada baixa para mamíferos (Amarante-Junior et al 2002; Benbrook 2016). É não-seletivo, sistêmico, tende a ser inativo em contato com o solo, sendo adsorvido e, portanto, não lixiviado, mas quando em contato com a água é adsorvido pelos sedimentos, que o carregam; seu uso constante tem resultado em plantas resistentes e em maior número de aplicações (Amarante-Junior et al 2002). Por ser não-seletivo, seu uso tornou-se extenso em lavouras apenas depois do desenvolvimento de sementes geneticamente modificadas para resistir às suas aplicações. Com a ampliação do uso, cresceu também a chance de risco para ecossistemas e para a saúde humana de tal forma que a Agência Internacional para Pesquisa sobre Câncer o considerou como “provavelmente carcinogênico para humanos” em 2015 (Benbrook 2016). No Brasil, onde a plantação de sementes modificadas para resistir à aplicação de glifosato é extensa, seu uso é amplo e não existem limites considerados máximos para sua ingestão (Amarante-Junior et al 2002). Ainda assim, sua comercialização e utilização foi proibida em agosto de 2018 a pedido do Ministério Público Federal até que seja feita sua reavaliação toxicológica pela Agência Nacional de Vigilância Sanitária (ANVISA), com prazo final até 12 de dezembro do mesmo ano¹. Uma alternativa ao uso de herbicidas sintéticos seria a utilização de herbicidas feitos a partir de compostos naturais extraídos de plantas, o que já acontece, porém, em pequena escala (Dayan et al 2009, Cantrell et al 2012). Um único herbicida baseado em composto natural extraído de planta foi registrado nos

¹ Notícia veiculada em inúmeros meios de comunicação, inclusive em <https://istoe.com.br/juiza-do-df-ordena-suspensao-de-comercializacao-e-registro-de-glifosato/> Acesso em 09/08/2018.

Estados Unidos entre os anos de 1997 e 2010, foi a tricetona (apresentada sob diferentes nomes comerciais) (Cantrell et al 2012).

1.3. Espécies estudadas

1.3.1. *Hedychium coronarium* König (Zingiberaceae)

Hedychium coronarium (lírio-do-brejo) é originário da região do Himalaia, na Ásia, encontrada naturalmente no Nepal, Índia leste da China até a Indochina, onde ocorre em matas tropicais e subtropicais de até 1.900 m de altitude (Manish, 2013), ocorrendo também naturalmente em Madagascar (Joly e Brandle, 1995). A espécie é considerada criticamente ameaçada de extinção em seu local de origem, devido à destruição de habitat, utilização massiva em medicina tradicional, sobrepasto e restrições de ocorrência na Ásia a áreas com características ecológicas particulares (Manish, 2013). Atualmente está presente na região neotropical e ocorre como invasora, junto de outras espécies do mesmo gênero, no Havaí (Funk, 2001; Motooka et al 2003), Austrália e Nova Zelândia (Williams et al. 2003). Foi introduzida no Brasil há mais de 300 anos pelos portugueses (Joly e Brandle 1995), sendo, por isso, amplamente distribuída em nossas planícies litorâneas. Entretanto, a espécie não se restringe apenas à região costeira do Brasil, tendo sido encontrada a 3.000 km do litoral no país (Soares e Barreto, 2008). Atualmente, a espécie pode ser encontrada em quase todos os estados brasileiros (Maas e Maas 2015) (fig. 7).



Figura 7: Estados onde foi registrada a presença de *Hedychium coronarium* no Brasil. Os que não estão em branco têm confirmada a presença da espécie. As cores indicam diferentes regiões: Norte (verde), Centro-oeste (amarelo), Nordeste (rosa claro), Sudeste (rosa), Sul (azul). Extraído de Maas e Maas (2015), disponível em http://servicos.jbrj.gov.br/flora/search/Hedychium_coronarium, acessado em 12 de agosto de 2018.

Plantas do gênero *Hedychium* são amplamente utilizadas como ornamentais em razão de suas flores admiráveis e perfumadas, sendo também muito utilizadas para fins medicinais e industriais (Sakhanokho e Rajasekaran, 2010). o que também pode ter contribuído para sua dispersão além das suas áreas de ocorrência originais.

H. coronarium é uma planta perene, herbácea e que se propaga principalmente por rizomas (Lorenzi, 2000). As partes aéreas da planta duram aproximadamente 11

meses (Santos *et al.*, 2005) atingem, em média, 2 m de altura, nunca ficando totalmente submersas durante períodos de cheia (Joly e Brandle, 1995), crescem mais durante períodos de alta temperatura (Santos *et al.*, 2005), em áreas de sombreamento médio (Joly e Brandle, 1995; Santos *et al.*, 2005; Manish, 2013) e com grande disponibilidade de umidade (Santos *et al.*, 2005) e húmus (Joly e Brandle, 1995). Apresenta rizomas (fig. 8) simpodiais horizontais que se espalham pela superfície do solo e possuem inúmeros grãos de amido (Joly e Brandle, 1995).

Em relação à fenologia de *H. coronarium*, podemos dizer que a sua floração se estende de janeiro a março, tendo seu pico em fevereiro no Brasil; a altura mínima de indivíduos portando inflorescência é de 102 cm e a máxima, de 240 cm (Santos *et al.*, 2005 Souza e Correa 2007). Sua frutificação ocorre com maior eficiência em áreas de sombreamento alto (60 a 80% de sombreamento), entre os meses de novembro e julho, com pico no mês de junho (Santos *et al.*, 2005).

Suas folhas apresentam formato elíptico, sésseis e dísticas, com ápice agudo, dispostas de maneira alternada com sobreposição das bainhas bem desenvolvidas; a nervação é penínérvea e a superfície abaxial da epiderme foliar é mais clara e pubescente do que a superfície adaxial; são megáfilas com diferentes orientações (Boeger et al, 2007). As flores (fig. 8) formam inflorescências terminais com botões formando cones, são brancas, produzem néctar e perfume, são hermafroditas e sua antese é noturna; a polinização ocorre por abelhas, formigas, moscas, coleópteros, dermápteros e beija-flores (Souza e Correia 2007). Os frutos (fig. 8) da espécie são do tipo baga deiscente, verdes quando imaturos e alaranjados quando maduros, o que acontece depois de dois meses de desenvolvimento. As sementes apresentam cor avermelhada e são ovaladas, possuem mucilagem envoltória e sua dispersão é feita por insetos e outros animais (Souza e Correia 2007).

A ecologia de *H. coronarium* é pouco estudada (Manish, 2013, Chiba et al 2016), entretanto, o conhecimento que se tem até o momento indica que as invasões por esta espécie constituem um risco para os ecossistemas naturais. É uma espécie de crescimento agressivo (Joly e Brandle, 1995; Soares e Barreto, 2008), dificultando a regeneração de matas de galerias onde invade, já que as sementes de espécies nativas não têm potencial de competir com sua propagação por rizoma (Joly e Brandle, 1995) e seu crescimento rápido sombreia e impede o estabelecimento e desenvolvimento de plantas de crescimento mais lento (Motooka et al., 2003). Além disso, o único gênero da família Zingiberaceae nativo no Brasil é *Renalmia* L. f., que tem sua distribuição restrita à Bacia Amazônica (Souza e Lorenzi, 2005).

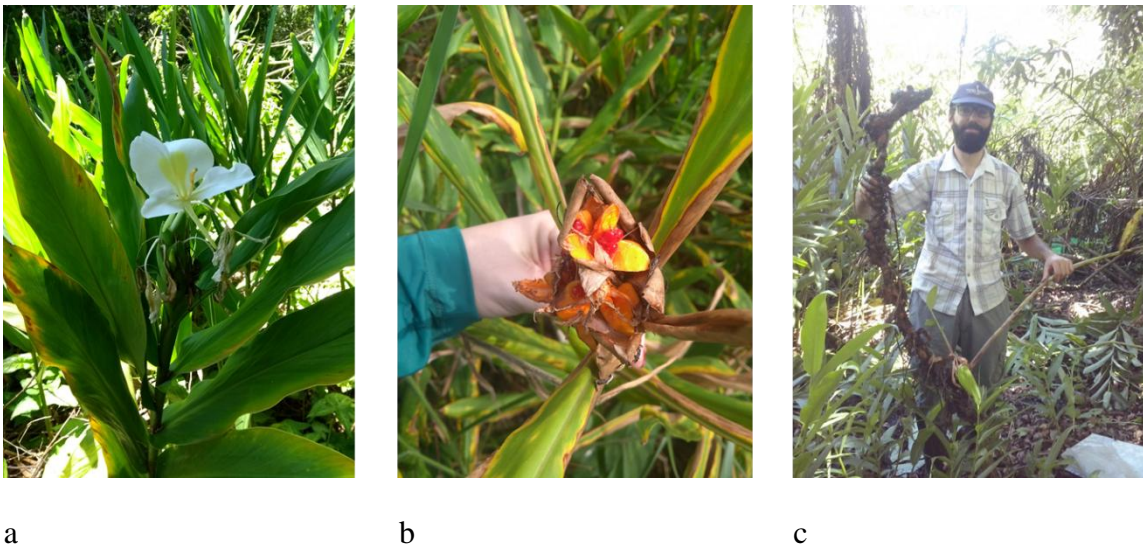


Figura 8: a) flor de *Hedychium coronarium*, b) fruto de *Hedychium coronarium* e c) rizoma de *Hedychium coronarium*. Fonte: Julia Ramos Estêvão (a, b) e Amanda Pinheiro (c).

1.3.2. *Urochloa decumbens* Stapf. (Poaceae)

Urochloa decumbens, de nome popular braquiária (fig. 9), é uma gramínea invasora originária do continente africano, que foi introduzida no Brasil na década de 1950 para formação de pastos utilizados pela pecuária, por ser boa para cria e engorda de animais, ter resistência alta ao pisoteio, apresentar de 7 a 9 % de proteína bruta em matéria seca e produzir até 45 toneladas de massa verde por hectare por ano (Crispim e Branco, 2002). É uma planta perene, de porte baixo (1,0 m de altura máxima), que cresce em touceiras, a largura do seu ramo é de 2 a 4 mm, a disposição das espiguetas de suas inflorescências é em fileira dupla (Figueiras et al 2012). É de coloração em geral verde escuro, rizomatosa, que se propaga por sementes ou por rizomas (Lorenzi 2000).



Figura 9: *Urochloa decumbens* em área de Cerrado *sensu stricto*. Fonte: Julia Ramos Estêvão.

Apresenta crescimento rápido, minimiza processos erosivos e é capaz de tolerar toxicidade, o que fez com que fosse plantada, por exemplo, em áreas de mineração na região do Amazonas (Ferreira et al 2016). Consegue recuperar a produção de biomassa

depois de estresse hídrico, se houver alteração (Mattos et al. 2005). Além disso, se adapta bem a solos com baixa fertilidade e de alta acidez (da Silva et al 2010).

A fenologia da espécie varia de acordo com a vegetação onde se encontra: sua floração no Brasil já foi registrada entre fevereiro - maio e outubro - dezembro e frutificação entre janeiro -agosto e novembro - dezembro em área de cerrado reflorestado, enquanto em cerrado queimado, sua floração foi observada entre janeiro a abril, junho, novembro e dezembro e sua frutificação entre janeiro e junho e em dezembro (Florencio et al 2009).

U. decumbens é a espécie invasora com o maior número de ocorrências relatadas no Brasil, onde foi registrada em várias fitofisionomias, tais como floresta semi decídua tropical e subtropical, floresta tropical ombrófila e estepe (Zenni e Ziller 2011), está presente em 21 estados brasileiros (Maas e Maas 2015) (fig. 10). Sua presença no cerrado é tão conspícua que se acredita que ocorra em todos os fragmentos deste ecossistema (Barbosa et al 2008). Seu potencial alelopático tem sido apontado como uma das causas de seu sucesso como invasora (Barbosa et al 2008).



Figura 10: Estados onde foi registrada a presença de *Urochloa decumbens* no Brasil. Os que não estão em branco têm confirmada a presença da espécie. As cores indicam diferentes regiões: Norte (verde), Centro-oeste (amarelo), Nordeste (rosa claro), Sudeste (rosa), Sul (azul). Extraído de Maas e Maas (2015), disponível em http://servicos.jbrj.gov.br/flora/search/Urochloa_decumbens, acessado em 12 de agosto de 2018.

1.3.3. *Melinis minutiflora* P. Beauv. (Poaceae)

A gramínea invasora *Melinis minutiflora* (capim-gordura) (fig. 11) é nativa da África e foi introduzida no continente americano como estofamento de colchões usados por escravos (Bor 1960 apud Aires 2009). É utilizada como gramínea de pastoreio por apresentar em sua matéria seca 9% de proteína bruta e rápido crescimento (Lorenzi 2000). Trata-se de uma herbácea perene ereta, que forma touceiras, cujos colmos com

nós pilosos e avermelhados atingem de 40-80 cm de altura e sua reprodução se dá apenas por sementes (Lorenzi 2000).



Figura 11: *Melinis minutiflora*. Fonte: Julia Ramos Estêvão.

Sua fenologia foi registrada no Brasil em área de cerrado queimado e exibiu floração em maio e junho e entre outubro e dezembro e sua frutificação foi registrada em janeiro, junho a agosto e outubro a dezembro (Florencio et al 2009). *M. minutiflora* foi uma das primeiras espécies invasoras registradas no país, tendo seu primeiro registro no século XVIII e ainda ocorre em muitas fitofisionomias, tais como estepe, floresta tropical e subtropical semi decídua, floresta ombrófila tropical e cerrado (Zenni e Ziller 2011) e na maioria dos estados do Brasil (Maas e Mass 2015) (fig. 12).



Figura 12. Estados onde foi registrada a presença de de *Melinis minutiflora* no Brasil. Os que não estão em branco têm confirmada a presença da espécie. As cores indicam diferentes regiões: Norte (verde), Centro-oeste (amarelo), Nordeste (rosa claro), Sudeste (rosa), Sul (azul). Extraído de Maas e Maas (2015), disponível em http://servicos.jbrj.gov.br/flora/search/Melinis_minutiflora, acessado em 12 de agosto de 2018.

Suas touceiras densas podem excluir espécies herbáceas (Pivello et al 1999a, Pivello et al 1999b) e dificultar o estabelecimento de espécies lenhosas (Hoffmann e Haridasan 2008), ocasionando diminuição da diversidade e da riqueza de espécies nas áreas invadidas (Williams e Baruch 2000). Ainda, a presença de *M. minutiflora* já foi associada a diminuição de regeneração de áreas degradadas (Martins et al. 2011), diminuição de recrutamento de espécies arbóreas (Hoffmann e Haridasan 2008) e diminuição de germinação de sementes e emergência de plântulas pela produção de aleloquímicos (Prates et al. 1998).

1.3.4. *Pennisetum purpureum* Schumach. (Poaceae)

A gramínea *Pennisetum purpureum* (capim-elefante ou napier) (fig. 13) também é originária da África e foi introduzida no Brasil em 1920. Trata-se de uma espécie perene, que atinge de 3 a 5 m de altura, apresentando colmos eretos que se dispõem em touceiras, são preenchidos por parênquima suculento de até 2 cm de diâmetro (Nascimento Junior 1981, Alcântara e Bufarah 1983e Deresz 1999). É rizomatosa e propaga-se tanto por sementes como por raízes (Lorenzi 2000).

Foi introduzida no Brasil para fins de forrageio e chaga a produzir 400 toneladas de massa verde por hectare em um ano (Lorenzi 2000). Sua ocorrência no país já foi registrada em estepe, savana, floresta ombrófila densa tropical e subtropical e campo (Zenni e Ziller 2011) e o clima brasileiro é considerado como muito favorável para a sobrevivência de *P. purpureum* (Barney e DiTomaso 2011).



Figura 13: Área de coleta de *Pennisetum purpureum* e indivíduo da espécie. Fontes: Julia Ramos Estêvão e Amanda Pinheiro, respectivamente.

Sua floração foi registrada nas Filipinas entre setembro e dezembro (meses de chuva) (Javier 1970) e duas espécies do mesmo gênero, *P. villosum* e *P. clandestina*,

tiveram sua floração registrada entre maio e novembro (meses de calor) na Grécia (Damanakis e Yannitsaros 1986).

P. purpureum produz substâncias alelopáticas capazes de inibir germinação de sementes e crescimento de radícula e de plântula (Norhafizah 2012; Zain et al. 2013; Ismail et al. 2015) e extratos de seus compostos fitotóxicos já foram testados para controle da espécie *Leptochloa chinensis*, que causa danos em plantações de arroz aeróbico na Ásia, apresentando resultados positivos (Chuah et al. 2014).

1.3.5. *Typha domingensis* Pers. (Typhaceae)

Typha domingensis, de nome popular taboa (fig. 14), é uma herbácea rizomatosa aquática, que ocorre em quase todos os estados brasileiros (Maas e Maas, 2015) (fig. 15). É uma planta nativa da América do Sul que apresenta distribuição cosmopolita (Boeger et al, 2007), que cresce de forma espontânea em áreas alagadas, podendo atingir até 4 m de altura, suas folhas são em forma de lâminas lineares com até 1,5 cm de largura (Boeger et al, 2007). Suas flores se apresentam reunidas em espiga e aparecem o ano todo, seu fruto mede de 1-15 mm (Carvalho et al 2014).



Figura 14: *Typha domingensis* na sua área de coleta e indivíduo. Fontes: Julia Ramos Estêvão e Amanda Pinheiro, respectivamente.



Figura 15: Estados onde foi registrada a presença de *Typha domingensis* no Brasil. Os que não estão em branco têm confirmada a presença da espécie. As cores indicam diferentes regiões: Norte (verde), Centro-oeste (amarelo), Nordeste (rosa claro), Sudeste (rosa), Sul (azul). Extraído de Maas e Maas (2015), disponível em http://servicos.jbrj.gov.br/flora/search/Typha_domingensis, acessado em 12 de agosto de 2018.

A espécie se reproduz tanto por sementes como por propagação vegetativa, e sua ocorrência está relacionada a corpos hídricos com alta disponibilidade de nutrientes (Miao e Sklar, 1998), tendo sido registrada no Brasil em campo rupestre, cerrado, reestinga, caatinga e floresta atlântica (Carvalho et al 2014).

O potencial alelopático de *T. domingensis* é conhecido, sabe-se que a espécie produz componentes fenólicos, tais como ácido linoleico, ácido α -linoleico, salicilaldeído e 2-clorofenol (Gallardo et al 1999, Hu & Hong 2008) e seus extratos já

foram relacionados com a inibição de produção de oxigênio pela macrófita aquática *Salvinia mínima*, assim como seus lixiviados (Gallardo et al 1999).

Suas folhas são utilizadas para confecção de esteiras e assentos de cadeira, e tanto palmito, como rizoma e pólen podem ser utilizados na alimentação humana (Kinupp e Lorenzi, 2014). Seu pólen é utilizado como fonte de alimento na Argentina e sua produção pode variar de 136 kg a 4000 kg.ha⁻¹ por ano (Arenas e Scarpa 2003). O pó de folhas de *Typha domingensis* mostrou-se um eficiente adsorvente para remoção de resíduos de alumínio, ferro e zinco em água (Abdel-Ghani et al 2009), e o uso da própria planta em água contaminada com esses resíduos mostrou-se eficiente na absorção radicular dos referidos metais (Hegazy et al 2011).

2. Objetivos e hipóteses

Nossos objetivos foram, no capítulo 1, determinar se:

1) a produção de biomassa (incluindo a de rizoma) e necromassa de *H. coronarium* estão relacionadas com as variáveis climáticas: número de dias de chuva, pluviosidade mensal, temperaturas mínima e máxima mensal e umidade relativa do ar média mensal nos três meses que antecedem a quantificação da biomassa, rizoma e necromassa,

2) a produção aérea primária líquida de *H. coronarium* ao longo do ano,

3) a produção de biomassa e necromassa de *U. decumbens*, *M. minutiflora* e *P. purpureum* estão relacionadas com as variáveis climáticas: número de dias de chuva, pluviosidade mensal, temperaturas mínima e máxima mensal e umidade relativa do ar média mensal nos três meses que antecedem a produção de biomassa, rizoma e necromassa,

4) produção aérea primária líquida de *U. decumbens*, *M. minutiflora* e *P. purpureum* ao longo do ano.

Nossas hipóteses foram 1) a produção de biomassa e de necromassa de todas as espécies será abundante ao longo de todo o ano, estando relacionadas às variáveis climáticas, uma vez que são espécies altamente produtivas e bem adaptadas ao ambiente onde ocorrem como invasoras, 2) a produção aérea primária líquida de todas as espécies será alta no ano de estudo, uma vez que todas as espécies são invasoras altamente produtivas.

No capítulo 2, nossos objetivos foram responder as seguintes perguntas:

- a) Diferentes tratamentos mecânicos têm algum efeito no crescimento e rebrotamento de *H. coronarium*?
- b) Diferentes tratamentos químicos com herbicida sintético têm algum efeito no crescimento e rebrotamento de *H. coronarium*? E
- c) Diferentes tratamentos químicos com extrato alcoólico de componentes fenólicos de *Typha domingensis* têm algum efeito no crescimento e rebrotamento de *H. coronarium*?

Para tal, testamos :1) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de se cortar uma vez ao ano os rametas de *H. coronarium*; 2) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de se cortar duas vezes ao ano os rametas de *H. coronarium*; 3) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de se cortar os rametas e se arrancar os rizomas uma vez ao ano de *H. coronarium*; 4) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de injeções do herbicida glifosato em rizomas de *H. coronarium*; 5) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de spray do herbicida glifosato em folhas de *H. coronarium* e 6) os efeitos na altura, no diâmetro na altura do solo e na taxa de mortalidade de injeções de extrato alcoólico de componentes

fenólicos de folhas e do rizoma de *T. domingensis* em duas concentrações distintas cada (5% e 10%) em rizomas de *H. coronarium*.

Nossa hipótese foi a de que os tratamentos testados teriam efeito no crescimento, na produção de rametas e na sobrevivência de *H. coronarium*.

3. Área de Estudo

A área de estudo está situada no município de São Carlos (22° 01' 03" S e 47° 53' 27" W), no estado de São Paulo. O solo da região é predominantemente latossolo vermelho-amarelo e latossolo roxo (Perez Junior 1997). O clima local é uma transição entre Cwai-Awi (segunda a classificação de Köppen), ou seja, subtropical úmido (apresenta verão quente e úmido, de outubro a março e inverno frio e seco, de abril a setembro); a média de precipitação ao longo do ano é de 1440 mm e ocorre principalmente nos meses mais quentes, a umidade relativa do ar média ao longo do ano é de 75,6%, a temperatura média compensada ao longo do ano é de 26,8°C e a média das temperaturas mínimas é de 15,6°C (Tolentino 1967). A bacia hidrográfica na qual se encontra o município é a do rio Monjolinho, um dos afluentes do rio Jacaré-Guaçu, que desemboca no rio Tietê (Lima 2003).

Para os experimentos de biomassa, necromassa e produção primária aérea líquida, as áreas de coleta de dados foram lago Fazzari (21°58'17.4" S e 47°53'17.7" O) do lado de uma área de Cerrado dentro do *campus* da Universidade Federal de São Carlos (para todas as espécies), lago Monjolinho (21°59'07.2" S e 47°52'54.1" O), também dentro do mesmo *campus*, mas dentro da área urbana, (para *Urochloa decumbens* e *Pennisetum purpureum*), no lado externo do rio Monjolinho na frente do Horto Florestal (21°59'13.2 S e 47°52'21.3" O) (para *Hedychium coronarium*) e na região chamada de "Y", também dentro do mesmo *campus* (para *Melinis minutiflora*).

No experimento de controle mecânico, as parcelas foram montadas em cinco áreas diferentes: lago Fazzari (fig. 16), lago Monjlinho (fig. 17), Horto Florestal (fig. 18), Sítio Paraíso (fig. 19) (21°58'48.2" S e 47°55'18.2" O), próximo à Rodovia Washington Luís Km 240, sentido Araraquara e Bosque Cambuci (fig. 20) (21°59'31.9" S e 47°54'13.8" O), dentro do perímetro urbano da cidade (fig. 21). A coleta dos indivíduos de *Typha domingensis* para fazer os extratos do experimento de controle químico foi feita dentro do município de São Carlos, na Estrada Municipal João Ponce da Costa (21°59'92" S e 47°50'26.05" O).



Figura 16: Área de coleta lago Fazzari. Fonte: Amanda Pinheiro.



Figura 17: Área de coleta lago Monjolinho. Fonte: Amanda Pinheiro.



Figura 18: Área de coleta Horto Florestal. Fonte: Amanda Pinheiro.



Figura 19: Área de coleta Sítio Paraíso. Fonte: Amanda Pinheiro.

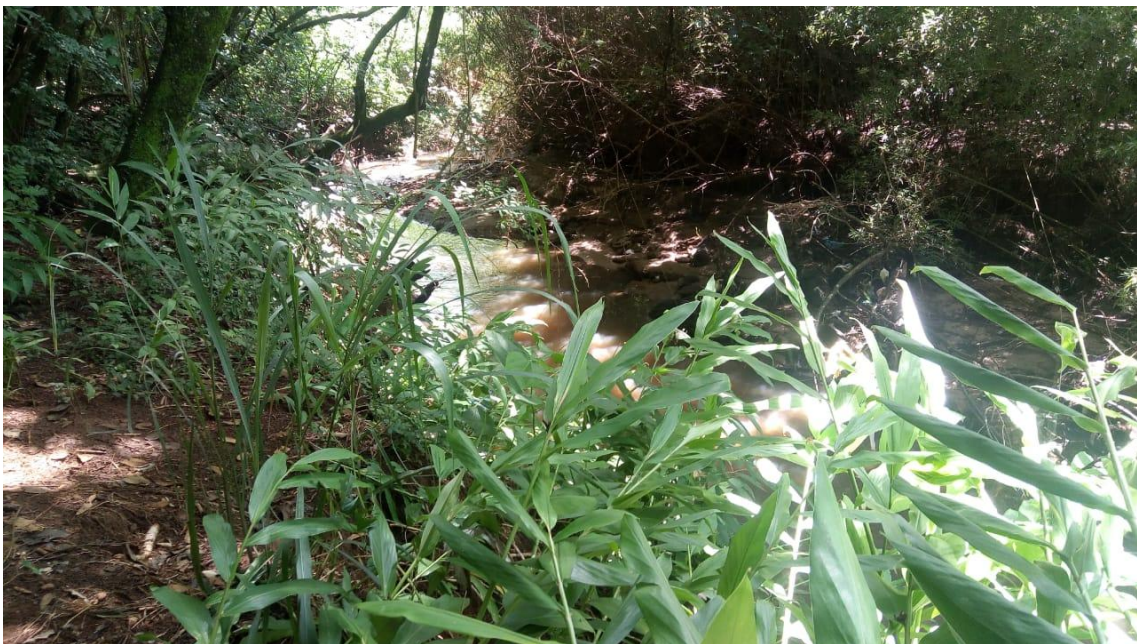


Figura 20: Área de coleta Bosque Cambuci. Fonte: Amanda Pinheiro.

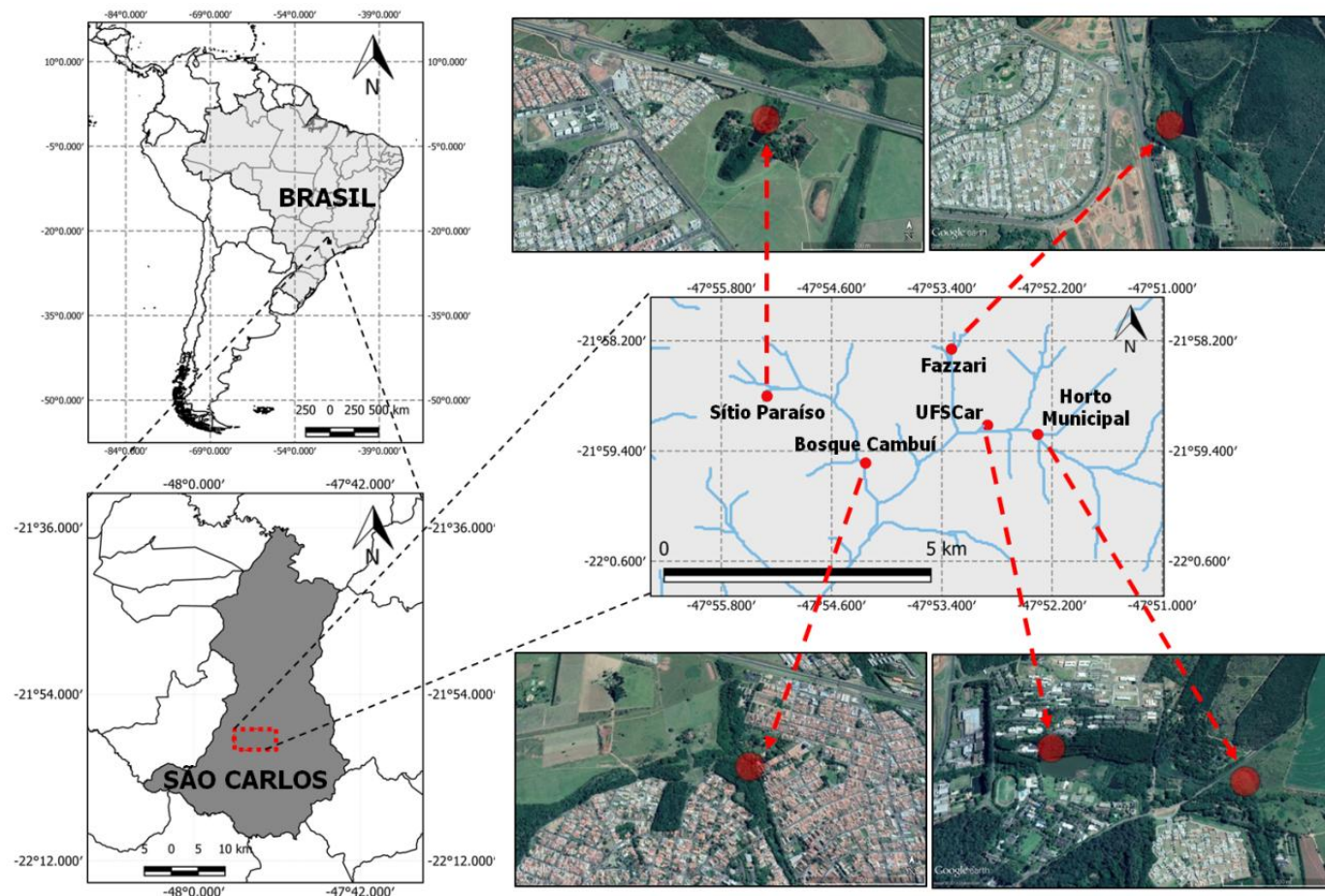


Figura 21: áreas de experimento mecânico de controle de *Hedychium coronarium*. Fonte: Pinheiro (2018), elaborada por Sérgio Henrique Vannucchi Leme de Mattos.

4. Bibliografia

- Abdel-Ghani NT, Hegazy AK, El-Chaghaby GA (2009). *Typha domingensis* leaf powder for decontamination of aluminium, iron, zinc and lead: Biosorption kinetics and equilibrium modeling. *Int. J. Environ. Sci. Tech.*, 6 (2): 243-248.
- Amarante-Junior OP, Santos TCR, Brito NM, Ribeiro ML (2002). Glifosato: propriedades, toxicidade, usos e legislação. *Quim. Nova* 25 (4): 589-593.
- Arenas P, Scarpa GF (2002). The consumption of *Typha domingensis* pers. (typhaceae) pollen among the ethnic groups of the gran chaco, South America. *Economic Botany* 57(2): 181-188.
- Barbosa EG, Pivello ER, Meirelles ST (2008). Allelopathic evidence in *Brachiaria decumbens* and its potential to invade the Brazilian cerrados. *Braz. arch. biol. technol.* 51 (4): 825-831.
- Barney JN, DiTomaso JM (2011) Global climate niche estimates for bioenergy crops and invasive species of agronomic origin: Potential problems and opportunities. *PLoS One*. doi: 10.1371/journal.pone.0017222
- Berendse F (1999). Implications of increased litter production for plant biodiversity Using integrative biology to explore constraints on evolution. *Trends Ecol Evol* 5347: 98–99.
- Boeger MRT, Pil MWBO, Belém Filho N (2007). Arquitetura foliar comparativa de *Hedychium coronarium* J. Koenig (Zingiberaceae) e de *Typha domingensis* Pers (Typhaceae). *IHERINGIA, Sér. Bot., Porto Alegre*, 62 (1): 115-122.
- Brooks M, D'Antonio C, Richardson D (2004) Effects of invasive alien plants on fire regimes. *Bioscience* 54:703–713. doi: 10.1641/0006-3568(2004)054[0677:EOIAP0]2.0.CO;2
- Cantrell CL, Dayan FE, Duke SO (2012). Natural products as sources for new pesticides. *J. Nat. Prod.* 75: 1231-1241.
- Carvalho MLS, Lima CT, Oliveira RP, Giulietti AM (2014) Flora da Bahia: Typhaceae. *Sitientibus série Ciências Biológicas* 14: 1-4. Doi: 10.13102/scb420
- Chiba WAC, Almeida RV, Leite MB, Mars RH Silva-Matos DM (2016). Invasion strategies of the white ginger lily *Hedychium coronarium* J. König (Zingiberaceae) under different competitive and environmental conditions. *Environmental and experimental Botany*. Doi: <http://dx.doi.org/10.1016/j.envexpbot.2016.03.010>
- Clewley GD, Eschen R, Shaw RH, Wright DJ (2012). The effectiveness of classical biological control of invasive plants. *Journal of Applied Ecology* 49: 1287-1295.
- Crispim SMA, Branco OD (2002). Aspectos Gerais das Braquiárias e suas Características na Sub-Região da Nhecolândia, Pantanal, MS. *Boletim de Pesquisa e Desenvolvimento* 33. 27 p.
- Da Silva TC, Perazzo AF, Macedo CHO, et al (2012) Morfogenese e estrutura de *Brachiaria decumbens* em resposta ao corte e adubação nitrogenada. *Arch Zootec* 61:91–102.
- Davis MA, Grime JP, Thompson K (2000) Fluctuating resources in plant communities: A general theory of invasibility. *J Ecol* 88:528–534. doi: 10.1046/j.1365-2745.2000.00473.x

- Damanakis M, Yannitsaros (1986) The genus *Pennisetum* (Poaceae) in Greece. *Willdenonia* 15: 401-406.
- Davis AD (2011). Invasion biology. 364-369. In Simberloff, D. e Rejmánek, M. (eds) 2011. *Encyclopedia of biological invasions*. University of California Press, Berkeley and Los Angeles, 792 p.
- Davis MA, Grime JP, Thompson K (2000). Fluctuating resources in plant communities: a general theory of invisibility. *Journal of Ecology*, 88: 528-534.
- Dayan FE, Cantrell CL, Duke SO (2009). Natural products in crop protection. *Bioorg & Med Chem* 17: 4022–4034. doi:10.1016/j.bmc.2009.01.046
- Dechoum MS, Ziller SR 2013. Métodos para controle de plantas exóticas invasoras. *Biotemas* 26 (1): 69-77. Doi: 10.5007/2175-7925.2013v26n1p69
- Elton CS (1958). *The Ecology of Invasions by animals and plants*. The University of Chicago Press. 181 p.
- Ferreira LV, Parolin P, Matos DCL, Cunha DA, Chaves PP, Neckel SO (2016). The effect of exotic grass *Urochloa decumbens* (Stapf) R.D.Webster (Poaceae) in the reduction of species richness and change of floristic composition of natural regeneration in the Floresta Nacional de Carajás, Brazil. *Anais da Academia Brasileira de Ciências* 88(1): 589-597. Doi: 10.1590/0001-3765201620150121
- Figueiras TS, Rodrigues RS, Shirasuma RT (2012). Braquiárias invasoras no estado de São Paulo. Instituto de Botânica. 2p.
- Foster BL, Gross KL (1998) Species Richness in a Successional Grassland : Effects of Nitrogen Enrichment and Plant Litter Species Richness in a Successional Grassland : Effects Of Nitrogen Enrichment And Plant Litter. *Ecology* 79:2593–2602. doi: 10.1890/0012-9658(1998)079[2593:SRIASG]2.0.CO;2
- Fridley JD. 2011. Invasibility of communities and ecosystems. 356-360 In: D. Simberloff and M. Hejmanek editors. *Encyclopedia of Biological Invasions*. University of California Press, London. 792 p.
- Funk, J. L. 2001. *Hedychium gardnerianum* invasion into Hawaiian montane rainforest: interactions among litter quality, decomposition rate, and soil nitrogen availability. *Biogeochemistry* 76: 441–451.
- Florêncio C, Figueiredo RA (2009). Phenology of herbaceous species in “cerrado”: comparisons between intact, burnt, and reforested areas. *Naturalia*, Rio Claro, 32: 1-12.
- Gallardo MT, Ascher JR, Collier MJ, Martin BB, Martin DF (1999). Effects of cattail (*Typha domingensis*) extracts, leachates, and selected phenolic compounds on rates of oxygen production by salvinia (*Salvinia minima*). *J. Aquat. Plant Manage.* 37: 80-82.
- Gray AJ, Raybould AF, Brown SL (1997). The environmental impact of *Spartina anglica*: past, present and predicted. In: Simberloff D (2011) How common are invasion-induced ecosystem impacts? *Biol Invasions* 13:1255–1268. doi: 10.1007/s10530-011-9956-3
- Hayes L (2012). What’s new in biological control of weeds? *Landcare Research New Zealand* 61. 16p.

- Hayes L, Fowler SV, Paynter Q, Groentman R, Peterson P, Dodd S, Bellgard S (2013). Biocontrol of weeds: achievements to date and future outlook. Ecosystem services in New Zealand – conditions and trends. 374-385.
- Hegazy AK, Abdel-Ghani, NT, El-Chaghaby GA (2011). Phytoremediation of industrial wastewater potentiality by *Typha domingensis*. Int. J. Environ. Sci. Tech., 8 (3): 639-648.
- Hobbs RJ, Humphries SE (1995). An integrated approach to the ecology and management of plant invasions. Conservation Biology 9 (4):761-770.
- Hoffmann WA, Haridasan M (2008) The invasive grass, *Melinis minutiflora*, inhibits tree regeneration in a Neotropical savanna. Austral Ecol 33:29–36. doi: 10.1111/j.1442-9993.2007.01787.x
- Ho H, Hong Y (2008). Algal-bloom control by allelopathy of aquatic macrophytes – A review. Front. Environ. Sci. Engin 2(4): 421-438. Doi: 10.1007/s11783-0080070-4
- Javier EQ (1970) The phenology, flowering habits, and mode of reproduction of *Pennisetum purpureum* Schumach, *B. mutica* (Forsk) Stapf., and *Panicum maximum* Jacq. Dissertação de mestrado. Cornell Univ. Ithaca. New York.
- Joly C. A e Brändle, R. 1995. Fermentation and adenylate metabolism of *Hedychium coronarium* J. G. Koenig (Zingiberaceae) and *Acorus calamus* L. (Araceae) under hypoxia and anoxia. Functional Ecology, 9: 505-510.
- Kohls GN, Landsberg E, Stock-Oliveira Souza K, Yamada T, Römheld V (2006). Relevance of glyphosate transfer to non-target plants via the rhizosphere. Journal of Plant Diseases and Protection. 963-969.
- Kinupp V, Lorenzi H (2014). Plantas alimentícias não convencionais (PANC) do Brasil – guia de identificação, aspectos nutricionais e receitas ilustradas. Nova Odessa: Editora Plantarum, 694-695 p.
- Kremer RJ (2005). The role of bioherbicides in weed management. Biopestic. Int. 1(3,4): 127-141.
- Lima RT (2003) Percepção ambiental e participação pública na gestão dos recursos hídricos: perfil dos moradores da cidade de São Carlos, SP (bacia hidrográfica do rio Monjolinho). Dissertação de mestrado. Universidade de São Paulo.
- Lockwood JL, Hoopes MF, Marchetti MP (2007). Invasion Ecology. Blackwell Publishing. 304 p.
- Lorenzi, H. 2000. Plantas daninhas do Brasil: terrestres, aquáticas, parasitas e tóxicas. 3. ed. Nova Odessa: Instituto Plantarium. 608 p.
- Lonsdale WM (1999). Global patterns of plant invasions and the concept of invasibility. Ecology 80 (5): 1522-1536. doi: 10.1890/0012-9658(1999)080[1522:gpopia]2.0.co;2
- Loydi A, Donath TW, Eckstein RL, Otte A (2014) Non-native species litter reduces germination and growth of resident forbs and grasses: allelopathic, osmotic or mechanical effects? Biol Invasions 17:581–595. doi: 10.1007/s10530-014-0750-x
- Maas P, Maas H. (2015). Zingiberaceae in Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. Disponível em: <<http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB110705>>.

- BFG. Growing knowledge: an overview of Seed Plant diversity in Brazil. *Rodriguésia*, v.66, n.4, p.1085-1113. 2015. (DOI: 10.1590/2175-7860201566411)
- Manish, M. 2013. Current status of endangered medicinal plant *Hedychium coronarium* and causes of Population decline in the natural forests of Anuppur and Dindori districts of Madhya Pradesh, India. *International Research Journal of Biological Sciences*, 2 (3): 1-6.
- Martins CR, Hay JDV, Walter BMT, et al (2011) Impact of invasion and management of molasses grass (*Melinis minutiflora*) on the native vegetation of the Brazilian Savanna. *Brazilian J Bot* 34:73–90. doi: 10.1590/s0100-84042011000100008
- Mattos JLS, Gomide JA, Huaman CAM (2005) Effect of water deficit on the growth of *Brachiaria* species in greenhouse. *Rev Bras Zootec* 34:746–754. doi: 10.1590/S1516-35982005000300005
- Miao SL, Sklar FH (1998). Biomass and nutrient allocation of sawgrass and cattail along a nutrient gradient in the Florida Everglades. *Wetlands Ecol. Manage.* 5: 245–263.
- Myers JH, Bazely D 2003. *Ecology and control of introduced plants*. University Press, Cambridge. 313 p.
- Motooka P, Ching L, Nagai G (2002). *Herbicidal weed control methods for pastures and natural areas of Hawaii*. Cooperative Extension Service, University of Hawaii. 36 p.
- Motooka P, Castro L, Duane N, Nagai G, Lincoln C (2003). *Weeds of Hawai‘i’s pastures and natural areas; an identification and management guide*. College of Tropical Agriculture and Human Resources, University of Hawai‘i. 184 p.
- Naiman RJ, Décamps H (1997). The ecology of interfaces: riparian zones. *Annu. Ver. Ecol. Syst* 28: 621-658.
- Pinheiro AM (2018). *Atributos ecológicos que contribuem para invasibilidade da macrófita Hedychium coronarium J. König (Zingiberaceae)*. Dissertação de mestrado, Universidade Federal de São Carlos. 50 p.
- Pivello, V.R. (2011) *Invasões Biológicas no Cerrado Brasileiro: Efeitos da Introdução de Espécies Exóticas sobre a Biodiversidade*. *Ecologia Info* 33. <http://ecologia.info/cerrado.htm> Acessado em 08/08/2018.
- Prates HT, Leite RC, Craveiro AA, Oliveira AB (1998) Identification of some chemical components of the essential oil from molasses grass (*Melinis minutiflora* Beauv.) and their activity against cattle-tick (*Boophilus microplus*). *J Braz Chem Soc* 9:193–197. doi: 10.1590/S0103-50531998000200013
- Primack, R. B. e Rodrigues, E. 2000. *Biologia da conservação*. Ed. Planta, 327p.
- Pysek P, Prach K (1993) Plant Invasions and the Role of Riparian Habitats: A Comparison of Four Species Alien to Central Europe. *J Biogeogr* 20:413. doi: 10.2307/2845589
- Richardson DM, Holmes PM, Esler KJ, et al (2007) Riparian vegetation: degradation, alien plant invasions, and restoration prospects RID A-1495-2008 RID F-5883-2010. *Divers Distrib* 13:126–139. doi: 10.1111/j.1472-4642.2006.00314.x
- Sakhanokho, H. F. e Rajasekaran, K. 2010. Pollen biology of ornamental ginger (*Hedychium* spp. J. Koenig). *Scientia Horticulturae* 125: 129–135.

- Santos, S.B., Pedralli, G. e Meyer, S.T. 2005. Aspectos da fenologia e ecologia de *Hedychium coronarium* (zingiberaceae) na Estação Ecológica do Tripuí, Ouro Preto-MG. *Planta Daninha*, 23 (2): 175-180.
- Setterfield SA, Rossiter-Rachor NA, Douglas MM, et al (2013) Adding Fuel to the Fire: The Impacts of Non-Native Grass Invasion on Fire Management at a Regional Scale. *PLoS One*. doi: 10.1371/journal.pone.0059144
- Schade JD, Fisher SG, Grimm NB, Seddon JA (2001) The influence of a riparian shrub on nitrogen cycling in a Sonoran Desert stream. *Ecology* 82:3363–3376. doi: 10.1890/0012-9658(2001)082[3363:TIOARS]2.0.CO;2
- Simberloff, D, Rejmánek M (eds) (2011). *Encyclopedia of biological invasions*. University of California Press, Berkeley and Los Angeles. 792 p.
- Simberloff D (2011) How common are invasion-induced ecosystem impacts? *Biol Invasions* 13:1255–1268. doi: 10.1007/s10530-011-9956-3
- Soares, D.J. e Barreto, R.W. 2008. Fungal pathogens of the invasive riparian weed *Hedychium coronarium* from Brazil and their potential for biological control. *Fungal Diversity* 28: 85–96.
- Souza JA, Correia, MCR (2007). *Biologia floral de Hedychium coronarium* Koen. (Zingiberaceae). *Revista Brasileira de Horticultura Ornamental* 13(1): 21-30.
- Souza, v. C., Lorenzi, H. 2005. *Botânica Sistemática: guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II*. Editora Platarum, Nova Odessa, São Paulo. 640 p.
- Strauss SY, Webb CO, Salamin N (2006). Exotic taxa less related to native species are more invasive. *PNAS* 103 (15): 5841-5845. Doi: 10.1073_pnas.0508073103
- Suding KN, Goldberg DE (1999) Variation in the Effects of Vegetation and Litter on Recruitment across Productivity Gradients. *J Ecol* 87:436–449. doi: 10.1046/j.1365-2745.1999.00367.x
- Thompson JD (1991). The biology of an invasive plant: what makes *Spartina anglica* so successful? *Bioscience* 41: 393-401. Doi: 10.2307/1311746
- Tuffi Santos LD, Ferreira FA, Barros NF, Siqueira, CH, Santos IC, Machado AFL (2005). Exsudação radicular do glyphosate por *Brachiaria decumbens* e Seus efeitos em plantas de eucalipto e na respiração Microbiana do solo. *Planta Daninha*, Viçosa-MG, 23 (1): 143-152.
- Turner PJ, Scott H (2008). The ecological barriers to the recovery of bridal creeper (*Asparagus asparagoides* (L.) Druce) infested sites: impacts on vegetation and the potential increase in other exotic species. *Aust. Ecol.* 33: 713-722. In: Simberloff D (2011) How common are invasion-induced ecosystem impacts? *Biol Invasions* 13:1255–1268. doi: 10.1007/s10530-011-9956-3
- Tyler AC, Lambrinos JG, Grosholz ED (2007). Nitrogen inputs promote the spread of an invasive mush grass. *Ecol. Appl.* 17: 1886-1898.
- Violle C, Richarte J, Navas ML (2006) Effects of litter and standing biomass on growth and reproduction of two annual species in a Mediterranean old-field. *J Ecol* 94:196–205. doi: 10.1111/j.1365-2745.2005.01061.x

- Vitousek, p. M., D'antonio, c. M., Loope, l. L., Rejmánek, m. e Westbrooks, R. 1997. Introduced species: a significant component of human-caused global change. *New Zealand Journal of Ecology*, 21(1): 1-16.
- Warner KD (2016). An ethical framework for integrating biological control into conservation practice. *In: Integrating Biological Control into Conservation Practice*, Roy van Driesche, Daniel Simberloff, Bernd Blossey, Charlotte Causton, Mark Hoddle, Christian O. Marks, Kevin M. Heinz, David L. Wagner, Keith D. Warner (eds). Oxford: Blackwell, 277-293.
- Williams DG, Baruch Z (2000). African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology. *Biological Invasions* 2: 123–140. Doi: 10.1023/A:1010040524580
- Williams PA, Winks C, Rijkse W (2003). Forest processes in the presence of wild ginger (*Hedychium gardnerianum*). *N. Zeal. J. Ecol.*, 27: 45–54.
- Zenni RD, Ziller SR (2011) An overview of invasive plants in Brazil. *Rev Bras Botânica* 34:431–446. doi: 10.1590/S0100-84042011000300016

Capítulo 1: Biomass and necromass variation of invasive species in Neotropical riparian zone

1 Biomass and necromass variation of invasive species in neotropical riparian zone

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10

11 Abstract: Riparian zones have fundamental functions to maintenance of species and are
12 among ecosystems that suffer large biological invasions. Our objective was to evaluate
13 net primary aerial production and necromass production of *Hedychium coronarium*,
14 *Urochloa decumbens*, *Melinis minutiflora*, and *Pennisetum purpureum* and their relation
15 to environmental variables minimum and maximum temperature, number of days with
16 rain, rainfall and relative humidity of the air. We collected 10 plots of 0.5 X 0.5 m
17 monthly during one year the biomass and the necromass of each species. We calculated
18 the production using the method proposed by Smalley (1958) and used R environment
19 to test the data normality (Shapiro-Wilk), their relation to the variables (Spearman) and
20 to select the most explicative model (AIC). All species had some degree of relation
21 among variables and biomass or necromass production. All studied species present
22 environment impacts through production of allelopathic compounds, broad capacity of
23 adaptation to riparian zones and high production of biomass and necromass. Among
24 them, *Hedychium coronarium* and *Pennisetum purpureum* stand out for high necromass
25 production.

26 Key-words: *Urochloa decumbens*, *Melinis minutiflora*, *Pennisetum purpureum*,
27 *Hedygium coronarium*, environmental impacts, net primary aerial production.

28 Declaration of interest: none.

29

30 1. Introduction

31 Biological invasions are so common they are reported everywhere in the world,
32 since continental areas to islands, in the tropics and temperate regions. Vitousek et al
33 (1997) have suggested they are one of the significant points of global environmental
34 changes, and they are considered the second cause of biodiversity loss (Vitousek et al.
35 1997, Simberloff & Rejmanek 2011). Some of the ecosystem impacts known to be
36 caused by invasive species are alteration on nutrients cycling and soil attributes
37 (nitrogen is the most studied one, though phosphorous and salinity also have been
38 studied); fire regime alteration, both for frequency increase and extent or intensity of
39 fires; structural physical changes that affect large portion of species that inhabit there,
40 either by changing their energy flow or nutrient cycling, or by constructing new habitat
41 and excluding dominant species (as reviewed by por Simberloff 2011).

42 In Brazil, one of the oldest records of invasive species occurrence is from the
43 XVIII century and it is about African grasses, riparian zones are among ecosystems that
44 suffer important biological invasions (Zenni and Ziller 2011). Riparian zones influence
45 local climate, flow rate of water stream and water levels at soil by evapotranspiration
46 (Richardson et al. 2007). Besides, the vegetation can act directly and indirectly in
47 nutrient cycling (such as nitrogen), water cycling (Schade et al. 2001) and soil cycling,
48 depending on available species necromass production rate; its plants can be used as food
49 for herbivores, detritivores insects, birds and mammals, as well as providing place for
50 nesting and shelter (Richardson et al. 2007). Thus, riparian zones present fundamental
51 functions to species maintenance.

52 Biomass and necromass accumulation interfere on vegetal community dynamics
53 significantly (Violle et al. 2006; Loydi et al. 2014). Biomass accumulation can act as

54 supply of combustible material, as seen with *Andropogon gayanus* in Australia
55 (Setterfield et al. 2013), including in riparian zones during drought (Brooks et al. 2004)
56 and to make higher competition for resources among individuals, decreasing light and
57 water availability and disturbing its growth and reproduction (Suding and Goldberg
58 1999; Violle et al. 2006). Necromass accumulation can be a barrier to species
59 establishment, preventing light from reaching places or producing phytotoxic
60 substances. Therewithal, soil nutrient supply through necromass decomposition can
61 cause species diversity declination in communities (Berendse 1999; Foster and Gross
62 1998).

63 Invasive plants in riparian zones have been more frequent both in abundance as
64 in diversity around the globe (Richardson et al. 2007). This is due to the fact that these
65 ecosystems are susceptible to plant invasions because of its hydrological dynamics,
66 propagule dispersion through rivers can be very effective (Pysek and Prach 1993).
67 Beyond that, riparian zones are ecosystems with systematic anthropic disturbances,
68 because many people settlements are very close to rivers, so that propagule introduction
69 of invasive species is facilitated in riparian zones (Richardson et al. 2007). Nowadays,
70 among the most expressive invasive species we find the macrophyte *Hedychium*
71 *coronarium* J Köenig and the grasses *Urochloa decumbens* Stapf, *Melinis minutiflora* P.
72 Beauv. and *Pennisetum purpureum* Schumach, which are also invasive in Brazil (Zenni
73 and Ziller 2011). *H. coronarium* is cultivated in Brazil as ornamental (Souza e Lorenzi
74 2005) and it is the invasive species in the country that occurs in the highest number of
75 phytophysionomies, *U. decumbens* is the invasive plant with the highest number of
76 records in Brazil, *M. minutiflora* is present in many phytophysionomies in the country,
77 such as *P. purpureum* (Zenni and Ziller 2011).

78 Our objective was to determine if 1) biomass (added to the rhizome production
79 for *H. coronarium*) and necromass production of *H. coronarium*, *U. decumbens*, *M.*
80 *minutiflora* and *P. purpureum* are related to climatic variables i) minimum and
81 maximum temperature, ii) number of days with rain, iii) average rainfall, iv) average
82 relative humidity in the previous three months affects the biomass and necromass
83 production; 2) the net primary aerial production of *H. coronarium*, *U. decumbens*, *M.*
84 *minutiflora* and *P. purpureum* during the year.

85 Our hypothesis were 1) biomass and necromass production of all studied species
86 will be abundant during the whole year, having a relation with climatic variables, since
87 the species are highly productive and well adapted to the environment where they occur
88 as invasive and 2) net primary aerial production of all studied species will be high, since
89 the species are highly productive invasive ones.

90 2. Material and methods

91 2.1. Studied species:

92 *Hedychium coronarium* J Koenig (Zingiberaceae) is native from Himalaya,
93 Nepal, India and east of China, where it occurs in tropical and subtropical areas with up
94 to 1900 m of altitude (Manish 2013). The species presents both sexual (by seeds
95 production) and asexual reproduction (by reproduction of aerial thicket from rhizome).
96 Rhizome fragments disperse itself through water, being able to spread across
97 watersheds and have vegetative grow in areas previously free of its presence (Tunison
98 1991). It is a widely distributed plant in Brazilian coastal plains, being already found up
99 to 3000 km of the coast in the country (Soares and Barreto 2008).

100 *Urochloa decumbens* Stapf (Poaceae) is a grass from the African continent that
101 was introduced in Brazil in the 1950 decade for pasture formation used by livestock, it
102 has up to 1 m of height and it is perennial (Crispim and Branco 2002).

103 The invasive grass *Melinis minutiflora* P. Beauv is native from the African
104 continent and, nowadays, it is used for pasture formation (Aires 2009). It is a plant with
105 high productivity C4 photosynthetic metabolism that spreads through rhizomes (Pivello
106 et al. 1999a).

107 *Pennisetum purpureum* Schumach is also from the African continent and it was
108 introduced in Brazil in the 1920 (Lorenzi 2000). It is a perennial species that can reach
109 up to 5 m of height, with erect culms that are arranged in tussocks, filled with succulent
110 parenchyma of up to 2 cm (Paciullo et al. 2008). Its propagation can be both by seeds
111 and rhizomes. The species infests canal banks, vacant lots, roadside, annual or perennial
112 crops (Lorenzy 2000).

113 2.2. Study area:

114 The study area is in São Carlos municipality, in São Paulo state, Brazil, in
115 coordinates latitude: 22° 01' 03" S and longitude: 47° 53' 27" W and all studied sites can
116 be characterized as riparian zone. Local climate is, according to Köppen's classification,
117 a transition between Cwai-Awi, characterized by hot and humid summer (months of
118 October to March) and dry cold and dry winter (months of April to September), that is,
119 subtropical humid; annual rainfall average is 1440 mm and occurs mostly in the hottest
120 months, average relative air humidity during the year is 75,6%, average temperature
121 during the year is 26,8°C and the average of minimum temperature during the year is
122 15,6°C (Tolentino 1967). Data collection sites are inside Federal University of São
123 Carlos campus and they are: Mayaca lake (all species), Fazary lake (*Urochloa*

124 *decumbens* and *Pennisetum purpureum*), outside margin of Forest Horto of São Carlos
125 (*Hedychium coronarium*) and the region called “Y” (for *Melinis minutiflora*) (fig. 1).

126

127 2.3. Data collection method:

128 From April of 2016 to March of 2017 we collected monthly aerial biomass and
129 necromass of *H. coronarium*, *U. decumbens*, *M. minutiflora* e *P. purpureum* in five
130 plots of 0,5 m X 0,5 m 10 m apart from each other, in two different sites and distancing
131 3 m from the water for *H. coronarium*, 40 m for *U. decumbens*, *M. minutiflora* e *P.*
132 *purpureum*, according to the presence of the species in riparian zones. We did not do
133 resampling of plots. For *H. coronarium*, we also collected the rhizome in each plot. We
134 considered as biomass all green material of the species collected inside the plot and, as
135 necromass, all dead material of the species collected inside the plot. The material
136 collected was dried in an oven at 60° C until constant weight. Data referring to climatic
137 variable were collected from São Carlos weather station (Brasil 2018, CEPTEC/INPE
138 2018).

139 2.4. Data analysis

140 2.4.1. Net Primary Aerial Production

141 To calculate net primary aerial production (NPAP) we used Smalley’s (1958)
142 method, as recommended by Gaona et al. (1996), that is, the differences between
143 temporal samples were added using biomass (B) and necromass (N) and the following
144 rules:

145 1) If B and N increased, $NPAP = B+N$;

- 146 2) If B and N decreased, NPAP = 0;
- 147 3) If B increases, but N decreases, NPAP = B and
- 148 4) If N increases while B decreases, we calculate the value we called T using the
149 formula $T = B + N$ and if T is smaller or equal to zero, NPAP = 0 or if $T > 0$, NPAP = T.
150 For *H. coronarium*, the rhizome production was added to B.

151 2.4.2. Biomass and necromass relation to minimum and maximum temperature, number
152 of days with rain, average rainfall and air average relative humidity

153 Minimum temperature of data collection month was named T_{min_0} , minimum
154 temperature the month before of data collection was named T_{min_1} , it was named T_{min_2}
155 for two months before, T_{min_3} for three months before and T_{min_4} for months before. We
156 used the same logic to name data regarding maximum temperature (T_{max_0} , T_{max_1} ,
157 T_{max_2} , T_{max_3} and T_{max_4}), the number of days with rain (C_0 , C_1 , C_2 , C_3 e C_4), the
158 average rainfall (P_0 , P_1 , P_2 , P_3 e P_4) and average air relative humidity of the months (U_0 ,
159 U_1 , U_2 , U_3 e U_4).

160 We tested the data for normality using Shapiro-Wilks test. After that, the
161 relations among climatic variables were tested with Spearman's test. Variables not
162 related to each other were tested with a mixed linear model (GLM) in its relation with
163 minimum and maximum monthly temperature (CEPTEC/INPE 2018) at the region,
164 number of days with rain (Brasil 2017), average rainfall of the month (Brasil 2017) and
165 air average relative humidity (Brasil 2018) for months we collected the data, one month
166 before, two months before, three months before and four months before. To select most
167 adequate model of explanation, we established area as random variable and used
168 AKAIKE test (AIC), with glmer function. When we found significant relation among
169 variables in Spearman's test, we did not test them together in AIC. For such, we used

170 the packages car (Fox e Weisberg 2011), MASS (Venables and Ripley 2002), lme4
171 (Bates et al. 2015), Matrix (Bates e Maechler 2017), bblme (Bolker and R development
172 Core Team 2017) and stats4 (R Core Team 2017) within R environment (1.0.143) (R
173 Development Core Team 2018). Figures were plotted on Excel.

174 3. Results

175 Minimum temperature in the region was 12°C (in July/2016) and maximum
176 temperature was 32°C (in December/2015), and the highest temperatures were
177 registered during summer, as expected. The number of days with rain varied from one
178 (June/2016) up to 26 (December/2015), rainfall varied from 2.5 mm (July/2016) up to
179 466.4 mm (January/2016), with the highest occurrence for both latter variables
180 coinciding with summer, which was also expected. Average air relative humidity varied
181 from 62% (October/2016) up to 85% (March/2016) (table. 1).

182 For *Hedychium coronarium*, the best model to describe biomass production
183 explained 53% of the results (table 2). For necromass production, the best model also
184 explained 53% of the findings (table 3). About *Urochloa decumbens*, the model that
185 explained the best the results of biomass production, it explained 79% of our findings
186 (table 2), while for necromass production, model selection pointed out explanation of
187 79% of our results (table 3). Concerning *Melinis minutiflora*, the model selection
188 explained 36% of our results of biomass production (table 2), and, for necromass
189 production, 38% (table 3). The model selected that best explain biomass production of
190 *Pennisetum purpureum* explains 98% of our findings (table 2). For necromass, the
191 selected model explains 100% of obtained results (table 3).

192 *H. coronarium* and *P. purpureum* had net primary aerial productivity equal to
193 zero, while they necromass was the highest ones (959,79 g¹m²a¹ and 1501,08 g¹m²a¹,
194 respectively, as can be seen in table 4).

195 *H. coronarium* and *P. purpureum* are the biggest producer of biomass during the
196 months of the year, and the amount of production was higher than the other two species
197 during May/2016, July/2016, August/2016, November/2016, January/2017 and
198 March/2017. *U. decumbens* and *M. minutiflora* production differed from each other
199 only in June/2016 and August/2016 (*M. minutiflora* production was higher) (table 4).
200 The lowest production during the whole year was *U. decumbens* (figs. 1 and 4).

201 Necromass production of *P. purpureum* was the most expressive, especially
202 during drought (peaking in June/2016). Its production is statistical equal to *M.*
203 *minutiflora* almost all year long. In regard with necromass production of *H. coronarium*,
204 in May/2016 and from August/2016 to March/2017, it has produced similar amount of
205 necromass with *P. purpureum*. *U. decumbens* have produced the lowest amount of
206 necromass, peaking in June/2016 and October/2016 (beginning and final of drought)
207 (figs. 2, 3 and 4).

208 4. Discussion

209 This study had its hypothesis corroborated, since for each species we could find
210 some relation among biomass and necromass productions and the studied variables,
211 therefore, studied variables are important to these species' invasion. All four species
212 presented high capability of adaptation to riparian zones and high production of biomass
213 and necromass that are potentially highly impacting. Among them, *Hedychium*
214 *coronarium* and *Pennisetum purpureum* stand out for their high necromass productivity.

215 The relation pointed by the model containing $T_{max_0(-)}$ for biomass production
216 of *H. coronarium* seems to be linked to the fact that the species grows better at lower
217 temperatures, that is corroborated by laboratory analysis (Pineiro, in prep.), in which it
218 was established that biomass production was higher in temperatures close to 25°C than
219 35°C. Also, since native species use less resources during cold and dry season, *H.*
220 *coronarium* may use more of the available resources to its growth.

221 *H. coronarium* can grow up to 2 m in height (Macedo 1997), and with its rapid
222 ramets growth (Lorenzy 2000), and the abundant biomass and necromass production all
223 year long (our data), it shows that the species can block sunlight to native species of
224 slower growth and it can prevent their germination and growth. Another impact that *H.*
225 *coronarium* may bring to riparian zones is the presence of phytotoxic compounds that
226 can inhibit germination, growth and even DNA synthesis of pioneer native species
227 (Miranda et al 2015, Costa, in prep.).

228 The most adequate model selected for biomass production of *Urochloa*
229 *decumbens* explains 79% of the results we found and the negative correlation with
230 T_{max_0} can explain the high production in October/2016. In artificial pastures, the
231 species decreases biomass production during cold season (Fagundes et al 2006), which
232 contradicts the results we found. One hypothesis that might explain this is the fact that
233 during cold and dry season, native species use less resources, so *U. decumbens* has more
234 resources available to grow. Also, in our experiment, we did not collect biomass from
235 the same plot, which can be another reason for different results from artificial pastures.
236 The species can recuperate its biomass after drought periods, if its biomass production
237 is altered (Mattos et al. 2005).

238 Although biomass and necromass production of *U. decumbens* are the lowest
239 ones in relation to the other species of this study, its invasion cannot be treated as less
240 impactful. The species is known for reducing incident light on soil by its thicket's
241 formation, decreasing recruitment and germination of other species in seed bank or
242 dispersed seeds, in addition to its invasion being capable of affecting negatively specie
243 richness, composition and distribution of life forms in tropical forest (as reviewed by
244 Ferreira et al. 2016).

245 In savana, both *U. decumbens* and *Melinis minutiflora* were considered capable
246 of producing matrix with high abundance of its individuals excluding native species
247 (Pivello et al. 1999b). *U. decumbens* is also capable of competing with other species
248 through production of phytotoxic compounds in different life cycles that present
249 allelopathic effect; its seeds, for example, produces substances capable of inhibiting
250 germination of other species, including *M. minutiflora* (Barbosa et al. 2008). However,
251 one of the reasons to cultivate *U. decumbens* in degraded areas is its capability of
252 decreasing erosion (Ferreira et al. 2016), but such procedure is not indicated for riparian
253 zones, since erosion occurs naturally in the environment (Richardson et al. 2007).

254 The most significant explicative model ($T_{min_1(-)}$) for *M. minutiflora* results help
255 understand biomass production peak in August/2016, after lower temperatures; lowest
256 production was in March, when the highest amounts of rain were happening, which can
257 also be explained by the results previously mentioned and corroborates results found for
258 others (Silva and Haridasan 2007). Although net primary aerial production of *M.*
259 *minutiflora* was the highest one, there is the possibility of resistance to the invasion of
260 this species: in Brazilian savanna areas, when *M. minutiflora* invasion has not exceeded
261 60% of total biomass present, significant richness of native species was found (Martins
262 et al. 2011).

263 Even though there is the possibility of resistance, *M. minutiflora* invasion can,
264 for example, complicate the establishment of native grasses in invaded areas (Martins et
265 al. 2004) and compromise degraded areas regeneration, altering herbaceous extract
266 biomass (Martins et al. 2011). Thickets of *M. minutiflora* were pointed as able to
267 exclude herbaceous species (Pivello et al. 1999a), natives from Brazilian savanna
268 (Pivello et al. 1999b), and also of affecting negatively arboreal species recruitment
269 (Hoffmann and Haridasan 2008), leading to species diversity and richness decrease at
270 invaded areas (Williams and Baruch 2000) and to produce allelopathic substances that
271 decrease germination and seedling (Prates et al. 1998).

272 Our results showed biomass of *P. purpureum* decreases significantly after the
273 beginning of lower temperatures season, which corroborates other studies (Deresz 2001;
274 Deresz et al. 2006; Paciullo et al. 2008). Even so, this plant has high production all year
275 long, as expected, since it is a grass used for cattle foraging because of its high
276 productivity and its fast growth rate (Silva et al. 2002; Silva and Rocha 2010). The fact
277 that net primary aerial production was zero in this study should not be used to lessen the
278 plant's production during the year or its potential of environment impact, especially
279 because of its high necromass production, that has potential to act as a physic and light
280 barrier to other species and it can increase soil nutrient supply (Berendse 1999, Foster e
281 Gross 1998). Harmful effects of *P. purpureum* invasions are the production of
282 phytotoxic compounds with allelopathic effects that can inhibit radicle and seedling
283 growth, seeds germination of native species, and these compounds can be found both in
284 biomass as in necromass of *P. purpureum* (Norhafizah 2012; Zain et al. 2013; Chuah et
285 al. 2014; Ismail et al. 2015).

286 Necromass production of *P. purpureum* explained by $T_{min0(-)} + T_{max2(+)}$ can
287 help understand production peak in June/2016. Relative humidity between 62% and

288 85% during the year and biomass production peak in June confirm Brazil's
289 classification as a very favorable location for this species growth (Barney and
290 DiTomaso 2011). Our data agrees with other studies carried out (Kubota et al. 1994; de
291 Morais et al. 2012) concerning temperature and humidity.

292 Another factor that can influence biomass and necromass production of *P.*
293 *purpureum* is nitrogen quantity in the soil: the higher nitrogen concentration on the soil,
294 the higher will be biomass and necromass production (Morais et al. 2012). We did not
295 collect data about nitrogen availability in our study sites, but it can be a factor
296 contributing to biomass and necromass production of the species in these sites.

297 It can occur a neutral or positive effect to seedlings of native species with
298 deposition of up to 500 g.m⁻² of necromass in pastures (Loydi et al. 2013). In that case,
299 *U. decumbens* may not be causing negative impact in the environment by necromass
300 production, since it is producing 226,01 g.m⁻².y⁻¹ (*H. coronarium* = 959,79 g.m⁻².y⁻¹, *M.*
301 *minutiflora* = 654,38 g.m⁻².y⁻¹ and *P. purpureum* = 1501,08 g.m⁻².y⁻¹). However, it does
302 not mean that *U. decumbens* presence is innocuous to the environment studied. Species
303 that also invade woody environments, such as *Panicum maximum* and *Pteridium*
304 *arachnoideum*, have close numbers on net primary aerial production and necromass
305 production and yet they can cause increase in fire risks (Portela et al. 2009).

306 *P. purpureum* was considered dominant invasive species in woody
307 environments in the Philippines, controlling ecosystem processes such as nutrient flow
308 with *Alternanthera sessilis*, *Synedrella nodiflora*, *P. maximum*, *Paspalum conjugatum*
309 and *Piper sarmentosum* (Torrefiel and Buot Jr 2017). Nonetheless, even though *P.*
310 *purpureum* produced more necromass than *H. coronarium* does not make its impact
311 higher, since necromass accumulation over 800 g.m⁻².y⁻¹ may not cause significant

312 higher impact than plots that produced up to $800 \text{ g.m}^{-2}.\text{y}^{-1}$ in pastures (Loydi et al.
313 2013).

314 Necromass production of *P. purpureum* and *H. coronarium* might have been
315 similar in May (end of humid season) and from August to March (end of dry season and
316 humid season), but *H. coronarium* production exceeds *P. purpureum* production in
317 October, end of dry season, what can guarantee soil isolation in terms of humidity
318 during drought (Eckstein and Donath 2005). *H. coronarium* is an amphibian
319 macrophyte, therefore, more dependent of humidity than the other species.

320 All four studied species had its biomass production related to temperature, the
321 higher the temperature, the smaller biomass production was (*H. coronarium* = T_{max_0} ,
322 *U. decumbens* = T_{max_0} , *M. minutiflora* = T_{min_1} and *P. purpureum* = T_{min_1}) and only
323 *U. decumbens* necromass production was not related to temperature (*H. coronarium* =
324 $C_1 + U_3 + T_{\text{max}_2}$, *U. decumbens* = C_2 , *M. minutiflora* = $U_2 + T_{\text{min}_1}$ and *P. purpureum*
325 = $T_{\text{min}_1} + T_{\text{max}_2}$), therefore, temperature can be considered the most important
326 variable to biomass and necromass production of the species.

327 Other relevant perspective is the high nitrogen supply that these species
328 necromass is bringing to the site. It can facilitate other species invasion, since plant
329 communities are more susceptible to invasions every time not used resources became
330 available (Davis et al. 2000), of course we take under consideration the species
331 composition of the area. Thus, it is reasonable to consider that any factor increasing
332 limiting resources availability will increase community vulnerability to invasions.
333 Necromass supply can also influence in native species germination, not only because its
334 leached, but also by changing osmotic potential on the soil (Loydi et al. 2014) and
335 necromass of invasive species seems to have higher effect in decreasing seedlings

336 establishment of native plants then necromass of native species (Scharfy et al. 2011).
337 Thereby, when species can get around shading caused both by biomass and necromass,
338 they can still be affected by phytotoxic substances (Hierro and Callaway 2003) and by
339 space and nutrient competition (Suding and Goldberg 1999; Violle et al. 2006).

340 Although studied species were from three different sites, they all occur in every
341 site we collected our data, which can lead to possible meltdown caused by multiple
342 species invasion in the same area at the same time, facilitating each other invasion and
343 causing even bigger impact (Simberloff and Holle 1999; Simberloff 2011). Loydi et al
344 (2014) point at studies that place necromass accumulation as a factor to increase
345 invasion success. As an example, in this study, nitrogen increase can facilitate biomass
346 production of *U. decumbens* and *P. purpureum* (Fagundes et al. 2005; Da Silva et al.
347 2012; Morais et al. 2012) and, as discussed before, necromass accumulation can
348 increase nitrogen availability in the environment (Berendse 1999, Foster and Gross
349 1998). Yet, the presence of invasive species can increase fire frequency in invaded areas
350 (as reviewed by Simberloff 2011) as with *Andropogon gayanus* in Australia (Setterfield
351 et al. 2013) and facilitate the entrance of new invasive species, as have occurred in
352 Hawai'i, where *Schizachyrium condensatum* and *M. minutiflora* converted forests in to
353 pastures after fire events (D'Antonio and Vitousek 1992).

354 5. Final considerations

355 The four species have its behavior directly connected to environmental variables
356 studied, temperature being the most important variable to all species, and they can cause
357 great impact in riparian zones because its high biomass and necromass production,
358 specially *Hedychium coronarium* and *Pennisetum purpureum*. Among the impacts of
359 biomass production are increased competition for resources decreasing light and water

360 offer and disturbing plant growth and reproduction (Suding and Goldberg 1999; Violle
361 et al. 2006). Necromass accumulation can act as a barrier to species growth, preventing
362 light to get to the soil or producing phytotoxic substances. Besides, increasing nutrient
363 supply on the soil though necromass decomposition can cause diversity decrease inside
364 the community (Berendse 1999, Foster and Gross 1998).

365 Since riparian zones process large flow of material from adjacent ecosystems,
366 they can be considered as critical transition zones (Ewel et al. 2001). Henderson (1998)
367 indicated that invasive tree species in riparian zones higher than 10 m are usually
368 specialists, while other types of species can invade riparian zones and its contiguous
369 environment. *Heracleum mantegazzianum*, in Czech Republic initiated its invasion in
370 riparian zone, but it continued to adjacent environment as well (Pysek et al. 2007).
371 These facts leads us to reinforce the necessity of invasive species management to
372 minimize impacts caused in riparian zones and neighbours ecosystems. Since net
373 primary aerial production and biomass production of studied species were considered
374 impactful, it is important that management measures are thought to decrease such
375 impacts.

376 We can take some measures to avoid or to remedy biological invasions. The first
377 step must be prevention (not letting exotic species to be introduced in a region),
378 followed by premature detection (to look for exotic species eradication before they are
379 invasive), rapid answer, erradication, and, at last, long management periods (the last one
380 tends to be more expensive and less succcessfull and can take years) aiming restauration
381 and, since erradication or decrease of the invasive presences is not always enough by
382 them selves, active restauration is fundamental (Simberloff et al. 2013). To riparian
383 zones, restauration does not depend on the area itself, but also of downstream catchment

384 areas, water flow restoration, increase of propagule pressure of native species and
385 revegetation to ensure no new infestation after control (Holmes et al. 2005).

386 One management strategy that can be considered when we talk about riparian
387 zones is to consider these systems as dynamics and open, that have as crucial part
388 human interference in it and, thus its objective becomes processes restoration, more than
389 original vegetation community restoration (Richardson et al 2007).

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397 6. References

398 Aires FS (2009) Desenvolvimento de técnica de manejo, sem uso de agentes químicos, no
399 controle da espécie invasora *Melinis minutiflora* Beauv. (capim-gordura) para
400 aplicação em áreas de campo sujo. 71p.

401 Bates D, Maechler M (2017). Matrix: Sparse and Dense Matrix Classes and Methods. R
402 package version 1.2-10. <https://CRAN.R-project.org/package=Matrix>

403 Bates D, Maechler M, Bolker B, Walker S (2015). Fitting Linear Mixed-Effects Models
404 Using lme4. *Journal of Statistical Software*, 67(1), 1-48. [doi:10.18637/jss.v067.i01](https://doi.org/10.18637/jss.v067.i01).

405 Barbosa EG, Pivello VR, Meirelles ST (2008) Allelopathic evidence in *Brachiaria*
406 *decumbens* and its potential to invade the Brazilian cerrados. *Brazilian Arch Biol*
407 *Technol* 51:825–831. doi: 10.1590/S1516-89132008000400021

408 Barney JN, DiTomaso JM (2011) Global climate niche estimates for bioenergy crops and
409 invasive species of agronomic origin: Potential problems and opportunities. PLoS
410 One. doi: 10.1371/journal.pone.0017222

411 Berendse F. 1999. Implications of increased litter production for plant biodiversity Using
412 integrative biology to explore constraints on evolution. Trends Ecol Evol 5347:98–99.

413 Bolker B e R Development Core Team (2017). bbmle: Tools for General Maximum
414 Likelihood Estimation. R package version 1.0.19. [https://CRAN.R-](https://CRAN.R-project.org/package=bbmle)
415 [project.org/package=bbmle](https://CRAN.R-project.org/package=bbmle)

416 Brasil. 2017. <http://www.inmet.gov.br/portal/index.php?r=tempo/graficos>. Acessado em
417 30/05/2017, 14:18.

418 Brasil. 2018. [http:// www.inmet.gov.br/portal/index.php?r=bdmep/bdmep](http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep). Acessado em
419 10/03/2018, 18:49.

420 Brooks M, D’Antonio C, Richardson D (2004) Effects of invasive alien plants on fire
421 regimes. Bioscience 54:703–713. doi: 10.1641/0006-
422 3568(2004)054[0677:EOIAP0]2.0.CO;2

423 CEPTEC/INPE. 2018. <http://www.clima1.cpte.inpe.br/monitoramentobrasil/pt>. Acessado
424 em 10/03/2018, 18:35.

425 Chuah TS, Norhafizah MZ, Ismail S (2014) Phytotoxic Effects of the Extracts and
426 Compounds Isolated from Napiergrass (*Pennisetum purpureum*) on Chinese
427 Sprangletop (*Leptochloa chinensis*) Germination and Seedling Growth in Aerobic
428 Rice Systems. Weed Sci 62:457–467. doi: 10.1614/WS-D-13-00128.1

429 Crispim SMA, Branco OD (2002) Aspectos Gerais das Braquiárias e suas Características
430 na Sub- Região da Nhecolândia, Pantanal, MS.

431 D’Antonio CM, Vitousek PM (1992) Biological Invasions by Exotic Grasses, the
432 Grass/Fire Cycle, and Global Change. Annu Rev Ecol Syst 23:63–87. doi:
433 10.1146/annurev.es.23.110192.000431

434 Da Silva TC, Perazzo AF, Macedo CHO, et al (2012) Morfogênese e estrutura de
435 *Brachiaria decumbens* em resposta ao corte e adubação nitrogenada. Arch Zootec
436 61:91–102.

- 437 Davis MA, Grime JP, Thompson K (2000) Fluctuating resources in plant communities: A
438 general theory of invasibility. *J Ecol* 88:528–534. doi: 10.1046/j.1365-
439 2745.2000.00473.x
- 440 Deresz F (2001) Influência do período de descanso da pastagem de capim-elefante na
441 produção de leite de vacas mestiças Holandês x Zebu. *Rev Bras Zootec* 30:461–469.
442 doi: 10.1590/S1516-35982001000200024
- 443 Deresz F, Paim-Costa ML, Cóser AC, et al (2006) Composição química, digestibilidade e
444 disponibilidade de capim-elefante cv. Napier manejado sob pastejo rotativo. *Rev Bras*
445 *Zootec* 35:863–869.
- 446 Eckstein RL, Donath TW (2005) Interactions between litter and water availability affect
447 seedling emergence in four familial pairs of floodplain species. *J Ecol* 93:807–816.
448 doi: 10.1111/j.1365-2745.2005.01015.x
- 449 Ewel KC, Cressa C, Kneib RT, et al (2001) Managing critical transition zones. *Ecosystems*
450 4:452–460. doi: 10.1007/s10021-001-0106-0
- 451 Fagundes JL, Da Fonseca DM, Gomide JA, et al (2005) Acúmulo de forragem em pastos
452 de *Brachiaria decumbens* adubados com nitrogênio. *Pesqui Agropecu Bras* 40:397–
453 403. doi: 10.1590/S0100-204X2005000400012
- 454 Fagundes JL, Da Fonseca DM, Morais RV, Mistura C, Vitor CMT, Gomide JA,
455 Nascimento Junior D, Santos MER, Lambertucci DM (2006). Avaliação das
456 características estruturais do capim-braquiária em pastagens adubadas com nitrogênio
457 nas quatro estações do ano. *R. Bras. Zootec.* 35 (1): 30-37.
- 458 Ferraz K, Bonach K, Verdade L (2005) Relationship between body mass and body length
459 in capybaras (*Hydrochoerus hydrochaeris*). *Biota Neotrop* 5:3–6. doi: 10.1590/S1676-
460 06032005000100020
- 461 Ferraz KMPMB, Ferraz SFB, Moreira JR, et al (2007) Capybara (*Hydrochoerus*
462 *hydrochaeris*) distribution in agroecosystems: A cross-scale habitat analysis. *J*
463 *Biogeogr* 34:223–230. doi: 10.1111/j.1365-2699.2006.01568.x
- 464 Ferreira LV, Parolin P, Matos DCL, et al (2016) The effect of exotic grass *Urochloa*
465 *decumbens* (Stapf) R.D.Webster (Poaceae) in the reduction of species richness and

466 change of floristic composition of natural regeneration in the Floresta Nacional de
467 Carajás, Brazil. An Acad Bras Cienc 88:589–597. doi: 10.1590/0001-
468 3765201620150121

469 Foster BL, Gross KL (1998) Species Richness in a Successional Grassland : Effects of
470 Nitrogen Enrichment and Plant Litter Species Richness in a Successional Grassland :
471 Effects Of Nitrogen Enrichment And Plant Litter. Ecology 79:2593–2602. doi:
472 10.1890/0012-9658(1998)079[2593:SRIASG]2.0.CO;2

473 Fox J, Weisberg S (2011). An R Companion to Applied Regression. Sage, Thousand Oaks
474 CA, 2nd edition.

475 Gaona CAP, Peixoto AR, Costa CSB. 1996. Produção primária de uma marisma raramente
476 alagada dominada por *Juncus effusus* L., no extremo sul do Brasil. Atlântica 18; 43-
477 54.

478 Hierro JL, Callaway RM (2003) Allelopathy and exotic plant invasion. Plant Soil 256:29–
479 39. doi: 10.1023/A:1026208327014

480 Hoffmann WA, Haridasan M (2008) The invasive grass, *Melinis minutiflora*, inhibits tree
481 regeneration in a Neotropical savanna. Austral Ecol 33:29–36. doi: 10.1111/j.1442-
482 9993.2007.01787.x

483 Holmes PM, Richardson DM, Esler KJ, et al (2005) A decision-making framework for
484 restoring riparian zones degraded by invasive alien plants in South Africa. S Afr J Sci
485 101:553–564.

486 Ismail BS, Tan PW, Chuah TS (2015) Assessment of the potential allelopathic effects of
487 *Pennisetum purpureum* Schumach. on the germination and growth of *Eleusine indica*
488 (L.) Gaertn. Sains Malaysiana 44:269–274. doi: 10.17576/jsm-2015-4402-15

489 Joly CA, Brandle R (1995) Fermentation and adenylate metabolism of *Hedychium*
490 *coronarium* J. G. Koenig (Zingiberaceae) and *Acorus calamus* L. (Araceae) under
491 hypoxia and anoxia. Functional Ecology, 9: 505-510.

492 Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. Ecol Evol
493 16:199–204.

494 Kubota F, Matsuda Y, Agata W, Nada K (1994) The relationship between canopy structure
495 and high productivity in napier grass, *Pennisetum purpureum* Schumach. F Crop Res
496 38:105–110. doi: 10.1016/0378-4290(94)90004-3

497 Lorenzy H. 2000. Plantas daninhas do Brasil. 3a Edição. Nova Odessa, São Paulo. 608 p.

498 Loydi A, Donath TW, Eckstein RL, Otte A (2014) Non-native species litter reduces
499 germination and growth of resident forbs and grasses: allelopathic, osmotic or
500 mechanical effects? Biol Invasions 17:581–595. doi: 10.1007/s10530-014-0750-x

501 Loydi A, Eckstein RL, Otte A, Donath TW (2013) Effects of litter on seedling
502 establishment in natural and semi-natural grasslands: A meta-analysis. J Ecol
503 101:454–464. doi: 10.1111/1365-2745.12033

504 Macedo J.F. 1997. O gênero *Hedychium* Koenig (Zingiberaceae) no Estado de Minas
505 Gerais. Daphne, 7(2): 27-31.

506 Manish M. 2013. Current status of endangered medicina plant *Hedychium coronarium* and
507 causes of population decline in the natural forests of Anuppur and Dindori districts of
508 Madhya Pradesh, India. International Research Journal of Biological Sciences, 2 (3):
509 1-6.

510 Martins CR, Hay JDV, Walter BMT, et al (2011) Impact of invasion and management of
511 molasses grass (*Melinis minutiflora*) on the native vegetation of the Brazilian
512 Savanna. Brazilian J Bot 34:73–90. doi: 10.1590/s0100-84042011000100008

513 Mattos JLS, Gomide JA, Huaman CAM (2005) Effect of water deficit on the growth of
514 Brachiaria species in greenhouse. Rev Bras Zootec 34:746–754. doi: 10.1590/S1516-
515 35982005000300005

516 Miranda CASF, Cardoso MG, Carvalho MLM, Figueiredo ACS, Andrade J (2015).
517 Chemical characterization and allelopathic potential of essential oils from leaves and
518 rhizomes of white ginger. Ciência Agronômica, 46 (3)

519 Morais RF, Quesada DM, Reis VM, et al (2012) Contribution of biological nitrogen
520 fixation to Elephant grass (*Pennisetum purpureum* Schum.). Plant Soil 356:23–34.
521 doi: 10.1007/s11104-011-0944-2

522 Moreira JR, Ferraz KMPMB, Herrera EA, Macdonald DW (2013) Capybara. Springer
523 New York, New York, NY

524 Norhafizah MZ (2012) Herbicidal activity of *Pennisetum purpureum* (Napier grass).
525 African J Biotechnol 11:6269–6273. doi: 10.5897/AJB11.3189

526 Paciullo DSC, Deresz F, Lopes FCF, et al (2008) Disponibilidade de matéria seca,
527 composição química e consumo de forragem em pastagem de capim-elefante nas
528 estações do ano. Arq Bras Med Vet e Zootec 60:904–910. doi: 10.1590/S0102-
529 09352008000400020

530 Pivello V, Carvalho V, Lopes P (1999a) Abundance and distribution of native and alien
531 grasses in a “Cerrado”(Brazilian Savanna) biological reserve. Biotropica 31:71–82.
532 doi: 10.1111/j.1744-7429.1999.tb00117.x

533 Pivello VR, Shida CN, Meirelles ST (1999b) Alien grasses in Brazilian savannas: A threat
534 to the biodiversity. Biodivers Conserv 8:1281–1294. doi: 10.1023/A:1008933305857

535 Portela CRQ, Silva-Matos DM, et al (2009) Variation in aboveground biomass and
536 necromass of two invasive species in the Atlantic rainforest, southeast Brazil. Acta
537 Bot Brasilica 23:571–577. doi: 10.1590/S0102-33062009000200029

538 Prates HT, Leite RC, Craveiro AA, Oliveira AB (1998) Identification of some chemical
539 components of the essential oil from molasses grass (*Melinis minutiflora* Beauv.) and
540 their activity against cattle-tick (*Boophilus microplus*). J Braz Chem Soc 9:193–197.
541 doi: 10.1590/S0103-50531998000200013

542 Pysek P, Prach K (1993) Plant Invasions and the Role of Riparian Habitats: A Comparison
543 of Four Species Alien to Central Europe. J Biogeogr 20:413. doi: 10.2307/2845589

544 R Core Team (2017). R: A language and environment for statistical computing. R
545 Foundation for Statistical Computing, Vienna, Austria. URL [https://www.R-](https://www.R-project.org/)
546 [project.org/](https://www.R-project.org/).

547 R_DEVELOPMENT_CORE_TEAM. 2018. R: A language and environment for statistical
548 computing. Vienna: R Foundation for Statistical Computing.

549 Richardson DM, Holmes PM, Esler KJ, et al (2007) Riparian vegetation: degradation, alien
550 plant invasions, and restoration prospects RID A-1495-2008 RID F-5883-2010.
551 *Divers Distrib* 13:126–139. doi: 10.1111/j.1472-4642.2006.00314.x

552 Schade JD, Fisher SG, Grimm NB, Seddon JA (2001) The influence of a riparian shrub on
553 nitrogen cycling in a Sonoran Desert stream. *Ecology* 82:3363–3376. doi:
554 10.1890/0012-9658(2001)082[3363:TIOARS]2.0.CO;2

555 Scharfy D, Funk A, Olde Venterink H, G??sewell S (2011) Invasive forbs differ
556 functionally from native graminoids, but are similar to native forbs. *New Phytol*
557 189:818–828. doi: 10.1111/j.1469-8137.2010.03531.x

558 Setterfield SA, Rossiter-Rachor NA, Douglas MM, et al (2013) Adding Fuel to the Fire:
559 The Impacts of Non-Native Grass Invasion on Fire Management at a Regional Scale.
560 *PLoS One*. doi: 10.1371/journal.pone.0059144

561 Silva E, Rocha CR (2010) Eucalipto e capim elefante: características e potencial produtivo
562 de biomassa. *Rev Agrogeoambiental* 2:143–152.

563 Silva JSO, Haridasan M (2007) Acúmulo de biomassa aérea e concentração de nutrientes
564 em *Melinis minutiflora* P. Beauv. e gramíneas nativas do cerrado. *Rev Bras Botânica*
565 30:337–344. doi: 10.1590/S0100-84042007000200016

566 Silva MMP da, Vasquez HM, Silva JFC da, et al (2002) Composição Bromatológica ,
567 Disponibilidade de Forragem e Índice de Área Foliar de 17 Genótipos de Capim-
568 Elefante (*Pennisetum purpureum* Schum .) sob Pastejo , em Campos dos Goytacazes ,
569 RJ. *Rev Bras Zootec* 31:313–320. doi: 10.1590/S1516-35982002000200004

570 Simberloff D (2011) How common are invasion-induced ecosystem impacts? *Biol*
571 *Invasions* 13:1255–1268. doi: 10.1007/s10530-011-9956-3

572 Simberloff D., Rejmánek (eds) 2011. *Encyclopedia of biological invasions*. University of
573 California Press, Berkeley & Los Angeles. 765 p

574 Simberloff D, Holle B Von (1999) Positive interactions of nonindigenous species:
575 invasional meltdown? *Biol Invasions* 21–32. doi: 10.1023/a:1010086329619

576 Simberloff D, Martin J-L, Genovesi P, et al (2013) Impacts of biological invasions: what's
577 what and the way forward. *Trends Ecol Evol* 28:58–66. doi:
578 10.1016/j.tree.2012.07.013

579 Soares DJ, Barreto RW (2008) Fungal pathogens of the invasive riparian weed *Hedychium*
580 *coronarium* from Brazil and their potential for biological control. *Fungal Divers*
581 28:85–96.

582 Souza VC, Lorenzy H (2005). *Botânica Sistemática: guia ilustrado para identificação das*
583 *famílias de Angiospermas da flora brasileira, baseado em APG II*. Editora Platarum,
584 Nova Odessa, São Paulo. 639 p.

585 Suding KN, Goldberg DE (1999) Variation in the Effects of Vegetation and Litter on
586 Recruitment across Productivity Gradients. *J Ecol* 87:436–449. doi: 10.1046/j.1365-
587 2745.1999.00367.x

588 Tolentino M. 1967. *Estudo crítico sobre o clima da região de São Carlos*. São Carlos:
589 Prefeitura Municipal, 78 p.

590 Torrefiel JT, Bout Jr IE (2017) Weed species composition in the riparian zone of molawin
591 river, laguna, Philippines. 57–73. *J. Wetlands Biodiversity* 7: 57-73

592 Tunison, J.T. 1991. Strategies and successes in controlling alien plants in an Hawai`ian
593 National Park. *Proc. Symp. Exotic Pest Plants*: 353-376.

594 Venables WN e Ripley BD (2002) *Modern Applied Statistics with S*. Fourth Edition.
595 Springer, New York. ISBN 0-387-95457-0

596 Violle C, Richarte J, Navas ML (2006) Effects of litter and standing biomass on growth
597 and reproduction of two annual species in a Mediterranean old-field. *J Ecol* 94:196–
598 205. doi: 10.1111/j.1365-2745.2005.01061.x

599 Vitousek PM, D'antonio CM, Loope LL, Rejmánek M & Westbrooks R. 1997. Introduced
600 species: a significant component of human-caused global change. *New Zealand*
601 *Journal of Ecology*, 21(1): 1-16.

602 Wilke CO (2017). cowplot: Streamlined Plot Theme and Plot Annotations for 'ggplot2'. R
603 package version 0.9.2. <https://CRAN.R-project.org/package=cowplot>

604 Williams DG, Baruch Z (2000) African grass invasion in the Americas: ecosystem
605 consequences and the role of ecophysiology. *Biol Invasions* 2:123–140. doi:
606 10.1023/A:1010040524588

607 Zain NM, Yew OH, Sahid I, Seng CT (2013) Potential of Napier grass (*Pennisetum*
608 *purpureum*) extracts as a natural herbicide. *Pakistan J Bot* 45:2095–2100.

609 Zenni RD, Ziller SR (2011) An overview of invasive plants in Brazil. *Rev Bras Botânica*
610 34:431–446. doi: 10.1590/S0100-84042011000300016

611

612 Table 1: Climatic variables during time and biomass and necromass production of *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora* and *Pennisetum purpureum* during time.

	Dez/15	Jan/16	Feb/16	Mar/16	Apr/16	May/16	Jun/16	Jul/16	Aug/16	Sep/16	Oct/16	Nov/16	Dec/16	Jan/17	Feb/17	Mar/17
Tmax	32	30	32	32	32	26	26	28	28	30	30	30	30	30	30	30
Tmin	20	22	22	20	18	14	14	12	14	16	18	18	20	20	20	20
U	77	78	75	85	69	79	83	67	67	65	62	77	80	82	79	76
C	26	22	13	25	2	5	9	1	6	6	16	15	21	21	14	11
P	227,3	191,1	463,4	156,7	10,4	135,6	101,7	2,5	22	26,3	131,6	120,1	178,2	173	141,3	227,3
Biomass																
<i>Hedychium coronarium</i>	-	-	-	-	282	541	446	681**	422	282	275	332	356	410	235*	444
Biomass																
<i>Urochloa decumbens</i>	-	-	-	-	64*	97	94	98	84	105	113**	65	106	105	100	66
Biomass																
<i>Melinis minutiflora</i>	-	-	-	-	136	129	215	192	220**	145	207	109	136	122	116	84*

	Dez/15	Jan/16	Feb/16	Mar/16	Apr/16	May/16	Jun/16	Jul/16	Aug/16	Sep/16	Oct/16	Nov/16	Dec/16	Jan/17	Feb/17	Mar/17
<hr/>																
Biomass																
<i>Pennisetum purpureum</i>	-	-	-	-	445	785	1209**	766	892	648	644	428*	652	660	521	601
Necromass																
<i>Hedychium coronarium</i>	-	-	-	-	171	130	104	116	144	75	207	165	99	200**	65	60*
Necromass																
<i>Urochloa decumbens</i>	-	-	-	-	52	40	73**	42	47	49	67	48	31*	51	38	59
Necromass																
<i>Menilis minutiflora</i>	-	-	-	-	176	144	210	163	170	120	159	303**	171	184	127	111*
Necromass																
<i>Pennisetum purpureum</i>	-	-	-	-	219	383	676**	401	322	193	207	249	178	116	80	69*

614 Tmin = minimum temperature (in °C), Tmax = maximum temperature (in °C), U = average air relative humidity (in %), C = number of days with rain, P = average rain fall
615 (in mm). Biomass and necromass are in g. * = lowest production of biomass or necromass. ** = highest production of biomass or necromass.

616 Table 2: models that explain biomass (g) production variation for the studied species.

<i>Hedychium coronarium</i>				
	Estimate	Std. Error	T value	
(intercept)	2084,49	427,06	4,88	
Tmax0	-45,13	11,25	-4,01	
U3	-5,04	2,7	-1,86	
Model	aAIC	dAIC	df	weight
Tmax0(-)+U3(-)	1566,4	0,0	5	0,53
Null model	1588,4	22,0	3	<0,001
<i>Urochloa decumbens</i>				
	Estimate	Std. Error	T value	
(intercept)	163,11	55,83	2,92	
Tmax0	-2,46	1,87	-1,31	
Model	aAIC	dAIC	df	weight
Tmax0(-)	1197,7	0,0	4	0,79
Null model	1200,4	2,7	3	0,21
<i>Melinis minutiflora</i>				
	Estimate	Std. Error	T value	
(intercept)	374,62	35,87	10,44	

Tmin1	-13,18	2,02	-6,51	
Modelo	aAIC	dAIC	df	weight
Tmin1(-)	1316,4	0,0,	4	0,36
Null model	1354,0	37,6	3	<0,001

Pennisetum purpureum

	Estimate	Std. Error	T value	
(intercept)	1485,92	307,13	4,83	
Tmin1	-47,06	15,67	-3,00	
Modelo	aAIC	dAIC	df	weight
Tmin1(-)	1793,6	0,0	4	0,98
Null model	1807,5	14	3	<0,001

617 Tmax₀= maximum temperature in month of biomass quantification, U₃= relative humidity of the month
618 three months before biomass quantification, Tmin₁=minimum temperature one month before biomass
619 quantification.
620

621 Table 3: models that explain necromass (g) production variation for the studied species.

<i>Hedychium coronarium</i>				
	Estimate	Std. Error	T value	
(intercept)	544,20	137,51	4,03	
C1	-3,77	1,24	-3,05	
U3	-6,04	1,22	-4,94	
Tmax2	1,80	4,52	0,40	
Modelo	aAIC	dAIC	df	weight
C1(-)+U3(-) +Tmax2(+)	1411,8	0,0	6	0,53
Null model	1440,5	28,7	3	<0,001
<i>Urochloa decumbens</i>				
	Estimate	Std. Error	T value	
(intercept)	59,27	5,58	10,61	
C2	-1,03	0,39	-2,58	
Modelo	aAIC	dAIC	df	weight
C2(-)	1186,4	0,0	4	0,79
Null model	1190,8	4,4	3	0,08
<i>Melinis minutiflora</i>				
	Estimate	Std. Error	T value	
(intercept)	389,9	85,49	4,56	

U2	-2,91	1,01	-2,87	
Tmin1	-0,22	2,77	-0,078	
Modelo	aAIC	dAIC	df	weight
U2(-)+Tmin1(-)	1387,3	0,0	5	0,38
Null model	1396,9	9,6	3	0,003

Pennisetum purpureum

	Estimate	Std. Error	T value	
(intercept)	219,44	207,91	1,05	
Tmin0	-55,14	4,77	-11,55	
Tmax2	33,07	6,53	5,06	
Modelo	aAIC	dAIC	df	weight
Tmin1(-) +Tmax2(+)	1515,2	0,0	5	1
Null model	1612,5	97,4	3	<0,001

622 C₁= number of days with rain one month before necromass quantification, U₃= relative humidity of the
623 month three months before biomass quantification, Tmax2= maximum temperature two months before
624 necromass quantification, C₂= number of days with rain two months before necromass quantification, U₂=
625 relative humidity of the month two months before biomass quantification, Tmin₁= minimum temperature
626 one month before biomass quantification. Tmax0= maximum temperature in month of biomass
627 quantification.

628

629

630 Table 4: net primary aerial production and necromass production of species.

	Net Primary Aerial Production	Necromass Production
<i>Hedychium. coronarium</i>	0	959,79 g ¹ m ² a ¹
<i>Urochloa decumbens</i>	79,56 g ¹ m ² a ¹	226,01 g ¹ m ² a ¹
<i>Melinis minutiflora</i>	470,83 g ¹ m ² a ¹	654,38 g ¹ m ² a ¹
<i>Pennisetum purpureum</i>	0	1501,08 g ¹ m ² a ¹

631

632

633 Capítulo 2: Mechanical and chemical control of

634 *Hedychium coronarium* J. König.

635 (Zingiberaceae) in neotropical riparian zone

636

637 Mechanical and chemical control of *Hedychium coronarium* J. König. (Zingiberaceae)
638 in neotropical riparian zone

639 Abstract

640 Riparian zones are ecotones among aquatic and terrestrial environments that are
641 very important regulating the link among these systems, but high threatened by
642 biological invasion. The amphibian macrophyte *Hedychium coronarium* is among the
643 invasive plants reported at many ecosystems in Brazil. It is important to investigate
644 ways to control it. In this study, we tested mechanical control and chemical control with
645 glyphosate injection and spray and *Typha domingensis* extracts injection. Mechanical
646 control was carried on the field, in five sites and four treatments: control, cutting off
647 ramets once, twice and pulling out rhizomes. Chemical control took place at the
648 laboratory, in aquariums. Injection had four control and four injection, spray had the
649 same and *T. domingensis* had three for each treatment, control, leaves extract at 5% and
650 10% concentration and rhizome extracts at the same concentration. We used linear
651 mixed effects model fit by maximum likelihood and mortality rate expressed in
652 percentage to analyze data. All treatments applied in our experiments have decrease
653 the production of *H. coronarium* populations, although none of the treatments have
654 shown total effectiveness, and every treatment showed re-sprout of ramets. The best
655 treatment is glyphosate injection into the rhizome with 97,3 % of mortality rate.

656

657 Key words: invasive plant, *Typha domingensis* extract, glyphosate injection, glyphosate
658 spray

659

660 1. Introduction

661 Invasive species are common all over the world and are considered the second
662 major cause of biodiversity loss (Vitousek et al 1997, Simberloff & Rejmanek 2011).
663 The first cause, habitat loss, occurs mainly through destruction of ecosystems for
664 agricultural purpose (Primack and Rodrigues 2000), while invasive species are usually
665 introduced as ornamentals or for monetary reasons (Zenni and Ziller 2011). Invasive
666 species can cause many impacts, such as changing nutrient cycling and its concentration
667 on the soil, fire regime alteration, and changes in physical structure of habitats,
668 removing previously dominant species (Simberloff 2011).

669 Riparian zones are ecotones among aquatic and terrestrial environments (Tickner
670 et al 2001) that are very important regulating the link among these systems (Naiman &
671 Décamps 1997), but high threatened by biological invasion. These ecosystems perform
672 important functions, such as the increase water flow resistance, increasing resistance to
673 soil erosion; the decrease water turbulence, controlling input of erosion material; they
674 influence microclimate, are used as way among areas and, furthermore, they filter
675 pesticides from agriculture in water bodies (Naiman & Décamps 1997, Tickner et al
676 2001). Both abundance and diversity of alien plants in riparian zones have been
677 increasing throughout the world (Richardson et al 2007). There are several impacts of
678 invasive species in riparian zones, such as water courses desiccation, alteration in fire
679 regime and native species displacement (Naiman & Décamps 1997). Besides that, he
680 invasion in this ecosystem can be facilitated once its stream can be a very effective way
681 of carrying reproductive parts (Pysek & Prach 1993, Tickner et al 2001).

682 The amphibian macrophyte *Hedychium coronarium* König. (Zingiberaceae) is
683 among the invasive plants reported at many ecosystems in Brazil (Zenni & Ziller 2011).
684 It has vegetative reproduction through rhizomes pieces that can be dispersed through

685 water streams (Tunison 1991), is already found 3000 km away from the coast (Soares &
686 Barreto 2008) and it is listed as invasive species by Paraná state (Paraná 2007), Santa
687 Catarina state (CONSEMA SC 2012), and it appears among the list of cultivated
688 invasive species that are present in Federal Conservation Units in Brazil (Sampaio and
689 Schmidt 2013) for example. Considering that *H. coronarium* is an aggressive invader, it
690 is important to investigate ways to control it.

691 Control of invasive species are done mostly in three ways: biologically,
692 mechanically and chemically (Simberloff & Rejmanek 2011). Biological control is done
693 through the introduction of a non-native organism that acts as a predator of the target
694 species; mechanical control is done through cutting off, pulling out or mowing of the
695 invasive species and chemical control is done using herbicides in the target plant (Myers
696 & Bazely 2003). As macrophytes are concerned, the technique used must take into
697 account the species habits, the ecosystem invaded and the size of the invasion (Tu et al
698 2001, Motooka et al 2002, Dechoum & Ziller 2013). One of the most used herbicides to
699 control unwanted species is glyphosate (Dechoum & Ziller 2013), whose effectiveness
700 is non-selective, except for plants genetically modified to endure it (RoundUp Ready
701 plant varieties) (Benbrook 2016). Glyphosate usage increased after the creation of
702 genetically modified crop seeds and, as a result, weeds are becoming resistant to it
703 (Benbrook 2016).

704 Rice (1984) states that the use of plants extracts could replace the use of
705 synthetic herbicides, or at least reduce it. Many pesticides have had natural substances
706 as an important part of their formula for the past years, even though herbicides are a
707 small fraction of it (Dayan et al 2009, Cantrell et al 2012). Also, the use of herbicides
708 must consider proximity to water to avoid contamination (Tu et al 2001), which makes
709 it important to find alternative for controlling invasive species. The Brazilian species

710 *Typha domingensis* Pers. (Typhaceae) is a rhizomatous macrophyte commonly found in
711 the waters of the country (Lorenzi 2000), but not commonly found co-existing with *H.*
712 *coronarium* (personal observation). *T. domingensis* is known for present allelochemical
713 effects, with phenolic compounds such as 2-chlorophenol, salicylaldehyde, linoleic acid
714 and α -linolenic acid (Gallardo et al 1999, Hu & Hong 2008) and its extract can inhibit
715 oxygen production in macrophytes, chlorophyll production, and growth of other
716 macrophytes (Gallardo et al 1999, Rao et al 2016). In this study, we tested mechanical
717 control and chemical control with glyphosate and *T. domingensis* extracts, therefore, the
718 aim of this study was to answer the following questions:

719 1) Do different mechanical treatment, chemical treatments with synthetic herbicide and
720 chemical treatments with alcoholic extracts of phenolic compounds of *T. domingensis*
721 have any effect on *H. coronarium* growth and re-sprouting?

722 To do so, we tested:

723 a) The effects of cutting off once and twice a year the ramets of *H. coronarium* to its
724 height and diameter growth and mortality rate;

725 b) The effect of pulling out once the ramets and rhizomes of *H. coronarium* to its height
726 and diameter growth and mortality rate;

727 c) The effects of glyphosate injections on *H. coronarium* rhizomes, glyphosate spray on
728 *H. coronarium* leaves and the effects of injections of alcoholic extracts of phenolic
729 compounds from leaves and rhizome of *T. domingensis* in two concentrations each (5%
730 and 10%) on *H. coronarium* rhizomes in its height and diameter growth and mortality
731 rate and

732 d) The in its height and diameter growth and mortality rate.

733 Our hypothesis is that tested treatments would decrease the growth, ramets
734 production and survival of *H. coronarium*.

735

736 2. Material and methods

737 2.1. Studied species

738 *Hedychium coronarium* J. König (Zingiberaceae) is a perennial rhizomatous
739 macrophyte that presents both sexual reproduction and asexual reproduction. Its
740 rhizomes fragments can be carried through the water and one piece can establish a new
741 population (Tunison 1991). Ramets can reach 2 m height; its leaves are coriaceous with
742 20 to 40 cm of length and 5 to 6 cm of width, and white fragrant flowers (Macedo
743 1997). The species is native from Himalaya, Nepal, India and west China, where it
744 occurs in tropical and subtropical woods up to 1.900 m of altitude (Manish 2013). In
745 Brazil it can be found all over the coast and 3.000 km away from the coastal area
746 (Soares & Barreto 2008).

747 *Typha domingensis* Pers. (Typhaceae) is a perennial herbaceous macrophyte that
748 can grow from 1,1 m to 4 m; its leaves have linear blades with up to 1,20 m of length
749 and 0,5 to 1,5 cm of width. It presents reproduction either via seeds or via rhizomes and
750 occurs naturally from the south of United States of America until Patagonia and in all
751 Brazilian regions (Lorenzi 2000, Carvalho et al 2014). Species of *Typha* genus tend to
752 form monotypic stands (Fraga & Kvet 1993) and *T. domingensis* tolerates both shallow
753 and deep waters locations (Grace 1989).

754 2.2. Study area

755 The study area is located in São Carlos municipality, (22° 01' 03" S and 47° 53'
756 27" W,) São Paulo state, southwest Brazil. The area soil is predominantly red-yellow
757 latosol and purple latosol (Perez Junior 1997). The local climate is, according to
758 Köppen's classification, a transition between Cwai-Awi, characterized as humid
759 subtropical (hot and humid summer, from October to March and cold and dry winter,

760 from April to September) (Tolentino 1967). The municipality is at the hydrographic
761 basin of Monjolinho river, one of Jacaré-Guaçu rivers affluent, which drains to Tietê
762 River (Lima 2003).

763 The experiment with mechanical control had replicates in five different riparian
764 sites: 1) Fazzari lake (21°58'17.4" S and 47°53'17.7" W), surrounded by a Cerrado
765 area; 2) Monjolinho lake (21°59'07.2" S and 47°52'54.1" W), within the Federal
766 University of São Carlos; 3) Horto Florestal (21°59'13.2 S and 47°52'21.3" W), in the
767 margins of Monjolinho river; 4) Sítio Paraíso (21°58'48.2" S and 47°55'18.2" W), near
768 Washington Luís highway and 5) Bosque Cambuci (21°59'31.9" S and 47°54'13.8" W),
769 in the urban perimeter of São Carlos. The individuals of *Typha domingensis* were also
770 collected at São Carlos municipality, at João Ponce da Costa Municipal Road
771 (21°59'92" S and 47°50'26.05" W).

772 2.3. Data collection method

773 2.3.1. Mechanical control

774 In May/2017 we established three plots of 1 m X 1m 10 m apart from each other
775 and 3 m away from the water course in each of the five sites. Each plot was subdivided
776 into four sub plots of 0,5 m x 0,5 m and in each sub plot we applied randomly: *i*) control
777 without any treatment, *ii*) cutting off ramets once a year (applied on the day we
778 established the plots), *iii*) cutting off ramets twice a year (applied on the day we
779 established the plots and six months later) and *iv*) pulling out ramets and rhizomes
780 (applied on the day we established the plots). We numbered and measured the diameter
781 at soil level and the total height of all ramets inside the plots. We re-measured every
782 three months, finishing in May/2018. All new ramet found was numbered and
783 measured. The started data collection in May because it is the period of the year the
784 species shows the lowest biomass production (see chapter 1).

785

786 2.3.2. Chemical control

787 To each test of chemical control of *H. coronarium* we collected rhizomes from
788 one site (Monjolinho Lake) and cut them in pieces of 10 cm length. In the lab we
789 planted five pieces in aquariums of 30 cm x 30 cm x 20 cm with 5 cm of fertilized soil.
790 The aquariums were kept in a climatized room with photoperiod of 12:12 h light/dark
791 and temperature 24+/-2°C, where the rhizomes were left to grow along three months,
792 watering with 500 mL of tap water twice a week.

793 To test glyphosate (RoundUp, produced by Monsanto) injection effectiveness
794 we used four aquariums for each treatment: control (IC) and injection (I). Thus, we had
795 4 x 5 replicates for each treatment. The injections were made with Monsanto stem gun
796 and followed the recommendation of the producer on applying 10 mL of the product
797 undiluted in a 90° angle. Controls were injected with tap water. All the tests with
798 glyphosate were made with proper gloves, mask and glasses and the area with the
799 aquariums was isolated for 24 hours after the injection test. The rhizomes were
800 monitored monthly in order to check the production of ramets which were numbered
801 and had their diameter at soil level and total height measured. Five months after the first
802 injection, we repeated the procedure and continued measuring the production and the
803 size of ramets until three months after the last treatment.

804 To test glyphosate spray effect, we used four aquariums for control (SC) and
805 four for spray (S). Thus, we also had 4 x 5 replicates for each treatment. The
806 concentration used, and quantity of spray applied were those recommended by the
807 producer: 1 part of RoundUp to 100 parts of water and we sprayed until the leaves were
808 wet by the solution. The controls were sprayed with tap water. All the tests with
809 glyphosate were made with proper gloves, mask and glasses and the area with the

810 aquariums was isolated for 24 hours after the spray test. Two months after the first
811 spray, we repeated the spraying and again after four months since first application. Once
812 a month, we numbered the ramets and measured their diameter at soil level and the total
813 height until two months after the last treatment was applied.

814 To test *Typha domingensis* alcoholic extract, three aquariums were used as
815 controls (TC) and had its ramets injected with tap water, three had its ramets injected
816 with leaf alcoholic extract at 5% concentration (LE5), three had its ramets injected with
817 leaf alcoholic extract at 10% (LE10), three had its ramets injected with rhizome
818 alcoholic extract at 5% (RE5) and three had its ramets injected with rhizome alcoholic
819 extract at 10% concentration (RE10). So, for each treatment we had 3 x 5 replicates.
820 The injections were made with Monsanto stem gun, the injected volume was 10 mL.
821 Once a month, we numbered the ramets and measured their diameter at soil level and
822 the total height until three months after the last treatment was applied.

823 To prepare the extracts of phenolic compounds of *Typha domingensis*, we
824 collected the plant with leaves and rhizome, the samples were dried in circular air heater
825 at 30° C until constant weight, and the dried material was powdered in an ultra turrax
826 grinder. The extraction was carried on with organic solvent ethanol in 5 L
827 Erlenmeyers's flasks. The procedure was repeated three times in order to retrieve the
828 most compounds possible. Obtained portions were concentrated in rotating evaporators
829 (as suggested in Dai & Mumper 2010). To reach the desired concentration, the
830 concentrate was diluted with water.

831 2.4. Statistical analysis

832 To test the differences for height and diameter among treatments in each
833 experiment, we used linear mixed effects model fit by maximum likelihood (with
834 function "lme"). For mechanical treatment, we considered ramets, plots and sites as

835 random effects, time as fixed effect and height and diameter as answer. Ramets and
836 aquariums were considered as random effects, and height and diameter as answer
837 variables, time as fixed effect for chemical control experiments conducted in the
838 laboratory. We also used mortality rates expressed in percentage of dead plant in each
839 treatment as evaluation criteria to assess treatments efficiency. All the analysis were
840 conducted within the R statistical environment, version 3.4.3 (R Development Core
841 Team 2018), using the packages lme4 (Bates et al 2015) and nlme (Pinheiro et al
842 2017). Graphics were made with Excel.

843 3. Results

844 Mechanical control experiment (table 1) showed that cutting ramets once a year
845 had a negative effect on height growth ($p=0,001$) (fig. 1) and on diameter growth
846 ($p=0,008$) (fig. 2). Cutting off ramets and pulling out rhizomes once a year had a
847 positive effect on diameter growth ($p=0,0029$), while control treatment had a negative
848 effect on diameter growth ($p=0,0391$) (fig. 2). Chemical control experiments had no
849 statistical effect on height growth (table 2 and figs. 3, 5 and 7), but for diameter growth
850 glyphosate injection control (fig. 4) and glyphosate spray control (fig. 6) had positive
851 effect ($p=0,026$ and $p=0,0002$, respectively) and *Typha domingensis* leaves extract at
852 5% concentration and *T. domingensis* rhizome extract at 5% concentration (fig. 8) had
853 negative effect on diameter growth ($p=0,0007$ and $p=0,01$ respectively).

854 Glyphosate injection on rhizomes increased the mortality rate (97,3%), followed
855 by cutting off ramets twice a year (85,4%) and glyphosate spray on leaves (83,3%)
856 (table 3). The variation of total number of ramets over time for each experiment can be
857 seen on figures 9, 10, 11 and 12. Injections of *Typha domingensis* extract decreased
858 mortality rate of ramets.

859

860

861 4. Discussion

862 None of the treatments applied to attempt the control of *Hedychium coronarium*
863 have shown total effectiveness in killing the plant, and every treatment showed re-
864 sprout of ramets, but our initial hypothesis was corroborated, which was that treatments
865 would have an effect on growth, ramets production and survival of *H. coronarium*.

866 Regarding mechanical control experiment, we chose to start our experiment in
867 May, because is the lowest biomass production of the species (see chapter 1), which
868 could make more difficult for the plant to re-sprout (cutting and pulling might take more
869 energy from the plant). Cutting ramets once a year can impact the growth in height and
870 diameter, but it was not effective to kill the plant, which was also observed in
871 experiments carried on rainforest in Brazil (Maciel 2011) and also, for height, in
872 experiments conducted for *Hedychium gardnerianum* in Azores (Andrade 2015),
873 although cutting ramets off had no results in Hawai'i after a year (Santos et al 1986).
874 While our findings do not indicate that cutting off ramets twice a year (mortality rate
875 85,4%) is any different from pulling out ramets and rhizomes (mortality rate 85,3%),
876 Maciel (2011) concluded that pulling out ramets and rhizome once or three times a year
877 were more effective in decreasing the density/abundance of *H. coronarium*; cutting off
878 ramets and pulling out rhizomes of *H. gardnerianum* showed a relation with smaller
879 ramet height in Azores (Andrade 2015). It is easier to cut off ramets than to pull out
880 ramets and rhizome, regarding to the amount of labor, and cutting preserves the soil
881 characteristics and decrease the risk of leave small pieces of rhizomes which can
882 regrowth and produce a new stand at the same area of in other area when carried by the
883 water flow. Yet, control by pulling out rhizome is best suited for small areas, since it is,
884 nevertheless, very laborious.

885 The highest mortality rate was achieved with glyphosate injections (97,3%),
886 however, since the herbicide tested is a broad spectrum one (Benbrook 2016), it can
887 only be used after making sure it is not going to affect other species co-occurring with
888 *H. coronarium*. Although its high mortality rate, we noticed the presence of newly born
889 ramets during the three months after the second injection, demonstrating that the
890 treatment does not inhibit the re-sprouting. Other studies had similar results, but despite
891 the high mortality rate, there were negative effects in the environment and in practical
892 terms. An effective injection treatment (100% of mortality rate for rhizomes one year
893 after treatment) for *H. gardnerianum* was established in Hawai'i with amitrol and
894 picloram potassium salt + potassium hydroxide (Tordon 22K). However, the first
895 herbicide was considered expensive for larger areas of application and too laborious,
896 whilst the latter was too damaging to native vegetation (Santos et al 1992), so it should
897 not be recommended for using in natural habitats. Perhaps, more glyphosate injections
898 could result in the control of *H. coronarium*.

899 The herbicide type and concentration utilized are important for the results of its
900 application. We used 1% concentration and sprayed the leaves three times, and the
901 mortality rate was lower than with glyphosate injection (83,33%). Spray application of
902 glyphosate had been tested before in semideciduous seasonal forest, and the mortality
903 rate obtained was 95% with a single time spray and 3% concentration (Dechoum &
904 Ziller 2013). Other herbicides have been used to attempt control of *H. coronarium*, such
905 as triclopyr and fluroxypyr combined, and had better results in a single application with
906 concentration of 2% (Dechoum & Ziller 2013). In Hawai'i, other herbicides like
907 triclopyr (Garlon 4), picloram potassium salt + potassium hydroxide (Tordon), amitrol
908 and glyphosate (RoundUp) (all at 5% concentration) were sprayed attempting to control
909 *H. gardnerianum* without success (Santos et al 1992). However, the application of these

910 herbicides requires caution. Foliar spraying with any herbicide in *H. gardnerianum* has
911 been considered inappropriate due to its potential risk of causing damage to native
912 species close to the invasive plant and the possibility of over spraying, which could lead
913 the herbicide to contaminate waters nearby (Santos et al 1992, Ward et al 1999). Even if
914 in Brazil the use of glyphosate spray at 3% concentration inside Conservation Units to
915 attempt to control of *H. coronarium* is legal (IBAMA 2016), one should consider the
916 possibility of treated plants exudate glyphosate applied on aerial parts through it roots,
917 as demonstrated in experiment carried out with *Urochloa brizanta* control in soy bean
918 plantation (Kohls et al 2006) (for further information see Tuffi Santos et al 2005).
919 Concerning what type of herbicide to use, while glyphosate tend to be inactive when
920 adsorbed in the soil (Amarante Junior & Santos 2002), it can also affect other species,
921 since it is a non-selective herbicide (Benbrook 2016). Triclopyr also may injure non-
922 target species seeds (Douglass et al 2016) and its residues were found in dam reservoir
923 in New Zealand, being banned for agrochemical uses (Ward et al 1999). Fluroxypyr can
924 leach to underground waters (Cederlund et al 2012) and applications of triclopyr and
925 fluroxypyr combined can reduce diversity and richness of non-target species (Power et
926 al 2013). In addition to choosing the least impacting herbicide, it is important to take
927 under consideration monetary cost, time spent and labor of different treatments to
928 properly assess the efficiency of control.

929 *Typha domingensis* extracts injection on rhizomes decreased the diameter
930 growth of *H. coronarium*. We observed that the diameter would decrease while the
931 ramet were increasing in height, therefore, diameter growth would be an indication of
932 slower growth in height, which would be desirable for control. Mortality rate was the
933 lowest among them all, even the control experiment had higher mortality rates. A study
934 aiming *Salvinia minima* control with *T. domingensis* extracts and leachates found that

935 both were able to inhibit oxygen production of *S. minima*, though the leachates were
936 more effective (Gallardo et al 1999). Other studies showed that *T. domingensis* extracts
937 inhibited oxygen production of *Lyngbya majuscula*, *Valisneria americana*, *Elodea*
938 *canadensis*, and *Myriophyllum spicatum* (Rao et al 2016). Further testing regarding the
939 effect of *T. domingensis* leachates on *H. coronarium* should be interesting. Also, if the
940 invasion is large, using plant extract to control it could become impracticable, since one
941 would need too much plant to extract phenolic compounds.

942 Our study did not measure costs of money and labor of controls techniques we
943 tested, but an experiment carried out with *H. gardnerianum* did. It considering 1)
944 Cutting off ramets, 2) Pulling out ramets and rhizomes, 3) Cutting off ramets and
945 applying herbicide (metsulfuron methyl), 4) Cutting off ramets and covering the ground
946 with black plastic canvas and 5) Controlled fire showed that cutting off ramets was the
947 cheapest treatment, cutting off ramets and pulling out rhizomes and cutting off ramets
948 and applying herbicide were more expensive and had no statistical difference between
949 their costs (Andrade 2015). Labor wise, the worst treatment was cutting off ramets and
950 pulling out rhizomes, while cutting off ramets was the easiest one.

951 Biological control for *H. coronarium* is not available for practical uses yet, but
952 its use has been suggested in the literature (Soares & Barreto 2008, Hayes et al 2013).
953 We observed ant attack on *H. coronarium* during our field experiment, when
954 approximately an area 40m² of ramets were completely defoliated. However, after a few
955 weeks we could not distinguish the difference between attacked and non-attacked sites.
956 The fungi *Gonatophragmium mori*, *G. mangiferae*, *Leptosphaeria* sp., *Mycosphaerella*
957 *hedychii*, *Pseudocercospora hedychii*, *Veronaea hedychii*, *Curvularia lunata* and
958 *Chalara aurea* were found in *H. coronarium* in Brazil, but none of them caused
959 significant damage to the plant (Soares & Barreto 2008). Further experiments to

960 establish whether herbivory decreases the population of the plant or not must be carried
961 out. However, the introduction of exotic species is illegal in Brazil in Conservation
962 Units (BRASIL 2000), so biological control for *H. coronarium* in such areas could not
963 take place in those sites.

964 After effective control of an invasive species, other invasive species might
965 occupy the site instead of native species. In one of our sites, after the establishment of
966 mechanical treatment (cutting off ramets and pulling out rhizomes), we found subplots
967 covered with the species *Philodendron* sp that occurred there. Similarly, *Pteridium*
968 *aquilinum*, *Rubus ulmifolius*, *Cyrtomium falcatum*, *Conyza bonariensis* and *Solanum*
969 *mauritanum*, all invasive in Azores, were found occupying plots after *H. gardnerianum*
970 was cut out and pulled off (Andrade 2015). Also, ecosystems where erosion is part of its
971 processes, such as riparian zones, may have a higher number of events after an invasive
972 species is controlled, which can increase the erosion of material in the water (Tickner et
973 al 2001). To eradicate invasive species, it is better to focus on early detection and to
974 control the source of the species rather than wait until the invasive populations become
975 established and the effort to eradicate must continue for at least 10 years (Mack &
976 Lonsdale 2002). In conservation areas, instead of focusing in one invasive species Mack
977 and Lonsdale (2002) suggest that it is more effective to create buffer zones and work
978 with reforestation along with control of invasive species, as it has been done for five
979 years in New Zealand with positive results for *H. gardnerianum* invasions, among other
980 species, reducing their populations to a smaller size, which can be easier to manage
981 (Lovegrove et al 2002).

982 5. Conclusion

983 All treatments applied in our experiments have failed to kill *Hedychium*
984 *coronarium* populations, and every treatment showed re-sprout of ramets, but we had

985 higher mortality rate in all treatments, except for those with *Typha domingensis* extract
986 injections, which partially corroborates our initial hypothesis.

987 The best treatment is glyphosate injection into the rhizome, but its use must
988 consider the place where the invasive plant is set, so to prevent unwanted contamination
989 by the herbicide to native plants. This is a challenge, because riparian zones are
990 sensible, and the herbicides could be easily carried from streams. Reforestation with
991 native species should be carried out along with attempt of control to prevent other
992 invasive species to take place.

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999 6. Refences

- 1000 Amarante Junior OP, Santos TCR (2002). Glifosato: propriedades, toxicidade, usos e
1001 legislação. *Quim. Nova*, 25 (4): 589-593.
- 1002 Andrade RCA (2015). Avaliação de métodos de controlo mecânicos e químicos da
1003 espécie invasora *Hedychium gardnerianum* Sheppard ex Ker Gawl. na ilha de São
1004 Miguel – Açores. Dissertação de mestrado. Universidade dos Açores.
- 1005 Bates D, Maechler M, Bolker B, Walker S (2015). Fitting Linear Mixed-Effects Models
1006 Using lme4. *Journal of Statistical Software*, 67(1), 1-48. doi:10.18637/jss.v067.i01.
- 1007 Benbrook CM (2016). Trends in glyphosate herbicide use in the United States and
1008 globally. *Environ Sci Eur* 28 (3): 1-15. Doi: 10.1186/s12302-016-0070-0
- 1009 BRASIL (2000) Sistema Nacional de Unidades de Conservação. In:
1010 [http://www.mma.gov.br/images/arquivos/areas_protegidas/snuc/Livro%20SNUC%](http://www.mma.gov.br/images/arquivos/areas_protegidas/snuc/Livro%20SNUC%20PNAP.pdf)
1011 [20PNAP.pdf](http://www.mma.gov.br/images/arquivos/areas_protegidas/snuc/Livro%20SNUC%20PNAP.pdf) Acesses in 16/08/2018
- 1012 Cantrell CL, Dayan FE, Duke SO (2012). Natural products as sources for new
1013 pesticides. *J. Nat. Prod.* 75: 1231-1241.

- 1014 Carvalho MLS, Lima CT, Oliveira RP, Giulietti AM (2014) Flora da Bahia: Typhaceae.
1015 Sitientibus série Ciências Biológicas 14: 1-4. Doi: 10.13102/scb420
- 1016 Cederlund H, Börjesson E, Jonsson E, Thierfelder T (2012). Degradation and leaching
1017 of fluroxypyr after application to railway tracks. J. of Environ. Qual. 41: 1894-
1018 1892. Doi: 10.2134/jeq2012.0035
- 1019 Dai J, Mumper RJ (2010) Plant phenolics: extraction, analysis and their antioxidant and
1020 anticancer properties. Molecules 15: 7313-7352. doi:10.3390/molecules15107313
- 1021 Dayan FE, Cantrell CL, Duke SO (2009). Natural products in crop protection. Bioorg &
1022 Med Chem 17: 4022–4034. doi:10.1016/j.bmc.2009.01.046
- 1023 Dechoum MS, Ziller SR (2013). Métodos para controle de plantas exóticas invasoras.
1024 Biotemas 26 (1): 69-77. Doi: 10.5007/2175-7925.201v26n1p69
- 1025 Douglass CH, Nissen SJ, Meiman PJ, Kniss AR (2016). Impacts of imazapyr and
1026 triclopyr soil residues on the growth of several restoration species. Rangeland
1027 Ecology and Management 69: 199-205. Doi: 10.1016/j.rama.2016.01.006
- 1028 CONSEMA SC – Conselho Estadual de Meio Ambiente de Santa Catarina (2012)
1029 Resolução CONSEMA N° 08, de 14 de setembro de 2012.
1030 <http://www.fatma.sc.gov.br/upload/rppne/resconsema201208.pdf> Access in
1031 13/08/2018.
- 1032 Fraga JMP, Kvet J (1993) Production dynamics of *Typha domingensis* (Pers.) Kunth in
1033 Cuba. J. Aquat. Plant. Manage, 31: 204-243.
- 1034 Gallardo MT, Ascher JR, Collier MJ, Martin BB, Martin DF (1999). Effects of cattail
1035 (*Typha domingensis*) extracts, leachates, and selected phenolic compounds on rates
1036 of oxygen production by salvinia (*Salvinia minima*). J. Aquat. Plant Manage. 37:
1037 80-82.
- 1038 Grace JB (1989) Effects of water depth on *Typha latifolia* and *Typha domingensis*.
1039 American Journal of Botany, 76 (5): 762-768.
- 1040 Hayes L, Fowler SV, Paynter Q, Groenteman R, Peterson P, Dodd S, Bellgard S (2013).
1041 Biocontrol of weeds: achievements to date and future outlook. In Dymond JR ed.
1042 Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua
1043 Press, Lincoln, New Zealand.
- 1044 Ho H, Hong Y (2008). Algal-bloom control by allelopathy of aquatic macrophytes – A
1045 review. Front. Environ. Sci. Engin 2(4): 421-438. Doi: 10.1007/s11783-0080070-4
- 1046 Kohls GN, Landsberg E, Stock-Oliveira Souza K, Yamada T, Römheld V (2006).
1047 Relevance of glyphosate transfer to non-target plants via the rhizosphere. Journal
1048 of Plant Diseases and Protection. 963-969.

- 1049 Lima RT (2003) Percepção ambiental e participação pública na gestão dos recursos
1050 hídricos: perfil dos moradores da cidade de São Carlos, SP (bacia hidrográfica do
1051 rio Monjolinho). Dissertação de mestrado. Universidade de São Paulo.
- 1052 Lorenzi H. (2000) Plantas daninhas do Brasil: terrestres, aquáticas, parasitas e tóxicas.
1053 3. ed. Nova Odessa: Instituto Plantarum. 608 p.
- 1054 Lovegrove TG, Zeiler CH, Greene BS, Green BW, Gaastas R, MacArthur AD (2002).
1055 Plant and animal control and aspects of ecological restoration in a small 'mainland
1056 island': Wenderholm Regional Park, New Zealand. *In*: Veitch CR, Clout MN
1057 (Eds). Turning the tide: the eradication of invasive species (Occasional Paper of the
1058 IUCN Species Survival Commission), 27: 155-163.
- 1059 Macedo J.F. 1997. O gênero *Hedychium* Koenig (Zingiberaceae) no Estado de Minas
1060 Gerais. *Daphne*, 7(2): 27-31.
- 1061 Mack RN, Lonsdale WN (2002). Eradicating invasive plants: hard-won lessons for
1062 islands. *In*: Veitch CR, Clout MN (Eds). Turning the tide: the eradication of
1063 invasive species (Occasional Paper of the IUCN Species Survival Commission), 27:
1064 164-172.
- 1065 Maciel LA (2011). Controle mecânico da herbácea exótica invasora lírio-do-brejo
1066 (*Hedychium coronarium* Koenig) no Parque estadual Turístico do Alto Ribeira –
1067 PETAR, SP. Dissertação de mestrado apresentada na Universidade de São Paulo,
1068 USP.
- 1069 Manish M. 2013. Current status of endangered medicinal plant *Hedychium coronarium*
1070 and causes of population decline in the natural forests of Anuppur and Dindori
1071 districts of Madhya Pradesh, India. *International Research Journal of Biological*
1072 *Sciences*, 2 (3): 1-6.
- 1073 Motooka P, Ching L, Nagai G (2002). Herbicidal weed control methods for pastures
1074 and natural areas of Hawaii. Cooperative Extension Service, University of Hawaii.
1075 36 p.
- 1076 Myers JH, Bazely D (2003). Ecology and control of introduced plants. Cambridge
1077 University Press. 313 p.
- 1078 Naiman RJ, Décamps H (1997). The ecology of interfaces: riparian zones. *Annu. Ver.*
1079 *Ecol. Syst* 28: 621-658.
- 1080 PARANÁ (2007). Portaria IAP nº095, de 22 de maio de 2007.
1081 [http://www.institutohorus.org.br/download/marcos_legais/PORTARIA_IAP_N_09](http://www.institutohorus.org.br/download/marcos_legais/PORTARIA_IAP_N_095_DE_22_DE_MAIO_DE_2007.pdf)
1082 [5_DE_22_DE_MAIO_DE_2007.pdf](http://www.institutohorus.org.br/download/marcos_legais/PORTARIA_IAP_N_095_DE_22_DE_MAIO_DE_2007.pdf) Access in 13/082018.
- 1083 Perez Junior OR (1997) A cidade de São Carlos. Projeto de Educação ambiental através
1084 da visão integrada de bacia hidrográfica via internet. Centro de divulgação
1085 Científica e Cultural. São Carlos.

- 1086 Pinheiro J, Bates D, DebRoy S, Sarkar D & R Core Team (2017). *nlme*: Linear and
 1087 Nonlinear Mixed Effects Models. R package version 3.1-131, <URL:
 1088 <https://CRAN.R-project.org/package=nlme>>.
- 1089 Power EF, Kelly DL, Stout JC (2013). The impacts of traditional and novel herbicide
 1090 application methods on target plants, non-target plants and production in intensive
 1091 grasslands. *Weed Research* 53: 131-139. Doi: 10.1111/wre.12009
- 1092 Primack, R. B. e Rodrigues, E. 2000. *Biologia da conservação*. Ed. Planta, 327p.
- 1093 Pysek P, Prach K (1993) Plant Invasions and the Role of Riparian Habitats: A
 1094 Comparison of Four Species Alien to Central Europe. *J Biogeogr* 20:413. doi:
 1095 10.2307/2845589
- 1096 R_DEVELOPMENT_CORE_TEAM. 2018. R: A language and environment for
 1097 statistical computing. Vienna: R Foundation for Statistical Computing.
- 1098 Rao MR, Saranya Y, Dyvia D (2016). Growth Inhibitory Study of *Typha domingensis*
 1099 Rhizome Aqueous Extracts on Gram Seeds. *Int. J. Pharm. Sci. Rev.* 37(1): 33-35.
- 1100 Rice EL (1984). Allelopathy. 2nd edition. London, Academic Press. *In*: HU H, Hong Y
 1101 (2008). Algal-bloom control by allelopathy of aquatic macrophytes – A review.
 1102 *Front. Environ. Sci. Engin* 2(4): 421-438. Doi: 10.1007/s11783-0080070-4
- 1103 Richardson DM, Holmes PM, Esler KJ, Galatowitsch SM, Stromberg JC, Kirkman SP,
 1104 Pysek P, Hobbs RJ (2007). Riparian vegetation: degradation, alien plant invasions,
 1105 and restoration prospects. *Diversity and Distrib.* 13: 126-139. Doi: 10.1111/j.1472-
 1106 4642.2006.00314.
- 1107 Sampaio AB, Schmidt IB (2013). Espécies Exóticas Invasoras em Unidades de
 1108 Conservação Federais do Brasil. *Biodiversidade Brasileira* 3(2): 32-49.
- 1109 Santos GL, Kageler D, Gardner DE, Stone CP (1986). Herbicidal control of selected
 1110 alien plant species in Hawai'i Volcanoes National Park: a preliminary report. *Tech.*
 1111 *Rep.* 60, Univ. Hawai'i Coop. Natl. Park Resour. Stud. Unit. Honolulu.
- 1112 Santos GL, Kageler D, Gardner DE, Cuddihy LW, Stone CP (1992). Herbicidal Control
 1113 of Selected Alien Plant Species in Hawai'i Volcanoes National Park. *In*: Stone CP,
 1114 Smith CW, Tunison JT (1992). *Alien Plant Invasions in Native Ecosystems of*
 1115 *Hawai'i*. Ed. University of Hawai'i Press
- 1116 Simberloff D (2011). How common are invasion-induced ecosystem impacts? *Biol.*
 1117 *Invasions* 13: 1255-1268. Doi: 10.1007/s10530-011-9956-3
- 1118 Simberloff D, Rejmánek (eds) 2011. *Encyclopedia of biological invasions*. University of
 1119 California Press, Berkeley & Los Angeles. 765 p
- 1120 Soares DJ, Barreto RW (2008) Fungal pathogens of the invasive riparian weed
 1121 *Hedychium coronarium* from Brazil and their potential for biological control.
 1122 *Fungal Divers* 28: 85–96.

- 1123 Tickner DP, Angold PG, Gurnell AM, Mountford O (2001). Riparian plant invasions:
1124 hydrogeomorphological control and ecological impacts. *Progress in Physical*
1125 *Geography* 25 (1): 22-52.
- 1126 Timmins S (1997). Environmental weed research plan: 1997-2006. Department of
1127 conservation, Wellington, New Zealand. 27 p.
- 1128 Tolentino M. (1967). Estudo crítico sobre o clima da região de São Carlos. São Carlos:
1129 Prefeitura Municipal, 78 p.
- 1130 Tu M, Hurd C, Randall JM (2001). Weed Control Methods Handbook: Tools &
1131 Techniques for Use in Natural Areas. All U.S. Government Documents (Utah
1132 Regional Depository). Paper 533. 220 p.
- 1133 Tuffi Santos LD, Ferreira FA, Barros NF, Siqueira, CH, Santos IC, Machado AFL
1134 (2005). Exsudação radicular do glyphosate por *Brachiaria decumbens* e Seus
1135 efeitos em plantas de eucalipto e na respiração Microbiana do solo. *Planta Daninha*,
1136 Viçosa-MG, 23 (1): 143-152.
- 1137 Tunison JT (1991). Strategies and successes in controlling alien plants in an Hawai`ian
1138 National Park. *Proc. Symp. Exotic Pest Plants*: 353-376.
- 1139 Vitousek PM, D'antonio CM, Loope LL, Rejmánek M & Westbrooks R (1997).
1140 Introduced species: a significant component of human-caused global change. *New*
1141 *Zealand Journal of Ecology*, 21(1): 1-16.
- 1142 Ward BG, Henzzel RF, Holland PT, Spiers AG (1999). Non-spray methods to control
1143 invasive weeds in urban area. *Urban Weeds and Pests. Proc. 52nd N. Z. Plant*
1144 *Protection Conf.*: 1-5.
- 1145 Zenni RD, Ziller SR (2011). An overview of invasive plants in Brazil. *Revista Brasil.*
1146 *Bot.* 34 (3): 431-446.
- 1147

1148 Table 1: Statistical results for height (cm) and diameter (mm) growth of *Hedychium*
 1149 *coronararium* in mechanical control experiment.

	Value	Sd error	DF	t-value	p-value
Height (cm)					
Control	-396,51	363,95	330	-1,09	0,27
Cut 1	-1191,57	361,1	330	-3,3	0,001
Cut 2	-75,8667	450,18	330	-0,17	0,87
Pull	998,37	571,8	330	1,75	0,082
Diameter (mm)					
Control	-4085,17	1972,21	330	-2,07	0,0391
Cut 1	-6647,42	1957,9	330	-3,4	0,0008
Cut 2	-2770,51	2439,29	330	-1,14	0,2569
Pull	9310,58	3099,73	330	3	0,0029

1150 Cut 1= cutting off ramets once a year, Cut 2 = cutting off ramets twice a year, Pull = cutting off ramets
 1151 and pulling out rhizome once a year, Sd Error=standard error, DF= degrees of freedom

1152

1153 Table 2: Statistical results for height (cm) and diameter (mm) growth of *Hedychium*
 1154 *coronararium* in chemical control experiment.

	Value	Sd error	DF	t-value	p-value
Height (cm)					
IC	142,86	495,5	6	0,29	0,7828
I	-1206,29	497,67	6	-2,42	0,0516
SC	19,69	558,8	31	0,04	0,9721
S	450,18	1028,3	31	0,44	0,6646
TEC	-74,7	341,05	10	-0,22	0,831
LE5	216,44	288,35	10	0,75	0,4702
LE10	48,05	414,6	10	0,12	0,91
RE5	-52,78	297,03	10	-0,18	0,8625
RE10	69,33	358,44	10	0,19	0,8505
Diameter (mm)					

IC	57,74	19,65	6	2,94	0,026
I	29,28	19,88	6	1,47	0,1913
SC	309,28	72,7	31	4,25	0,0002
S	76,78	139,17	31	0,55	0,5851
TEC	-84,3	52,41	10	-1,61	0,1388
LE5	-213,13	44,51	10	-4,79	0,0007
LE10	47,54	63,74	10	0,75	0,4729
RE5	-143,46	45,76	10	-3,13	0,0106
RE10	-49,92	55,02	10	-0,91	0,3856

1155 IC= glyphosate injection control, I= glyphosate injection, SC= glyphosate spray control, S= glyphosate
1156 spray, TEC= *Typha domingensis* extracts control, LE5= *Typha domingensis* leaf extract at 5%
1157 concentration, LE10= *Typha domingensis* leaf extract at 10% concentration, RE5= *Typha domingensis*
1158 rhizome extract at 55 concentration, and RE10= *Typha domingensis* rhizome extract at 10%
1159 concentration, Sd Error=standard error, DF= degrees of freedom

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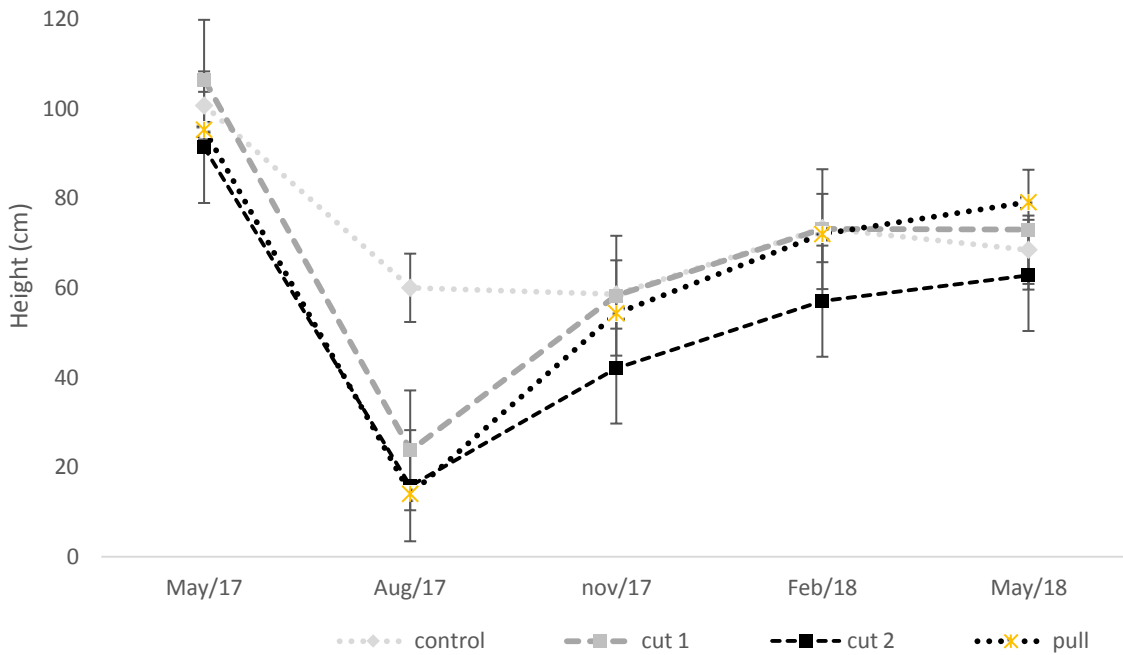
1163 Table 3: number of ramets of *Hedychium coronarium* during control experiments and
1164 total mortality rates of laboratory experiments.

	MC	C1	C2	P	IC	I	SC	S	TEC	LE5	LE 10	RE5	RE 10
Total number of ramets	283	282	220	129	41	37	24	12	19	17	11	21	18
Mortality rate (%)	79,9	76,2	85,4	85,3	61%	97,3	62,5	83,3	52,6	41,2	18,2	42,9	27,8

1165 MC= mechanical control, C1= cutting off once, C2= cutting off twice, P= pulling out, IC= glyphosate
1166 injection control, I= glyphosate injection, SC= glyphosate spray control, S= glyphosate spray, TEC=
1167 *Typha domingensis* extracts control, LE5= *Typha domingensis* leaf extract at 5% concentration, LE10=
1168 *Typha domingensis* leaf extract at 10% concentration, RE5= *Typha domingensis* rhizome extract at 55
1169 concentration, and RE10= *Typha domingensis* rhizome extract at 10% concentration

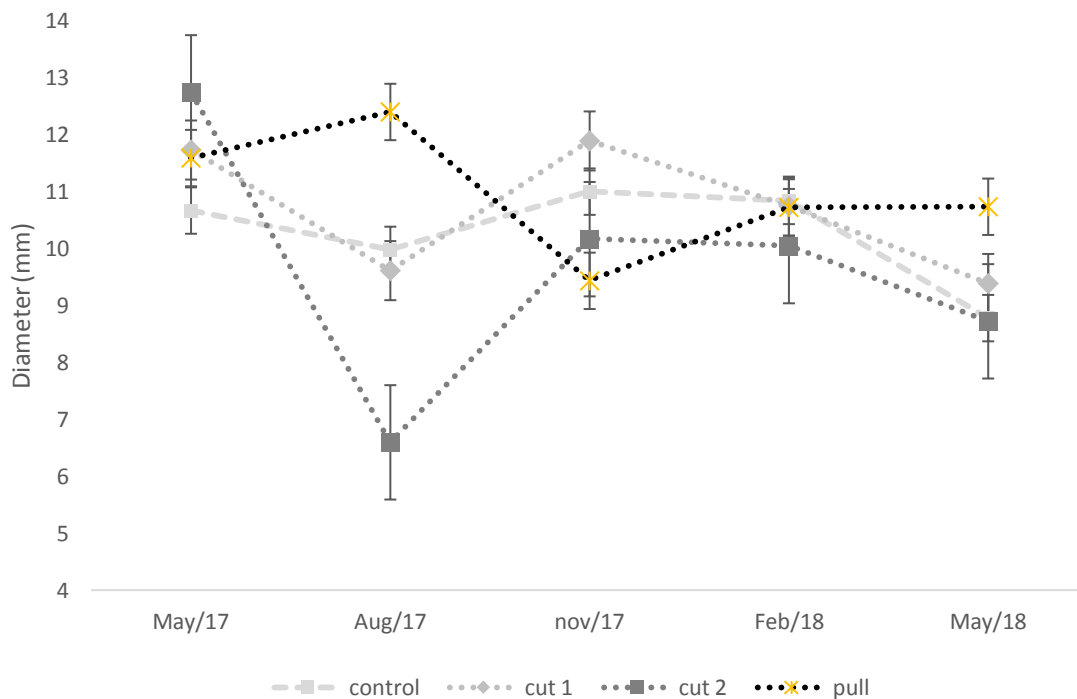
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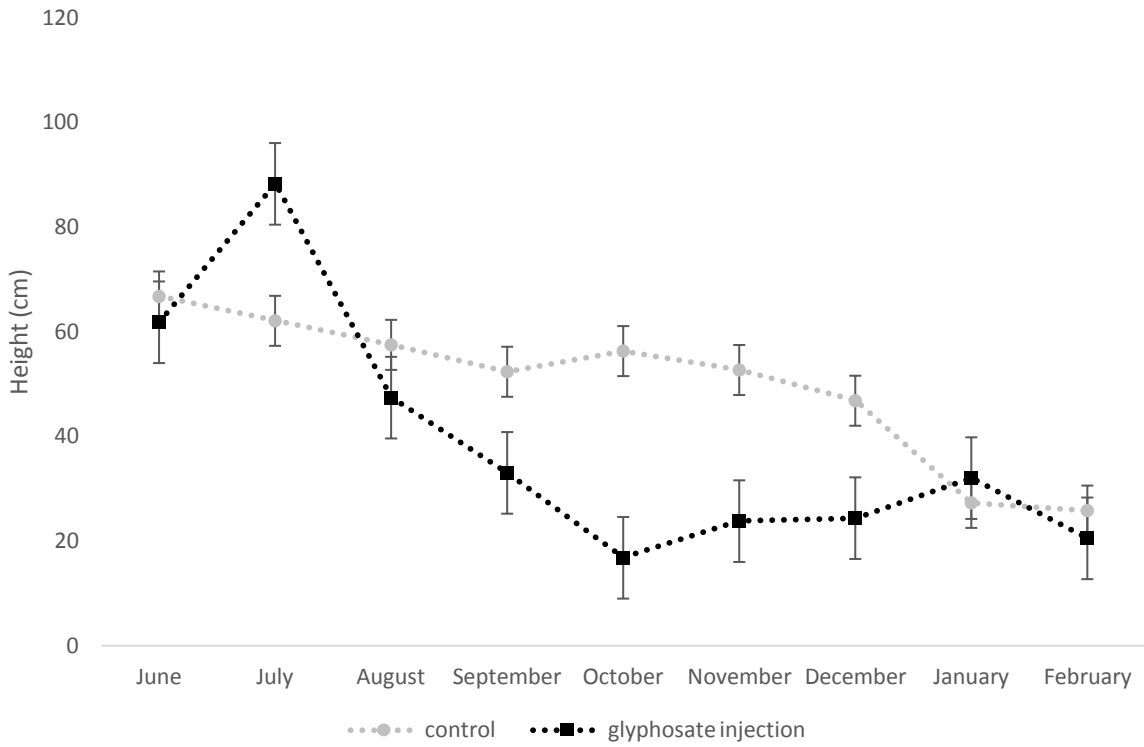
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1173 Figure 1: Results for height (cm) variation in mechanical experiment for *Hedychium*
1174 *coronararium* control. Cut 1= cutting ramets off once a year, Cut 2= cutting ramets off
1175 twice a year and Pull= cutting ramets off and pulling rhizomes out once a year.



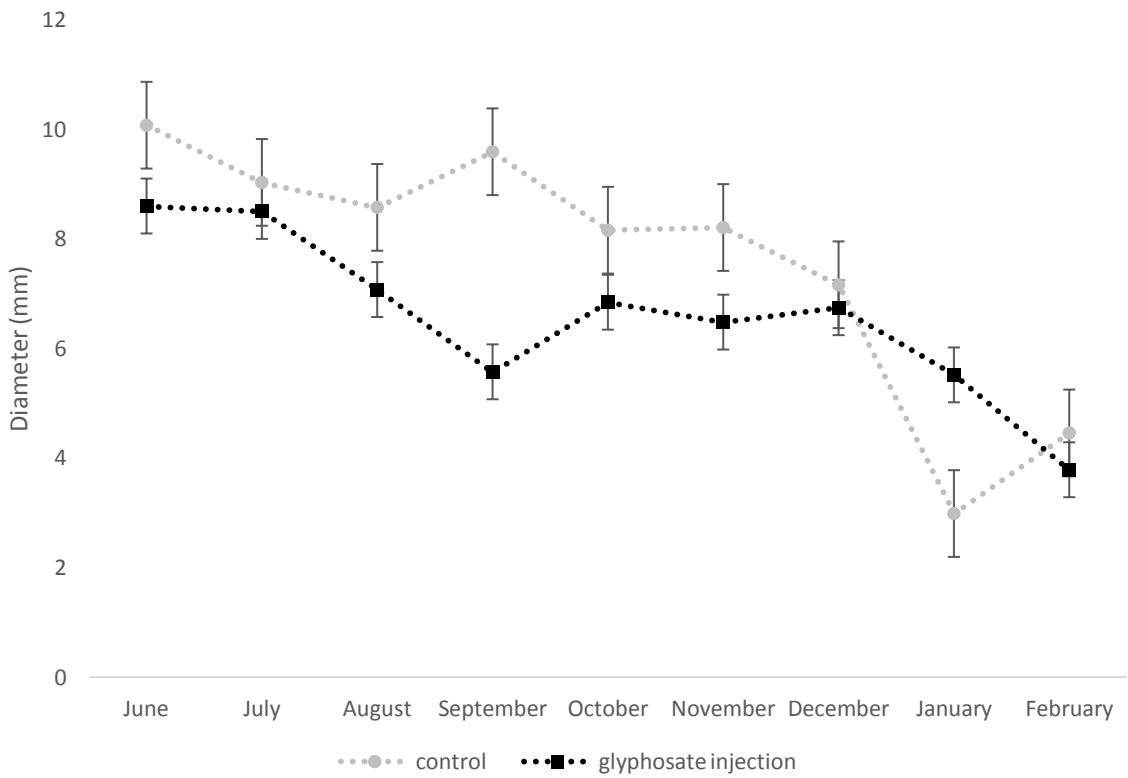
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1177 Figure 2: Results for diameter (mm) variation in mechanical experiment for *Hedychium*
1178 *coronararium* control. Cut 1= cutting ramets off once a year, Cut 2= cutting ramets off
1179 twice a year and Pull= cutting ramets off and pulling rhizomes out once a year.



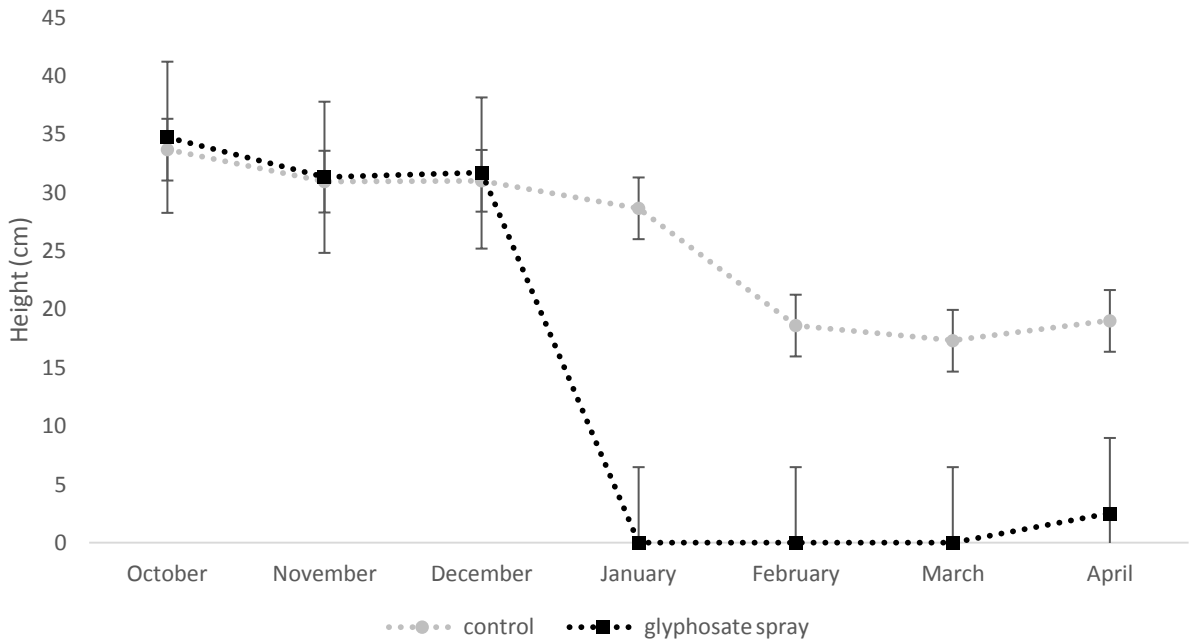
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1181 Figure 3: Results for height (cm) variation in glyphosate injection experiment for
 1182 *Hedychium coronarium* control.



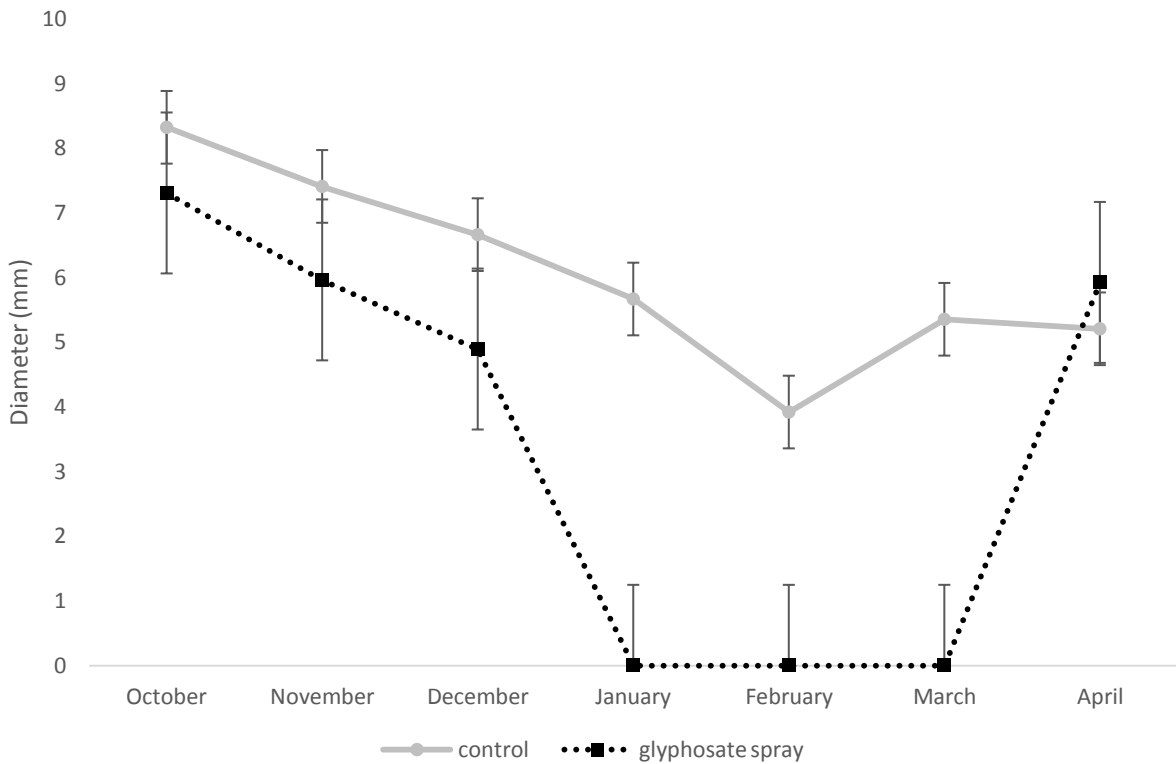
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1184 Figure 4: Results for diameter (mm) variation in glyphosate injection experiment for
 1185 *Hedychium coronarium* control.



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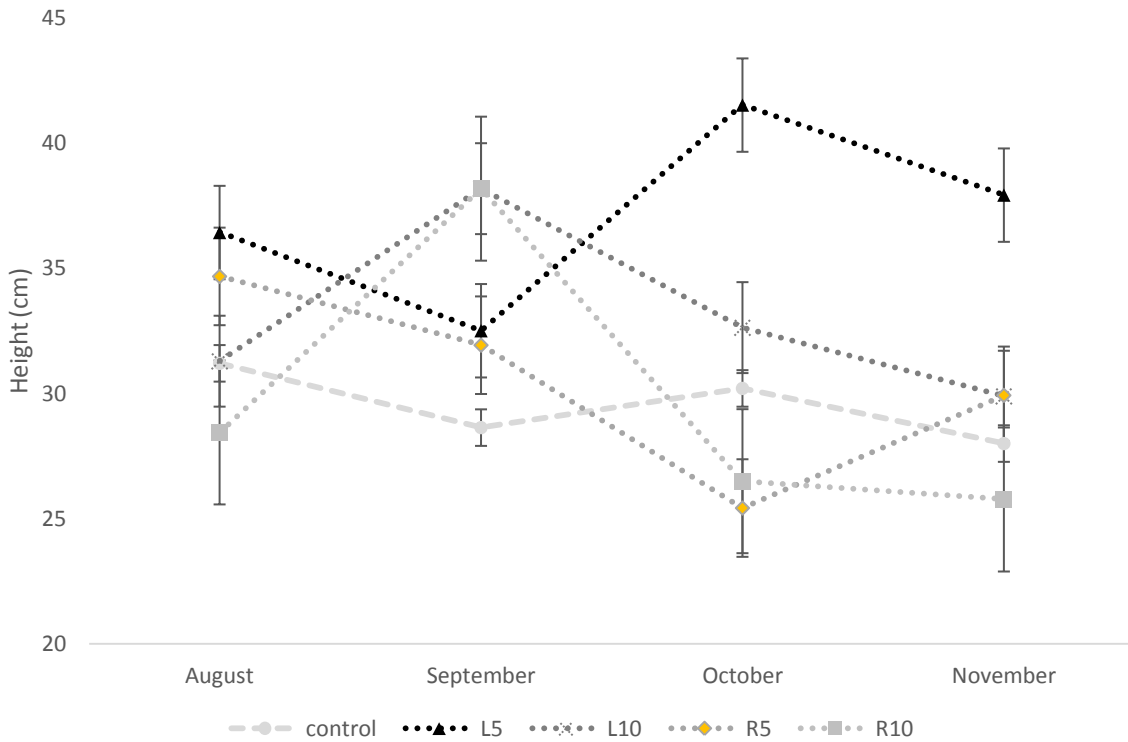
1187 Figure 5: Results for height (cm) variation in glyphosate spray experiment for
 1188 *Hedychium coronarium* control.



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1190 Figure 6: Results for diameter (mm) variation in glyphosate spray experiment for
 1191 *Hedychium coronarium* control.

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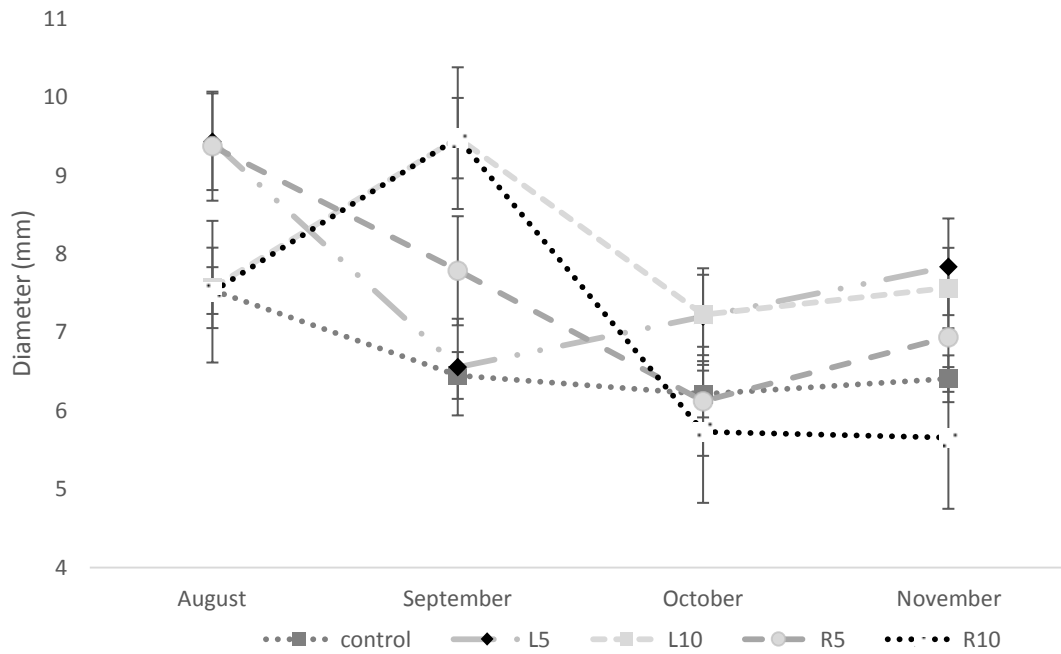


119.

1194 Figure 7: Results for height (cm) variation in *Typha domingensis* injection experiment
 1195 for *Hedychium coronarium* control. C= control, L5= leaf extract at 5% concentration,
 1196 L10= leaf extract at 10% concentration, R5= rhizome extract at 5% concentration, R10=
 1197 rhizome extract at 10% concentration.

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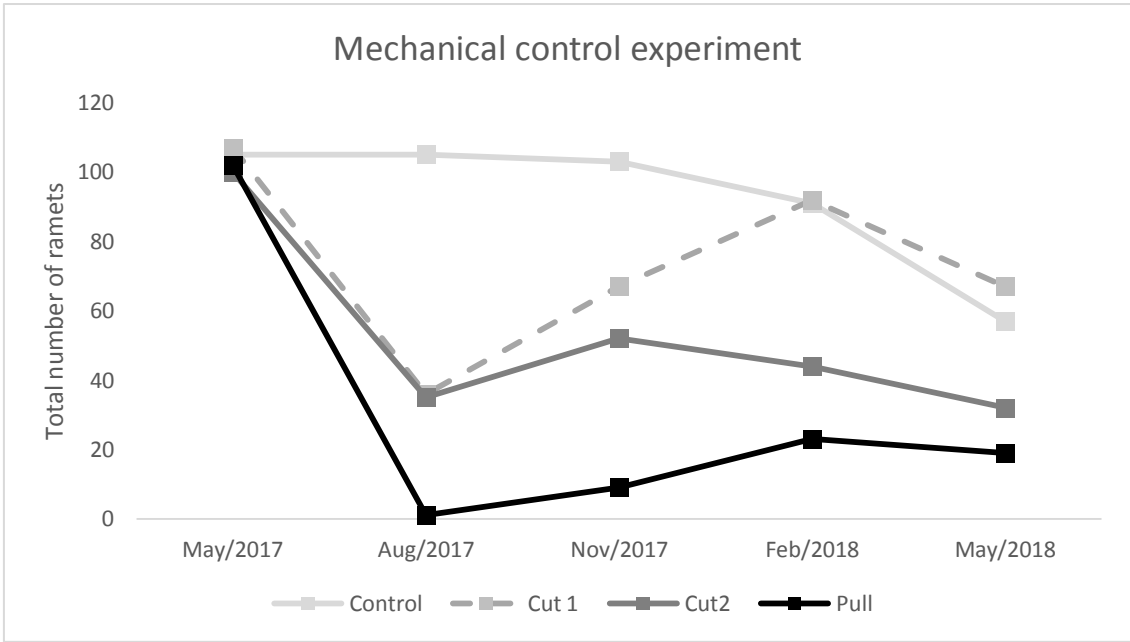
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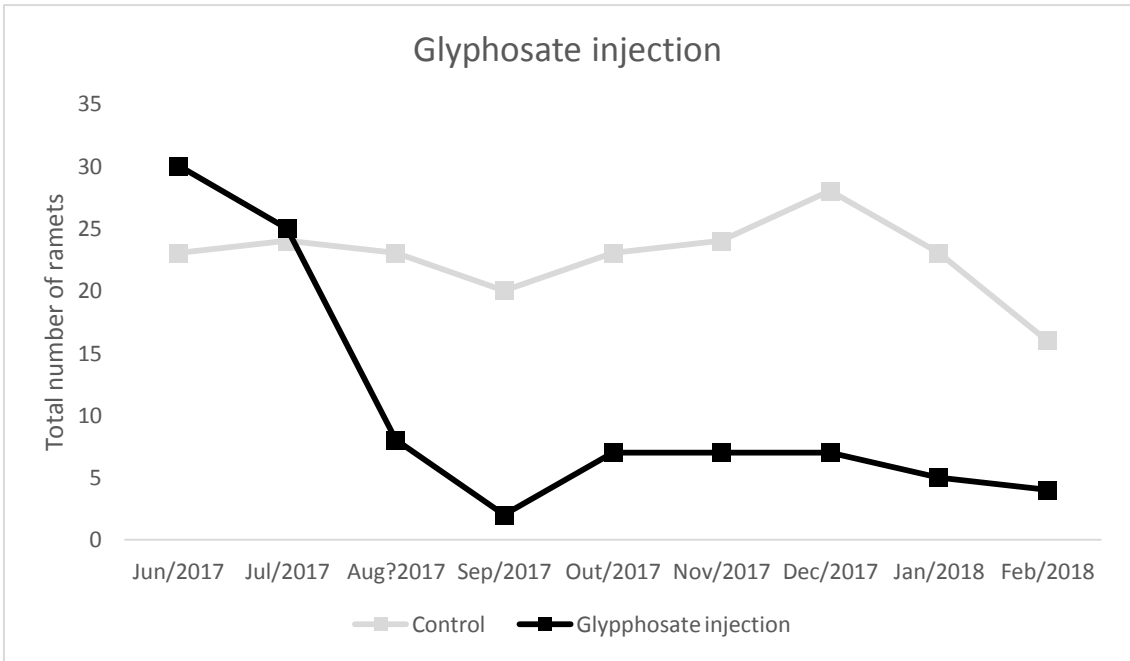
1201 Figure 8: Results for diameter (mm) variation in *Typha domingensis* injection control
 1202 experiment for *Hedychium coronarium*. C= control, L5= leaf extract at 5%
 1203 concentration, L10= leaf extract at 10% concentration, R5= rhizome extract at 5%
 1204 concentration, R10= rhizome extract at 10% concentration.

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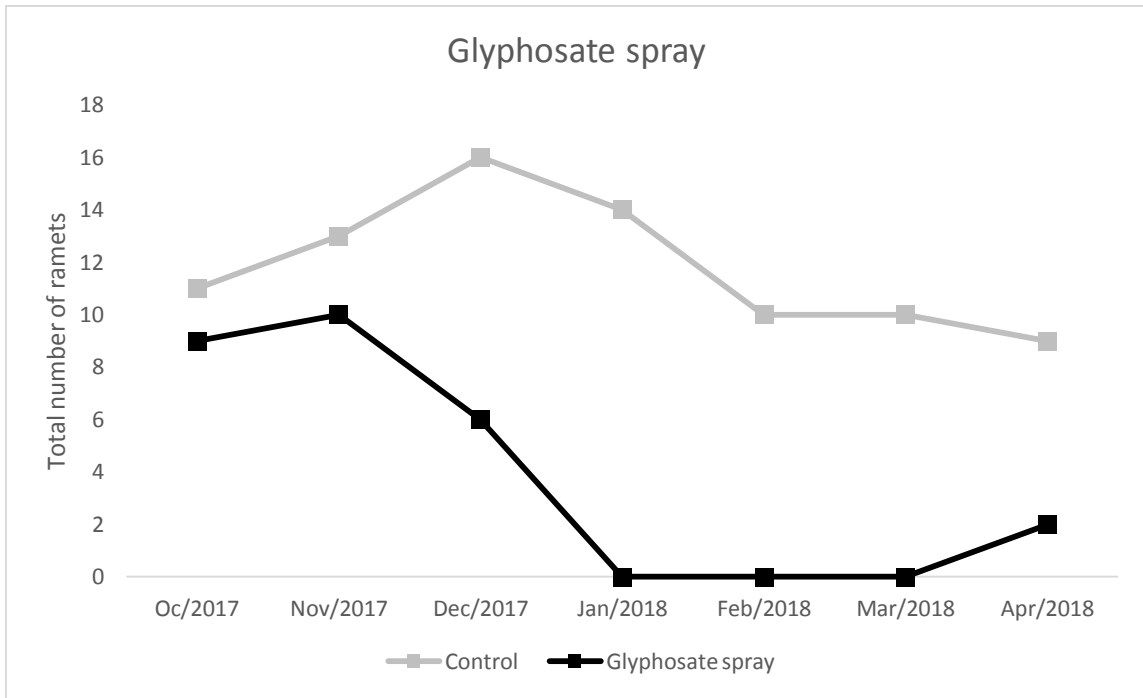
1207 Figure 9: Total number of ramets variation over time on mechanical control experiment.
 1208 Cut 1= cutting off ramets once a year, Cut 2= cutting off ramets twice a year, Pull=
 1209 cutting off ramets and pulling out rhizome.



1210

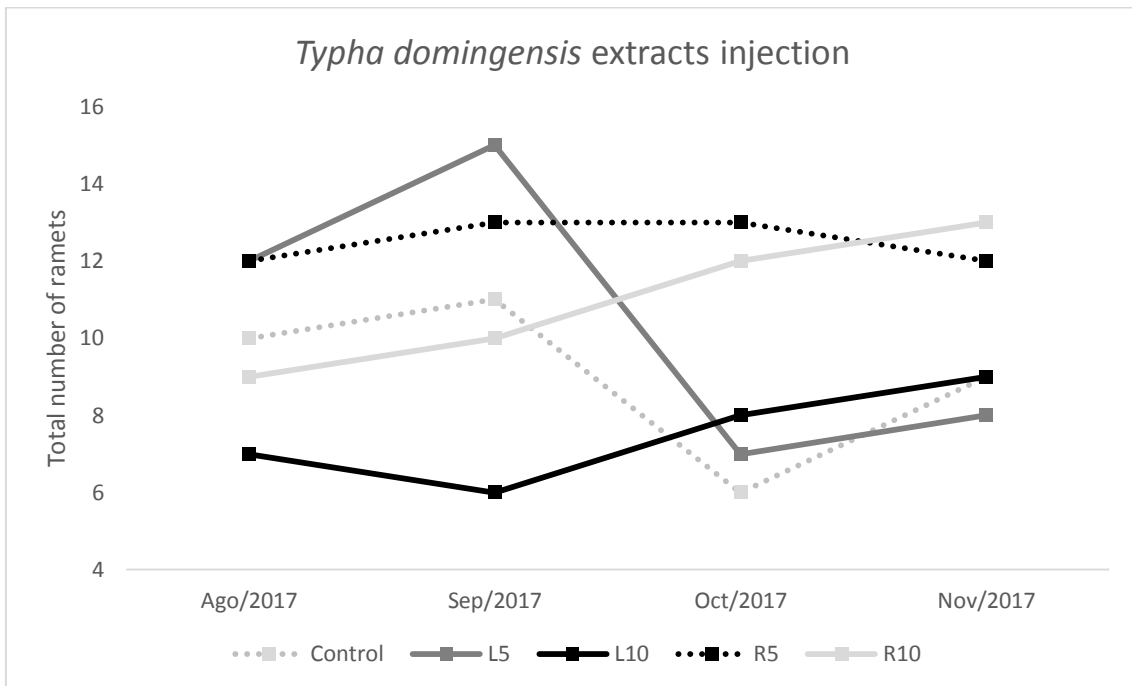
1211 Figure 10: Total number of ramets variation over time on glyphosate injection control
 1212 experiment.

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1215

1216 Figure 11: Total number of ramets variation over time on glyphosate spray control
1217 experiment.



1218

1219 Figure 12: Total number of ramets variation over time on *Typha domingensis* extracts
1220 injection control experiments. L5= leaves extract of *T. domingensis* at 5%
1221 concentration, L10= leaves extract of *T. domingensis* at 10% concentration, R5=
1222 rhizome extract of *T. domingensis* at 5% concentration, R10= rhizome extract of *T.*
1223 *domingensis* at 10% concentration.

1225

Considerações finais

1226

1227 Considerações finais

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1229 *Hedychium coronarium*, *Urochloa decumbens*, *Melinis minutiflora* e *Pennisetum*
1230 *purpureum* têm seu funcionamento diretamente relacionado com as variáveis ambientais
1231 estudadas, especialmente com a temperatura e podem causar impactos significativos em
1232 zona ripária por causa da sua alta produção de biomassa e necromassa ao longo do ano,
1233 especialmente *H. coronarium* e *P. purpureum*, por causa da maior produção de
1234 necromassa. Entre os possíveis impactos estão o aumento da competição por recursos
1235 com outros indivíduos, que diminui a disponibilidade de luz e água e dificulta seu
1236 crescimento e reprodução. Já o acúmulo de necromassa pode atuar como barreira para o
1237 crescimento de espécies, impedindo a chegada de luz em certo ponto ou produzindo
1238 substâncias fitotóxicas. Além disso, o aumento de aporte de nutrientes do solo pela
1239 decomposição de necromassa pode causar o declínio da diversidade de espécies em uma
1240 comunidade. Portanto, medidas de controle são de extremo interesse para a manutenção
1241 das áreas povoadas por essas espécies.

1242 Os experimentos de controle de *H. coronarium* não foram eficientes em matar a
1243 espécie, mas o tratamento com injeção de glifosato nos rizomas da planta foi o que
1244 obteve o melhor resultado, com taxa de mortalidade de 97,3%. Outros tratamentos
1245 também apresentaram taxa de mortalidade alta (85,4% para corte de rametas duas vezes
1246 por ano, 85,3% para arranque de rizomas uma vez por ano, 83,3 % para spray foliar de
1247 glifosato), os únicos tratamentos que tiveram a taxa de mortalidade menor do que o
1248 observado nos controles foram corte uma vez por ano (76,2 % contra 79,9 % de
1249 controle) e os tratamentos com injeção de extrato de *Typha domingensis* (controle =
1250 52,6 %, injeção de extrato foliar a 5% de concentração = 41,2 %, injeção de extrato
1251 foliar a 10 % de concentração = 18,2 %, injeção de extrato de rizoma a 5 % de
1252 concentração = 42,9 % e injeção de extrato de rizoma a 10 % de concentração = 27,8
1253 %). Mesmo com essa alta taxa de mortalidade, constatamos o rebrotamento da
1254 macrófita em todos os tratamentos, mostrando que uma ou duas aplicações do herbicida
1255 não é eficiente para a erradicação. Portanto, para o uso de herbicida deve-se considerar a
1256 localidade onde se encontra a invasão por *H. coronarium* para que não haja mortalidade
1257 de outras espécies quando da aplicação do herbicida, e também a possibilidade de
1258 múltiplas aplicações ou associação com outros métodos de controle

1259 A melhor estratégia para diminuir o número de invasões e seus impactos é a
1260 prevenção de entrada de espécies exóticas, bem como sua detecção precoce. Quando

1261 isso não é possível, qualquer medida de controle é mais efetiva quando associada à
1262 restauração ecológica da área em questão, para prevenir que outras espécies invasoras
1263 ocupem o lugar e para diminuir a disponibilidade de áreas que podem ser ocupadas pela
1264 espécie a qual tenta-se controlar.
1265