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2014 年甘肃省逆境生理生态重点实验室

科研工作总结

一、实验室基本信息

实验室名称： 甘肃省寒区旱区逆境生理与生态重点实验室

学科（领域）：生物学(生态环境)

建立时间： 2012 年 12 月

建设依托单位：中国科学院寒区旱区环境与工程研究所

二、实验室主任及学术委员会组成

2.1 实验室主任

李新荣，1995 年在 Moscow State University 获博士学位。现为寒旱所研究员，博士生导师，国家重点基础研究发展计划 973 项目首席科学家、国家杰出青年基金获得者、人事部“新世纪百千万人才工程”国家级人才、国务院政府津贴获得者、甘肃省先进工作者、甘肃省领军人才、甘肃省欧美学会副会长、甘肃省优秀专家。先后在澳大利亚联邦科工组织水土所、美国宾夕法尼亚州立大学、德国柏林工业大学进修和高访。2009 年获德国 Stiftung Alfried Krupp Kolleg 高级研究员奖，并在格拉夫斯沃德大学进行为期一年的合作研究。 主要从事干旱区植被生态学和沙地生态水文学研究。发表论文 100 余篇，SCI 收录 70 余篇，出版专著 4 部。获国家科技进步二等奖 1 项，省部级自然科学一等奖 1 项和科技进步一等奖 1 项。

2.2 学术委员会主任

魏江春，中科院院士，中国科学院微生物研究所研究员，主要从事微生物多样性、微生物系统与演化生物学和微生物资源生物学研究。曾担任中国科学院微生物研究所副所长、学术委员会主任、微生物资源国家重点实验室学术委员会主任等学术职务，现任中国科学院微生物研究所微生物资源中心顾问委员会主任。在国内外科学刊物发表论文 80 多篇，专著 4 部。曾获中国科学院科技进步特等奖、国家海洋局科技进步特等奖和二等奖。

实验室学术委员会组成

	姓 名	专业	职称	学委会职务	工作单位
1	魏江春	生物学	院士	主 任	中科院微生物所

2	安黎哲	植物生理学	教授	副主任	兰州大学
3	李新荣	生态学	研究员	副主任	中科院寒旱所
4	张敬仁	微生物学	教授	委员	清华大学
5	向成斌	分子生物学	教授	委员	中国科技大学
6	刘建全	分子生态学	教授	委员	四川大学
7	康振生	植物生理学	教授	委员	西北农林科技大学
8	王　刚	理论生态学	教授	委员	兰州大学
9	张文浩	生理生态学	研究员	委员	中科院植物所
10	毕玉蓉	逆境生理学	教授	委员	兰州大学
11	陈国雄	遗传发育学	研究员	委员	中科院寒旱所
12	王晓茹	进化生物学	研究员	委员	瑞典 Umea 大学
13	谢忠奎	农业生态学	研究员	委员	中科院寒旱所
14	赵学勇	恢复生态学	研究员	委员	中科院寒旱所
15	Jae-Seoun Hur	微生物学	教授	委员	韩国国立顺天大学
16	Eviatar Nevo	进化生物学	院士	委员	以色列海法大学

三、 2014 年实验室学术委员会会议和实验室学术年会

2014 月 12 月 13 日，甘肃省寒区旱区逆境生理生态重点实验室在挂靠单位中科院寒旱所召开第二次学术委员会会议暨实验室 2014 年学术年会。学术委员会委员、实验室科研人员、硕博研究生及兄弟单位相关学者共 80 余人参会。

实验室主任李新荣研究员作了“甘肃省寒区旱区逆境生理生态重点实验室 2014 年工作总结”，对实验室本年度的主要项目研究进展、承担课题、发表论文、申报专利、学术交流、国际合作、学生培养与实验室管理等做了全面汇报。在学术交流中李新荣研究员作了“我国风沙危害区生态重建的若干问题探讨”。此外，实验室 13 位科研人员作了逆境下生物生理生态学最新科研进展报告。在听取了实验室 2014 年工作总结和 13 位的学术报告后，委员们就实验室科研工作展开了热烈讨论。

委员们一致认为 2014 年实验室各项科研工作进展态势良好。在科研项目争取、论文发表、成果产出、人才培养、国际合作等方面都取得了优异成绩。同时，委员们对实验室下一步工作提出要求，建议瞄准学科国际前沿，发挥实验室多学科交叉、微观宏观纵横的特点，进一步凝练代表性成果，申报省部级和国家级奖励。学术报告题目如下：

1. 陈国雄 植物耐逆之角质层研究，粮食安全之沙米驯化
2. 马小飞 荒漠植物种群动态对季风气候的响应

3. 王若愚 解淀粉芽孢杆菌研究进展

4. 赵　昕 干旱胁迫下柠条转录组和代谢组学研究

5. 张玉宝 百合主要病毒的快速检测和致病机理研究

6. 刘玉冰 MAP 激酶级联信号途径与黄酮代谢在红砂响应逆境胁迫中的相互作用

7. 罗亚勇 科尔沁沙地不同生境与功能型植物的水分与氮素利用特性

8. 陈翠云 牛心朴子的干旱适应性研究——转录组数据分析

9. 王　进 生物土壤结皮中固氮微生物多样性研究

10. 赵鹏善 沙米转录组学研究及其适应沙丘高温环境的相关基因调控

11. 黄文达 小叶锦鸡儿遗传多样性与环境因子之间的相互关系研究

12. 杨　果 青藏高原藏系绵羊群体 ADRB3 通路基因群遗传学研究

13. 回　嵘 UV-B 辐射对生物结皮层藓类植物生理生化指标的影响

四、实验室人才队伍建设及人才培养

实验室现有研究员 17 名（其中杰青 1 名，中科院“百人计划”6 人，人事部跨世纪百千万人才工程国家级人选 1 人，甘肃省领军人才 1 人），副研究员 16 名，助理研究员 25 名，全部拥有博士学位，支撑系列工程师 6 名，总共 62 名固定人员。在读研究生 46 名。

2014 年毕业研究生 15 人，其中硕士 7 人，博士 8 人。2014 年新入学研究生 15 人，其中硕士 6 人、博士 9 人。

2014 年实验室科研人员所获奖项

✧ 李新荣研究员获中国生态系统研究网络科技贡献奖

✧ 李玉强研究员获中科院寒旱所年度先进个人奖

✧ 赵昕获兰州资源环境大型仪器区域中心先进个人奖

2014 年实验室研究生所获奖项：

✧ 张亚峰博士获 2014 年度中国科学院大学院长优秀奖学金。

✧ 刘美玲、杨昊天获 2014 年度中国科学院大学“朱李月华优秀博士生奖”。

✧ 第三届中科院寒旱所博士生学术论坛赵霞荣获三等奖。

✧ 张亚峰博士、杨小菊硕士获 2014 年度优秀毕业生。

✧ 博士生刘美玲、硕士生周欣获“国家奖学金”。

五、实验室科研基础

5. 1 在研的科研项目

在研项目共计 80 多项：国家自然科学基金项目 50 多项， 973 项目 1 项，科技支撑 2 项，科学院部委项目 9 项，总计经费 8 千万元。

2014 年新增国家自然科学基金项目 9 项，中科院百人计划 1 项（左小安研究员）国际合作 3 项，院地合作 4 项，其他项目 24 多项，经费合计 1600 多万元。

5. 2 2014 年新申请到的科研项目

序号	负责人	项目名称	项目类别	总经费
1	左小安	沙地植物–土壤系统生态过程及对区域环境变化的响应	中国科学院“百人计划”项目	200
2	李峰瑞	荒漠绿洲土壤生态系统结构功能对景观格局变化的响应及尺度效应	国家自然科学基金	110
3	赵学勇	沙漠化土地恢复与持续利用国际研讨会	国家自然科学基金	8
4	李玉霖	凋落物输入对半干旱区沙地灌丛碳氮积累和转化的影响	国家自然科学基金	83
5	张志山	干旱区固沙植物的地形塑造及成土作用研究	国家自然科学基金	90
6	王增如	典型红砂珍珠荒漠灌丛群落碳通量对降水变化的响应及其机制	国家自然科学基金	26
7	王少昆	科尔沁沙地植被恢复对土壤微生物多样性的影响	国家自然科学基金	24
8	苏洁琼	温性荒漠草原不同功能型草本植物对氮沉降的生理生态响应	国家自然科学基金	26
9	潘成臣	气温和降水变化对科尔沁沙地小叶锦鸡儿生殖物候的调控机制	国家自然科学基金	25
10	虎　瑞	温带荒漠生物土壤结皮–土壤系统氮矿化特征及其对水热因子的响应	国家自然科学基金	26
11	何明珠	中科院青年促进会人才项目	中科院人才项目	40
15	陈国雄	Cuticle development in barley leaves （经费由瑞士国家基金委拨款到瑞士洛桑大学）	瑞士中国科技合作项目	16
16	王增如	降雨变化对典型荒漠灌丛群落碳交换关键过程的影响	中科院人才培养计划“西部博士”项目	20
17	张鹏	荒漠生物土壤结皮氮固定及其对气候变化的响应	中科院西部之光博士项目	20
18	高艳红	腾格里荒漠红砂–珍珠群落 CO_2 收支及各组分贡献率动态及其环境控制机理	中科院“西部之光”博士项目”	20
19	鲍婧婷	固沙植物的水分利用特征研究	中科院西部之光在职博士项目	2
20	李新荣	日喀则光伏电站中草药与生态农业示范园规划设计	院地合作	50
21	回嵘	隐花植物光合特性及防御体系对 UV–B 增强的响应和适应机制	西部之光博士项目	20

22	苏洁琼	氮沉降对荒漠草原不同功能型草本植物个体生长特征的影响	寒旱所人才基金项目	10
23	赵洋	固沙灌木建立初期对干旱沙区微地形地貌的塑造	寒旱所人才基金项目	10
24	虎瑞	温带荒漠生物土壤结皮--土壤系统氮矿化作用对增温的响应	寒旱所人才基金项目	10
25	张定海	固沙植被稳定性维持的生态-水文阈值研究	中科院人才培养计划“地方在职博士生项目”	2
26	赵学勇	沙地生态系统监测与评估及风险预测技术研究	内蒙古科技重大专项	55
27	赵学勇	科尔沁沙地资源保护与利用规划集成及对策	内蒙古科技厅软科学研究计划项目	35
28	张铜会	科尔沁沙地水资源保护与利用规划	内蒙古自治区软科学研究计划项目	40
29	潘成臣	科尔沁沙地小叶锦鸡儿生殖物候对降雨增减变化的响应	所人才基金项目	10
30	潘成臣	降水变化对花棒生殖物候的影响及其生理响应机制	博士后基金	5
31	毛伟	荒漠-草原过渡带植物功能多样性格局及形成机制初探	中科院西部之光博士项目	20
32	毛伟	增温和干旱对青藏高原植物功能多样性的调控机理	博士后特别资助项目	15
33	曲浩	乌拉特荒漠草原优势植物凋落物分解特征及混合效应	所人才基金项目	10
34	刘新平	流动沙丘先锋植物沙米对风沙环境的生态适应对策	自然基金科技协作项目	3
35	王少昆	科尔沁沙地土壤微生物多样性特征及其与环境因子的关系	沙漠与沙漠化重点实验室开放基金	2
36	张铜会	内蒙古库伦旗科技扶贫试验与示范	中国科学院 STS 项目	260
37	王亚军	百合优质籽球繁育及栽培技术示范推广	宁夏农业发展 办公室	150
38	张玉宝	百合病毒快速检测及抗病毒技术开发应用	中科院“西部之光”重点项目	50
39	王若愚	枸杞液态菌肥研发与产业化	宁夏枸杞产业科技合作项目	75
40	王若愚	堆肥发酵秸秆还田技术试验	宁夏农业发展办公室	27
41	王亚军	当归等中药材抗病基因的克隆及生物防治体系的建立	甘肃省国际科技合作专项	12
				1662

5. 3. 2014 年主要科研成果

1）奖励：

✧ 实验室沙坡头沙漠研究试验站获得中国生态系统研究网络科技贡献奖 1 项 。

✧ 甘肃省科技进步二等奖 1 项。

✧ 实验室荣获甘肃省重点实验室中期评估优秀，配套 20 万运行经费。

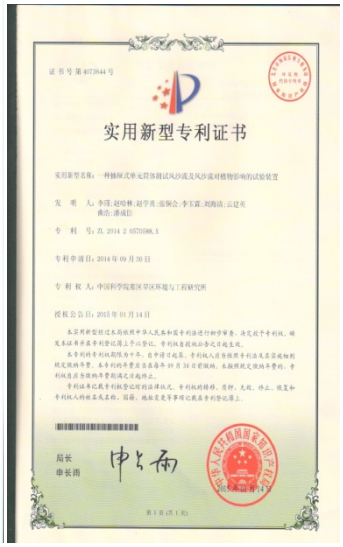
2）专著：

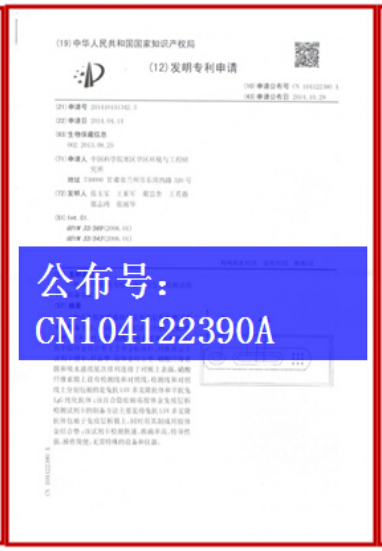
王涛，赵哈林，英汉沙漠科学词典。北京：科学出版社，2014.6。

3）专利：

申报受理与授权专利目录

专利申请号	名称	类型	申请人	状态
201410151342.3	一种百合隐症病毒胶体金免疫层析检测试剂卡及制备方法	发明专利	张玉宝	授权
201410151332.X	一种百合斑驳病毒胶体金免疫层析检测试剂卡及制备方法	发明专利	张玉宝	授权
201410151345.7	一种百合隐症病毒和百合斑驳病毒复合胶体金免疫层析检测试剂卡及制备方法	发明专利	张玉宝	授权
201420394118.2	一种漏斗式单元筒体对植物生理生态的试验装置	实用新型	李瑾	授权
201420570588.X	一种抽屉式单元筒体测试风沙流及风沙流对植物影响的试验装置	实用新型	李瑾	授权
201410339482.3	漏斗式单元筒体装置在植物生理生态方面的应用	发明专利	李瑾	受理
201410524273.6	一种百合隐症病毒、百合斑驳病毒和百合黄瓜花叶病毒双向复合胶体金免疫层析速测卡及制备方法	发明专利	张玉宝	受理
201410719410.1	降水入渗过程及根系生长动态综合观测系统	发明专利	刘新平	授权
201410024462.7	高山离子芥内质网型ω–3 脂肪酸去饱和酶基因及其应用	发明专利	石玉兰	受理
201420358930.X	自动化有氧发酵装置	实用新型	王少昆	受理





六、2014 年逆境生理生态重点实验室科研进展

1、植物耐逆之角质层和粮食安全之沙米驯化研究，

角质层是植物地上部分各器官与其环境的生态界面。实验室陈国雄研究员克隆了大麦叶片角质层形成相关基因 cer-zv 和 cer-zh。关于沙米驯化研究，已在沙地和黄土地成功种植了沙米。

2、荒漠植物种群动态对季风气候的响应

实验室马小飞研究员通过对广布于温带荒漠地区的超旱生灌木红砂和一年生先锋植物沙米的核基因和叶绿体基因变异调查，模拟和回溯其遗传结构和种群动态历史，发现这两个广布种都存在显著地理遗传结构，季风气候敏感区域的种群增长速度显著高于其他区域，其基因组的加速进化可能与第四纪以来反复发生的季风气候回旋有关。这一研究为全面理解亚洲内部干旱区的时空演化提供分子谱系证据支持。

3、解淀粉芽孢杆菌研究进展

解淀粉芽孢杆菌（Bacillus amyloliquefaciens）是一种生物防治及作物促进生长菌，定植于植物根际。它通过合成分泌小分子脂肽类抗生物质抑制植物病原微生物；通过合成并释放生长素类物质促进植物生长；并分泌植酸酶、铁载体等实现解磷、补铁的功能。王若愚研究员对其FZB42 菌株的胶原样蛋白、气态挥发分子等进行了研究，初步揭示了其定殖及促生功能的分子机理。

4、荒漠植物逆境胁迫转录组学研究进展

刘玉冰研究员通过转录组和数字基因表达谱技术分析了红砂干旱适应的相关基因，总共发现干旱诱导的差异表达基因有 1325 个。这些基因相互作用，通过有效的信号传导和功能蛋白的保护而提高植物的抗旱能力。差异表达基因的分析为后续深入研究红砂抗旱的基因调控网络提供了重要的信息（Liu et al., PLoS ONE, 2014, 9(4): e94277）。

赵昕副研究员选择沙坡头收获的柠条种子，室内培养生长 1 个月后，断水干旱胁迫 10 天，提取叶片 RNA。通过二代测序技术，组装了两组对照和干旱胁迫下的柠条转录本，获得了一个包含 8 万多个 unigenes 的转录组数据库；根据 ITS 基因构建豆科植物系统发育树发现柠条与鹰嘴豆、蒺藜苜蓿、日本百脉之间存在比较近的亲缘关系。unigenes 基因注释比对与差异表达结果筛选出 4000 多上调基因和 1000 多下调基因，为下一步耐旱基因克隆和功能研究打下基础。通过 GC–MS 技术测定 1 年生柠条干旱胁迫 20 天后根茎叶主要代谢产物的变化，发现重要生理过程的化合物的积累和消耗差异显著。

陈翠云通过对照与中重度干旱胁迫的对比处理，获得转录组数据，Clean Data 各样品均达到 4.64Gb，组装后获得 51,555 条 Unigene，对 Unigene 进行功能注释和结构的分析，最后获得对比的差异表达基因以及这些差异表达基因的聚类、功能注释和富集分析。

赵鹏善通过二代测序，第一次组装了沙米各组织器官转录本，获得了一个包含 67,741 个 unigenes 的转录组数据库；根据 221 个单拷贝核基因构建系统发育树直接证明沙米是一个处于真双子叶较为基部的物种，沙米和甜菜之间存在比较近的亲缘关系，进一步证明石竹目在蔷薇类和菊类植物分化之前就已经形成；比较基因组学发现，沙米和甜菜之间有大量基因是高度保守的，GO 功能注解同源基因发现富集程度最高的是盐胁迫相关基因，说明沙米有可能和甜菜一样，也是盐耐受植物；沙米对高温的耐受能力远高于其他植物，比如大麦、藜麦。根据基因的表达水平、注释，以及和拟南芥非生物胁迫表达谱结果，筛选得到一批和沙米热耐受相关候选基因，深入研究这些基因将有助于我们理解沙米的高温耐受的分子机制。总之，本研究为沙

米农艺性状的解析提供了重要基因组信息支持，将加速我们对沙米的驯化工作(Zhao et al. BMC Genomics 2014, 15:872)。

5、百合主要病毒的快速检测和致病机理研究

研究开发了百合主要病毒胶体金速测技术，该技术耗时短，成本低，方便田间操作，已申报 4 项国家发明专利；首次证实了单一或复合侵染的花叶病毒（LMoV 和 CMV）CP 均会迅速进入百合叶绿体，从而影响叶绿体的正常功能。

6、生物土壤结皮中固氮微生物多样性研究

王进在沙坡头固沙区开展了生物土壤结皮中的固氮微生物多样性研究，发现与形成初期的结皮相比，形成后期的结皮限制了土壤表层固氮菌生物多样性；土壤表层的固氮菌丰富度随着表层土壤 N 贫瘠的逐渐解除而表现为先增加后减少的趋势。

7、小叶锦鸡儿遗传多样性与环境因子之间的相互关系研究

黄文达通过对中国北方不同区域尺度小叶锦鸡儿种群遗传多样性研究。结果发现两种区域尺度小叶锦鸡儿种群均具有较高的遗传多样性水平，阐明了小叶锦鸡儿种群遗传差异与水热梯度、生境类型以及环境因子之间存在一定的作用关系。该研究结果为防止草原退化、退化草原恢复和持续利用提供了遗传学理论基础

8、生物土壤藓类植物对增强 UV-B 辐射生理响应

通过室内模拟沙坡头地区臭氧损耗所达到的 UV-B 强度梯度，研究了增强 UV-B 辐射对两种藓类植物渗透调节物质、膜质过氧化程度及抗氧化酶活性和光合特性及相关生理参数的影响。结果表明，随着 UV-B 辐射增加，两种藓类植物丙二醛（MDA）含量显著升高；可溶性糖含量、超氧化物歧化酶（SOD）及过氧化氢酶（CAT）活性则降低；且 UV-B 辐射对真藓的影响大于土生对齿藓，说明真藓对 UV-B 辐射相对更敏感(Hui et al., Photosynthetica, 2014, 52(1): 36-49)。叶绿素荧光参数、光合色素、可溶性蛋白及叶绿体超微结构都受到负面影响，负面影响随着 UV-B 强度的增加而增加，且真藓对于 UV-B 辐射较土生对齿藓更敏感。因此，我们认为真藓结皮可以作为荒漠地区生物对 UV-B 辐射响应的生物指示剂（回嵘等, 干旱区地理, 2014, 37(2): 1222-1230）。本研究结果也预示着在未来 UV-B 辐射增强的情况下，温带荒漠生物土壤结皮（BSC）的组成和结构将会发生显著变化，这种变化将会深刻地影响 BSC 在荒漠生态系统中的功能，进而影响荒漠生态系统的健康和稳定。

9、荒漠植物红砂在 UV-B 辐射胁迫的黄酮类代谢途径响应机制

对荒漠植物红砂在 UV-B 辐射胁迫下不同时间内脂质过氧化、叶绿素和类胡萝卜素含量的变化以及黄酮类代谢途径关键酶活性、代谢产物及代谢产物的抗氧化活性进行了分析，探讨黄酮类代谢响应 UV-B 辐射胁迫的变化以及与脂质过氧化和光和色素系统的相关性，结果表明，次生物质黄酮类代谢途径在 UV-B 胁迫下发挥了抗氧化功能，提高了红砂在 UV-B 辐射下的自我保护能力（刘美玲等，中国沙漠, 2014, 34(2): 426-432）。

10、荒漠植物耐盐离子平衡机制研究

对腾格里沙漠荒漠植物耐盐的离子吸收分布调控特征的研究表明，珍珠猪毛菜叶片具有“吸钾排钠的”耐盐特征，红砂叶片具备“吸钠排钾”的特征，吸收利用无机矿质离子存在互补性。红砂与珍珠猪毛菜的群落在耐盐离子吸收分配方面，根中吸收的离子侧重不同，红砂以 Na^+、Cl^-、Si^{4+}为主，珍珠猪毛菜以 K^+、Ca^{2+}为主，珍珠猪毛菜耐盐性比红砂更强。随着盐胁迫的程度加强，二者 Na^+在叶部的选择性吸收降低，对 K^+的选择性吸收升高，从而增强了二者的抗盐性，最终减弱了盐害程度，共同促进它们的耐盐适应性。综合腾格里沙漠植物耐盐性离子积累分布特征，主要表现为植物根、茎拦截 Na^+减缓了对地上部分的伤害，荒漠植物还可通过叶片对 K^+的选择性吸收，增加矿质离子 Si^{4+}、K^+ 的含量保持地上部分离子平衡，荒漠共生红砂与珍珠猪毛菜、柠条与油蒿、牛心朴子和沙米在 Na^+含量、K^+含量吸收利用方面具有互补效应。从典型盐生植物到典型沙生植物都具备相似鲜明的离子平衡耐盐特征（赵昕等，生态学报，2014, 34(4):963-972; 赵昕等，干旱区研究, 2014. 31(6):1086-1092）。这将为深入揭示盐碱地区荒漠植物抗逆性与适应性，提出新的科学依据。

11、量化了干旱区、半干旱区和半湿润等不同气候带沙区土壤水分的最大植被承载能力，建立了典型区域植被的水量平衡关系，初步建立了区域尺度的降水-土壤水-植物水-地下水转化模型，构建了评价固沙植被稳定性维持的阈值，为沙区生态建设和管理提供了重要参考。

根据我国风沙危害区对人工固沙植被稳定性与土壤水分动态关系的长期监测，初步揭示了土壤水分的时空动态变化驱动着固沙植被的演替，而固沙植被从结构和功能上的改变反馈作用于土壤水分的时空变化（Li et al., Science in China (C), 2014. 57: 539-548. Li et al., Applied Soil Ecology, 2014. 78: 57-64.）；研究了主要固沙植物水分利用的来源，指出在干旱沙区柠条的最大适宜盖度为≤10%，在半干旱沙区杨柴的最大适宜盖度为 34%-40%、沙柳最大适宜盖度为 31%-38%、油蒿的最大适宜盖度约为 60%左右。基于水分在各界面层之间的传输规律，将区

域尺度水分转化的动力学模型分成上中下 3 个模块，上层模块为蒸散遥感反演模型（SEBS），中层模块为垂直方向土壤水热传输数值模型（HYDRUS 和 CoupModel），下层模块为二维饱和地下水流数值模型（FEFLOW），每个模块采用相对独立的模型，最后进行集成并构建动力学模型，初步建立了区域尺度的降水–土壤水–植物水–地下水转化模型；划分了我国主要固沙植物的生态适宜气候分布区，初步构建了评价固沙植被稳定性维持的阈值。量化了荒漠植物的蒸腾耗水特征，并实现了植物蒸腾耗水叶片–个体–群落的尺度转换（Huang et al., Hydrology Research, 2014, doi: 10.2166/nh.2014.171）。模拟研究了沙埋对藓类结皮吸附凝结水及其蒸发的影响，指出沙埋后对吸附凝结水降低的抵制能力有可能作为沙埋驱动沙区藓类结皮演替的一个重要机制（Jia et al., Journal of Hydrology, 2014, 519: 2341–2349.）。拟合了不同藓类生物土壤结皮与沙丘沙表层吸湿凝结水形成过程预测模型，探明了在人工固定沙丘地区吸湿凝结水的形成机制（Wang et al., Journal of Earth System Science, 2014, 123(2): 297–305.）。提出了地表反照率与土壤湿度关系的变化可作为评估沙丘固定程度的一个有用的指示性指标（Zhang et al., Environmental Earth Sciences, 2014, 71: 1281–1288.）。探明了灌丛植被形成的沃岛对微生境的渐变影响机制，质疑并完善了以往研究中将灌丛植被微生境一分为二的研究方法（Pan et al., Hydrological Sciences Journal, 2014, DOI: 10.1080/02626667.2013.862337）。

对黑岱沟露天煤矿排土场的研究结果表明，在退化生态系统中进行人工植被建立有利于 BSCs 的拓殖和发育。资源竞争可能是导致 BSCs 的总盖度和藓类结皮与草本植物盖度间以及 BSCs 的厚度与木本植物和草本植物盖度间的关系均呈现出负相关关系的主要原因。不同的植物类型对环境的适应性以及对水分和养分的需求不同，这就造成了不同植物类型与 BSCs 竞争的差异，因此，BSCs 与草本植物间对资源竞争较木本植物更强烈，植被恢复有助于生物土壤结皮的拓殖和发育，植被类型和植被盖度显著影响生物土壤结皮的盖度和厚度（Yang Zhao et al., Arid Land Research and Management, 2014, DOI: 10.1080/15324982.2014.962192）。

12、研究了温带荒漠植物氮、磷化学计量特征对气候和土壤养分的响应，提出了干旱对植物氮、磷化学计量特征的影响机制，为认识日益加剧的干旱天气对于生态系统氮、磷循环过程提供了新的思路。

通过对干旱与植物氮、磷生态计量方面的文献进行数据汇总，并采用 meta–analysis 方法，指出植物氮和磷水平对于干旱的响应存在差异，根据研究结果提出三类概念模型来解释，在养

分和水分胁迫条件下，干旱对于植物氮、磷化学计量特征的影响机制（He et al., New Phytologist, 2014, 204: 924–931）。探讨了地理位置、气候条件以及土壤养分的垂直分布对荒漠植物氮、磷化学计量特征的影响，结果表明不同生活型的植物氮、磷水平主要取决于土壤的磷含量；深根性的植物可能会通过植物养分循环过程将深层土壤养分转移到土壤表层，以满足浅根系植物的养分需求（He et al., Scientific Reports, 2014, 4: 6932）。研究了施氮对荒漠化草原土壤理化性质和土壤酶活性的影响，结果表明，氮素增加对荒漠化草原土壤理化属性和酶活性的改变可能影响荒漠生态系统 C、N 等的循环，在水分仍是植被生长的首要限制性因素的前提下，氮素增加可能对荒漠化草原植物物种多样性和群落结构产生重大的影响，导致荒漠化和水土流失加剧，最终威胁荒漠生态系统功能的稳定性（苏洁琼等, 应用生态学报, 2014, 25(3): 664–670. Su et al., Sciences in cold and arid regions. 2014, 6(3): 0219–0225.）。研究了不同生物土壤结皮覆盖土壤氮矿化作用对水热因子的响应机制，结果表明，生物土壤结皮特别是藓类结皮能够增加土壤氮素有效性，促进土壤氮素转化过程，是影响干旱区土壤氮循环过程的重要生物因子（Hu et al., European Journal of Soil Biology, 2014, 62: 66–73.）。

13、通过对土壤水分的连续测定，建立了土壤水分驱动下的固碳模型。探讨了人工植被建立后沙丘的固碳现状及潜力，为准确评估区域生态系统在全球碳循环中的作用提供了重要理论依据。

确定了 BSCs 光合和呼吸作用的有效湿润时间及其与土壤水分、温度和太阳辐射的关系，建立了受土壤水分驱动下的固碳模型：

$$FS(w,t,l)=FS_p(t,l)\cdot\frac{f_p(w)}{\sum N_{pi}}\cdot N_p+FS_r(t)\cdot\frac{f_r(w)}{\sum N_{ri}}\cdot N_r,$$

。

结果表明降雨是 BSC 固碳活性的重要来源，并且苔藓结皮更容易受到非降雨水（如雾水、凝结水等）的影响而使其固碳潜力大于藻类结皮。苔藓结皮和藻类结皮的年固碳量可以达到 64.9 and 38.6 g C m^{-2} yr^{-1}，其中由非降雨水所引起的固碳量达到了 11.6 and 8.8 g C m^{-2} yr^{-1}，充分肯定了 BSC 在荒漠人工植被区碳汇的功能。同时通过实测数据验证了在降雨量相同的情况下，降雨频度与 BSC 的固碳量成正比（Huang et al., J Arid Land, 2014, 6(6): 725–734; Huang et al., Environ Earth Sci, 2014,72: 767–777）。

采用静态箱式法研究了红砂–珍珠群落的净生态系统 CO_2 交换量（NEE）、生态系统呼吸（R_{eco}）、土壤呼吸（R_{soil}）的日变化规律，以及它们在总初级生产力（GPP）中的比例。研究表明，红砂和珍珠种群白天均出现 NEE 为正的时刻（表明土壤–植被系统向大气中释放 CO_2），

且在每天白天出现一个正的释放高峰值，同时也发现在每天 6:00–9:00 左右出现一个吸收的高峰值。红砂种群和珍珠种群的呼吸、土壤呼吸和群落的生态系统呼吸的日变化规律一致，均表现为明显的单峰变化趋势，在每天的 12:00–15:00 左右出现一个释放的高峰值。以盖度为加权因子计算红砂种群呼吸、珍珠种群呼吸、土壤呼吸占生态系统呼吸的比例，分别为：9%、21%、70%，因此生态系统呼吸主要来源于土壤呼吸。将箱式法和涡动相关法的结果进行比较，这两种方法观测的碳通量变化规律基本一致，相关系数达到 0.7，但是涡动相关法的观测结果仅为箱式法观测结果的 54%（高艳红等，生态学报，2014, 35(7), DOI:10.5846/ stxb201306101636）。通过对藓类结皮和藻类结皮的降雪处理，研究了降雪后生物土壤结皮净光合速率和呼吸速率的变化特征。实验发现，冬季生物土壤结皮的光合呼吸作用受到空气温度、辐射以及水分的影响，其中水分是影响生物土壤结皮光合呼吸的关键因子。生物土壤结皮的光合及呼吸作用主要有三个阶段性的变化：降雪后生物土壤结皮的净光合速率和呼吸速率都会先增加后降低。生物土壤结皮的净光合速率和呼吸速率都会受到积雪覆盖的影响，生物土壤结皮净光合速率和呼吸速率与降雪量正相关（李刚等，中国沙漠，2014, 34(4): 998–1006.）。

采用空间代替时间的方法，对流沙区、1956（55 龄）、1964（47 龄）、1981（30 龄）、1991（20 龄）年建植的人工植被区以及附近的天然植被区进行了调查研究。量化了每个类型生态系统的总有机碳(TOC)、土壤有机碳(SOC)、灌木生物量碳（地上部分和根系）以及草本生物量碳（地上部分和根系）。研究发现，固沙植被建立后，TOC、SOC、灌木及草本生物量碳均显著增加（$p < 0.05$）。且随着时间的延长，TOC 和 SOC 不断增大，与流沙区相比，55 龄植被区的 SOC 和 TOC 分别增加了 1.06 $kg \cdot m^{-2}$ 和 1.31 $kg \cdot m^{-2}$。在固沙植被建立后的 20 年内，生态系统的年均固碳速率较高（$3.26 \times 10^{-2} kg \cdot m^{-2} \cdot year^{-1}$），在固沙植被建立 47 年后，生态系统的年均固碳速率达到较稳定的值（2.14×10^{-2} $kg \cdot m^{-2} \cdot year^{-1}$）。土壤有机碳库是生态系统中最大的碳库，是 TOC 的 67.6%–85.0%，SOC 主要分布在 0–20 cm 土层，随着土层的深度呈现减小的趋势。草本根系、草本地上部、枯落物、灌木地上部和灌木根系生物量碳占生态系统总有机碳的比率分别为 10.0%–21.0%, 0.2%–0.6%, 0.1%–0.2%, 1.7%–12.1% ,0.9%–6.2%。与天然植被区生态系统相比，55 龄人工植被生态系统还具有较大的固碳潜力（1.02 $kg \cdot m^{-2}$）。研究结果表明，在流沙区进行科学的植被建设是一个经济的、环境友好的方法，可以有效的把大气中的 CO_2 固存到生态系统中，为减缓全球气候变化提供了一种科学可行的管理方法与措施（Yang et al., Science of total

environment, 2014, 478: 1–11.)。

14、**通过研究乌拉特荒漠草原 3 种典型植被群落（小针茅群落、红砂群落、芨芨草群落）及其覆盖下土壤碳氮含量差异。发现了小针茅群落的植被盖度显著高于芨芨草群落和红砂群落，但其地上生物量却显著低于另两个群落**；3 种植被群落间的 C 含量差异不显著；N 含量则表现为芨芨草<小针茅<红砂群落，且差异均达到显著水平；C/N 表现出红砂<小针茅<芨芨草群落，差异同样达显著水平；小针茅群落覆盖下的土壤有机碳含量在 0–30 cm 层显著高于其余两群落，红砂群落覆盖下土壤表层(0–10 cm)全氮含量则显著高于另外两群落。阐明了较高的植被盖度有利于减少风蚀对土壤有机碳造成的损失，芨芨草群落较高的 C/N 不利于其凋落物通过分解进行养分归还，因此，其覆盖下土壤有机碳及全氮含量均较低。对促进荒漠草原植被–土壤正常物质循环和养分平衡，揭示荒漠植物在极端环境下生存机制具有一定的作用。

15、半干旱沙地生境变化对植物地上生物量及其碳、氮储量的影响的研究

通过开展半干旱沙地生境变化对植物地上生物量及其碳、氮储量的影响的研究，发现了沙地生境变化对植物叶干重、枝干重、总生物量及其碳、氮含量与储量均有显著影响(P<0.01)；固定沙丘的叶干重、枝干重、总生物量及其碳氮储量均大于流动沙丘与半固定沙丘，草地的叶干重、枝干重、总生物量、枝和总生物量的碳储量、枝的氮储量均小于固定沙丘而大于流动沙丘；半固定沙丘叶、枝及总碳含量与枝的碳储量大于流动沙丘，而叶、枝及总氮含量小于流动沙丘。一年生植物分别占流动沙丘、固定沙丘和草地总生物量的 63.99%、79.28%、70.86%；灌木占半固定沙丘总生物量的 73.15%；C3 植物生物量分别占流动、半固定、固定沙丘和草地总生物量的 39.99%、90.87%、96.01%和 82.67%。固定沙丘上的一年生植物和 C3 植物的生物量、碳氮储量在 4 个生境中最高；半固定、固定沙丘和草地中 C3 植物碳含量及其储量、氮储量均高于 C4 植物。沙丘固定过程中生物量及其碳氮储量逐渐增加，固定沙丘植被具有较大的碳氮固存潜力，一年生植物、C3 植物对其碳氮的固存具有重要的贡献作用；沙丘固定过程中 C3 植物对 C4 植物生物量的下降具补偿作用。阐明了科尔沁沙地沙丘固定过程中的流动沙丘、半固定沙丘和固定沙丘以及草地 4 种生境类型的植物地上生物量及其碳、氮含量与储量特征，为沙地退化生态系统的恢复重建与可持续管理提供理论依据。

16、不同功能群(以生活史为划分依据)尺度和群落尺度植物生物量分配格局对氮素和水分的响应

以氮素和水分(冬季增雪和夏季增雨)为控制因子，开展相关田间控制实验，分析了不同功能群(以生活史为划分依据)尺度和群落尺度植物生物量分配格局对氮素和水分的响应，得出以下结论：1)一年生植物的繁殖生物量比重要明显高于多年生植物，而多年生物种的叶/地上生物量比值显著高于一年生植物；2)一年生植物植物对氮素和水分添加的响应剧烈，氮添加耦合夏季增雨、氮添加耦合冬季增雪显著增加了一年生植物的繁殖生物量比重和叶生物量比重。多年

生植物对氮素和水分添加的响应不敏感，表现为多年生植物的各器官生物量分配格局对氮素添加和水分添加的响应不明显。3)氮素添加和水分处理改变了群落尺度生物量分配格局：氮素添加耦合冬季增雪处理降低了群落植物的繁殖生物量比重和茎生物量比重，提高了群落植物的叶生物量比重。4)冬季增雪和夏季增雨与氮素添加的交互作用对群落生物量分配格局的改变不相同。夏季增雨耦合氮素添加处理下群落的茎生物量比重显著提高，群落茎生物量分配的改变引起群落的垂直结构发生改变。冬季增雪氮素处理下群落的叶生物量比重增加，但茎生物量比重增加不明显。冬季增雪也改变了群落的结构和功能。不同生活史类型植物的生物量分配对氮素和水分添加的响应不一致，这一差异是导致群落结构发生改变的重要原因，氮素和水分添加后一年生植物生物量格局分配迅速发生改变，其叶面积迅速增加，叶面积的增加表明其对群落中光资源竞争能力增加，并最终引起群落结构发生改变。群落茎、叶、繁殖器官生物量分配格局变化反映了植物种群对特定环境的进化与适应特征，植物总是尽可能通过调整自身的生长方式和资源分配来适应环境，维持种群的延续。植物群落为适应氮素添加(模拟大气氮沉降)和水分添加(模拟不同形态的自然降水补给)所表现出的植物形态可塑性和资源分配策略的变化，表明在环境扰动下，为了维持物种组成与结构稳定性，群落自身具有一定的调节功能，这种调节功能是群落适应性的一种表现。

17、**科尔沁沙地沙丘恢复过程中植物生物量及土壤特性**

通过开展科尔沁沙地沙丘恢复过程中植物生物量及土壤特性的研究，发现了植物地上生物量与地下生物量显著正相关，0–10cm 土层地下生物量最大，随着沙丘的固定，地下 10–20、20–40、40–60cm 深度土层的生物量显著增加，植物地上生物量依次增大，分别为 2.20、98.10、131.41、190.38 g•m–2，地下地上生物量比依次为 10.44、1.67、0.81、1.18；随着沙丘的固定，表层土壤容重由 1.62 g•cm3 下降到 1.33 g•cm3，各土层的粉沙和极细沙的占比依次增加，中沙比例依次减小，土壤碳氮含量、碳氮比、pH、电导率均逐渐增加；地上、地下生物量均与表层土壤碳氮含量、pH、电导率显著正相关，土壤碳、氮含量均与 pH、电导率、土壤水分显著正相关，与土壤容重显著负相关（$p<0.05$）；沙丘恢复过程中植物生物量的增加与表层土壤颗粒细化、营养物质增多、水分增加密切相关，土壤–植被系统构成了有机的综合体。阐明了不同沙丘固定化阶段植物群落的生物量特点及土壤理化特性的变化规律，为探究沙漠化逆转阶段沙地植物群落特征，改良及治理当地生态环境提供一定的科学依据。

18、**不同土壤层次凋落物分解实验**

选用 8 种玉米植物组织：叶、苞叶、地上茎、叶、地下茎、粗根（直径> 2 mm）、细根（直径< 2 mm）、玉米粒和玉米芯，分不同土壤层次进行为期 1 年的凋落物分解实验，发现不同层深（0 cm 和 15 cm）凋落物不同组分残留率和瞬时分解速率均存在差异。凋落物残留率：15 cm < 0 cm，瞬时分解速率：15 cm > 0 cm；同层凋落物不同组分残留率和瞬时分解速率也存在显著差异性，残留率的大小顺序为：0 cm，玉米粒 < 叶 < 苞叶 < 玉米芯< 粗根 < 细根 < 地上茎 < 地下茎，15 cm，玉米粒 < 苞叶 < 叶 < 玉米芯 < 粗根 < 地上茎 < 细根 < 地下茎。

整个分解过程中玉米凋落物八种组分的最大瞬时分解速率（%/d）：0 cm 层为玉米粒（3.47）> 叶（2.39）> 苞叶（2.36）>玉米芯（1.38）> 粗根（1.03）>地上茎（0.94）> 细根（0.77）> 地下茎（0.72），15 cm 层为叶（1.33）> 玉米粒（1.30）> 苞叶（0.99）> 玉米芯（0.47）> 细根（0.46）> 粗根（0.42）> 地上茎（0.41）> 地下茎（0.25）。不同组分凋落物 C 含量变化波动性较大，变化不一。不同组分 C 残留率整体表现为：0 cm > 15 cm。分解末期，0 cm 和 15 cm 层不同组分的 C 残留率变化范围分别为：17.79% ~ 88.10%和 2.17% ~ 62.05%，均值分别为：49.72%和 30.47%，平均向土壤中的 C 释放量为 50.28%和 69.53%。 生长季不同层深（0 cm 和 15 cm）凋落物不同组分 N 含量的整体变化是波动性上升，独立样本 T 检验得层深（0 cm 和 15 cm）对凋落物分解中 N 含量变化的影响是很显著的。相同层深（0 cm 或 15 cm）不同组分 N 含量之间也存在极显著性差异（$P < 0.001$）。0 cm 和 15 cm 层不同组分的 N 残留率变化范围分别为：26.69% ~ 77.40%和 14.13% ~ 66.11%，均值分别为：55.69%和 42.08%，平均分别向土壤中的 N 释放量为 44.32%和 57.92%。 凋落物 C/N 在分解初期，部分组分的 C/N 呈现增大的趋势（地上茎和地下茎，0 cm 叶和苞叶），之后波动性下降的。而其余组分的 C/N 从分解初期到生长季末期整体变化趋势都是波动下降的。相同层深凋落物不同组分 C/N 之间存在极显著性差异（$P < 0.001$）。凋落物残留率和凋落物质量指标中的凋落物 C 和 N 成负相关关系，与凋落物 C/N 成正相关关系。凋落物瞬时分解速率和凋落物质量指标中的凋落物 C 成显著正相关关系，和凋落物 N 无显著相关关系，与凋落物 C/N 成显著负相关关系。

19、流动沙地生长季土壤水分和深层补给对降雨特征的响应

通过开展流动沙地生长季土壤水分和深层补给对降雨特征的响应研究，发现大的降雨事件（>20mm）在增加土壤含水量和产生深层补给具有重要作用，降雨量较大持续时间较长的降雨事件对深层补给贡献更大。2010–2012 年生长季流动沙地潜在补给系数分别为 67.48 %, 61.86 %和 65.04 %。潜在补给量与降雨量和降雨强度显著相关，但是与降雨间隔时间相关不显著。表明该区域流动沙地的存在对于补充土壤水分和形成深层补给乃至地下水补给具有重要的生态水文功能，本研究对于流动沙地的植被恢复决策及恢复格局和规模的制定上具有一定的指导意义。

20、沙米和大果虫实耐沙埋能力研究

通过研究不同沙埋深度下内蒙古科尔沁沙地沙米（*Agriophyllum squarrosum*）和大果虫实(*Corispermum marocarpum*)在第5、10、15天的净光合速率、气孔导度、蒸腾速率、水分利用效率的变化，发现沙米较大果虫实具有较强的耐沙埋能力，其中沙米幼苗最大耐沙埋深度超过苗高10 cm，大果虫实在埋深等于其苗高时全部死亡；随沙埋深度增加，沙米和大果虫实的存活率均显著下降，但沙米的下降幅度明显小于大果虫实；沙埋后，2种植物的气孔关闭或开放程度减小，通过降低蒸腾速率和提高水分利用效率来适应沙埋胁迫；随着沙埋胁迫的加剧，2种植物的净光合速率下降，表明沙埋胁迫对植物的光合作用破坏较大；相比于大果虫实，沙米对

于沙埋胁迫有着更好的光合适应，随着胁迫的时间增加，其净光合速率有所恢复。该研究阐明了沙埋对沙生植物存活的影响及其光合生理响应特征，比较了不同藜科沙生植物耐沙埋能力及其光合响应，对当地人工植被的恢复重建具有一定意义。

21、沙米幼苗的生长和生理特性耐沙埋的研究

通过在内蒙古科尔沁沙地开展不同沙埋深度下沙米幼苗的生长和生理特性耐沙埋的研究，发现相比于非沙生植物，沙米有很强的耐沙埋的能力。当沙埋深度超过沙米幼苗株高的 133%时，其存活率、株高和生物量才显著降低，丙二醛（MDA）和膜透性(membrane permeability)则显著增加。随着沙埋深度的增加，为了抑制膜脂过氧化作用和降低细胞渗透势下降，超氧化物歧化酶（SOD）、过氧化物酶（POD）含量增加，但是过氧化氢酶（CAT）是下降的，没有起到抑制作用。通过以上研究，阐明了沙米这种沙生植物耐沙埋的能力和机理，对于揭示沙生植物在沙埋下的受损过程及其适应机制具有重要科学意义。

22、玉米幼苗不同风速吹袭的逆境生理特征

通过在内蒙古东部科尔沁沙地开展玉米幼苗受到不同风速吹袭危害时逆境生理特征的变化的研究，发现风吹并未造成水分胁迫，风吹后玉米幼苗膜脂过氧化程度并不严重，并且风吹未造成膜结构的破坏。超氧化物歧化酶（SOD）、过氧化物酶（POD）和过氧化氢酶（CAT）均起到一定的清除氧自由基的作用，随着风速的增加，SOD 和 CAT 二者能力有限，最终活性降低，只有 POD 活性增强，起到主要的保护作用。而风吹后可溶性糖和脯氨酸含量只分别在 6m/s 和 18m/s 时起到渗透调节作用，其余各处理可溶性糖和脯氨酸均未发挥渗透调节作用。通过以上研究，阐明了不同风速下农作物幼苗生长状况以及生理特征的变化，对于揭示风吹胁迫对其生理特征的影响及其响应机制具有重要的经济和生态意义。

23、尖头叶藜的萌发和幼苗建成对春季小降雨事件的响应

通过人工模拟降雨试验研究了科尔沁沙地优势草本植物尖头叶藜萌发和幼苗建成对春季小降雨事件（2mm、4 mm、 8 mm 和自然降雨）的响应。结果表明：不同降雨处理对尖头叶藜的萌发和幼苗建成有显著影响（$P<0.05$）。8mm 降水量是促使尖头叶藜萌发的最小降雨阈量。不同降雨量处理下尖头叶藜萌发数量大小顺序为：8mm 处理 > 对照 > 4 mm 处理 > 2mm 处理；而高度和冠幅依次是 2 mm 处理（2.23 cm 和 7.15 cm2.）> 对照（2.03 cm 和 6.21 cm2）> 4mm 处理（1.86 cm 和 5.01 cm2） > 8mm 处理（1.48cm 和 4.72 cm2）；降雨量为 8mm 的地上生物量最多(45.26 g/m2),对照为 35.49g/m2、4mm 处理为 26.54g/m2 、2mm 处理为 15.26g/m2。尖头叶藜幼苗的水分利用效率与每次降水量呈显著地正相关关系，随着每次降雨量的增大地上生物量逐渐增大。本试验中各处理的总降雨量一致，但地上生物量不同且差异显著。每次降雨量*降雨次数的分布状况影响了尖头叶藜幼苗的地上生物量。科尔沁沙地尖头叶藜萌发及其幼苗建成在密度、形态和水分利用效率和地上生产力上对不同模式的小降雨做出了积极的响应。

24、极端降雨事件对沙地一年生植被的影响

通过观测人工模拟降雨总量为历年平均水平（Normal），降雨总量加倍（Double）*每次降雨量为 16mm 和 32mm 四种极端降雨模式（N-16mm、 N-32mm、D-16mm、 D-32mm）和对照（CK 接收 2011 年的自然降雨）条件下科尔沁沙地一年生植被的密度动态，多样性指数，生物量及根冠比等指标，来研究极端降雨事件对沙地一年生植被的影响。结果表明：在萌发期，各处理对植株密度无显著作用，均维持在 2000 株/m2，而在生长发育后期，D-16mm、 D-32mm 维持在 400 株/m2，而 N-16mm、 N-32mm 维持在 1600 株/m2，略大于对照处理（1200 株/m2），说明降雨总量能决定能够完成生活史的沙地一年生植被的数量。N-16mm、N-32mm、D-16mm 三种极端降雨模式能显著提高沙地一年生植被的生物多样性指数。说明科尔沁沙地一年生植被的生物多样性不是简单地由降雨总量决定的，而是由每次降雨量与降雨次数的分布情况决定的。而 D-16mm、 D-32mm 均会显著降低沙地一年生植被的水分利用效率。这是由于总雨量加倍的模式下水分入渗深度远远大于一年生植被的根系生长的分布范围，导致一年生植被无法充分利用，换言之，极端降雨模式对沙地一年生植被的干物质积累是不利的。

25、科尔沁沙地不同生境植物及叶片的碳氮元素计量特征

通过开展科尔沁沙地不同生境植物及叶片的碳氮元素计量特征的研究，发现了随着沙丘的固定，植物群落及群落叶片的碳含量逐渐上升而氮含量逐渐下降，且碳含量的变异系数较氮含量小；各生境植物及叶片碳氮含量表现为灌木>一年生植物、C3 植物>C4 植物、豆科植物>非豆科植物，各功能型植物的碳氮含量正相关于其叶片的碳氮含量；沿沙丘固定梯度，一年生、C4 与非豆科植物及其叶片碳含量趋于上升，而一年生、多年生、C3、非豆科植物及其叶片氮含量趋于下降。沙丘固定过程中群落碳含量的变化主要源于一年生、C4、非豆科植物，而氮含量的下降则受草本、C3、非豆科植物的共同影响。适当补植灌木、C3 植物、豆科植物对于该地区的固碳效率和生物固氮以及改良土壤肥力会起到积极作用。阐明了科尔沁沙地植物及叶片的碳氮元素在沙丘固定过程中的化学计量差异及变化规律，为科学恢复科尔沁沙地植被，估算植物碳氮储量提供理论依据。

26、科尔沁沙地植物群落分布与土壤特性关系

通过开展科尔沁沙地植物群落分布与土壤特性关系的 DCA，CCA 及 DCCA 分析的研究，发现了 DCA、CCA 和 DCCA 的物种排序第 1 轴代表的土壤特性梯度一致，其解释总方差超过 33%，即土壤碳氮含量、pH、电导率、容重、粘粉粒等共同的梯度决定了群落生境的变化，进而影响着沙地植物群落类型的分布格局；三种排序法的物种排序第 2 轴土壤因子的相关性有较大差异，DCA 第 2 轴仅与土壤细沙含量显著正相关，CCA 第 2 轴与土壤碳氮比和细沙含量显著负相关，DCCA 第 2 轴与土壤碳氮比和细沙含量显著正相关，而与粗沙含量显著负相关。Shannon-Weiner 指数和 Simpson 指数分别与 DCA、CCA 和 DCCA 前两个排序轴存在显著二元线性关系，且 Shannon-Weiner 指数的拟合程度及统计学意义均好于 Simpson 指数。三种排序分

析方法中 CCA 物种排序前两轴的累计解释方差（58.6 %）高于 DCA 和 DCCA，因此 CCA 排序法更适合于沙地植被分布格局研究及其环境的解释。阐明了除趋势对应分析法（DCA）、典范对应分析法（CCA）和除趋势典范对应分析法（DCCA）分析并比较沙地植物群落分布与环境因子的关系，对定量地揭示科尔沁沙地植被分布格局及其土壤影响因子，为科学认识和恢复科尔沁沙地植被提供理论依据。

27、科尔沁沙地中南部 34 种植物叶功能性状及其相互关系的研究

通过开展科尔沁沙地中南部 34 种植物叶功能性状及其相互关系的研究，发现了一二年生植物的 LDMC（0.23 g•g−1）显著小于多年生植物（0.31 g•g−1）和灌木（0.32 g•g−1）；而一二年生植物的 SLA（22.14 m2•kg−1）显著大于多年生草本（17.18 m2•kg−1）和灌木（13.41 m2•kg−1）。一二年生和多年生 C4 植物的 LDMC 显著大于 C3 植物；多年生 C4 植物 SLA 显著大于 C3 植物；C3 植物的 LDMC 表现为一二年生生活型<多年生<灌木。沙地植物的叶鲜重、叶干重和叶面积三者间极显著正相关，植物叶干重与 SLA 显著负相关；C4 植物和多年生植物叶干重与 SLA 显著负相关。沙地不同生活型、功能型植物叶片的功能性状差异明显，沙地灌木和多年生植物能够较强的适应干旱环境，一二年生植物则具有较强的保持体内营养和获取土壤资源的能力。阐明了不同植物生活型（一二年生植物、多年生植物、灌木）和功能型（C3、C4 植物）的叶片性状的差异性，植物叶片性状相互之间的内在联系及其对环境的适应性。为该区沙地植物对环境的适应机制和沙地退化植被恢复与重建提供理论依据。

28、科尔沁沙地植物功能性状的尺度变异及关联的研究

通过开展科尔沁沙地植物功能性状的尺度变异及关联的研究，发现了随着沙丘的固定，群落平均 LA 逐渐增大，群落平均 SLA 及 LDMC 在半固定沙丘上最小；群落平均 SLA 的生态位宽度随着沙丘固定程度依次减小，流动、半固定沙丘植物群落的适应能力较固定沙丘更广；沙丘固定过程中物种性状值的变化与群落内共生植物种性状间变异的关联相比于群落间性状的变异更密切。沙丘固定导致了物种 LA 与 LDMC 较强的正相关关系，两性状在群落间的依赖性比群落内的强。物种在群落内和群落间采取不同的策略来适应沙丘固定过程生境的变化。阐明了沙丘固定过程中叶面积（LA）、比叶面积（SLA）和叶干物质含量（LDMC）3 个植物功能性状的尺度变异及其与生境变化的关系，为深入了解科尔沁沙地沙丘固定梯度下植物群落的构建及植被恢复提供一定的理论依据。

29、多枝柽柳的开花物候和繁育特性

通过对荒漠地区霸王，多枝柽柳等优势种群的研究，发现其开花物候和繁育特性，阐明了干旱区植物繁殖、建植对策和演变机理，对维持景观和生态系统的稳定性具有重要意义，也为该植被的人工栽培、杂交育种、种群繁殖提供理论依据或技术支持，并从群落和生态系统水平揭示干旱区水文环境对植物生殖过程与系统演变的影响。

30、沙丘固定过程中物种丰富度、植物盖度、土壤特性和地形特征

通过测定沙丘固定过程中的流动沙丘、半固定沙丘和固定沙丘内 1、10、100 和 1000m2 的物种丰富度、植物盖度、土壤特性和地形特征。分析表明，物种丰富度随着研究尺度和沙丘固定程度在增加,并且具有明显的尺度依赖性。沙丘植物的分布主要受土壤 C、全 N、C/N、pH、EC、土壤水分、细沙、极细沙、粘粉粒和海拔形成的环境梯度来决定。在 1 m2 的研究尺度上，流动沙丘上物种丰富度与土壤 C 和全 N 有显著的正相关关系；半固定沙丘上物种丰富度与土壤 C、全 N、C/N、pH、EC、细沙和粘粉粒有密切的正相关关系；固定沙丘物种丰富度与环境因素没有关系。这些结果表明，沙丘上小尺度的物种丰富度决定于沙丘的固定程度及其土壤资源的可利用性，而由沙丘固定导致的沙丘生境及其土壤资源是影响沙地植物多样性尺度依赖性的重要因素。

31、建立荒漠植物转录组数据库

物种	拉丁文名	数据量	类型	完成时间	持有人	论文备注
牛心朴子	*Cynanchum komarovii*	4G	干旱	2014.11	陈翠云	数据分析中
红砂	*Reaumuria soongorica*	4G	PEG	2012.12	刘玉冰	plos one
红砂	*Reaumuria soongorica*	4G	UV-B	2012.12	刘玉冰	撰写中
蚓果芥	*Braya humilis*	5G+5G	两种生态型	2013.11	赵鹏善	已投稿
沙米	*Agriophyllum squarrosum*	6G	根茎叶花果实混合	2013.12	赵鹏善	BMC genomic
二穗短柄草	*Brachypodium distachyon*	2Gx3+2Gx3	低磷处理	2013.7	赵鹏善	撰写中
红砂	*Reaumuria soongorica*	4G	根茎叶花果实混合	2012.1	马小飞	plos one
Rioctia（以色列进化谷）	*Ricotia lunaria*	5G+5G	欧洲-非洲生态型分化比较，根茎叶花全转录组	2012.1	马小飞	撰写中
柠条	*Caragana korshinskii*	5G+5G	干旱胁迫	2014.9	赵　昕	撰写中
大麦	*hordeum vulgare*	4G	eibi1 突变体	2012.1	陈国雄	Int. J. Mol. Sci.
大麦	*hordeum vulgare*	4G	cer-zv 突变体	2013.9	陈国雄	Thero Appl Genet
大麦	*hordeum vulgare*	4Gx5	cer-zj/cer-za/cer-ze/cer-b/cer-yg 突变体	2014.9	陈国雄	数据分析中

32、百合产业化经济和社会效益

2014 年百合产业化技术应用面积达到 12470 亩，生产切花百合 930 万支，繁育优质种球 40 万粒，增收兰州百合 675.5 万公斤，新增产值 1.86 亿元，增收节支总额达 1.43 亿元。兰州百合病害综合防治技术及连作障碍克服技术在兰州产区得到了广泛应用，并取得了良好效果，实现了我国西北地区百合产业的合理布局，降低了生产成本，提高了产业效益和市场竞争力，使百

合产业真正成为六盘山贫困区农业增效、农民增收、农村致富的富民产业。

七、2014 年发表的学术论文

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八、2014 年国际合作与学术交流活动

8.1 国际合作项目

1. 李新荣主持韩国中国科技合作项目：Rapid formation of biological soil crust(BSC) with use of desert lichen and cyanobacteria
2. 陈国雄主持瑞士中国科技合作项目：Cuticle development in barley leaves （经费由瑞士国家基金委拨款到瑞士洛桑大学）
3. 受国家外专局出国培训项目资助，皋兰站王亚军副研于 2014 年 6 月赴荷兰 Wageningen 大学进行为期 10 个月的培训交流。
4. 谢忠奎研究员与荷兰 Wageningen 大学 Wopke van der Werf 副教授（作物与杂草生态系统分析研究中心）联合申报的 2015 年度中国科学院“国际人才计划”–国际访问学者项目已获批。

8.2 主办国际会议

沙漠化土地恢复与持续利用国际研讨会

2014 年 8 月沙漠化土地恢复与持续利用国际研讨会”在内蒙古通辽市成功举办，此次会议由奈曼站具体承办。共有来自美国、日本、韩国、以色列、埃及以及国内大学、研究所的 260 多位专家学者参加了此次会议。

此次研讨会由开幕式、大会报告、分会场报告、墙报、会后参观交流等组成。

开幕式：开幕式于 2014 年 8 月 17 日上午 8 点整在通辽市政府东配楼会议举行，开幕式由大会主席冯起研究员主持，通辽市政府胡达古拉市长、中国科学院寒区旱区环境与工程研究所马巍所长、中国女科技工作者协会王志珍院士、内蒙古人民政府白向群副主席、中国科学院原副院长孙鸿烈院士出席开幕式并致辞，出席大会开幕式的还包括通辽市市委政府、内蒙古科技厅、内蒙古林业厅、中国科学院兰州分院、内蒙古民族大学的主要领导。开幕式上，大会执行主席赵学勇研究员向参会领导和专家学者介绍了会议的背景、筹备等具体情况。会议开幕式于

上午 9:10 结束。

大会报告：大会报告于 2014 年 8 月 17 日上午 9:40 开始，至下午 18:00 结束。地点在通辽市政府东配楼会议。大会邀请了中国科学院兰州分院院长王涛研究员、日本鸟取大学 Atsushi Tsunekawa 教授、韩国国民大学 Eun-Shik Kim 教授、中国科学院地理科学与资源研究所赵士洞研究员、内蒙古大学牛建明教授等 12 名国内外著名专家做大会报告，与会代表对中国土地沙漠化研究及其面临的问题、沙漠化与人类活动的关系、退化草原生态系统恢复重建、沙漠化地区资源环境长期观测与评价等问题进行了热烈的讨论和交流。

分会报告：除大会报告之外，此次研讨会还设三个分会：

第一分会主题为“妇女、环境与生计”，于 2014 年 8 月 17 日上午 10:00 在通辽市碧桂园凤凰酒店米兰会议室召开，至下午 18：00 结束。来自中国、韩国和日本的 70 多位女科技工作者参加了第一分会。韩国科技研究院生命科学部主任 Young Sook Yoo 教授、日本大学 Yasuko Yoshino 教授、北京大学自然保护与社会发展研究中心主任中心主任吕植教授、内蒙古大学经济管理学院杜凤莲教授等 9 位学者和专家在分会做专题报告。参会女科技工作者围绕“妇女赋权”、“妇女与可持续生计”和“科技促进环境保护与发展”三个专题开展了热烈的讨论和交流。

第二分会的主题为“土地沙漠化及其恢复”于 2014 年 8 月 18 日上午 8:00 在通辽市碧桂园凤凰酒店米兰会议室开始，至下午 18:00 结束。来自中国、日本、韩国、埃及、瑞典、美国的 100 多位专家和学者参加了第二分会。埃及沙漠研究中心主任 Hassan Shaer 教授、日本东京大学 Toshiya Okuro 教授、 美国内布拉斯加林肯大学 Johannes Knops 教授、瑞典农业大学 Olof Andren 教授、中国科学院寒区旱区环境与工程研究所赵文智研究员、兰州大学沈禹颖教授、湖南师范大学韩广教授等 17 位专家和学者在第二分会上做学术报告。报告围绕国内外土地沙漠化及其治理中的各种问题展开讨论和交流。最后由中国科学院寒区旱区环境与工程研究所赵学勇研究员对第二分会进行总结。

第三分会的主题是“沙漠化土地可持续利用”。于 2014 年 8 月 18 日上午 8:00 在通辽市碧桂园凤凰酒店温莎会议室召开，至下午 18:00 结束。来自中国科学院寒区旱区环境与工程研究所、内蒙古大学、宁夏大学、北京师范大学、内蒙古农业大学、内蒙古民族大学等单位的 100 余名学者参加了第二分会。中科院寒旱所赵哈林研究员、段增虎研究员、南开大学何兴东教授、宁夏大学李国旗教授、内蒙民族大学杨恒山、赤峰学院陈凤臻教授等 19 位专家和学者在第二分会上做学术报告。报告主要围绕沙漠化地区资源可持续利用中的科学和技术问题展开讨论和

交流。最后由内蒙古大学牛建明教授对第三分会进行总结。

会后参观：2014 年 8 月 19 日共有 90 余名参会代表前往中国科学院寒区旱区环境与工程研究所奈曼沙漠化研究站参观交流。上午，会议代表主要参观了奈曼沙漠化研究站实验室、根系地下室、农田综合观测场、沙地综合观测场等各种实验设施。奈曼沙漠化研究站工作人员为会议代表详细讲解了各种观测场和实验设施的功能、运行情况，并与参会专家和学者进行了现场交流。下午，参会代表参观了奈曼旗仁创集团、灰砂砖厂、沙地衬膜水稻等企业，奈曼旗科技局领导向参会专家学者详细介绍了奈曼旗立足沙地资源，开发利用各种沙地资源以及治理沙漠化土地等各方面的主要成果和经验。

此次会议上，共有 56 位专家在大会或分会上做学术报告， 33 位专家通过墙报展示研究成果。会议共收到 180 余篇中英文研究论文，编辑印刷会议论文集一本。其中 20 余篇论文拟推荐到学术期刊“中国沙漠”，以专刊形式在 2015 年出版发表；10 多篇英文论文拟推荐到学术期刊“Science in Cold and Arid Regions”，在 2015 年出版发表。

8.3 国际合作与学术交流

1) 2014 年 1 月 22 日应马小飞研究员邀请，捷克查理大学贾东瑞博士来寒旱所做题为“Influence of climatic fluctuations in the Neogene and Quaternary on evolution of ecologically diverse plant genus: an example of Hippophae L. (Elaeagnaceae)”的报告。
2) 1 月 21–22 日，《国家重点基础研究发展计划》（973 项目）“植物固沙的生态–水文过程、机理及调控”（2013CB429900）2013 年项目年会在北京召开。本次年会，全面总结了 2013 年度的工作进展和成果，并对 2014 年的研究工作进行了统筹安排。
3) 3 月 28 日，西北农林科技大学教授陪同康奈大学教授一行来沙坡头站参观。
4) 4 月 2 日，尚千涵参加在漳州举办的“第三届百合属研讨会”，并做大会报告。报告题目为“An Investigation of Fungal Pathogens Causing Wilt Disease on Lanzhou Lily (Lilium davidii var.unicolor)”。
5) 4 月 11 –14 日，马小飞研究员和钱朝菊博士参加在江苏镇江举办的“遗传学与表观遗传学前沿暨第三届中国青年遗传学家论坛”。并作大会报告。题目为：荒漠植物遗传结构与种群动态与亚洲中部干旱区时空演化的关系和 The mechanism of adaptive evolution of the early flowering in wild barley to mitigate global climate

change

6) 4 月 27 日–5 月 2 日，刘玉冰、谭会娟、黄磊、王增如参加了在维也纳举办的 2014 年欧洲地球科学联盟(EGU)会议，并分别做了相关报告和墙报。

7) 5 月 1 日，甘肃省科技厅李文卿厅长一行 8 人到沙坡头站参观考察。

8) 2014 年 4 月 24 日，中科院成都有机化学研究所刘白玲研究员和皖维高新材料公司领导来奈曼站考察，并就其研制和生产的生态固沙材料在科尔沁沙地进行试验示范工作进行了探讨和商议，制定试验示范合作规划

9) 2014 年 5 月 3 日~8 日期间，以色列沙地农业专家 Raanan Katzir 教授应奈曼站站长赵学勇研究员的邀请来奈曼站访问并授课，Katzir 教授从农业节水（saving water）、滴灌（drip Irrigation）、暴晒消毒（solarisation）、精准农业（precise agriculture）、有机农业（organic agriculture）、研究与开发模式（R&D）等方面介绍了以色列的先进农业方法与措施，并就中国北方干旱半干旱区的水资源问题与节水措施进行了深入的探讨和总结。同时，在奈曼站科研人员的带领下参观了奈曼旗传统农业设施和有机农业示范基地，Katzir 教授为奈曼旗农业的长期发展提出了宝贵的意见和建议。

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12) 5 月 2–5 日，美国生物土壤结皮专家 Jayne Belnap、中科院水保所赵允格等来沙坡头站参观、考察。

13) 5 月 8 日，中国科学院地球环境研究所安芷生、周卫健院士一行 10 余人来到沙坡头站实

地考察。

14) 5 月 17–18 日，中科院第十届公众科学日活动。实验室接待西北民族大学 200 名生物工程专业大学生参观实验室，开展科普宣传活动。

15) 5 月 19 日，中国科学院院士方精云及随行专家来奈曼站进行了考察访问，并与站上研究人员进行了座谈。

16) 6 月 24 日，河海大学暑期实践学生 8 人沙坡头到站参观、学习。

17) 6 月 25 日，陕师大职工学生 5 人到沙坡头站参观、学习。

18) 7 月 1 日，西安交大学生 20 余人到沙坡头站参观、学习。

19) 7 月 2 日，在宁夏银川举办的“第三届西北地区花卉产业交流暨学术研讨会”上尚千涵博士做会议报告。题目为“兰州百合枯萎病病原真菌调查”。

20) 7 月 2 日，中国科学院党组副书记方新在宁夏回族自治区人民政府副主席屈冬玉陪同下到中科院寒旱所沙坡头沙漠研究试验站视察指导工作并看望了沙坡头站工作人员。

21) 7 月 2–5 日，刘玉冰参加厦门召开的第三届植物代谢国际会议并做报告“Regulation of flavonoid biosynthetic pathway in response to abiotic stress in the desert plant, Reaumuria soongorica”。

22) 7 月 4 日，中山大学地理科学与规划学院国土资源与环境系本科班 40 多名师生到沙坡头站参观学习。

23) 7 月 11 日，西安交通大学通信学院学生 10 余人到沙坡头站参观、学习。

24) 7 月 14 日，北京交通大学暑期实践队 18 人到沙坡头站参观、学习。西北师大师生 10 余人来沙坡头站参观学习。兰州大学师生 60 余人来沙坡头站参观、学习。

25) 7 月 15–16 日，法国“沙漠星球”科学纪录片剧组的总导演、制片人，法国蒙娜丽莎科学纪录片公司(MONALISA production) Thierry Berrod 先生及合作编导、北京大学文明研究中心的申娟博士来沙坡头沙坡头站参观调研。

26) 7 月 16 日，长安大学公路学院社会实践队 10 余人来沙坡头站参观、学习。

27) 7 月 22 日，陕西师范大学 80 余人来沙坡头站参观、学习。

28) 7 月 27 日，北京林业大学 6 人到沙坡头站参观、考察。西双版纳植物园 4 人来沙坡头站参观、学习。中科院水保所 41 人来沙坡头站参观。

29) 7 月 28–29 日，高艳红参加了在北京地理所举办的 “中国通量观测研究联盟(China FLUX)成立暨第一次学术研讨会”。

30) 7 月 28–30 日，李新荣、王新平参加了在甘肃合作举办的首届甘肃省生态学会会议。

31) 7 月 31 日，王若愚研究员、赵霞博士、郝海婷博士参加在沈阳举办的“中国植物病理学会第十届全国会员代表大会暨 2014 年学术年会及第四届中美植物病理学学术研讨会”。并作报告：“解淀粉芽孢杆菌类胶原蛋白与植物相互作用的研究”和“解淀粉芽孢杆菌气态信号分子对植物促生机制研究”。

32) 8 月 4 日，北京海淀区科协“夏令营”80 余人来沙坡头站参观、学习。

33) 8 月 6–13 日，赵洋、回嵘在韩国国立顺天大学进修，学习有关“生物土壤结皮中藻类、地衣鉴定、分离和培养”内容。

34) 8 月 14–16 日，《国家重点基础研究发展计划》（973 项目）“植物固沙的生态–水文过程、机理及调控”（2013CB429900）的中期会议在北京召开。沙坡头沙坡头站李新荣、王新平、刘立超、张志山、谭会娟、贾荣亮、黄磊、赵洋、回嵘参加了会议，李新荣研究员就项目的进展做了详细汇报。

35) 8 月 16–19 日，李新荣、王新平、王增如参加了在内蒙古通辽举办的“沙漠化土地恢复与资源持续利用国际研讨会”。

36) 9 月 2–3 日，王增如参加了在北京召开的生态固碳项目 2014 年自评估会议。

37) 9 月 25 日，赵昕研究员赴北京参加中科院地质所举办的地学类资源环境大型仪器区域中心举办的技术交流大会，并作技术交流报告。

38) 为了加强研究所和高校之间的“科教融合与协同育人计划”合作，2014 年 11 月 28 日上午，寒旱所奈曼站站长赵学勇研究员等一行 6 人应邀参观访问了西北师范大学地理与环境科学学院，探讨有关生态环境领域的科教合作与共同发展，并达成战略合作共识。

39) 9 月 17–20 日，李新荣、王新平、刘玉冰、赵昕、黄磊、虎瑞、张定海、徐冰鑫参加在辽宁沈阳举办的“第 13 届中国生态学会 2014 年学术年会”。黄磊、虎瑞、张定海、徐冰鑫分别做了报告，黄磊获得青年优秀报告奖。

40) 9 月 21 日，内蒙古自治区鄂尔多斯市林业局局长、党委书记丁崇明一行 10 人到沙坡头沙坡头站参观、考察。

41) 9月26–28日实验室周琴博士和张继伟参加上海阿趣公司生物代谢组研究培训班。

42) 10月24–27日，李新荣、王新平、张志山、李爱霞、谭会娟、贾荣亮、黄磊、冯丽参加了在福建福州举办的“中国地理学会沙漠分会2014年学术研讨会”，并分别做了报告。

43) 11月20–21日，王增如参加了在北京举办的“碳专项自评估会议”。

44) 12月6–7日，刘丹在北京参加了由中科院植物所主办的主题为“植物逆境生理学与植物次生代谢及代谢工程”的首届全国植物生理与分子生物学前沿论坛。

45) 应甘肃省寒区旱区逆境生理与生态重点实验室陈国雄研究员的邀请，日本国立农业资源研究所Takao Komatsuda博士将于11月8—10月16日来我所进行访问及学术交流，并参加甘肃省创新研究群体计划(1308RJIA002) 2014年学术讨论会。

46) 11月10日召开实验室甘肃省创新研究群体计划(1308RJIA002)学术研讨会，学术报告题目如下：

1. Takao Komatsuda：Genetic and molecular studies on floret closing (cleistogamy) in barley
2. 陈国雄：Introduction to the project of Gansu Innovation Research Group Fund (1308RJIA002), plant cuticle and drought resistance
3. 杨 果：A new family of collagen–like proteins (CLPs) identified in Bacillus amyloliquefaciens FZB42 and roles in Plant–microbe–soil interactions
4. 赵 昕：干旱胁迫下柠条锦鸡儿转录组和代谢组研究
5. 王 进：生物土壤结皮中固氮微生物对降雨事件的响应研究设想
6. 陈翠云：荒漠植物牛心朴子的干旱适应性机制研究

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Ants mediate soil water in arid desert ecosystems: Mitigating rainfall interception induced by biological soil crusts?

X.R. Li[a,b,*], Y.H. Gao[a,b], J.Q. Su[a,b], R.L. Jia[a,b], Z.S. Zhang[a,b]

[a] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[b] Gansu Provincial Key Laboratory of Stress Eco-physiology, Lanzhou 730000, China

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Biological soil crusts

ABSTRACT

As vital components of desert systems, the roles of ants in arid ecological processes have been well documented, while little attention has been given to their effects on soil water. We conducted a six-year investigation in sand dune systems stabilized via revegetation, to explore the hydrological role of ants through comparing the influence of ant nests on rainfall infiltration in different-aged revegetated dunes. The presence of ant nests markedly enhanced infiltration due to weakening the rainfall interception by biological soil crusts (BSCs) in revegetated dunes. The distribution of ant nest was denser in older revegetated areas, due to better developed BSCs of later successional stages, compared to younger revegetated areas. Ants prefer later to early successional BSCs because the later lichen–moss dominated crusts were thicker and their surface was more stable than the early cyanobacteria dominated crusts. Conversely, the crustal rainfall interception was positively correlated with BSC thickness. These findings suggest that the occurrence of ant nests in older revegetated areas benefited to the planted shrubs with deeper root systems and maintain a relative constant cover of shrubs in artificial sand-binding vegetation following an increase in infiltration to deeper soil layers.

1. Introduction

Numerous studies have predicted that the large area of woody sand-binding vegetation will degrade or become extinct due to soil water depletion and underground water decreasing in sandy areas of northern China (Cao, 2008; Wang et al., 2010). However, in some cases, sand-binding vegetation can sustainably develop even for annual precipitation <200 mm (SDRES, 1991; Li et al., 2004; Wang et al., 2004; Li et al., 2007a). Amongst these debates, ecologists and land managers have become interested in the hydrological role of biological soil crusts (BSCs) (Li et al., 2010), which are widespread and develop in the processes of dune stabilization from revegetation and sand-binding vegetation succession (Li et al., 2002; Su et al., 2007). The occurrence of BSCs in stabilized dunes, and the conversion of early cyanobacteria to the later lichen–moss dominated crusts (Li et al., 2011), markedly increases the interception of rainfall (Belnap et al., 2005; Fischer et al., 2010). This favors annual plants (Su et al., 2007) and disadvantages woody plants with deeper root systems due to increasing shallow soil water and reducing infiltration to deeper soil (Li et al., 2007a). BSCs enhance the water-holding capacity of topsoil via increasing the clay and silt proportion content in topsoil thus stabilizing the dune surface and entrapping dust-fall in topsoil with the succession of artificial sand-binding vegetation (Li et al., 2007b). Therefore, BSCs alter the pattern of rainfall infiltration in soil (Maestre et al., 2002) and result in deep-rooted woody species disappearing from current communities and developing of shallow-rooted herbaceous species and, in particular, establishment of annual plants (Su et al., 2007; Li et al., 2007a). We want to determine how artificially established sand-binding vegetation systems respond and adapt to the changes induced by BSCs; and whether such ecosystems can maintain stability via systematic self-adjustment such as via altering species composition and performance, including invertebrate disturbance.

The presence and development of BSCs create safe sites for ants (Perfecto and Vandermeer, 1996; Bestelmeyer, 1997; Retana and Cerda, 2000) in wind erosion environments; and the distribution of ant nests is closely related to the successional stages of BSCs in the Tengger Desert (Li et al., 2011; Chen and Li, 2012). As ecosystems engineers, ants are abundant and conspicuous components of

* Corresponding author at: Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China. Tel.: +86 931 8277921; fax: +86 931 8273894.
E-mail address: lxinrong@lzb.ac.cn (X.R. Li).

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Ecological restoration and recovery in the wind-blown sand hazard areas of northern China: relationship between soil water and carrying capacity for vegetation in the Tengger Desert

LI XingRong[1,2*], ZHANG ZhiShan[1,2], TAN HuiJuan[1,2], GAO YanHong[1,2], LIU LiChao[1,2] & WANG XingPing[1,2]

[1]*Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China;*
[2]*Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions of Gansu Province, Lanzhou 730000, China*

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The main prevention and control area for wind-blown sand hazards in northern China is about 320000 km^2 in size and includes sandlands to the east of the Helan Mountain and sandy deserts and desert-steppe transitional regions to the west of the Helan Mountain. Vegetation recovery and restoration is an important and effective approach for constraining wind-blown sand hazards in these areas. After more than 50 years of long-term ecological studies in the Shapotou region of the Tengger Desert, we found that revegetation changed the hydrological processes of the original sand dune system through the utilization and space-time redistribution of soil water. The spatiotemporal dynamics of soil water was significantly related to the dynamics of the replanted vegetation for a given regional precipitation condition. The long-term changes in hydrological processes in desert areas also drive replanted vegetation succession. The soil water carrying capacity of vegetation and the model for sand fixation by revegetation in aeolian desert areas where precipitation levels are less than 200 mm are also discussed.

desert areas, sand fixation by plant, succession of the artificial vegetation, soil water dynamics, carrying capacity for vegetation

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The areas suffering from wind-blown sand hazard events in China are distributed from longitude 75°–125° and latitude 35°–50° and form a discontinuous arc-shaped desert zone (including sandlands) from the western Tarim Basin in the west to the western Songnen Plain in the east. It traverses northwest, north and northeast-China with a length of 4500 km from east to west and a width of 600 km from south to north, crossing arid, semi-arid and sub-humid climatic zones and covering the eight largest deserts and the four largest sandlands in China [1,2]. The sandlands and the farming-pastoral ecotone in eastern China, where annual precipitation is more than 250 mm and the desert and oasis, desert and desert-steppe transition regions to the west of the Helan Mountain, where annual precipitation is less than 200 mm, cover about 320000 km^2. They are the regions most seriously affected by desertification and sand hazards. The main prevention and control areas in China for wind-blown sand hazards are also the main areas for non-irrigated vegetation construction and ecological barrier building [3–5].

Using revegetation as a method to control sand damage in China has been practiced for nearly 60 years and is one of most successful approaches to constraining wind-blown

*Corresponding author (email: lxinrong@lzb.ac.cn)

Condensation of water vapour on moss-dominated biological soil crust, NW China

Xin-Ping Wang*, Yan-Xia Pan, Rui Hu, Ya-Feng Zhang and Hao Zhang

Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320, Donggang West Road, Lanzhou 730000, PR China.
**Corresponding author. e-mail: xpwang@lzb.ac.cn*

Characteristics of water vapour condensation, including the onset, duration, and amount of water vapour condensation on moss-dominated biological soil crust (BSC) and dune sand were studied under simulated conditions with varying air temperature and relative humidity. The simulations were performed in a plant growth chamber using an electronic balance recording the weight of condensation. There was a positive linear correlation between the water vapour condensation and relative humidity while the mean temperature was negatively linearly related to amounts of water vapour condensation for both soil surfaces. The amount of water vapour condensation on BSC and dune sand can be described by the difference between air temperature and dew point with an exponential function, indicating that when the difference of air temperature and dew point exceeds a value of 35.3°C, there will be zero water vapour condensed on BSC. In contrast, when the difference of air temperature and dew point exceeds a value of 20.4°C, the water vapour condensation will be zero for dune sand. In general, when the air is fully saturated with water and the dew point is equal to the current air temperature, the water vapour condensed on BSC attained its maximum value of 0.398 mm, whereas it was 0.058 mm for dune sand. In comparison, water vapour condensed on BSC was at a relatively high temperature and low relative humidity, while we did not detect water vapour condensation on the dune sand under the similar conditions. Physical and chemical analyses of the samples pointed to a greater porosity, high content of fine particles, and high salinity for BSC compared to the dune sand. These results highlight that soil physicochemical properties are the likely factors influencing the mechanism of water vapour condensation under specific meteorological conditions, as onset was earlier and the duration was longer for water vapour condensation on BSC in comparison with that of dune sand. This contributed to the greater amount of vapour absorbed on BSC compared to the dune sand under an identical meteorological condition. The feedback of water vapour condensation on BSC formation and its contribution to sustain the revegetation desert ecosystems was discussed.

1. Introduction

Water vapour exchange at the earth's surface has received increasing attention in desert ecology. Though the condensation of water vapour has a far-smaller quantitative output relative to rainfall, it is a very common natural phenomenon and has ecological significance (Stone 1963). Dew, one of the major condensed water vapour, occurs when humid air condenses onto a substrate and transforms into liquid water (Beysens 1995; Veste *et al.* 2008), and originates either from air (dewfall) or from soil (Wells 1815; Aitken 1885; Monteith 1957; Garratt and Segal 1988). Considering the

Keywords. Condensation; water vapour; desert ecosystem; moss; biological soil crust.

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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

A psammophyte *Agriophyllum squarrosum* (L.) Moq.: a potential food crop

Guoxiong Chen · Jiecai Zhao · Xin Zhao · Pengshan Zhao · Ruijun Duan · Eviatar Nevo · Xiaofei Ma

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Abstract *Agriophyllum squarrosum* is an annual psammophyte adapted to mobile sand dunes in arid and semi-arid regions of Central Asia. The species has evolved a range of physiological, morphological, and ecological adaptations to allow it to be a pioneer species of unstable, nutrient-poor, drought-prone and hot sand dunes. Local populations in the sandy desert regions of China consume the seed of the species during periods of food shortage, and refer to the plant as "shami" in Chinese, which translates as "sand rice". The sand rice seeds have high nutritional value, containing around 23 % protein, 9 % lipid, 45 % carbohydrates, 8 % crude fiber and 5 % ash. The protein fraction includes the full range of essential amino acids required in the human diet. The lipid fraction comprises mostly polyunsaturated fatty acid. The ash fraction is rich in iron. Sand rice is a good candidate species for domestication to provide a food crop resilient to future climate change.

Keywords *Agriophyllum squarrosum* · Chenopodiaceae · Heat tolerance · Quinoa · Sandy desert · Wild plant domestication

G. Chen (✉) · J. Zhao · X. Zhao · P. Zhao · R. Duan · X. Ma
Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions, Lanzhou, Gansu, P.R. China
e-mail: guoxiong@lzb.ac.cn

G. Chen · J. Zhao · X. Zhao · P. Zhao · R. Duan · X. Ma
Shapotou Desert Research & Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, P.R. China

R. Duan
College of Eco-environmental Engineering, Qinghai University, Xining 810016, P.R. China

E. Nevo
Institute of Evolution, University of Haifa, Mount Carmel, 31905 Haifa, Israel

Introduction

Continuing global population growth, rising expectations of the standard of living, potential climate change and ongoing degradation of soil and water resources are conspiring to put pressure on crop production. The global future climate is likely to be warmer than the present one; while overall the amount of rainfall should increase, the expectation is that its distribution, both temporally and spatially, will become more unpredictable, and some regions which are already short of rainfall may well become even drier. The negative consequences of climate change on global food security (Wheeler and von Braun 2013) have encouraged interest in accessing crop wild relatives as a genetic resource for crop adaptation (Tester and Langridge 2010; McCouch et al. 2013), but at the same time there is also a need to identify

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Identification of Differentially Expressed Genes in Leaf of *Reaumuria soongorica* under PEG-Induced Drought Stress by Digital Gene Expression Profiling

Yubing Liu[1,2*☯], Meiling Liu[1,2,3☯], Xinrong Li[1,2], Bo Cao[1,2,3], Xiaofei Ma[2]

1 Shapotou Desert Research & Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, P. R. China, **2** Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions of Gansu Province, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, P. R. China, **3** University of Chinese Academy of Sciences, Beijing, China

Abstract

Reaumuria soongorica (Pall.) Maxim., a resurrection semi-shrub, is a typical constructive and dominant species in desert ecosystems in northwestern China. However, the gene expression characteristics of *R. soongorica* under drought stress have not been elucidated. Digital gene expression analysis was performed using Illumina technique to investigate differentially expressed genes (DEGs) between control and PEG-treated samples of *R. soongorica*. A total of 212,338 and 211,052 distinct tags were detected in the control and PEG-treated libraries, respectively. A total of 1,325 genes were identified as DEGs, 379 (28.6%) of which were up-regulated and 946 (71.4%) were down-regulated in response to drought stress. Functional annotation analysis identified numerous drought-inducible genes with various functions in response to drought stress. A number of regulatory proteins, functional proteins, and proteins induced by other stress factors in *R. soongorica* were identified. Alteration in the regulatory proteins (transcription factors and protein kinase) may be involved in signal transduction. Functional proteins, including flavonoid biosynthetic proteins, late embryogenesis abundant (LEA) proteins, small heat shock proteins (sHSP), and aquaporin and proline transporter may play protective roles in response to drought stress. Flavonoids, LEA proteins and sHSP function as reactive oxygen species scavenger or molecular chaperone. Aquaporin and proline transporters regulate the distribution of water and proline throughout the whole plant. The tolerance ability of *R. soongorica* may be gained through effective signal transduction and enhanced protection of functional proteins to reestablish cellular homeostasis. DEGs obtained in this study may provide useful insights to help further understand the drought-tolerant mechanism of *R. soongorica*.

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* E-mail: ybliu13@163.com

☯ These authors contributed equally to this work.

Introduction

Water deficit is one of the most significant abiotic stresses that influence germination, growth, development, and productivity of plants [1]. Drought stress causes stomatal closure, limited gas exchange, and reduced photosynthesis in plants [2]. Over-reduction of photosynthetic electron transport chain induces the generation of reactive oxygen species (ROS), such as singlet oxygen ($^1O_2$), superoxide anion (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radical (•OH), which damage cellular structures and macromolecules [3]. Plants have enzymatic and non-enzymatic systems to eliminate ROS. Moreover, plants have developed drought-resistance strategies such as succulent leaves, formation of osmophilic globules, stomatal movement, and reduction of leaf water potential [4,5]. The understanding of plant responses to water deficit have improved because of the application of molecular techniques. The expression of numerous genes in response to drought stress was described in previous studies [6,7]. Seki et al. [8] classified the genes expressed during stress into two groups: (i) genes encoding proteins involved in signal transduction (protein kinases and transcription factors) and (ii) genes with products, such as late embryogenesis abundant (LEA) proteins, chaperone, osmoprotectants, and detoxification enzymes, that directly protect cells against stress. Genomic and transcriptomic analyses revealed that various transcriptional regulatory systems are involved in stress-responsive gene induction. Several different sets of *cis*- and *trans*-acting factors are known to be induced by drought stress at the molecular level [9]. A large number of metabolites and proteins have also been reported to be up regulated in response to drought stress [10].

Reaumuria soongorica (Pall.) Maxim. is an extreme xerophytic semi-shrub and a typical constructive and dominant species in the desert vegetation in China. *R. soongorica* forms the zonal landscape and is widely distributed in northwest China [11]. Water supply is one of the main limiting factors in the habitat of this species. The unique adaptive strategies in the morphology and physiology of *R. soongorica*, such as thick cuticle, hollow stomata, and accumulation of some low-molecular-weight metabolites, are attributed to its

Research

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Drought effect on plant nitrogen and phosphorus: a meta-analysis

Mingzhu He[1]* and Feike A. Dijkstra[2]*

[1]Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, 730000, China;

[2]Department of Environmental Sciences, Centre for Carbon, Water and Food, The University of Sydney, Camden, NSW 2570, Australia

Author for correspondence:
Mingzhu He
Tel: +86 931 4967193
Email: hmzecology@lzb.ac.cn

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Key words: drought duration, drought manipulation type, drought stress, drying–rewetting cycle, N : P ratio, nutrient mineralization.

Summary

- Climate change scenarios forecast increased aridity in large areas worldwide with potentially important effects on nutrient availability and plant growth. Plant nitrogen and phosphorus concentrations (plant [N] and [P]) have been used to assess nutrient limitation, but a comprehensive understanding of drought stress on plant [N] and [P] remains elusive.
- We conducted a meta-analysis to examine responses of plant [N] and [P] to drought manipulation treatments and duration of drought stress.
- Drought stress showed negative effects on plant [N] (−3.73%) and plant [P] (−9.18%), and a positive effect on plant N : P (+ 6.98%). Drought stress had stronger negative effects on plant [N] and [P] in the short term (< 90 d) than in the long term (> 90 d). Drought treatments that included drying–rewetting cycles showed no effect on plant [N] and [P], while constant, prolonged, or intermittent drought stress had a negative effect on plant [P].
- Our results suggest that negative effects on plant [N] and [P] are alleviated with extended duration of drought treatments and with drying–rewetting cycles. Availability of water, rather than of N and P, may be the main driver for reduced plant growth with increased long-term drought stress.

Introduction

Most climate change scenarios forecast that much of the global land area will undergo increasing aridity (Handmer *et al.*, 2012). Because nitrogen (N) and phosphorus (P) frequently limit plant growth, an improved understanding of the N and P cycles within the soil–plant system in response to drought stress is becoming increasingly important. From a global point of view, drought (simply defined as water deficit in soil and/or atmosphere) affects plant survival (Bray, 1997), ecosystem production (Farooq *et al.*, 2012) and function (Ledger *et al.*, 2013). Water availability is a key driver of ecosystem processes, therefore drought stress will probably alter ecosystem N and P cycles (Sardans & Peñuelas, 2012).

Plant N and P concentrations (hereafter plant [N] and [P]) are important indicators of N and P limitation (Aerts & Chapin, 2000; Güsewell, 2004), but impacts of drought on plant [N] and [P] remain unclear. Drought can depress plant growth by reducing N and P uptake, transport and redistribution (Rouphael *et al.*, 2012). A majority of studies have indicated that plants decrease N and P uptake with a decline in soil moisture (Cramer *et al.*, 2009; Waraich *et al.*, 2011; Sardans & Peñuelas, 2012). Owing to a reduction in stomatal conductance, photosynthesis and transpiration rates also decrease, and CO_2 assimilation rates progressively decline in response to drought (Farooq *et al.*, 2012). Therefore, drought effects on plant [N] and [P] may depend on the reduction in N and P uptake relative to the decrease in CO_2 assimilation.

Drought stress and associated reduction in soil moisture can reduce plant nutrient uptake by reducing nutrient supply through mineralization (Fierer & Schimel, 2002; Schimel *et al.*, 2007; Sanaullah *et al.*, 2012), but also by reducing nutrient diffusion and mass flow in the soil (Chapin, 1991; Lambers *et al.*, 2008). When drought stress is followed by rewetting, this often results in enhanced mineralization (Austin *et al.*, 2004), which has been attributed to nutrient release from dead microbial biomass that has accumulated during the drying period (Borken & Matzner, 2009).

The net effect of drought stress on nutrient supply through mineralization may depend on the duration and intensity (or severity) of these drying–rewetting cycles, which can be attributed to many factors, such as frequency and occurrence of rainfall, soil type affecting water potential, and evapotranspiration demand (Farooq *et al.*, 2009). Generally, negative effects on soil microbial activity and plant nutrient uptake become larger with increased drought stress, but frequent rewetting events after drought periods may, at least in part, compensate for the negative effects of

*These authors contributed equally to this work.

BMC Genomics

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Transcriptomic analysis of a psammophyte food crop, sand rice (*Agriophyllum squarrosum*) and identification of candidate genes essential for sand dune adaptation

Pengshan Zhao[1,2*], Salvador Capella-Gutiérrez[3,4,5], Yong Shi[1,2], Xin Zhao[1,2], Guoxiong Chen[1,2], Toni Gabaldón[3,4,6*] and Xiao-Fei Ma[1,2]

Abstract

Background: Sand rice (*Agriophyllum squarrosum*) is an annual desert plant adapted to mobile sand dunes in arid and semi-arid regions of Central Asia. The sand rice seeds have excellent nutrition value and have been historically consumed by local populations in the desert regions of northwest China. Sand rice is a potential food crop resilient to ongoing climate change; however, partly due to the scarcity of genetic information, this species has undergone only little agronomic modifications through classical breeding during recent years.

Results: We generated a deep transcriptomic sequencing of sand rice, which uncovers 67,741 unigenes. Phylogenetic analysis based on 221 single-copy genes showed close relationship between sand rice and the recently domesticated crop sugar beet. Transcriptomic comparisons also showed a high level of global sequence conservation between these two species. Conservation of sand rice and sugar beet orthologs assigned to response to salt stress gene ontology term suggests that sand rice is also a potential salt tolerant plant. Furthermore, sand rice is far more tolerant to high temperature. A set of genes likely relevant for resistance to heat stress, was functionally annotated according to expression levels, sequence annotation, and comparisons corresponding transcriptome profiling results in *Arabidopsis*.

Conclusions: The present work provides abundant genomic information for functional dissection of the important traits in sand rice. Future screening the genetic variation among different ecotypes and constructing a draft genome sequence will further facilitate agronomic trait improvement and final domestication of sand rice.

Keywords: *Agriophyllum squarrosum*, Sand rice, Salt tolerance, Heat tolerance, Comparative transcriptomics, Wild plant domestication

Background

Food security is one of this century's key global challenges. Food system is precarious in the face of increasing global human population, changing consumption patterns, ongoing climate change and soil degradation, and growing scarcity of water and land [1-5]. The pace of global warming is expected to accelerate; while extreme weather events will become more frequent and the temporal and spatial precipitation is likely to be unpredictable [2,5]. To date, wheat, maize, rice, and soybean are the main sources for human and livestock calories in many agricultural regions around the world [1]. The time lags of these crops in adapting to a changing environment urge scientists to exploit crop wild relatives as a new genetic resource in crop improvement [3,4]. Furthermore, one recent assessment of national food supplies worldwide demonstrated that the diversity of crop species is reducing and global food homogeneity is increasing over the past 50 years, which are potential threats to food security [6]. Thus,

* Correspondence: zhaopengshan@lzb.ac.cn; toni.gabaldon@crg.eu
[1]Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions, Gansu Province, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, People's Republic of China
[3]Bioinformatics and Genomics Programme, Centre for Genomic Regulation (CRG), Dr. Aiguader, 88, 08003 Barcelona, Spain
Full list of author information is available at the end of the article

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Correspondence and requests for materials should be addressed to M.Z.H. (hmzecology@lzb.ac.cn)

Leaf nitrogen and phosphorus of temperate desert plants in response to climate and soil nutrient availability

Mingzhu He[1], Feike A. Dijkstra[2], Ke Zhang[1], Xinrong Li[1,3], Huijuan Tan[1,3], Yanhong Gao[1] & Gang Li[1]

[1]Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, 730000, China, [2]Department of Environmental Sciences, Centre for Carbon, Water and Food, The University of Sydney, NSW, 2006, Australia, [3]Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions of Gansu Province, Lanzhou, 730000, China.

In desert ecosystems, plant growth and nutrient uptake are restricted by availability of soil nitrogen (N) and phosphorus (P). The effects of both climate and soil nutrient conditions on N and P concentrations among desert plant life forms (annual, perennial and shrub) remain unclear. We assessed leaf N and P levels of 54 desert plants and measured the corresponding soil N and P in shallow (0–10 cm), middle (10–40 cm) and deep soil layers (40–100 cm), at 52 sites in a temperate desert of northwest China. Leaf P and N : P ratios varied markedly among life forms. Leaf P was higher in annuals and perennials than in shrubs. Leaf N and P showed a negative relationship with mean annual temperature (MAT) and no relationship with mean annual precipitation (MAP), but a positive relationship with soil P. Leaf P of shrubs was positively related to soil P in the deep soil. Our study indicated that leaf N and P across the three life forms were influenced by soil P. Deep-rooted plants may enhance the availability of P in the surface soil facilitating growth of shallow-rooted life forms in this N and P limited system, but further research is warranted on this aspect.

Nitrogen (N) and phosphorus (P) availability affect community structure[1–2], species diversity[3–5], and other ecosystem functions[6], such as nutrient cycling and productivity[7–8], and the ratio of these two elements in leaf tissue may indicate if a system is limited by N, P or both[9]. Studies about ecological stoichiometry of N and P have been performed across local[10], regional[8,11] and global scales[12–14]. Plant N and P levels can be influenced by various biotic and abiotic factors, such as habitat[15], growth stages[16], and plant functional groups[3].

N- and P- limitation are typically determined by plant nutrient levels and/or soil nutrient availability[17]. In turn, plant adaptations to soil nutrient levels may exert control over critical N : P values. Studies from terrestrial plant species of China revealed that due to low soil P levels compared to the global average, overall leaf N : P ratios were markedly higher than that of global flora[8]. However, it was suggested that critical leaf N : P values could not effectively predict nutrient limitation of desert plants. Due to water and nutrient co-limitations and adaptation to low nutrient conditions, desert plants show little plasticity in N : P stoichiometry[17] and maintain low tissue nutrient uptake[18]. This unique pattern highlights the need of considering soil nutrient conditions for plant specific adaptation and plant-soil interactions in desert environments.

In desert ecosystems, low soil moisture coupled with high soil alkalinity acts to decrease both soil N and P availability[19]. Infrequent and low precipitation limits soil weathering, organic matter production, and mineralization[20], leading to slow P release from primary material, low soil organic matter content, and N bound in organic matter[17]. A study from 224 dryland sites indicated an increased decoupling of carbon (C), N and P with increased aridity resulting in greater P availability compared to N[18]. Plant N fixation rates in arid regions have long been considered to be low because of low soil moisture and high temperatures[21]. In contrast, ammonia volatilisation of dryland soils can be high, as volatilisation rates are positively related to soil pH, total salt content and $CaCO_3$, and negatively related to soil organic matter, cation-exchange capacity and clay content[22]. There is also good evidence that sometimes nutrients, with limited water, can limit plant growth[17], although relationships between plant growth and leaf N or P concentration are not always clear[16].

What is the intrinsic relationship between soil nutrients and leaf nutrients of desert plants? Soil nutrients are the main driver for leaf nutrient concentrations. Plant available soil P, primarily derived from weathering of primary materials such as apatite, and from dissolution and diffusion of P within the soil solution, is considered lower than that of N[21]. Available forms of N and P mostly remain in the surface soil because the high temperature

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Effects of sand burial on dew deposition on moss soil crust in a revegetated area of the Tennger Desert, Northern China

Rong-liang Jia [a,*], Xin-rong Li [a], Li-chao Liu [a], Yan-xia Pan [a], Yan-hong Gao [a], Yong-ping Wei [b]

[a] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou 730000, China
[b] Australian–China Centre on Water Resource Research, The University of Melbourne, Parkville, Victoria 3010, Australia

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Succession

SUMMARY

Sand burial and dew deposition are two fundamental phenomena profoundly influencing biological soil crusts in desert areas. However, little information is available regarding the effects of sand burial on dew deposition on biological soil crusts in desert ecosystems. In this study, we evaluated the effects of sand burial at depths of 0 (control), 0.5, 1, 2 and 4 mm on dew formation and evaporation of three dominant moss crusts in a revegetated area of the Tengger Desert (Northern China) in 2010. The results revealed that sand burial significantly decreased the amount of dew deposited on the three moss crust types by acting as a semi-insulator retarding the dew formation and evaporation rates. The changes in surface temperature cannot fully explain the variations of the formation and evaporation rates of dew by moss crusts buried by sand. The extension of dew retention time was reflected by the higher dew ratios (the ratio of dew amount at a certain time to the maximum value in a daily course) in the daytime, and may to some extent have acted as compensatory mechanisms that diminished the negative effects of the reduction of dew amount induced by sand burial of moss crusts. The resistances to reduction of dewfall caused by sand burial among the three moss crusts were also compared and it was found that *Bryum argenteum* crust showed the highest tolerance, followed by crusts dominated by *Didymodon vinealis* and *Syntrichia caninervis*. This sequence corresponds well with the successional order of the three moss crusts in the revegetated area, thereby suggesting that resistance to reduction of dewfall may act as one mechanism by which sand burial drives the succession of moss crusts in desert ecosystems. This side effect of dew reduction induced by sand burial on biological soil crusts should be considered in future ecosystem construction and management of desert area.

1. Introduction

The availability of water largely determines the ecological processes of arid areas and ancillary water from sources other than rainfall, e.g. dew, fog and atmospheric water vapor, serves as an important additional source of moisture for organisms. Although usually smaller in quantity, ancillary water wets and dries the upper soil surface more frequently than rainfall in arid areas, and strongly influences organisms that dwell on the soil surface (Agam and Berliner, 2006; Kaseke et al., 2012).

Biological soil crusts (BSCs) are comprised mostly of cryptogams, such as moss, lichen, and algae. They dominant the soil surface in arid areas and have critical roles in determining the composition, structure, and function of many desert ecosystems (Belnap and Lange, 2003). In addition to strongly increasing the stability and nutritional levels of upper soil layers, BSCs also provide a favorable micro-habitat for other organisms. However, the functions of BSCs are very sensitive to changes in water availability, sourced not only from rainfall (Belnap et al., 2004; Coe et al., 2012), but also from fog and dew (Csintalan et al., 2000; Jacobs et al., 1999; Kidron et al., 2002; Wilske et al., 2008). Considering the poikilohydric features, small-size with low growth habit, and overall small biomass of BSCs, dew may have very strong influences on crust biota and may further have critical roles in arid ecosystems. Dew provides short-term amelioration of vapor-pressure deficits, maintains a pre-activated state for subsequent rainfall events (Wilske et al., 2008), activates photosynthesis (Jacobs et al., 1999), and prolongs metabolic activity (eg. Lange et al., 1998). Dew may also influence the growth (Pan et al., 2013), distribution, development and succession of BSCs in the long-term (Kidron et al., 2002; Liu et al., 2006; Prado and Sancho, 2007). Thus,

* Corresponding author. Tel.: +86 931 4967185; fax: +86 931 8273894.
E-mail address: rongliangjia@163.com (R.-l. Jia).

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Effects of shrub species and microhabitats on dew formation in a revegetation-stabilized desert ecosystem in Shapotou, northern China

YanXia PAN, XinPing WANG*

Shapotou Desert Experimental Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract: Dew is an important supplement water source in arid and semi-arid areas. In order to determine the dew formation on different kinds of soils associated with various shrub species and microhabitats, we performed measurement of accumulated dew formation amount and duration in October 2009 in a revegetation-stabilized arid desert ecosystem in Shapotou area, northern China. The results indicated that the accumulated dew formation amount was four times larger at open spaces as compared to under the canopy, and it was nearly twice as much under living *Artemisia ordosica* plants (L.A.) as compared to under living *Caragana korshinskii* plants (L.C.). The opposite characteristics were found for dew duration between different microhabitats. Dew amounts at different vertical heights around the shrub stands were in the order of 50 cm above the canopy>the canopy edge>under the canopy. Dew amount continued to increase after dawn, and the proportion of average accumulated dew amount after dawn accounting for the average maximum amount increased from above the canopy to under the canopy. Dew formation duration after sunrise accounted for more than 50% of the total formation duration during the day time. Contrary to the distribution characteristics of dew amount, dew duration after dawn and total dew formation duration during the day time were both highest under the canopy, followed by at the canopy edge and then at 50 cm above the canopy. The portion of dew duration after dawn accounting for the total dew duration during the day time increased from above the canopy to under the canopy. From these results, we may conclude that dew availability as a supplemental water resource for improving the microhabitats in water-limited arid ecosystems is position dependent especially for the plant microhabitats at different stands layers.

Keywords: dew amount; dew duration; shrub species; microhabitat; soil surface type

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An important component of micro-hydrology in arid regions is the input of non-rainfall atmospheric moisture via dew (Kosmas et al., 1998; Agam and Berliner, 2006; Brown et al., 2008). Dew is an important usable water resource in desert environments with scarce water, where dew can efficiently reduce water loss caused by soil evaporation and is crucial to maintaining water balance, especially over large time scales (Lekouch et al., 2011; Hao et al., 2012). Dew is also beneficial to the growth and development of biological soil crusts (Agam and Berliner, 2002; Pan et al., 2010). Moreover, some plants can directly absorb the dew that forms on the canopy surface through their leaves, thereby alleviating water deficit (Jacobs et al., 2000; Zheng et al., 2011; Zhuang and Ratcliffe, 2012), extending life period, improving flowering and fruit quantity, promoting growth and increasing above- or below-ground biomass (Martin and Willert, 2000; Gouvra and Grammatikopoulos, 2003; Breshears et al., 2008; Simonin et al., 2009). In the semi-arid regions of Chile, forests are largely dependent on the deposition of fog water (Del-Val et al., 2006). Dew is also an

*Corresponding author: XinPing WANG (E-mail: xpwang@lzb.ac.cn)
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The influence of Caragana korshinskii shrub on soil and hydrological properties in a revegetation-stabilized desert ecosystem

Yan-Xia Pan[a], Xin-Ping Wang[a], Xin-Rong Li[a], Ya-Feng Zhang[a], Rui Hu[a] & Hao Zhang[a]
[a] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China
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Photosynthesis of two moss crusts from the Tengger Desert with contrasting sensitivity to supplementary UV-B radiation

R. HUI[*,**], X.R. LI[*,**,+], R.L. JIA[*,**], L.C. LIU[*,**], R.M. ZHAO[***], X. ZHAO[*,**], and Y.P. WEI[****]

Shapotou Desert Research and Experimental Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, P.R. China[*]
Extreme Stress Resistance and Biotechnology Laboratory, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, P.R. China[**]
College of Life Science and Technology, Gansu Agricultural University, Lanzhou 730070, P.R. China[***]
Australian-China Center on Water Resource Research, The University of Melbourne, Parkville, Victoria 3010, Australia[****]

Abstract

Predicting the effects of increased ultraviolet-B (UV-B) radiation due to stratospheric ozone depletion on temperate desert ecosystems requires better knowledge of the ecophysiological response of common moss species. The aim of the current work was to determine whether elevated UV-B radiation affected photosynthetic performance and chloroplast ultrastructure of two moss crusts and whether response differences were observed between the crusts. In laboratory experiments, *Bryum argenteum* and *Didymodon vinealis*, which show microdistributions and are dominant in soil crusts at the Tengger Desert, Northern China, were subjected to four levels of UV-B radiation of 2.75 (control), 3.08, 3.25, and 3.41 W m^{-2} for 10 days, simulating 0, 6, 9, and 12% of stratospheric ozone at the latitude of Shapotou, respectively. The results showed that chlorophyll *a* fluorescence parameters (*i.e*., the maximal quantum yield of PSII photochemistry, the effective quantum yield of PSII photochemistry, and photochemical quenching coefficient), pigment contents, soluble protein contents, and the ultrastructure were negatively influenced by elevated UV-B radiation and the degree of detrimental effects significantly increased with the intensity of UV-B radiation. Moreover, results indicated that *B. argenteum* was probably more sensitive to supplementary UV-B radiation than *D. vinealis*. Therefore, we propose the use of *B. argenteum* crusts as a bioindicator of responses to elevated UV-B radiation.

Additional key words: biological soil crusts; chlorophyll *a* fluorescence; photosynthesis; ultraviolet-B.

Introduction

The depletion of stratospheric ozone by the emissions of man-made halocarbons has increased the intensity of UV-B radiation reaching the Earth surface (UNEP 2003). Considerable effort has been invested in determining plant responses to simulated ozone depletion, especially in economically important crops (McKenzie *et al*. 2003, Caldwell *et al*. 2007). Ozone depletion and the associated enhancement of intensity in shortwave UV-B radiation may influence the morphological, reproductive, physiological, and metabolic properties of higher plants, such as biomass and yields, pigment contents, nucleic acids, photosystem II (PSII), thylakoid membranes, and proteins (Reddy *et al*. 2003, Germ *et al*. 2005, Bashandy *et al*. 2009, Newsham and Robinson 2009, Hectors *et al*. 2010).

The effects of UV-B radiation on plants differ among species and are highly dependent on experimental conditions, UV-B radiation dosages, and the duration of exposure (Bassman *et al*. 2003, Bassman and Robberecht 2006). Several studies have found that elevated intensities of UV-B radiation have detrimental effects on

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[+]Corresponding author; phone: :+86 0931 8277921, e-mail: lxinrong@lzb.ac.cn
Abbreviations: BSC – biological soil crusts; Car – carotenoids; Chl – chlorophyll; DE – days of exposure; F_0 – the minimal fluorescence of dark-adapted state; F_m – the maximal fluorescence of dark-adapted state; F_v/F_m – the maximal quantum yield of PSII photochemistry; $^{\bullet}OH$ – hydroxyl radicals; $O_2^{\bullet-}$ – superoxide anions; PAL – phenylalanine ammonia-lyase; PSII – photosystem II; q_P – photochemical quenching coefficient; ROS – reactive oxygen species; Rubisco – ribulose-1,5-bisphosphate carboxylase/oxygenase; TEM – transmission electron microscope; UV-B – ultraviolet-B; Φ_{PSII} – the effective quantum yield of PSII photochemistry.
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Carbon fixation and influencing factors of biological soil crusts in a revegetated area of the Tengger Desert, northern China

Lei HUANG[1,2*], ZhiShan ZHANG[1,2], XinRong LI[1,2]

[1] Shapotou Desert Research and Experimental Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China;
[2] Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions of Gansu Province, Lanzhou 730000, China

Abstract: Biological soil crusts (BSCs) are an important type of land cover in arid desert landscapes and play an important role in the carbon source-sink exchange within a desert system. In this study, two typical BSCs, moss crusts and algae crusts, were selected from a revegetated sandy area of the Tengger Desert in northern China, and the experiment was carried out over a 3-year period from January 2010 to November 2012. We obtained the effective active wetting time to maintain the physiological activity of BSCs basing on continuous field measurements and previous laboratory studies on BSCs photosynthesis and respiration rates. And then we developed a BSCs carbon fixation model that is driven by soil moisture. The results indicated that moss crusts and algae crusts had significant effects on soil moisture and temperature dynamics by decreasing rainfall infiltration. The mean carbon fixation rates of moss and algae crusts were 0.21 and 0.13 g C/(m^2·d), respectively. The annual carbon fixations of moss crusts and algae crusts were 64.9 and 38.6 g C/(m^2·a), respectively, and the carbon fixation of non-rainfall water reached 11.6 g C/(m^2·a) (30.2% of the total) and 8.8 g C/(m^2·a) (43.6% of the total), respectively. Finally, the model was tested and verified with continuous field observations. The data of the modeled and measured CO_2 fluxes matched notably well. In desert regions, the carbon fixation is higher with high-frequency rainfall even the total amount of seasonal rainfall was the same.

Keywords: moss crusts; algae crusts; soil moisture dynamics; non-rainfall water; effective wetting time

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Biological soil crusts (BSCs) are vital features of arid desert regions. BSCs are widespread communities of diminutive organisms, such as cyanobacteria, green algae, lichens, mosses and other organisms that are closely integrated with particles of the surface soil. Therefore, these communities form a cohesive, thin horizontal layer over the desert landscape (Belnap and Lange, 2003; Li et al., 2004). BSCs are considered desert ecosystem engineers and cover up to 40%–70% of the landscape (Bowker, 2007), especially in extreme environments with low interference. Several studies have confirmed that BSCs are vital carbon sinks in a desert ecosystem because of their considerable photosynthetic capacities (Evans and Lange, 2001; Wilske et al., 2009; Su et al., 2011; Li et al., 2012). For example, under the optimal conditions of hydration and light, the photosynthetic rates of *Collema tenax* are in the upper range of or even higher than the maximal area-related leaf net photosynthesis rates of the plants that characterize the phanerogamous vegetation of the collection site (Lange et al., 1998). Beymer and Klopatek (1991) estimated that the potential annual carbon contribution of lichen soil crusts is 12–37 g C/(m^2·a). Lange et al. (1994) estimated that lichen crusts in Namibia contribute 16 g C/(m^2·a). Therefore, the photosynthetic aspect of BSCs-related

*Corresponding author: Lei HUANG (E-mail: mathecology@163.com)
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ORIGINAL ARTICLE

Soil CO_2 concentration in biological soil crusts and its driving factors in a revegetated area of the Tengger Desert, Northern China

Lei Huang · Zhishan Zhang · Xinrong Li

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Abstract Biological soil crusts (BSCs) are an important cover in arid desert landscapes, and have a profound effect on the CO_2 exchange in the desert system. Although a large number of studies have focused on the CO_2 flux at the soil–air interface, relatively few studies have examined the soil CO_2 concentration in individual layers of the soil profile. In this study, the spatiotemporal dynamics of CO_2 concentration throughout the soil profile under two typical BSCs (algae crusts and moss crusts) and its driving factors were examined in a revegetated sandy area of the Tengger Desert from Mar 2010 to Oct 2012. Our results showed that the mean values of the vertical soil CO_2 concentrations under algal crusts and moss crusts were 600–1,200 μmol/mol at the 0–40 cm soil profiles and increased linearly with soil depth. Daily CO_2 concentrations showed a single-peak curve and often had a 1–2 h time delay after the maximum soil temperature. During the rainy season, the mean soil CO_2 concentration profile was 1,200–2,000 μmol/mol, which was 2–5 times higher as compared to the dry season (400–800 μmol/mol). Annually, soil moisture content was the key limiting factor of the soil CO_2 concentration, but at the daily time scale, soil temperature was the main limiting factor. Combined with infiltration depth of crusted soils, we predicted that precipitation of 10–15 mm was the most effective driving factor in arid desert regions.

Keywords Soil CO_2 concentration · Revegetated desert area · Biological soil crusts · Driving factors

Introduction

In addition to development of the soil profile in terrestrial ecosystems, soil CO_2 has become the major component in soil air. It is one of the key pathways of subsurface CO_2 concentrations that releases into the atmospheric CO_2 pool, which accounts for approximately 5–20 % of the total CO_2 emissions per year (Hansen and Lacis 1990). Previous studies have shown that it is nearly 10 times greater than the contribution of fossil fuel burning (Post et al. 1990). Thus, even small changes or disturbances in CO_2 in the soil horizons may have significant effects on atmospheric CO_2 concentrations and global carbon dynamics in desert regions, since a large portion of organic C is stored in the deeper soil horizons (Fierer et al. 2005; Li et al. 2010a). Biological soil crusts (BSCs) are vital landscapes in desert areas, which occupy more than 40 % of the terrestrial surface (Bowker 2007) and 70 % in extreme environments with less interference. BSCs have a direct effect on the CO_2 production in soil. Thus, the BSCs-related spatiotemporal dynamics of CO_2 production throughout the soil profile should be specifically examined in the surface CO_2 efflux at both the local and regional scales (Li et al. 2010b). In addition, BSCs in the revegetated desert zone have an important ecohydrological effect on rainfall infiltration and shallow water replenishment, which results in further profound changes in the original sand water cycle and soil CO_2 production.

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L. Huang (✉) · Z. Zhang · X. Li
Shapotou Desert Research and Experimental Station, Cold and Arid Regions Environmental and Engineering Research Institute, CAS, Lanzhou 730000, China
e-mail: mathecology@163.com

L. Huang · Z. Zhang · X. Li
Key Laboratory of Stress Physiology and Ecology, Cold and Arid Regions Gansu Province, Lanzhou 730000, China

The extrapolation of the leaf area-based transpiration of two xerophytic shrubs in a revegetated desert area in the Tengger Desert, China

L. Huang, Z. Zhang and X. Li

ABSTRACT

Plant transpiration plays a key role in sand-binding zones, but obtaining accurate estimates at an integrated leaf-individual-canopy scale is difficult. In this study, transpiration rates of two typical xerophytic shrubs, *Caragana korshinskii* and *Artemisia ordosica*, were investigated during the growing season (April–October) from 2008 to 2012 in the Tengger Desert, a revegetated desert area in China. Gas exchange techniques, sap flow measurements, and the crop evapotranspiration minus micro-lysimeter method were used to evaluate plant transpiration. Transpiration data were subsequently compared with the dynamical normalized leaf area-based extrapolation. The results indicated that at leaf level, the transpiration rates of *C. korshinskii* and *A. ordosica* were 2.67 and 4.51 mmol H_2O m^{-2} s^{-1}, respectively. The sap flow rates were 0.071 and 0.086 g h^{-1} cm^{-2} at the tree level, and the transpiration rates were 0.42 and 0.35 mm d^{-1} at the stand level. The total seasonal transpiration of the two xerophytic shrubs reached 71.79 and 55.62 mm, representing approximately 48.4 and 37.5% of the total rainfall over this period. Direct measurements of plant transpiration and upscaling transpiration from leaf level to the stand level exhibited good correspondence, which verified that leaf area was a reliable representation of scaled transpiration, especially in arid desert regions.

Key words | *Artemisia ordosica*, *Caragana korshinskii*, sap flow measurement, transpiration, upscaling

L. Huang (corresponding author)
Z. Zhang
X. Li
Shapotou Desert Research and Experimental Station,
Cold and Arid Regions Environmental and Engineering Research Institute,
CAS,
Lanzhou 730000,
China
E-mail: *mathecology@163.com*
and
Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions Gansu Province,
Lanzhou 730000,
China

INTRODUCTION

Artificial vegetation restoration is considered to be one of the most effective ways to combat desertification and land degradation in arid desert areas (Wang 2004). Xerophytic shrubs, such as *Caragana korshinskii* and *Artemisia ordosica*, have been planted at the southeastern fringe of the Tengger Desert in Western China since 1956 (Li *et al.* 2004). The implementation of this strategy has progressed remarkably over the past years and has played a large role in the control of soil erosion, land degradation, and desertification, as well as in grassland reconstruction (Li *et al.* 2007). However, restoration implementation still faces a number of problems, such as poor understanding of water requirements of desert-living plants. Furthermore, inappropriate tree selection and planting could lead to a reduction in groundwater and the death of sand-binding vegetation in certain regions (Li 2005; Ford *et al.* 2007; Xia *et al.* 2008). Scientists have sought to solve this problem and have developed reliable techniques for estimating the total amount of water transpired by plants (Kelliher *et al.* 1992; Granier *et al.* 1996; Kumagai *et al.* 2004; Dierick & Holscher 2009). Wang *et al.* (2004a, 2004b) have studied the evapotranspiration of *C. korshinskii* and *A. ordosica* using the auto-weighing lysimeter method, and the results have demonstrated that cumulative precipitation and cumulative evapotranspiration were linearly correlated. Huang *et al.* (2010) have studied the sap flow rate of *A. ordosica* and its

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RESEARCH PAPERS

MicroRNA399 Expression Profiles in *Arabidopsis* Seedlings, Callus, and Protoplasts in Response to Phosphate Deficiency[1]

P. Zhao[a, 2], F. Liu[b, 2], and H. Liu[b]

[a] *Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions, Gansu Province, Cold and Arid Regions Environmental and Engineering Research Institute, CAS, Lanzhou 730000, P.R. China*

[b] *Institute of Cell Biology, Life Science School, Lanzhou University, 222# Tianshui Nan Lu, Lanzhou 730000, P.R. China; e-mail: hengliu@lzu.edu.cn*

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Abstract—The functions of microRNA399 (miR399) in response to phosphate (P_i) deficiency have been extensively studied in *Arabidopsis*; however, previous studies have focused on relatively late responses of seedlings. In this study, the expression profiles of five miR399 primary transcripts (pri-miR399s) and mature miR399 were investigated in seedlings, calli, and mesophyll protoplasts. P_i deficiency rapidly stimulated the accumulation of pri-miR399s in the seedlings except pri-miR399b at 1 day; the amount of pri-miR399a decreased at 3 and 5 days. pri-miR399c and pri-miR399e/f showed continuously increasing patterns; the greatest accumulation of pri-miR399d was observed at 3 days. The expression of pri-miR399b, c, and f was significantly induced in the callus after 15 days of exposure to P_i deficiency. In protoplasts, the expression patterns of five pri-miR399s were comparable to those in seedlings at 1 day of P_i deficiency. Mature miR399 accumulated in the treated seedlings; and more than 460-fold of induction was observed in the calli without P_i. The expression profiles of pri-miR399s suggest that these primary transcripts are temporally and tissue-specific regulated in plant responses to P_i deficiency. Moreover, fresh isolated protoplasts could be used to study physiological perception and local signaling of P_i deficiency during early stages.

Keywords: Arabidopsis, microRNA399, phosphate deficiency, expression profile, callus, protoplast

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INTRODUCTION

Phosphate (P_i) availability is a limiting factor of plant growth, development, and yield [1, 2]. To cope with P_i deficiency, plants have developed sophisticated and tightly controlled mechanisms and thus maintain P_i homeostasis in acquisition, storage, allocation, and recycling of plants [1, 3, 4]. Various adaptive strategies are involved in these processes, such as reprogramming their transcriptome, proteome, and metabolome. Recent advances have unveiled that several important components, including transcription factors, SPX domain-containing proteins, and proteins involved in posttranslational modification processes, such as phosphorylation, dephosphorylation, and small ubiquitin-like modifier conjugation (SUMOylation), are involved in a coordinated network that adapts plants to P_i limitation [1–5]. Moreover, sugars and phytohormones, such as gibberellins, ethylene, auxins, cytokinins, abscisic acid, and strigolactones, as well as ions, such as iron, have crucial functions in mediating gene expression profiles and in altering the root system architecture in response to P_i deficiency [1–3]. Aside from these components, microRNAs (miRNAs), such as miR156, miR169, miR395, miR398, miR399, miRNA778, miR827, and miR2111, and non-coding RNAs are uncovered as essential for the plant strategy to cope with P_i status [1, 3, 6, 7].

The miR399 is one of the most characterized miRNAs in the regulation of P_i homeostasis in plants [6, 8–11]. Grafting assays have verified that mature miR399 can be transported via phloem from the shoot to the root, where it directs the cleavage of the transcripts of an ubiquitin-conjugating E2 enzyme UBC24/PHO2 [12, 13]. The suppression of *PHO2* increases the transcript levels of root P_i transporter genes *PHT1;8* and *PHT1;9*, thereby activating P_i uptake [1, 3, 11]. PHO2 regulates P_i transport by ubiquitin-mediated protein degradation; the appropriate expression of *PHO2* is crucial to maintain P_i homeostasis under P_i deficiency and sufficient conditions [3]. The accumulation of miR399 upon P_i limitation is positively regulated by a MYB transcription factor,

[1] This text was submitted by the authors in English.

[2] These authors contributed equally to this work.

Abbreviations: CIM—callus induction medium; IPS1—induced by P_i starvation 1; miRNA—microRNA; PHR1—phosphate starvation response 1; pri-miR399s—primary transcripts of miR399s.

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ORIGINAL ARTICLE

Yang Zhao · Xinrong Li · Zhishang Zhang
Yigang Hu · Yongle Chen

Biological soil crusts influence carbon release responses following rainfall in a temperate desert, northern China

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Abstract How soil cover types and rainfall patterns influence carbon (C) release in temperate desert ecosystems has largely been unexplored. We removed intact crusts down to 10 cm from the Shapotou region, China, and measured them in PVC mesocosms, immediately after rainfall. C release rates were measured in soils with four cover types (moss-crusted soil, algae-crusted soil, mixed (composed of moss, algae, and lichen)-crusted soil, and mobile dune sand). We investigated seven different rainfall magnitudes (0–1, 1–2, 2–5, 5–10, 10–15, 15–20, and >20 mm) under natural conditions. C release from all four BSCs increased with increasing rainfall amount. With a rainfall increase from 0 to 45 mm, carbon release amounts increased from 0.13 ± 0.09 to 15.2 ± 1.35 gC m^{-2} in moss-crusted soil, 0.08 ± 0.06 to 6.43 ± 1.23 gC m^{-2} in algae-crusted soil, 0.11 ± 0.08 to 8.01 ± 0.51 gC m^{-2} in mixed-crusted soil, and 0.06 ± 0.04 to 8.47 ± 0.51 gC m^{-2} in mobile dune sand, respectively. Immediately following heavy rainfall events (44.9 mm), moss-crusted soils showed significantly higher carbon release rates than algae- and mixed-crusted soils and mobile dune sands, which were 0.95 ± 0.02, 0.30 ± 0.03, 0.13 ± 0.04, and 0.51 ± 0.02 μmol CO_2 m^{-2} s^{-1}, respectively. Changes in rainfall patterns, especially large rain pulses (>10 mm) affect the contributions of different soil cover types to carbon release amounts; moss-crusted soils sustain higher respiration rates than other biological crusts after short-term extreme rainfall events.

Y. Zhao (✉) · X. Li · Z. Zhang · Y. Hu · Y. Chen
Shapotou Desert Research and Experimental Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou 730000, China
E-mail: zhaoyang66@126.com

Keywords Arid regions · Biological soil crusts · Extreme rainfall event · Rainfall pattern · Tengger Desert

Abbreviations

BSCs	Biological soil crusts
C	Carbon
EPS	Extracellular polysaccharide
MDS	Mobile dune sand
Rs	Soil respiration
SOC	Soil organic carbon

Introduction

Biological soil crusts (BSCs) are globally widespread communities of diminutive organisms such as cyanobacteria, green algae, lichens, mosses and other organisms. BSCs are closely integrated with surface soil particles, resulting in the formation of a cohesive thin-layer; they may constitute as much as 40 % of the living cover in arid and semi-arid ecosystems. These soil organisms can significantly improve soil stability and fertility by alleviating soil erosion, contributing greatly to carbon (C) assimilation and nitrogen fixation, and creating favorable microhabitats for other organisms (Belnap and Lange 2003; Bowker et al. 2006; Li 2012).

BSCs are major players in the global C cycles, in terms of C uptake from and release to the atmosphere (Elbert et al. 2012). The high photosynthetic C fixation potential of BSCs, such as lichen crusts, makes them an important C uptake pathway (C sink) in desert ecosystems. Thus, researchers have recently become interested in studying BSCs, and their role in C cycling (Zaady et al. 2000; Huxman et al. 2004a, b; Li et al. 2012). BSCs also contribute to C release in desert ecosystems; however, many studies neglect this role (Thomas et al. 2008; Thomas and Hoon 2010; Gao et al. 2012; Li et al. 2012). Castillo-Monroy et al. (2011) found that BSC-domi-

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Soil-Plant Relationships in the Hetao Irrigation Region Drainage Ditch Banks, Northern China

Yang Zhao, Xin-rong Li, Zhi-shan Zhang, Yi-gang Hu, and Pan Wu

Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

Species-environment relationships is a central issue in ecology and important to plant reconstruction and management in degraded ecosystems. We explored how the interactions among soil nutrients, salinity, and ion ratios influence vegetation distribution in the Hetao Irrigation Region drainage ditch banks. Twoway indicator species analysis (TWINSPAN) techniques and Canonical Correspondence Analysis (CCA) were used to classify the vegetation and to examine the relationships between vegetation and soil chemical properties. The plant communities of Saussurea salsa–Phragmites australis–Sonchus arvensis *and* Leymus chinensis–Sonchus arvensis *occurred within 161 of a total 245 plots. Edaphic factors exerted the strongest influence on vegetation patterns and distributions, with available soil nutrient content being identified as the dominant factor, followed by soil salinity and soil pH. Maintaining soil nutrient and salinity at moderate levels is an efficient approach to prevent species loss in the drainage ditch banks.*

Keywords available nutrient, CCA, ion ratios, soil salinity, vegetation distribution

Species-environment relationships is a central issue in ecology and necessary to vegetative reconstruction and management of degraded ecosystems (Guisan and Zimmermann, 2000; Fallu et al., 2002; Li et al., 2009). Water availability was the most important factor in arid and semi-arid regions and high salinity soils, controlling the plant species distribution (Rogel et al., 2001; Li et al., 2008). In irrigated farmland regions, however, water limitation can be mitigated with regular irrigation and can be beneficial to the establishment and survival of plant species. For example, the Hetao Irrigation Region, which uses Yellow River water to supply drainage ditches among crops during the growth season, is the oldest and largest artificial

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Address correspondence to Yang Zhao, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, 730000, Lanzhou, China. E-mail: zhaoyang66@126.com

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ORIGINAL ARTICLE

Variation of albedo to soil moisture for sand dunes and biological soil crusts in arid desert ecosystems

Ya-feng Zhang · Xin-ping Wang · Rui Hu · Yan-xia Pan · Hao Zhang

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Abstract Surface albedo plays a crucial role in the energy balance of soils. The surface albedo and surface soil moisture of bare sand and biological soil crusts (BSCs) were concurrently observed on field plots of shifting sand dune and in revegetated desert ecosystems at Shapotou, northwestern China, to study relationships between surface albedo, solar elevation angle, and surface soil moisture. Results indicated that rainfall exerted a remarkable lowering effect on the variation of surface albedo by increasing surface soil moisture. Surface albedo was an exponential function of solar elevation angle, and the normalized surface albedo (solar elevation angle effect was removed) decreased exponentially with the increase of surface soil moisture. Sand surface had a higher albedo (0.266) than BSCs (0.226) when the surfaces were very dry. However, sand surface albedo became increasingly lower than that of BSCs when the surfaces were in wet conditions and when the soil moisture exceeded a critical value. The changes in soil surface albedo from sand dune to BSCs after revegetation in shallow soil profiles associated with the variation of the surface soil moisture can be seen as an indicator of the degree of sand dune stabilization when compared with the original shifting sand dune soil.

Y. Zhang · X. Wang (✉) · R. Hu · Y. Pan · H. Zhang
Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou 730000, China
e-mail: xpwang@lzb.ac.cn

Y. Zhang
e-mail: zhangyafeng1986@gmail.com

Y. Zhang · R. Hu · H. Zhang
University of Chinese Academy of Sciences, Beijing 100049, China

Keywords Biological soil crusts · Desert ecosystem · Sand dune · Soil moisture · Surface albedo

Introduction

An important consideration when dealing with migrating sand dune-stabilization activities in water-limited ecosystems is the evolution of soil surface albedo. Knowing if and how soil surface albedo is altered by revegetation practices is essential to create vegetation-protective systems that control or cease migration of sand dunes. Research in the field of soil surface albedo has contributed to the knowledge of energy balance of the soil, but the general application of this knowledge to revegetation climatology has not kept pace with the increasing need to understand problems of how water use, heat transfer, and evapotranspiration are interacting in these dune environments. Surface albedo is an important variable in regulating the energy balance of the earth–atmosphere interface. For a given surface, surface albedo is defined as the ratio of reflected shortwave to the incoming shortwave (0.3–3 μm) of solar radiation (e.g., Otterman 1977; Wang et al. 2005). The term albedo is closely related to reflectance, which is usually referred to as a given narrow spectral band and a specific incidence angle. Albedo, then, can be described as effective reflectance, integrating all the wavelengths of the solar radiation over the hemisphere of all possible reflection directions (e.g., Otterman 1977; Ranson et al. 1991; Chapin et al. 2002).

Generally, bare soil albedos are predominantly controlled by soil moisture content, surface type, weather conditions, solar elevation angle, etc. (Zuo et al. 1991; Song 1999; Liu et al. 2008; Zhang et al. 2013). Surface albedo and soil moisture are two important control factors

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Carbon sequestration capacity of shifting sand dune after establishing new vegetation in the Tengger Desert, northern China

Haotian Yang [a,c,*], Xinrong Li [a], Zengru Wang [a], Rongliang Jia [a], Lichao Liu [a], Yongle Chen [a,c], Yongping Wei [b], Yanhong Gao [a], Gang Li [a,c]

[a] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[b] Australian-China Center on Water Resources, Melbourne University, Australia
[c] University of Chinese Academy of Sciences, Beijing 100049, China

HIGHLIGHTS

- Carbon sequestration capacity and potential of restoring desert system are assessed.
- The contribution of different components to TOC is quantified.
- The TOC significantly increased over time in the restoring desert areas.
- Restoring desert ecosystems may accumulate more TOC compared to natural vegetation.
- SOC represented the largest carbon pool for restored systems.

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ABSTRACT

Reconstructing vegetation in arid and semiarid areas has become an increasingly important management strategy to realize habitat recovery, mitigate desertification and global climate change. To assess the carbon sequestration potential in areas where sand-binding vegetation has been established on shifting sand dunes by planting xeric shrubs located near the southeastern edge of the Tengger Desert in northern China, we conducted a field investigation of restored dune regions that were established at different times (20, 30, 47, and 55 years ago) in the same area. We quantified the total organic carbon (TOC) in each ecosystem by summing the individual carbon contributions from the soil (soil organic carbon; SOC), shrubs, and grasses in each system. We found that the TOC, as well as the amount of organic carbon in the soil, shrubs, and grasses, significantly increased over time in the restored areas. The average annual rate of carbon sequestration was highest in the first 20 years after restoration (3.26×10^{-2} kg·m^{-2}·year^{-1}), and reached a stable rate (2.14×10^{-2} kg·m^{-2}·year^{-1}) after 47 years. Organic carbon storage in soil represented the largest carbon pool for both restored systems and a system containing native vegetation, accounting for 67.6%–85.0% of the TOC. Carbon in grass root biomass, aboveground grass biomass, litter, aboveground shrub biomass, and shrub root biomass account for 10.0%–21.0%, 0.2%–0.6%, 0.1%–0.2%, 1.7%–12.1% and 0.9%–6.2% of the TOC, respectively. Furthermore, we found that the 55-year-old restored system has the capacity to accumulate more TOC (1.02 kg·m^{-2} more) to reach the TOC level found in the natural vegetation system. These results suggest that restoring desert ecosystems may be a cost-effective and environmentally friendly way to sequester CO_2 from the atmosphere and mitigate the effects of global climate change.

1. Introduction

Arid and semiarid areas occupy approximately one-third of the land surface worldwide (Reynolds, 2001; Reynolds et al., 2007; Lal, 2004a). These areas are particularly prone to desertification as a result of climatic changes and human activities (Wang, 2003; Schlesinger et al., 1990; Puigdefábregas and Mendizabal, 1998). As a result, the vegetation and soil structure in these areas are degraded, which in turn decreases the capacity of regional ecosystems to store carbon and leads to the release of carbon into the atmosphere (Helldén and Tottrup, 2008). A recent estimate suggests that deserts and semi-deserts cover nearly 22% of the Earth's land surface (Janzen, 2004). However, arid and semiarid areas are spreading because of the desertification occurring in the farming-pastoral transition zone that borders these areas. Historically, it has been estimated that global desertification has caused total carbon

* Corresponding author at: Donggang West Road 320, Lanzhou, Gansu 730000, China. Tel.: +86 0931 4967185, +86 13669377976; fax: +86 09318273894.
E-mail address: yanghaotian6516@163.com (H. Yang).

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Degradation and reorganization of thylakoid protein complexes of *Bryum argenteum* in response to dehydration and rehydration

Jihong Li, Xinrong Li and Cuiyun Chen

Shapotou Desert Research and Experiment Station, Extreme Stress Resistance and Biotechnology Laboratory, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, 730000, P. R. China

Abstract. We analyzed the desert moss *Bryum argenteum* Hedw., a dominant moss in biological soil crusts in northwestern China, during dehydration and rehydration. There was almost no change in chlorophyll content between hydrated and almost completely desiccated *B. argenteum* samples. The amounts of thylakoid protein complexes, including the PSI monomer, PSII supercomplex, the PSII monomer, and LHCII, gradually decreased as the dehydration time of *B. argenteum* was extended. Analysis by two-dimensional sodium dodecylsulfate-urea-polyacrylamide gel electrophoresis showed that the amount of the PSII core subunits CP47 and CP43 and the PSI core subunits PsaA/B decreased during dehydration. The amount of thylakoid protein complexes increased rapidly during rehydration under light conditions, but increased slowly, and to lower levels, during rehydration in the dark. Rehydration of *B. argenteum* in chloramphenicol solution under light conditions resulted in a decrease in F_V/F_M within 10 min. An analysis of chloroplast ultrastructure showed that the number of grana decreased during dehydration. Taken together, our results suggest that the thylakoid protein complexes of *B. argenteum* degrade during dehydration and then reassemble during rehydration, and that this affects the full recovery of photosynthesis in this species.

Keywords. Chloroplast ultrastructure, desiccation tolerance, mosses, northwestern China, thylakoid proteins.

◆ ◆ ◆

Desiccation tolerance (DT) is a characteristic of many organisms, and has been studied for more than 300 years (Alpert 2000; Vicré et al. 2004). In plants, DT is often a feature of reproductive structures, including pollen, spores and seeds (Alpert 2006; Wood 2007). However, the ability to survive during desiccation in vegetative tissues occurs mainly in algae, lichens and mosses (Leprince & Buitink 2010). Phylogenetic analyses have suggested that DT of vegetative tissues existed primitively in basal land plants such as bryophytes. The fact that DT is a rare occurrence in vascular plants suggests that DT evolved independently in different groups of vascular plants (Oliver et al. 2000; Wood & Oliver 2004).

For bryophytes, DT has been defined as the ability to equilibrate internal water potential to that of moderately dry air, and to resume normal function upon rehydration (Alpert 2000). Although DT is a common and characteristic feature of bryophytes, it is not universal among members of this group (Proctor et al. 2007b; Wood 2007). The ecological range of desiccation-tolerant mosses is narrow and marginal; they are found mainly in habitats with very low levels of water availability (Alpert 2000). In many arid and semiarid ecosystems, vegetative cover is generally sparse. The open spaces in such areas are usually covered by desiccation-tolerant mosses, cyanobacteria, fungi, green algae and lichens, which are the main components of biological soil crusts (Belnap & Lange 2003; Li 2003). There has been a large body of research on the ecological roles of biological soil crusts in arid regions. Such roles include reducing soil erosion, improving water infiltration and contributing to carbon assimilation and nitrogen fixation (Belnap et al. 2004; Elbert et al. 2009; Li 2012). Among the different types of crusts, the appearance of moss crusts is considered an indicator of a more stable and late successional stages (Zhang et al. 2009). In the desert environment, moss crusts are frequently subjected to cycles of dehydration, desiccation and rewetting (Charron & Quatrano 2009; Pressel & Duckett 2010; Xu et al. 2009).

Studies on DT plants often use some aspect of photosynthesis as an index of dehydration and recovery. The preservation of the photosynthetic apparatus and chlorophylls during desiccation has been used as a

[1] Corresponding author's e-mail: lxinrong@lzb.ac.cn
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Micro-morphology, ultrastructure and chemical composition changes of *Bryum argenteum* from a desert biological soil crust following one-year desiccation

Jihong Li, Xinrong Li[1] and Peng Zhang

Shapotou Desert Research and Experiment Station, Extreme Stress Resistance and Biotechnology Laboratory, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, 730000, P. R. China

Abstract. Biological soil crusts dominated by mosses are commonly found in arid and semiarid areas, where mosses spend large parts of their time in a state of intense desiccation. The effective recovery of moss crusts after long-term desiccation is vital for their survival. In this study, we analyzed the changes in micromorphology, ultrastructure and chemical composition in *Bryum argenteum* samples desiccated for 1 week or 1 year. We used non-destructive and anhydrous methods of analysis, including scanning electron microscopy, transmission electron microscopy and Fourier transform infrared analysis. After long-term desiccation (1 year), *B. argenteum* samples showed a rapid recovery of F_V/F_M in the light after rehydration. For the 1-year desiccated samples, the thallus remained intact but shrunken. Within the thallus, cell arrangement was disorderly, cell shapes were irregular, and cell walls were thinner. Inside cells, chloroplasts remained intact, but some thylakoids were degraded. In terms of the major cellular components, the lipid and carbohydrate contents increased, the numbers of α helixes and β sheets in protein secondary structures increased, while the number of turn structures in proteins decreased. The changes in protein secondary structure appear to be an important factor in the tolerance of *B. argenteum* to long-term desiccation. The recovery mechanisms that function after rehydration include processes for the repair of protein conformation and the re-synthesis of thylakoids.

Keywords. Biological soil crusts, desiccation tolerance, FTIR, micro-morphology.

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Biological soil crusts dominated by desiccation-tolerant mosses are commonly found in arid and semiarid areas in various geographical regions around the world. In such areas, mosses are in a state of intense desiccation for long periods (Belnap & Lange 2003). Many studies have focused on the ecological roles of biological soil crusts in arid regions. Soil crusts can reduce soil erosion, improve water infiltration, assimilate carbon and fix nitrogen from the atmosphere (Belnap et al. 2004; Elbert et al. 2009; Li, 2012). Among the different types of soil crusts, moss crusts show the strongest ability to prevent wind erosion (Zhang et al. 2009). Furthermore, mosses can improve the soil structure and help to create conditions that favor the growth of vascular plants (Zhang et al. 2009; Li 2012). The appearance of moss crusts is considered to represent a stable part of the late successional biological soil crust progression (Zhang et al. 2009).

Most mosses are defined as poikilohydric desiccation-tolerant plants. This means that their thallus water content tends to be in equilibrium with the water status of their environment (Proctor & Tuba 2002). Mosses become hydrated and active under wet conditions, and dry and dormant under dry conditions (Alpert 2000, 2005). The mechanisms underlying the desiccation tolerance of mosses have been studied extensively (Oliver et al. 2005). It is generally accepted that a constitutive protection system and rehydration-induced recovery mechanisms are responsible for desiccation tolerance (Farrant & Moore 2011). The degree of desiccation tolerance, that is, tolerance to extremely dry conditions, or extremely long dry periods, is thought to rely on the effectiveness of cellular protection mechanisms and the efficiency of repair processes. *Tortula caninervis* and *Tortula ruralis* were shown to resume normal metabolic activity after dry storage for 3 years (Oliver et al. 1993), and *Grimmia laevigata* was able to grow after 10 years of dry storage in a herbarium (Keever 1957). However,

[1] Corresponding author's e-mail: lxinrong@lzb.ac.cn
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Effects of biological soil crusts on soil enzyme activities in revegetated areas of the Tengger Desert, China

Yanmei Liu[a,b,*], Hangyu Yang[c], Xinrong Li[b], Zisheng Xing[d]

[a] School of Life Science and Chemistry, Tianshui Normal University, Tianshui 741001, China
[b] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[c] Gansu Forestry Technological College, Tianshui 741020, China
[d] Faculty of Forestry and Environmental Management, University of New Brunswick, PO Box 4400, 28 Dineen Drive, Fredericton, NB, Canada E3B 5A3

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ABSTRACT

Biological soil crusts (BSCs) cover up to 70% of the sparsely-vegetated areas in arid and semiarid regions throughout the world and play a vital role in dune stabilization in desert ecosystems. Soil enzyme activities could be used as significant bioindicators of soil recovery after sand burial. However, little is known about the relationship between BSCs and soil enzyme activities. The objective of this study was to determine whether BSCs could affect soil enzyme activities in revegetated areas of the Tengger Desert. The results showed that BSCs significantly promoted the activities of soil urease, invertase, catalase and dehydrogenase. The effects also varied with crust type and the elapsed time since sand dune stabilization. All the soil enzyme activities tested in this study were greater under moss crusts than under cyanobacteria–lichen crusts. The elapsed time since sand dune stabilization correlated positively with the four enzyme activities. The enzyme activities varied with soil depth and season, regardless of crust type. Cyanobacteria–lichen and moss crusts significantly enhanced all test enzyme activities in the 0–20 cm soil layer, but negatively correlated with soil depth. All four enzyme activities were greater in the summer and autumn than in spring and winter due to the vigorous growth of the crusts. Our study demonstrated that the colonization and development of BSCs could improve soil quality and promote soil recovery in degraded areas of the Tengger Desert.

1. Introduction

Biological soil crusts (BSCs) are a sub-ecosystem or a microcosm (Castillo-Monroy et al., 2011) and cover up to 70% of the interspaces between sparse vegetation in semiarid and arid regions throughout the world (Belnap, 1995). They are a complex mosaic of soil, green algae, lichens, mosses, micro-fungi, cyanobacteria and other bacteria (Belnap and Lange, 2003). They all develop on the surface of stabilized sand dunes and vary from 2 mm thick, relatively homogeneous cyanobacteria crusts (Zaady and Bouskila, 2002; Li et al., 2011) to complex crusts dominated by lichens and mosses that are up to 30 mm thick (Li et al., 2002). BSC succession generally starts with colonization by large filamentous cyanobacteria (such as *Microcoleus* sp.), which adhere to soil particles by secreting gelatinous polysaccharide materials (Belnap, 2006; Zaady et al., 2010). Smaller pigmented cyanobacteria (such as *Nostoc* sp. and *Scytonema* sp.) and green algae then invade the spaces within the filamentous cyanobacteria. Subsequently, lichens and mosses may grow and colonize as the soil surface stability increases and/or moisture availability improves (Eldridge and Greene, 1994; Kidron et al., 2008; Yu et al., 2012). BSCs have been found to play a number of important ecological roles in desert ecosystems, including enhancing soil aggregation and stability (Belnap, 1996; Guo et al., 2008), adjusting soil temperature and moisture (Belnap, 1995; George et al., 2003), improving soil aeration and porosity (Harper and Marble, 1988; Belnap et al., 2006), adjusting local hydrology (Evans and Johansen, 1999; Belnap and Lange, 2003), promoting vascular plant colonization (Zhao et al., 2011) and improving soil invertebrate and microbial diversity (Darby et al., 2007, 2010; Neher et al., 2009; Liu et al., 2011, 2013).

Soil enzyme activity changes quickly if soil conditions alter and are, therefore, sensitive indicators of changes in soil quality (Puglisi et al., 2006; Trasar-Cepeda et al., 2008; Lebrun et al., 2012).

* Corresponding author at: Tianshui Normal University; Cold and Arid Regions Environmental and Engineering, School of Life Science and Chemistry, Tianshui, Gansu province 741001, China. Tel.: +86 0938 2726327; fax: +86 0938 2726327.
E-mail address: lym-781118@163.com (Y. Liu).

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ORIGINAL PAPER

The effects of urbanization on temperature trends in different economic periods and geographical environments in northwestern China

Feng Fang · Junqin Guo · Landong Sun · Jing Wang · Xinping Wang

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Abstract Using data collected from 22 urban and 65 rural meteorological stations in northwestern China between 1961 and 2009, this paper presents a study concerning the effects of urbanization on air temperature trends. To distinguish among the potential influences that stem from the economic development levels, population scales, and geographic environments of the cities in this region, the 49-year study period was divided into two periods: a period of less economic development, from 1961 to 1978, and a period of greater economic development, from 1979 to 2009. Each of the cities was classified as a megalopolis, large, or medium–small, depending on the population, and each was classified as a plateau, plain, or oasis city, depending on the surrounding geography. The differences in the air temperature trends between cities and the average of their rural counterparts were used to examine the warming effects of urbanization. The results of this study indicate that the magnitude of warming effects due to urbanization depends not only on a city's economic level, but also on the population scale and geographic environment of the city. The urbanization of most cities in northwestern China resulted in considerable negative warming effects during 1961–1978 but evidently positive effects during 1979–2009. The population scale of a city represents a significant factor: a city with a larger population has a stronger warming influence, regardless of whether the effect is negative or positive. Among the three geographic environments of the cities considered, plateaus and plains more significantly enhance warming effects than oases. The urban population trend has a very significant logarithm relationship with the urban temperature effect, but no clear relationships between urban temperature effects and city elevation were detected. The majority of the temperature trends, accounting for more than 60 % of the trends during 1961–2009, can be explained by natural factors, although urbanization has had some obvious effects on temperatures in northwestern China.

F. Fang · J. Wang · X. Wang
Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

F. Fang (✉) · J. Guo
Northwest Regional Climate Center, Lanzhou, China
e-mail: fangfeng0802@126.com

L. Sun
Shanghai Climate Center, Shanghai, China

1 Introduction

Many studies have concentrated on climate change in recent decades, with more and more of the literature predicting that anthropogenic activities may be the most important force driving global warming. The fourth assessment report of Intergovernmental Panel on Climate Change (IPCC) (Trenberth et al. 2007) stated that between 1906 and 2005, the global surface air temperature increases at an average annual rate of 0.74 °C (0.56–0.92 °C/100 a) which is a higher estimate than that of IPCC's Third Assessment Report, which was 0.6 °C (0.4–0.8 °C/100 a). Research results related to temperature trends in China have appeared in a number of studies in the past 20 years. Wang et al. (1998) observed that the average temperature in China increased by 0.44 °C from 1880 to 1996. Ding et al. (2007) found that the rate of increase in surface temperatures in China climbed to 0.79 °C/century (1905–2001) and was higher, 1.1 °C/50a, in the latter half of that period (1951–2001). Zhou et al. (2004) reported that surface temperature warming trends ranging from –0.112 to 0.494 °C/10 a have been detected in different regions across China. Li et al. (2012) reported that the temperature in

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Soil water repellency and influencing factors of *Nitraria tangutorun* nebkhas at different succession stages

HaoTian YANG, XinRong LI, LiChao LIU*, YanHong GAO, Gang LI, RongLiang JIA

Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract: Soil water repellency (WR) is an important physical characteristic of soil surface. It is capable of largely influencing the hydrological and geomorphological processes of soil, as well as affecting the ecological processes of plants, such as growth and seed germination, and has thus been a hot topic in recent research around the world. In this paper, the capillary rise method was used to study the soil WR characteristics of *Nitraria tangutorun* nebkhas. Soil water repellencies at different succession stages of *Nitraria tangutorun* were investigated, and the relationships between soil WR and soil organic matter, total N, and total P, soil texture, pH, and concentrations of CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} were discussed. Soil WR may be demonstrated at the following nebkhas dune evolvement stages: extremely degraded>degraded>stabilized>well developed>newly developed>quick sand. Apart from some soil at the bottom, the WR of other soils (crest and slope of dune) was found to be largest at the topsoil, and decreased as the soil depth increased. The results showed that multiple factors affected soil WR characteristics, e.g. WR increased significantly as the contents of soil organic matter and total N increased, but did not change as the total P content increased. Soil texture was a key factor affecting soil WR; soil WR increased significantly as clay content increased, and decreased significantly as sand content increased. Low pH was shown to be more suitable for the occurrence of soil WR. Four cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and two anions (Cl^- and SO_4^{2-}) enhanced soil WR, while CO_3^{2-} decreased it. HCO_3^- did not show any observable effect. Finally, we established a best-fit general linear model (GLM) between soil-air-water contact angle (CA) and influencing factors (CA=5.606 sand+6.496 (clay and silt)–2.353 pH+470.089 CO_3^{2-}+11.346 Na^+–407.707 Cl^-–14.245 SO_4^{2-}+0.734 total N–519.521). It was concluded that all soils contain subcritical WR (0°<CA<90°). The development and succession of *Nitraria tangutorun* nebkhas may improve the formation of soil subcritical WR. There exist significant relationships between soils subcritical WR and soil physical or chemical properties.

Keywords: hydrophobicity; soil-air-water contact angle; capillary rise method; *Nitraria tangutorun* nebkhas; vegetation succession stage

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Water repellency (WR) is a fundamental physical property of soils. The term refers to the ability to reduce the affinity of soils to water where water entry is resisted or inhibited (Doerr et al., 2000; Blanco and Lal, 2009). The degree of WR may be quantified by the soil-air-water contact angle (CA), which is measurable at the three-phase boundary (i.e. the boundary among the gas, liquid and solid phases; Letey, 1969). In general, a soil surface exhibiting a CA=0° is considered to be hydrophilic (Siebold et al., 1997). CA in the soil surface below 90° represents a subcritical water repellency (slight WR but non-hydrophobic) (Morrow, 1976; Yang and Xi, 1995; Siebold et al., 1997; Shirtcliffe, 2006). When CA>90°, the soils possess an extreme or severe water repellency (DeBano, 2000a; Doerr et al., 2007). Almost all soils show a

*Corresponding author: LiChao LIU (E-mail: lichao@lzb.ac.cn)
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ORIGINAL PAPER

Converting natural vegetation to farmland alters functional structure of ground-dwelling beetles and spiders in a desert oasis

Feng-Rui Li · Ji-Liang Liu · Te-Sheng Sun · Bo-Wen Jin · Li-Juan Chen

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Abstract A vast area of native shrub-dominated steppe at the margins of desert oases in arid regions of China had been reclaimed as farmland in the last century for grain production to feed growing human populations. This study evaluated the consequences of this land-use change on the activity density, taxa richness and composition of functional groups (herbivores, predators and detritivores) of ground-dwelling beetles and spiders, which include some important ecological groups of natural enemies of insect pests (e.g. predatory spiders and beetles), pollinators and decomposers (e.g. detritivorous beetles). Ground-dwelling beetles and spiders were collected using pitfall traps in native steppe habitats and adjacent irrigated farmland of different ages (cultivated either for 27 or at least for 90 years). It was found the conversion of native steppe to farmland, regardless of farmland age, led to a significant increase in activity density of predators, with a greater increase in 90-year-old farmland than in 27-year-old farmland, but did not affect their taxa richness. However, native steppe conversion to farmland, regardless of farmland age, led to significant declines in activity density and taxa richness of both detritivores and herbivores, with a much greater decrease of activity or richness in detritivores than in herbivores in both farmland types. We also observed taxa-specific responses to the land conversion within functional groups. The functional composition of the beetle and spider community shifted from a community dominated by detritivores in the native steppe sites to one dominated by predators in the irrigated farmland sites. Our results suggest that the different functional groups of ground-dwelling beetles and spiders responded in a different way to the land conversion. The remarkable increase in predators and the dramatic decline in detritivores by converting natural vegetation to agricultural land are expected to strongly affect the desert ecosystem services such as biological pest control, pollination and decomposition.

Keywords Agricultural expansion · Biological pest control · Detritivorous arthropods · Ecosystem services · Land-use change · Predatory arthropods

F.-R. Li (✉) · J.-L. Liu · B.-W. Jin
Chinese Ecosystem Research Network Linze Inland River Basin Research Station, Cold and Arid Regions Environment and Engineering Institute, Chinese Academy of Sciences, Lanzhou 730000, China
e-mail: lifengrui@lzb.ac.cn

F.-R. Li · T.-S. Sun
Gansu Key Laboratory of Stress Physiology and Ecology, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

J.-L. Liu · B.-W. Jin · L.-J. Chen
Laboratory of Water and Soil Resources, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Introduction

Ground-dwelling arthropods, which include keystone ecological groups of biological control agents (e.g. predatory spiders and insects) against insect pests (Shelton et al. 1983; Riechert and Lockley 1984; Marc and Canard 1997; Suenaga and Hamamura 2001), pollinators (Stanley and Stout 2013) and decomposers (e.g. detritivorous arthropods), have been shown to be important for the functioning of agricultural systems (Landis et al. 2000; Nyffeler and Sunderland 2003; Woltz et al. 2012; Stanley et al. 2013). The globe is undergoing a rapid loss of ground-dwelling

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Gravel-sand mulch thickness effects on soil temperature, evaporation, water use efficiency and yield of watermelon in semi-arid Loess Plateau, China

Yajun Wang [a], Zhongkui Xie [a,*], Sukhdev S. Malhi [b], Cecil L. Vera [b], Yubao Zhang [a]

[a] Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[b] Agriculture and Agri-Food Canada, Research Farm, P.O. Box 1240, Melfort, Saskatchewan S0E 1A0, Canada

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ABSTRACT

Mulch thickness is one of the important factors affecting soil moisture and temperature. Two field experiments were conducted at Gaolan, Gansu, China, to investigate the influence of gravel-sand mixture mulch thickness on soil temperature, evaporation, evapotranspiration, water use efficiency (WUE) and yield. There were 5 levels of gravel-sand mulch thickness in Experiment 1 (3, 5, 7, 9 and 11 cm; without crop) and 4 levels of gravel-sand mulch thickness plus 80% plastic film mulch in Experiment 2 (3, 5, 8 and 11 cm; cropped to watermelon). There was a close negative relationship between mulch thickness and soil evaporation, with exponential function. Mulch decreased soil evaporation up to a thickness of 7 cm. The soil temperature from 11:00 to 18:00 was slightly lower with mulching compared to no mulching and, as a result, mulch not only decreased the temperature difference between day and night, but also it had a lag. In addition, the peak soil temperature at 5 cm depth was reduced and the soil temperature at night was raised with increased mulch thickness. Mulch had no further effect on soil temperature when thickness is greater than 7 cm. With 80% plastic film mulch, a significant effect on watermelon yield and WUE was detected among the different treatments used in this study, with the highest yield and WUE obtained with the 8 cm mulch thickness treatment. Therefore, 7–8 cm of mulch thickness appears to be the most appropriate option for gravel-sand mulch to sustain high watermelon yield and WUE.

1. Introduction

Gravel and sand mulch is a traditional water conservation technique that has been used for hundreds of years in the loess area of northwestern China. Recently, this technique has expanded its usage, due to the lack of water sources and high irrigation costs. In parts of this region, irrigating fields have almost been replaced by the use of gravel-sand mulch on dry land. Extensive research and practical experience have proved that gravel-sand mulch could markedly reduce soil evaporation and increase soil temperature at night as well as reduce soil temperature fluctuations ([1–5]). Nachtergaele et al. (1998) determined that gravel mulch causes a significant increase in the soil temperature measured at two soil depths (mean increase of 1.0 °C and 1.5 °C at 3 and 10 cm soil depth, respectively) in vineyards of southern Switzerland. Chen et al. [6] and Xie et al. [5] studied the effect of gravel size on soil evaporation, and showed a positive linear relationship between gravel size and soil evaporation. Also, gravel size impacted the porosity of mulch layer and the process of hydraulic transfer and thermal conduction [7].

Besides gravel size, however, there has been little research reported in the literature with respect to mulch thickness as another important factor affecting hydraulic transfer and thermal conduction. Tsutomu et al. [8] measured the influence of mulch thickness on soil evaporation resistance. His results showed that soil evaporation resistance can exponentially increase with the increase of mulch thickness. In China, the mulch thickness effect on soil temperature was only mentioned in reference to the ballast embankment and revetment along the Tibet-Qing railway [9]. However, the purpose of using mulch is totally different between the revetment of an embankment and mulching of farm land. In addition, gravel-sand mulch is a high-cost technique under conservation tillage (no-tillage) and its thickness is a considerable factor when linked with the total cost. Thus, it is essential to determine the impact of mulch thickness on soil evaporation and temperature, in order to optimize the structure of the gravel-sand layer to preserve maximum soil temperature and moisture at the minimum cost. Therefore, the objective of this study was to investigate the influence of mulch thickness on soil temperature and evaporation (Experiment 1, without crop), and to determine the relationship between mulch

* Corresponding author.
E-mail address: wxhcas@lzb.ac.cn (Z. Xie).

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ORIGINAL ARTICLE

Response of soil properties and C dynamics to land-use change in the west of Loess Plateau

Lihua ZHANG[1], Ruifeng ZHAO[2] and Zhongkui XIE[1]

[1]*Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China,*
[2]*College of Geography and Environment Science, Northwest Normal University, Lanzhou 730070, China*

Abstract

Land-use change (LUC) is widely considered a major factor that affects soil organic carbon (SOC) sequestration. The impacts of four LUC types on soil properties, SOC, particulate organic carbon (POC) and labile organic carbon (LOC) at the 0–100 cm depth were examined in the west of Loess Plateau, northwest China. Bulk density at the 20–40 cm depth increased significantly after native grassland conversion to cropland, while artificial grassland establishment and abandonment on former cropland caused reverse change. Soil water content in the profile increased 60–230% after cultivation and decreased 32–49% after abandonment ($p < 0.01$). The particle size distribution also showed a response to LUC. Only artificial grassland establishment caused an SOC sink of 32% at the 0–10 cm depth as well as two labile fractions. SOC tended to increase after cultivation and after abandonment, with 6% and 20% at soil surface, respectively. There were increasing trends in POC and LOC. After afforestation on former native grassland, SOC tended to decrease (23%) at the 0–10 cm depth while POC and LOC tended to increase (33% and 6%, respectively). Principal component analysis was successful in separating LUC through soil property parameters. Carbon sequestration is largely ascribed to increased below-ground production and tillage elimination after perennial alfalfa (*Medicago sativa* L.) plantation. Irrigation and fertilization activities contribute to SOC accumulation after cultivation to some extent. The self-restoration dynamic depending on time since abandonment is important to SOC change. A lower proportion of stabilized carbon results in a slow rate of SOC accumulation after afforestation. It is necessary to investigate the long-term dynamic after LUC.

Key words: Land use change, soil organic carbon sequestration, labile organic carbon, particulate organic carbon, semiarid region

INTRODUCTION

Stabilization of rising atmospheric carbon dioxide (CO_2) concentration is the biggest ecological interest nowadays in the world (Kerr 2007). Globally, the soil organic carbon (SOC) stock is 1550 Pg to a 1-m depth; it is about three times higher than the atmospheric carbon pool and two times higher than in the biota (Lal 2008). Therefore, the balance between inputs and outputs of SOC has a critical influence on the atmospheric concentration of CO_2 (Post and Kwon 2000). Land-use change (LUC) is widely considered a major factor that affects SOC sequestration (Lal 2008; Poeplau and Don 2013). Conversion of primary forest into perennial crops reduced SOC stocks by 30%, and they were the highest SOC losses related to LUC in the tropics (Don *et al.* 2011). The global average SOC sequestration rate was 33.2–33.8 g m^{-2} yr^{-1} due to revegetation on cultivated lands (Post and Kwon 2000). Therefore, monitoring SOC for LUC is essential for estimating the SOC distribution and sequestration.

A number of studies have been performed on the effect of LUCs on SOC concentration at global (Post and Kwon 2000; Don *et al.* 2011), country (Wu *et al.* 2003; Poeplau and Don 2013), regional (Wang *et al.* 2011; Schulp *et al.* 2013) and site (Raiesi 2012; Shimoda and Koga 2013) scales. LUC in semiarid and

Correspondence: L. ZHANG, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China 320 West Donggang Road, Lanzhou, Gansu 730000, China. Email: zhangzhuang80@126.com
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Regular research paper

Yuhui HE*, Xinping LIU, Zhongkui XIE

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou, 730000, China
*e-mail: ahuihyh@126.com (*corresponding author*)

SHRUB EFFECTS ON HERBACEOUS VEGETATION VARY WITH GROWTH STAGES AND HERB RELATIVE LOCATION

ABSTRACT: In arid and semi-arid ecosystems, shrubs have an important effect on neighboring plants. However, little is known about the interaction of herb growth stages and shrub location on herb performance. We selected *Reaumuria soongorica*, (Pall.) Maxim a shrub dominant in the semiarid region of northwest China, to determine whether (1) shrubs facilitate or have negative effects on neighbouring herbaceous vegetation, and (2) such effects vary with herb growth stage and with shrub orientation relative to herbs. The presence of herbaceous plant species, plant density, plant height, and percent cover were determined along 2 m long transects spreading in four directions from the base of shrub – east (transect E), west (transect W), south (transect S), and north (transect N); this was repeated for three growth stages (in May, June and July). Results indicated that the effects of *R. soongorica* on neighboring herbs in different growth stages were similar. Species number of herb-layer plants tended to increase from beneath the canopy to the opening, but plant density, cover and plant height decreased with distance away from shrub base. The presence of *R. soongorica* had positive effects on density, cover, and plant height, and negative on the number of herbaceous species during the entire growing season. Herbaceous plants growing on transect N under the shrub canopy had significantly higher density and percent cover than those growing in other directions. Biomass of herbs on transect N grown under the shrub canopy was higher than that of herbs on other transects. We concluded that shrub effects on neighbouring herbaceous vegetation were closely related to the shrub orientation relative to the herbs. Therefore, using shrubs as nurse plants for grass-growing must consider the relative placement of shrubs.

KEY WORDS: shrub effects, *Reaumuria soongorica*, herbaceous plants, relative location, growth stage, microhabitats, northwest China

1. INTRODUCTION

In arid and semi-arid ecosystems, shrubs exert important effects on the neighboring plants. Shrubs can influence the growth of other plants, and the structure and function of the herbaceous vegetation in these ecosystems (Armas and Pugnaire 2005, Cavieres and Badano 2009). Research revealed both positive and negative effects of shrubs on neighbouring plants in arid and semiarid ecosystems, the type of outcome commonly related to specific environmental conditions and studied species. Research has focused on shrub effects in relation to soil properties and soil moisture (Rossi and Villagra 2003, Li *et al.* 2010). Shrub effects in different stress gradients and about different shrub species are especially well documented

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ORIGINAL ARTICLE

Long-term gravel–sand mulch affects soil physicochemical properties, microbial biomass and enzyme activities in the semi-arid Loess Plateau of North-western China

Yang Qiu, Yajun Wang* and Zhongkui Xie

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 West Donggang Road, Lanzhou 730000, China

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The use of gravel–sand mulch is a traditional water-conservation technique in the semi-arid Loess Plateau of North-western China. In this study, we investigated the 16-year effects of this mulch on soil physicochemical properties (total organic C, N and P; bulk density; Ca, Cu, Fe, Mg, Mn and Zn; soil texture; pH), microbial biomass C, N and P and enzymatic activities (peroxidase, dehydrogenase, invertase, β-glucosidase, alkaline phosphomonoesterase and urease) in a field trial in China's Gaolan County. We examined how these parameters changed after 7, 11 and 16 years of mulching. After 16 years, soil bulk density and sand content increased significantly. Soil Ca and Cu contents did not change significantly during the study period, but Fe, Mg, Mn and Zn contents all decreased significantly after 16 years. The total N increased significantly after 11 years, but total C and N both decreased dramatically and significantly after 16 years (by 22% and 13%, respectively, compared to the control). The mulch significantly increased microbial biomass C (by 29% after 11 years), with similar results for N and P, but these positive effects were lost after 16 years. Enzyme activities revealed changes in the soil microbial community over time; the mulch increased enzyme activities until 11 years, followed by a significant decrease that suggested degradation of soil quality after long-term mulching. The positive effects of the mulch (increasing soil temperature) could explain the high microbial biomass and enzyme activities after 11 years. However, long-term increases in soil bulk density and sand content (caused by mixing of the mulch layer with the surface soil) and a lack of inputs of organic matter (caused by the barrier created by the mulch layer) led to degradation of the soil after 16 years.

Keywords: gravel–sand mulch; mulching; soil enzymatic activity; soil microbial biomass; total organic carbon; total nitrogen

Introduction

Gravel–sand mulch is a traditional water-conservation technique that has been used for hundreds of years in the loess area of North-western China. The mulch is a mixture of particles ≥2 mm in diameter, about 10 cm thick, that is used to reduce the risk of crop failure, which frequently occurs due to low rainfall and high rates of evaporation in this region. The porous mulch layer is built on the soil surface to change the processes of heat conduction and hydraulic transfer. Fields mulched with gravel and sand are mainly distributed in the North-western part of the Loess Plateau, which lies in the transitional zone between the arid and semi-arid regions. In this region, the mean annual precipitation is between 250 and 350 mm, of which nearly 70% occurs between June and September (Li & Gong 2002). In the 1990s, 118 000 ha of such fields had been established in Gansu Province.

Gravel–sand mulch effectively reduces evaporation and run-off, increases soil temperature and retains soil moisture (Lightfoot & Eddy 1994; Li 2003; Wang et al. 2008; Yuan et al. 2009; Ma & Li 2011). The efficiency of the mulch varies widely, depending on its characteristics, position, thickness and particle-size distribution (Poesen et al. 1990; Kemper et al. 1994; Pérez 1998, 2000; Yuan et al. 2009; Xie

*Corresponding author. Email: w.yajun@yahoo.com

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Long-term effects of gravel–sand mulch on soil organic carbon and nitrogen in the Loess Plateau of northwestern China

Yang QIU[1], ZhongKui XIE[1*], YaJun WANG[1], Sukhdev S MALHI[2], JiLong REN[1]

[1] Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China;
[2] Northeast Agricultural Research Foundation (NARF), Melfort S0E 1A0, Canada

Abstract: Gravel–sand mulch has been used for centuries to conserve water in the Loess Plateau of northwestern China. In this study, we assessed the influence of long-term (1996–2012) gravel–sand mulching of cultivated soils on total organic carbon (TOC), light fraction organic carbon (LFOC), microbial biomass carbon (MBC), total organic nitrogen (TON), particulate organic carbon (POC), mineral-associated organic carbon (MOC), permanganate-oxidizable carbon ($KMnO_4$-C), and non-$KMnO_4$-C at 0–60 cm depths. Mulching durations were 7, 11 and 16 years, with a non-mulched control. Compared to the control, there was no significant and consistently positive effect of the mulch on TOC, POC, MOC, $KMnO_4$-C and non-$KMnO_4$-C before 11 years of mulching, and these organic C fractions generally decreased significantly by 16 years. LFOC, TON and MBC to at a 0–20 cm depth increased with increasing mulching duration until 11 years, and then these fractions decreased significantly between 11 and 16 years, reaching values comparable to or lower than those in the control. $KMnO_4$-C was most strongly correlated with the labile soil C fractions. Our findings suggest that although gravel–sand mulch may conserve soil moisture, it may also lead to long-term decreases in labile soil organic C fractions and total organic N in the study area. The addition of manure or composted manure would be a good choice to reverse the soil deterioration that occurs after 11 years by increasing the inputs of organic matter.

Keywords: gravel mulch; mulching duration; permanganate-oxidizable carbon; light fraction organic carbon; microbial biomass carbon

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The use of gravel–sand mulch is a traditional water-conservation technique that has been used for centuries in the loess region of northwestern China (Li, 2003). A porous layer of gravel and sand about 10 cm thick that lies on the soil surface could reduce the risk of crop failure, which frequently occurs due to a combination of low precipitation and high evaporation that creates severe soil moisture deficits. This technique has been promoted and widely adopted due to the lack of sufficient water or high irrigation costs (Wang et al., 2011). In the Loess Plateau, the mean annual precipitation is between 250 and 350 mm, of which nearly 70% occurs between June and September (Xie et al., 2006). The gravel-sand mulch could effectively reduce evaporation and runoff, and increase the soil temperature and retain soil moisture (Nachtergaele et al., 1998; Wang et al., 2008, 2010; Xie et al., 2010; Ma and Li, 2011). However, the efficiency of the mulch varies widely, depending on mulch characteristics such as its color, thickness, particle size distribution and gravel texture (Fairbourn, 1973; Poesen et al., 1990; Kemper et al., 1994; Pérez, 1998, 2000; Yuan et al., 2009).

Soil organic matter (SOM) is key component of soil fertility and vegetation productivity because of its importance for soil physical, chemical and biological properties (Johnston, 1986; Stevenson, 1986; Reeves, 1997; Zhang et al., 2012). However, two soils with the

*Corresponding author: ZhongKui XIE (E-mail: wxhcas@lzb.ac.cn)
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Disease Notes

First Report of *Fusarium tricinctum* Causing Stem and Root Rot on Lanzhou Lily (*Lilium davidii* var. *unicolor*) in China

Q. H. Shang and X. Zhao, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China, and University of Chinese Academy of Sciences, Beijing 100049, China; Y. Y. Li, School of Life Sciences, Lanzhou University, Lanzhou 730000, China; andZ. K. Xie and R. Y. Wang, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Lanzhou lily (*Lilium davidii* var. *unicolor* Cotton) is an important bulb edible crop which mostly distributes in middle area of Gansu Province in China (2). Recently, plants of Lanzhou lily developed symptoms of severe wilting. In early autumn of 2012 to 2013, a survey of Lanzhou lily disease was carried out in Yuanjiawan, Caoyuan, Xiguoyuan, and Hutan villages of Lanzhou City and Xuding and Guanshan villages of Linxia Prefecture. Disease symptoms included stem and root rot, vessels showed a brown to dark brown discoloration, plus a progressive yellowing and wilting of leaves from the base. Small pieces of symptomatic leaves, stems, and roots were surface disinfected with 75% ethanol for 30 s, 3% sodium hypochlorite for 5 min, and then washed three times in sterile distilled water. The tissues were placed on Martin Agar at 25°C for 7 days. Three isolates were consistently isolated from diseased tissues and all isolates with morphology similar to*Fusarium* spp. Isolates were transferred to potato dextrose agar (PDA) and carnation leaf agar (CLA) and incubated at 25°C in darkness. These isolates grew rapidly on PDA and formed abundant dense aerial mycelium, initially white, that became deep pink with age and formed red pigments in the medium. On CLA, macroconidia with 3 to 5 septa were abundant, relatively slender, and curved to lunate. Microconidia were abundant, oval and 0 to 1 septa. Chlamydospores were globose with a smooth outer wall in chains. The rDNA internal transcribed spacer (ITS) region comprising ITS1, ITS2, and 5.8S rDNA was amplified using primers ITS-1 and ITS-4 (3) and sequenced. On the basis of a comparison of 563 bp, all the three isolates had the identical sequence (GenBank Accession No. KF728675). BLASTn analysis of the sequence showed 100% match with the ITS sequences of those *F. tricinctum* sequences in GenBank (Accession Nos. FJ233196, AY188923, and JF776663). Pathogenicity test was performed by transplanting 2-month-old tissue culture seedlings to plastic pots in a sterile mixture of vermiculite and torf substrate at 1:3 (v/v). Seedlings were inoculated with 6 ml of the conidial suspension (10^4conidia/ml) on the roots of plant in each pot, three plants per pot, and three replicates for each treatment. Seedlings treated with sterile water served as controls. The seedlings were placed in a plant growth chamber maintained at 22 ± 3°C, relative humidity >70%, 16 h light per day, and irrigated with sterile water. After 4 weeks, inoculated plants exhibited wilting foliage that with symptoms similar to those observed in the field, while the control plants remained healthy. *F. tricinctum*was re-isolated from all inoculated plants. The disease has been reported previously in ornamental lily in China (1). However, to the best of our knowledge, this is the first report of *F. tricinctum* causing wilt on edible

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Single and Mixed Viral Infection Reduced Growth and Photosynthetic Pigment Content, Damaged Chloroplast Ultrastructure and Enhanced Virus Accumulation in Oriental Lily (*Lilium auratum* cv. Sorbonne)

Yubao Zhang[1], Zhongkui Xie[1,*], Ruoyu Wang[1], Hadley Randal Kutcher[2], Yajun Wang[1] and Zhihong Guo[1]

[1]Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[2]College of Agriculture and Bioresources, University of Saskatchewan, Saskatoon SK S7N, 5A8, Canada
[*]Author for correspondence; e-mail: zyubao@yahoo.com, wxhcas@lzb.ac.cn; Tel.: + (86) 931 4967198; + (86) 931 4967206; Mobile: + (86) 13139250136; Fax: + (86) 931 8273894
Portion of the Ph.D. dissertation of Yu bao Zhang, under the supervision of Zhongkui Xie.

Both single- and mixed-infection experiments were performed to study the effects of *Lily mottle virus* (LM_0V) and *Cucumber mosaic virus* (CMV) on the growth, photosynthetic pigment content, chloroplast structure and virus accumulation in oriental lily (*Lilium auratum* L. cv. Sorbonne). Virus infection with LM_0V significantly reduced plant height and leaf length and width. Mixed infection with LM_0V and CMV caused significantly more severe effects on growth than single infection by LM_0V. In leaves exposed to mixed infection, there was a decrease in content of chlorophyll a (chl *a*), chlorophyll b (chl *b*), and carotenoids (car) as well as in the chl *a*/*b* and chl (*a*+*b*)/ car ratios. In addition, mixed infection greatly damaged the chloroplast ultrastructure. Plants infected with both viruses exhibited a significantly greater accumulation of LM_0V coat protein (CP) gene compared with the single infection by LM_0V. These results clearly indicated that mixed infection by LM_0V and CMV brought about more damage to the growth and photosynthetic apparatus of lily plant compared with single infection by LM_0V.

Key Words: *Lily mottle virus* (LM_0V), *Cucumber mosaic virus* (CMV), mixed viral infection, oriental lily, *Lilium auratum* L. cv. Sorbonne, real-time PCR assay

Abbreviations: 18S rRNA – 18S ribosomal Ribonucleic acid, car – carotenoids, chl *a*+*b* – total chlorophyll, chl *a* – chlorophyll a, chl *b* – chlorophyll b, CP – coat protein, CMV – *Cucumber mosaic virus*, Ct – threshold cycle value, LM_0V – *Lily mottle virus,* real-time PCR – real-time polymerase chain reaction, RNA – ribonucleic acid

INTRODUCTION

Lily (*Lilium* spp.) is a worldwide floricultural crop and ranks seventh in terms of the economic value of cut flower production (Lian et al. 2003; Wang et al. 2007). In China, oriental lily (*Lilium auratum* L.) is commonly cultivated in regions with a mild climate in both the northern and the southern parts of the country. Gansu Province is an important location for the production of oriental lily in northwestern China.

One of the main limitations to lily cultivation is the susceptibility of this species to viral diseases (Sharma et al. 2005). More than 10 viruses have been reported to infect lilies worldwide (Ryu et al. 2002), and the two frequently occurring viruses are the *Lily mottle virus* (LM_0V) and *Cucumber mosaic virus* (CMV) (Asjes 2000). LM_0V is a member of the potyvirus genus within the potyviridae family. LM_0V-infected plants exhibit mosaic patterns and necrotic spots on leaves which may also be elongated and distorted. Other symptoms include dwarfing, flower breaking and failure to bloom (Kong et al. 2009). CMV is a member of the genus *Cucumovirus* (family *Bromoviridae*). Leaves infected with CMV initially display chlorotic, yellow spots or stripes, or vein-clearing, followed by the development of grey or brown necrotic spots. A coarse breaking pattern in the flowers occurs in some cultivars, and leaves and petals may curl and become malformed (Ryu et al. 2002). Mixed infection by both LM_0V and CMV has been

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Photosynthetic Pigment Content, Phenol and Flavonoid Concentration, and Defense Enzyme Activity of Oriental Lily (*Lilium auratum* L. cv. Sorbonne) Infected with *Lily Mottle Virus*

Yubao Zhang[1], Zhongkui Xie[1,*], Hadley Randal Kutcher[2], Yajun Wang[1], Ruoyu Wang[1] and Zhihong Guo[1]

[1]Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Science, Lanzhou 730000, China
[2]College of Agriculture and Bioresources, University of Saskatchewan, Saskatoon SK S7N, 5A8, Canada
[*]Author for correspondence; e-mail: zyubao@yahoo.com; wxhcas@lzb.ac.cn; Tel.: + (86) 9314967198; + (86) 9314967206; Mobile: + (86) 13139250136; Fax: + (86) 9318273894

The effects of *Lily mottle virus* (LMoV) infection were determined on the photosynthetic pigment content, total phenol and flavonoid concentration, and the activities of defense enzymes including peroxidase (POD), polyphenol oxidase (PPO), superoxide dismutase (SOD) and phenylalanine ammonia lyase (PAL) of oriental lily (*Lilium auratum* L. cv. Sorbonne). Compared with the healthy control, the chlorophyll content varied in the LMoV-infected plants. The levels of chlorophyll a (Chl *a*), chlorophyll b (Chl *b*) and total chlorophyll (Chl *a+b*) in the LMoV-infected plants were either not significantly different from the control, or were significantly decreased. The effect of LMoV infection on carotenoid levels was rather variable. Moreover, total phenol and flavonoid concentration were significantly enhanced after LMoV infection, and significantly higher POD activity was observed in all the LMoV-infected plants. Significantly higher PPO, SOD and PAL activity was noted only in partly LMoV-infected plants. Furthermore, when the LMoV CP gene copies ranged between negative and 1.24×10^{-5}, a quadratic relationship was confirmed between the values for the LMoV CP gene copies and the photosynthetic pigment content, total phenol and flavonoid concentration. Our results indicate that the reduced proliferation of viral gene copies decreased the damage of disease to some extent.

Key Words: *Lilium* species, *Lily mottle virus*, phenol and flavonoid concentration, photosynthetic pigment content, defense enzyme activity, LMoV CP gene copies

Abbreviations: 18S rRNA – 18S ribosomal RNA, Chl *a+b* – total chlorophyll, Chl *a* – chlorophyll a, Chl *b* – chlorophyll b, CP – coat protein, LMoV – *Lily mottle virus*, NBT – nitro-blue tetrazolium, PAL – phenylalanine ammonia lyase, POD – peroxidase, PPO – polyphenol oxidase, RNA – ribonucleic acid, SOD – superoxide dismutase, TBV – *Tulip breaking virus*

INTRODUCTION

Lilies are in demand in the floriculture industry both as cut and potted flowers and are one of the top 10 flowers in China and for the export market worldwide. In China, oriental lily (*Lilium auratum* L.) is commonly cultivated in regions with a mild climate in both the northern and the southern regions across the country. Gansu Province is an important location for the production of oriental lily in northwestern China.

One of the main limitations to the cultivation of lily is its susceptibility to viral diseases (Sharma et al. 2005). Over 10 viruses have been reported to infect lilies worldwide, and the *Lily mottle virus* (LMoV) is one of the most prevalent (Ryu et al. 2002). LMoV is closely related to the *Tulip breaking virus* (TBV) (Alper et al. 1982; Maeda et al. 1984), and is a member of the Potyvirus; its particles are 750 to 770 nm long (King et al. 2011). LMoV can be transmitted by mechanical inoculation, grafting and aphids, and is disseminated when lily bulbs are transported (Brunt et al. 1996), so that a number of avenues exist for the spread of LMoV during propagation (Kong et al. 2009). LMoV-infected leaves are light to yellowish green, appear in a mottled or mosaic pattern, and become twisted or tapered. Diseased plants are often shorter than healthy plants, die prematurely and have a shorter vase life as cut flowers (Ryu et al. 2002).

Biochemical parameters play a vital role to impart resistance against many diseases (Arora et al. 2009). Multiplication of virus particles in the infected plant cell alters the amounts of the biochemical compounds such as chlorophyll, β-carotene, phenolic compounds, flavonoid and the activity of defense enzymes, e.g., polyphenol oxidase (PPO), peroxidase (POD), superoxide dismutase (SOD), phenylalanine ammonia-lyase (PAL) and nucleic acids (Devi and Radha 2012). POD participates in a variety of plant defense mechanisms in which H_2O_2 is

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Identification of autotoxins from root exudates of Lanzhou lily (*Lilium davidii* var. *unicolor*)

Z. J. WU, Z. K. XIE*, L. YANG, R. Y. WANG, Z. H. GUO, Y. B. ZHANG, L. WANG and H. R. KUTCHER[1]

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
E. Mail: zjw1234@yahoo.com

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ABSTRACT

Replant problem is a serious production constraint in continuously cropped Lanzhou lily (*Lilium davidii* var. *unicolor*), an edible bulb lily. However, relatively little is known about the autotoxins that cause replant problems of lily. Autotoxins from root exudates of lily were collected using XAD-4 resin, analyzed by GC-MS and quantified in soil by HPLC. Radicle growth of lettuce was significantly inhibited by lily root exudates and the degree of inhibition increased with increasing concentration of exudates. In the most phytotoxic fraction, most of the compounds were phenolic and aliphatic acids and phthalic acid was dominant. The identified phytotoxic allelochemicals were phthalic, adipic, palmitic, oleic and stearic acids. In *in vitro* tissue culture assay of lily, phthalic and adipic acids were very autotoxic to lily. As the number of years of continuous lily monoculture increased, so did the concentrations of phthalic acid in soil (from 9.73 to 27.73 $\mu g \cdot g^{-1}$ dry soil, after 3 years cropping). It was concluded that phthalic acid was released in large quantities from roots and accumulated in soil with the increase in duration of monoculture. Phthalic acid may be one of the major factors causing replant problem in lily.

Key words: Allelochemicals, autotoxins, autotoxicity, continuous cropping, Lanzhou lily, *Lilium davidii*, *monoculture,* phthalic acid, replant problem, root exudates.

INTRODUCTION

Lanzhou lily (*Lilium davidii* var. *unicolor*), bulbs are consumed as food and is major crop in central Gansu province, China. The unique climate in the region gives edible lily a special sweet taste and quality, hence, it is popular in southern China, Korea and Japan. However, due to its perennial habit and limited area in which it can be grown, lily is cultivated in continuous monoculture resulting in serious soil replant problem or soil sickness, which significantly decreases the yield and quality.

Replant problems occurs in many crops (1,6,8,10,11,12) mainly in glasshouse cropping systems. There are many factors causing replant problems, viz., soil nutrients depletion, build up of plant diseases and autotoxicity (8). In natural or manipulated ecosystems, plant species possessing the autotoxic phenomenon regulates their populations over space and time, avoid intra-competition, self-perpetuation and have

*Correspondence author. [2]College of Agriculture and Bioresources, University of Saskatchewan, Saskatoon SK S7N 5A8. Canada

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Influence of gravel mulch stratum thickness and gravel grain size on evaporation resistance

Yang Qiu [a], Zhongkui Xie [a,*], Yajun Wang [a], Jilong Ren [a], Sukhdev S. Malhi [b]

[a] Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[b] Northeast Agricultural Research Foundation (NARF), Melfort S0E 1A0, Canada

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SUMMARY

In the Loess Plateau of northwestern China, a system for dry farming has evolved based on the employ of gravel mulch. A couple of lab experiments were conducted to study the influences of mulch stratum thickness and gravel grain size on water vapor flow, with a focus on resistance to evaporation in gravel mulch stratum. In Experiment 1, six treatments included mulching with gravel of different thickness (2 cm, 4 cm, 6 cm, 8 cm and 10 cm) plus no mulching (control) were studied. In Experiment 2, the 10 cm thick mulch layer consisted of different grain size gravel [2–5 (A), 5–20 (B), 20–40 (C), 40–60 (D) and 60–80 (E) mm], plus three mixture treatments. Compared to bare soil, mulched soils had significantly lower accumulated evaporation, and gravel mulch significantly increased resistance to evaporation. The aerodynamic resistance to evaporation in bare soil is higher than that in mulched treatments and the relationship between equivalent grain size and aerodynamic resistance in mulched surface can be described by a line function. The relationships between mulch resistance and mulch stratum thickness or grain size of gravel, were represented by logistic curves. The findings showed that equivalent grain size and specific surface area of gravel were sensitive indicators of mulch resistance. Based on the results of laboratory experiments, we put forward a new calculated model of mulch resistance, but further research is needed for verification and exact parameterization of this model under field conditions.

1. Introduction

In the northwestern Loess Plateau, the mean annual precipitation ranges between 250 and 350 mm, and over 70% of the precipitation occurs between June and September (Li et al., 2001). The rainy seasons usually do not coincide with growth stages for most crops and the mean annual pan evaporation ranges from 1500 to 2000 mm. Farm fields mulched with gravel has been used for more than three hundred years in this region due to its effectiveness in reducing evaporation, improving infiltration and increasing soil temperature (Nachtergaele et al., 1998; Xie et al., 2006, 2010). A porous layer of gravel about 10 cm thick that lies on the soil surface lessens the risk of crop failure, which frequently occurs due to a combination of low precipitation and high evaporation that creates severe soil moisture deficits. This technique has been promoted and widely adopted due to the lack of sufficient water or high irrigation costs. The gravel mulched fields are mainly distributed in the west of the Loess Plateau, which first developed in the middle part of Gansu Province and gradually introduced into neighboring provinces such as Ningxia Hui Autonomous Region and Qinghai Province. By the late 1990s, 118,000 ha of fields with gravel mulch were distributed in Gansu Province and 66,000 ha of such fields were distributed in Ningxia Hui Autonomous Region. The effect on the resistance to evaporation is the most important function of gravel mulch. Although previous studies (Mellouli et al., 2000; Rasiah et al., 2001; Ma and Li, 2011) have reported a lot of determinations or comparisons about evaporation and pointed out that gravel mulch can reduce evaporation markedly compared to un-mulched soil, they did not find suitable parameters and a reliable model to calculate or simulate the evaporation in gravel mulch fields. Yamanaka et al. (2004) defined r_t as the gross resistance to evaporation from evaporating surface to an arbitrary level in the air, and evaporation rate is computed by an analogy of Ohm's law. They confirmed the gross resistance over soil surface to evaporation did not rely on gradient of temperature (i.e. atmospheric stability condition) and increased exponentially with the effective mulch thickness (i.e. the depth from the soil surface). However, previous results were difficult to be applied in practice due to a lack of attention about other parameters and studies about resistance to evaporation in the mulch stratum received little attention. To understand the mechanisms of the

* Corresponding author. Tel.: +86 931 4967198; fax: +86 931 8273894.
E-mail address: wxhcas@lzb.ac.cn (Z. Xie).

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ORIGINAL ARTICLE

Genetic variation in the ovine uncoupling protein 1 gene: association with carcass traits in New Zealand (NZ) Romney sheep, but no association with growth traits in either NZ Romney or NZ Suffolk sheep

G. Yang[1], R. Forrest[2], H. Zhou[3], S. Hodge[3] & J. Hickford[3]

1 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Science, Lanzhou, China
2 Faculty of Health Sciences, Eastern Institute of Technology, Napier, New Zealand
3 Gene-Marker Laboratory, Faculty of Agriculture and Life Sciences, Lincoln University, Lincoln, New Zealand

Keywords
Carcass composition; growth rate; NZ Romney sheep; NZ Suffolk sheep; PCR-SSCP; Uncoupling protein 1.

Correspondence
J. Hickford, Gene-Marker Laboratory, Faculty of Agriculture and Life Sciences, PO Box 84, Lincoln University, Lincoln 7647, New Zealand.
Tel: +64 3 423 0665;
Fax: + 64 3 325 3851;
E-mail: Jonathan.Hickford@lincoln.ac.nz

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Summary

The uncoupling protein 1 (UCP1) plays an important role in the regulation of lipolysis and thermogenesis in adipose tissues. Genetic variation within three regions (the promoter, intron 2 and exon 5) of the ovine UCP1 gene (*UCP1)* was investigated using polymerase chain reaction-single-strand conformational polymorphism (PCR-SSCP) analyses. These revealed three promoter variants (designated *A, B and C*) and two intron 2 variants (*a* and *b*). The association of this genetic variation with variation in lamb carcass traits and postweaning growth was investigated in New Zealand (NZ) Romney and Suffolk sheep. The presence of *B* in a lamb's genotype was associated with decreased subcutaneous carcass fat depth (V-GR) ($p = 0.004$) and proportion of total lean meat yield of loin meat ($p = 0.005$), and an increased proportion of total lean meat yield of hind-leg meat ($p = 0.018$). In contrast, having two copies of *C* was associated with increased V-GR ($p < 0.001$) and proportion of total lean meat yield of shoulder meat ($p = 0.009$), and a decreased hind-leg yield ($p = 0.032$). No associations were found with postweaning growth. These results suggest that ovine *UCP1* is a potential gene marker for carcass traits.

Introduction

The uncoupling protein 1 (UCP1) belongs to a family of mitochondrial membrane carrier proteins (MCPs). It is predominantly expressed in brown adipose tissue and plays a pivotal role in thermogenesis, the regulation of energy expenditure and protection against oxidative stress (Ricquier & Bouillaud 2000; Cannon & Nedergaard 2004). UCP1 has been reported to be associated with the pathogenesis of type 2 diabetes mellitus and obesity, and it is considered to be an antiobesity factor (Nedergaard *et al.* 2005).

Impaired fat metabolism has been observed in *UCP1* 'knockout' mice, and these mice have a higher risk of becoming obese, than normal mice (West *et al.* 1992; Surwit *et al.* 1998; Bachmanov *et al.* 2001). In humans, several studies have reported that synonymous substitutions in the promoter of *UCP1* and non-synonymous substitutions in exon 2 (Ala64Thr) and exon 5 (Met299Leu) are associated with obesity risk and/or type 2 diabetes mellitus risk (Brondani *et al.* 2012).

Recently, ovine *UCP1* (GenBank Accession Number JN604985.1) has been cloned and sequenced (Yuan *et al.* 2012). It is approximately 6.7 kb in length, with a coding sequence of about 1621 bp. It is composed of six exons and five introns. Ten SNPs were described in the exon 2, exon 5 and the 3′UTR regions, and this variation appears to affect the *UCP1* mRNA level in different tissues. Whether this variation is associated

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Scale dependence of plant species richness and vegetation-environment relationship along a gradient of dune stabilization in Horqin Sandy Land, Northern China

XiaoAn ZUO[1,2*], ShaoKun WANG[1,2], XueYong ZHAO[1,2], Jie LIAN[1,2]

[1] Naiman Desertification Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China;
[2] Laboratory of Stress Ecophysiology and Biotechnology, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract: Ecological patterns and processes in dune ecosystems have been a research focus in recent years, however the information on how dune stabilization influences the spatial scale dependence of plant diversity is still lacking. In this study, we measured the plant species richness, soil properties and altitude across four spatial scales (1, 10, 100 and 1,000 m^2) at three different dune stabilization stages (mobile dune, semi-fixed dune and fixed dune) in Horqin Sandy Land, Northern China. We also examined the relationships between plant species richness, community composition and environmental factors along the gradient of dune stabilization. Our results showed that plant species richness increased with the increase of spatial scales in each dune stabilization stage, as well as with the increase of dune stabilization degrees. Canonical correspondence analysis (CCA) showed that plant distributions in the processes of dune stabilization were determined by the combined environmental gradient in relation to soil organic carbon (SOC), total nitrogen (TN), carbon/nitrogen (C/N), pH, electrical conductivity (EC), soil water content (SWC), fine sand (FS), very fine sand (VFS), silt and clay (SC), and altitude. Plant species richness was significantly and positively correlated to SOC and TN in mobile dune, and significantly and positively correlated to SOC, TN, C/N, VFS and SC in semi-fixed dune. However, no significant correlation between plant species richness and environmental factors was observed in fixed dune. In addition, plant species richness in different dune stabilization stages was also determined by the combined gradient of soil properties and altitude. These results suggest that plant species richness has obvious scale dependence along the gradient of dune stabilization. Soil resources depending on dune habitats and environmental gradients caused by dune stabilization are important factors to determine the scale dependence of species diversity in sand dune ecosystems.

Keywords: CCA; environmental gradient; sandy land ecosystem; spatial scale dependence; species diversity

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Species richness in arid and semi-arid ecosystems is spatial scale dependent (Crawley and Harral, 2001; He et al., 2006; Palmer, 2006). Understanding how species richness varies with spatial scales is very important to improve our ability to conserve biodiversity and to manage ecosystems (Palmer and White, 1994; Turner and Tjorve, 2005; He et al., 2006). Species-area relationships are one of the most studied ecological patterns in assessing the response of plants to environmental stress (Cantero et al., 1998; Weiher and Howe, 2003; Palmer, 2006). The study of ecosystems has always been highly influenced by the spatial

*Corresponding author: XiaoAn ZUO (E-mail: zuoxa@lzb.ac.cn)
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N and P resorption in a pioneer shrub (*Artemisia halodendron*) inhabiting severely desertified lands of Northern China

YuLin LI*, Chen JING, Wei MAO, Duo CUI, XinYuan WANG, XueYong ZHAO

Naiman Desertification Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract: Nutrient resorption is an important conservation mechanism for plants to overcome nutrient limitation in the less fertile area of desertified land. In the semi-arid Horqin Sandy Land of Northern China, the shrub *Artemisia halodendron* usually colonizes into the bare ground of severely desertified land as a pioneer species. It is, therefore, expected that *A. halodendron* will be less dependent on current nutrient uptake through efficient and proficient resorption of nutrients. In this study, we found that averaged nitrogen (N) and phosphorus (P) concentrations in senesced leaves significantly varied from 12.3 and 1.2 mg/g in the shifting sand dune to 15.9 and 1.9 mg/g in the fixed sand dune, respectively, suggesting that foliar N and P resorption of *A. halodendron* were more proficient in the shifting sand dune. In particular, positive relationships between nutrient concentrations in senesced leaves and soil nutrient availability indicate that *A. halodendron* in infertile habitats is more likely to manage with a low level of nutrients in senesced leaves, giving this species an advantage in infertile soil. Moreover, foliar N- and P-resorption efficiencies and proficiencies showed limited inter-annual variability although annual precipitation varied greatly among 2007–2009. However, N and P resorption of *A. halodendron* were not more efficient and proficient than those previously reported for other shrubs, indicating that the pioneer shrub in sand dune environments does not rely more heavily than other plants on the process of resorption to conserve nutrients. Incomplete resorption of nutrients in *A. halodendron* suggests that senesced-leaf fall would return litter with high quality to the soil, and thereby would indirectly improve soil nutrient availability. The restoration of desertified land, therefore, may be accelerated after *A. halodendron* pioneers into shifting sand dunes.

Keywords: foliar nutrient concentration; nutrient-resorption efficiency; nutrient-resorption proficiency; senesced vs. green leaves; desertification; soil nutrient availability

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Land desertification, a human-induced land degradation process, is one of the most serious environmental and socioeconomic issues (Lal, 2000; Wang, 2000), and has resulted in large areas of shifting sand lands with bare sandy soils in the semi-arid regions of Northern China. The bare sandy soil is generally low in soil nutrients and tends to inhibit the establishment of new seedlings as well as the growth of herbaceous plants (Liu et al., 1996; Yan and Liu, 2010). However, there are some common perennial shrubs which are able to pioneer by growing in the less fertile bare sandy areas in North China (Zhao et al., 2007). These plant species, with an ability of invading bare sandy areas, must possess some kind of strategies adapting to poor soil nutrient availability, especially when sufficient soil moisture is available (Su et al., 2005).

Withdrawal of nutrient before leaf death and abscission is one of the strategies employed by plants to

*Corresponding author: YuLin LI (E-mail: lyulin@gmail.com)
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Artificial root exudates and soil organic carbon mineralization in a degraded sandy grassland in northern China

YongQing LUO[1,2*], XueYong ZHAO[1], Olof ANDRÉN[1,3], YangChun ZHU[1,2], WenDa HUANG[1]

[1] Naiman Desertification and Farmland Research Station of the Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China;
[2] University of Chinese Academy of Sciences, Beijing 100049, China;
[3] Bjorklundavagen 3, SE-756 46 Uppsala, Sweden

Abstract: Plant root exudates contain various organic and inorganic components that include glucose, citric and oxalic acid. These components affect rhizosphere microbial and microfaunal activities, but the mechanisms are not fully known. Studies concerned from degraded grassland ecosystems with low soil carbon (C) contents are rare, in spite of the global distribution of grasslands in need of restoration. All these have a high potential for carbon sequestration, with a reduced carbon content due to overutilization. An exudate component that rapidly decomposes will increase soil respiration and CO_2 emission, while a component that reduces decomposition of native soil carbon can reduce CO_2 emission and actually help sequestering carbon in soil. Therefore, to investigate root exudate effects on rhizosphere activity, citric acid, glucose and oxalic acid (0.6 g C/kg dry soil) were added to soils from three biotopes (grassland, fixed dune and mobile dune) located in Naiman, Horqin Sandy Land, Inner Mongolia, China) and subjected to a 24-day incubation experiment together with a control. The soils were also analyzed for general soil properties. The results show that total respiration without exudate addition was highest in grassland soil, intermediate in fixed dune and lowest in mobile dune soil. However, the proportion of native soil carbon mineralized was highest in mobile dune soil, reflecting the low C/N ratio found there. The exudate effects on CO_2-C emissions and other variables differed somewhat between biotopes, but total respiration (including that from the added substrates) was significantly increased in all combinations compared with the control, except for oxalic acid addition to mobile dune soil, which reduced CO_2-C emissions from native soil carbon. A small but statistically significant increase in pH by the exudate additions in grassland and fixed dune soil was observed, but there was a major decrease from acid additions to mobile dune soil. In contrast, electrical conductivity decreased in grassland and fixed dune soil and increased in mobile dune. Thus, discrete components of root exudates affected soil environmental conditions differently, and responses to root exudates in soils with low carbon contents can differ from those in normal soils. The results indicate a potential for, e.g., acid root exudates to decrease decomposition rate of soil organic matter in low carbon soils, which is of interest for both soil restoration and carbon sequestration.

Keywords: artificial root exudates; carbon mineralization; pH variation; deteriorated grassland ecosystem; Inner Mongolia

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The major pathway of carbon (C) inputs to soil is through plant litter-fall and roots, and the corresponding loss of carbon mainly occurs through microbial breakdown of soil organic matter. Since soil organic carbon (SOC) is the largest carbon sink in the terrestrial ecosystem, changes in the SOC pool size are directly linked to changes in atmospheric CO_2 concentration. Low molecular weight compounds (LMWC) that rapidly can be assimilated by the microbial community appear to be a main source in the total CO_2 flux from soils, in spite of their low concentration at any given moment (van Hees et al., 2005; Glanville et

*Corresponding author: YongQing LUO (E-mail: luoyongqing8401@sina.com)
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ORIGINAL ARTICLE

Soil organic carbon in relation to cultivation in arable and greenhouse cropping systems in Lanzhou, NW China

Yongqing Luo[a]*, Xueyong Zhao[a] and Olof Andrén[a,b]

[a]*Naiman Desertification and Farmland Research Station of the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou 730000, People's Republic of China;* [b]*Oandren.com, Björklundavägen 3, SE-756 46 Uppsala, Sweden*

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Soil organic carbon (SOC) is a major source/sink in atmospheric carbon balances. Farmland usually has a high potential for carbon dioxide (CO_2) uptake from the atmosphere, but also for emission. Data from different areas are valuable for global SOC calculations and model development, and a survey of 108 agricultural fields in Lanzhou, China was performed. The fields were grouped by: cropping *intensity* (3 levels), cropping *methodology* (3), and crop *species* (10). *Intensive* cropping (two or more crops per year, typically vegetables), *moderate* (annuals in monoculture: wheat, maize, potato, melons), and *extensive* (orchards, lily [*Lilium brownii*] fields, fallow) were the *intensity* classes; and *open* field, *greenhouse* field, and *sand-covered* field (10–20 cm added on top of the topsoil) were the three *methodologies*. SOC concentration, pH, electrical conductivity, and soil bulk density were measured, and SOC mass ($g \cdot m^{-2}$ 0–20 cm depth) was calculated. SOC concentration was high in *cauliflower*, *wheat*, *leaf vegetables,* and *fruit vegetables;* moderate in *potato*, *fallow* (3–5 years), *tree orchards,* and *melons;* while low in *lily* and *maize* fields, and differences in SOC mass followed the same pattern. SOC concentration and mass were lowest in the *extensive* fields while *moderate* and *intensive* fields showed higher values. Soil bulk density in *open* fields was significantly lower than those in *greenhouse* and *sand-covered* fields. The climate-induced soil activity factor r_{e_clim} was calculated, compared with European conditions, and was fairly similar to those in central Sweden. Other factors behind the measured results, such as the influence of initial SOC content, manure addition, crops, etc., are discussed.

Keywords: agriculture; soil organic carbon; Gansu province; land use; r_{e_clim}

Introduction

Soil organic matter levels are crucial for the physical, chemical, and biological properties of soil; and soil organic carbon (SOC) is the largest C sink in terrestrial ecosystems. Thus, changes in the SOC pool size are directly linked to changes in atmospheric carbon dioxide (CO_2) concentration. China has 122 million hectares of farmland, and arable soil carbon data from NW China are scarce.

At a given moment, the SOC level in an agricultural soil depends on preagricultural SOC content and the inputs and outputs after first cultivation. The balance is affected by a number of climatic, edaphic, and crop-related factors such as temperature, precipitation, potential evapotranspiration, topography, crop yield, root/shoot ratio, etc. Since the agricultural ecosystem by definition is managed, cultivation, fertilization, manure addition, and irrigation are major determinants (Andrén & Kätterer 2008).

Intensity of the management is a major factor in SOC dynamics in agricultural ecosystems, and manure addition and fertilization will increase crop yields and SOC in soil (Bolinder et al. 2012), whereas cultivation and irrigation often will increase SOC decomposition rates and decrease SOC mass, but not always (Angers & Eriksen-Hamel 2008). A productive crop, and even several harvests per year, will give more residues to the soil and also transpire more water, thereby reducing SOC decomposition rates.

*Corresponding author. Email: luoyongqing8401@sina.com

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ORIGINAL PAPER

Photosynthetic performance and growth traits in *Pennisetum centrasiaticum* exposed to drought and rewatering under different soil nutrient regimes

Yayong Luo · Xueyong Zhao · Hao Qu · Xiaoan Zuo · Shaokun Wang · Wenda Huang · Yongqing Luo · Min Chen

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Abstract Responses of plants exposed to drought and rewatering have been well documented; however, little is known concerning strategies of psammophyte to drought and rewatering under different soil nutrient regimes. For this study, *Pennisetum centrasiaticum* under two soil nutrient regimes was subjected to progressive drought and subsequent rewatering. Soil water status, gas exchange characteristics, chlorophyll *a* fluorescence characteristics as well as biomass traits were measured to investigate ecophysiological responses. Net photosynthesis rate (P_n), stomatal conductance (g_s), water use efficiency, maximum quantum efficiency of photosynthesis system II (PSII, F_V/F_M), electron transport flux per cross section (ET_0/CS_0), and performance index on cross section basis (PI_{CS}) were suppressed during drought periods for both nutrient regimes. Meanwhile, leaf intercellular CO_2 concentration (C_i), minimal fluorescence intensity (F_0), and dissipated energy flux per cross section (DI_0/CS_0) increased. Reversible downregulation of PSII photochemistry and enhanced thermal dissipation of excess excitation energy (DI_0/CS_0) contributed to enhanced photo-protection in drought-stressed plants. Thus, the results indicate that *P. centrasiaticum* is capable of withstanding and surviving extreme drought events, and the recovery pattern of stressed *P. centrasiaticum* under both nutrient regimes was similar. However, fertilization increased the biomass and the variation in gas exchange and chlorophyll *a* fluorescence characteristics during drought periods. Additionally, fertilization accelerated the process of drought and aggravated stress under extreme drought events. Thus, the fertilization strategy used in *P. centrasiaticum* restoration should be carefully selected—fertilization may not always be beneficial.

Keywords *Pennisetum centrasiaticum* · Drought and rewatering · Nutrient · Photosynthesis · Chlorophyll *a* fluorescence

Introduction

Water and nutrients are critical resources for plant life and associated physiological processes. The supply of water and nutrients in arid and semi-arid ecosystems usually is so low that plants repeatedly suffer from water and nutrient deficiency (Chen et al. 2005; Miyashita et al. 2005). Additionally, desertification processes usually result in significant decreases in soil nutrient levels (Zhou et al. 2008; Zhao et al. 2009).

Water is the crucial limiting factor for plant recruitment, photosynthesis, growth, and net ecosystem productivity in arid ecosystems. Hence, arid ecosystems rapidly respond to precipitation events (Xu et al. 2007). The responses of crops and trees to soil drought and rewatering are well documented (Ortuno et al. 2005; Galle et al. 2007; Perez-Perez et al. 2007; Santesteban et al. 2009), but little is known about the specialized strategies of psammophytes dealing with drought and rewatering. It is known that vegetative growth of stressed plants can recover after rewatering (Galle et al. 2007; Luo et al. 2011), suggesting a reversibility of physiological changes generated by water

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Y. Luo (✉) · X. Zhao · H. Qu · X. Zuo · S. Wang · W. Huang · Y. Luo · M. Chen
Department of Ecology and Agriculture, Cold and Arid Regions of Environmental and Engineering Research Institute, Chinese Academy of Sciences, No. 320 Donggang West Road, Lanzhou 730000, Gansu, China
e-mail: luoyy@lzb.ac.cn

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Response of stomatal conductance of two tree species to vapor pressure deficit in three climate zones

Jing LI, XiaoMing LI*

School of Environmental Science and Engineering, Shandong University, Jinan 250100, China

Abstract: Stomatal behavior is a central topic of plant ecophysiological research under global environmental change. However, the physiological mechanism controlling the response of stomata to vapor pressure deficit (VPD) or relative humidity (RH) has been inadequately understood till now. In this study, responses of stomatal conductance (g_s) to VPD in two species of trees (*Fraxinus chinensis* Roxb., *Populus alba* L. var. *pyramidalis* Bge.) in three different climate zones (Jinan with typical warm humid/semi-humid climate, Urumqi with temperate continental arid climate and Turpan with extreme arid desert climate) were measured. Levels of two phytohormones (abscisic acid, ABA; indole-3-acetic acid, IAA) in the leaves of the two tree species at these three sites were also measured by high performance liquid chromatography. The results showed that the responses of g_s to an increasing VPD in these two tree species at the three sites had peak curves which could be fitted with a Log Normal Model ($g_s=a\cdot\exp(-0.5(\ln(D/c)/b)^2)$). The VPD/RH values corresponding to the maximum g_s can be calculated using the fitting models for the two tree species in the three sites. We found that the calculated $g_{s\text{-}max}$-VPD correlated negatively with relative air humidity in the three sites during the plant growth period (April to October 2010), which showed the values of $g_{s\text{-}max}$-VPD were related to the climate conditions. The prevailing empirical stomatal model (Leuning model) and optimal stomatal behavior model could not properly simulate our measured data. The water use efficiency in the two tree species did not show obvious differences under three very different climatic conditions, but the highest g_s, photosynthetic and transpiration rates occurred in *P. alba* var. of Turpan. The sensitivity in response of g_s to VPD in leaves of the two trees showed positive correlations with the concentration of ABA, which implied that ABA level could be used as an indicator of the sensitivity of stomatal response to VPD. Our results confirmed that the prediction of the response of g_s to VPD might be incomplete in the two current popular models. Therefore, an improved g_s model which is able to integrate the results is needed. Also, the stomatal response mechanism of single peak curves of g_s to VPD should be considered.

Keywords: abscisic acid; relative humidity; stomatal conductance; stomatal model; vapor pressure deficit

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Stomatal conductance plays a fundamental role in acquiring both carbon and limiting water, which is a critically influential factor in tree growth. Stomatal conductance is influenced by light, temperature and water supply, and stomatal opening or closing is regulated by phytohormones. Stomatal behavior under global environmental change is a key to predicting vegetation function. Plants have developed advanced strategies and mechanisms through evolution to adapt local and global environmental changes by compromising photosynthesis and transpiration, and they also affect and promote local and global environmental changes (Hetherington and Woodward, 2003).

A number of studies have been done on the response of stomatal conductance to environmental factors. A number of models on stomatal conductance

*Corresponding author: XiaoMing LI (E-mail: lxming@sdu.edu.cn)
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Original article

Relationship between the genetic diversity of *Artemisia halodendron* and climatic factors

Wenda Huang [a,b,*], Xueyong Zhao [a,b], Xin Zhao [b], Yuqiang Li [a], Jie Lian [a], Jianying Yun [a]

[a] *Naiman Desertification Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China*

[b] *Extreme Stress Resistance and Biotechnology Laboratory, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China*

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ABSTRACT

Artemisia halodendron (Asteraceae) is a dominant sand-fixing semi-shrub species native to the Horqin Sandy Land of northeastern China. In this study, we evaluated levels of genetic variation within and among sampled *A. halodendron* populations from two different hydrothermal regions of the Horqin Sandy Land using inter-simple sequence repeat (ISSR) markers. We also investigated possible relationships between genetic diversity of this species and climatic factors. Our analysis revealed that *A. halodendron* is highly genetically diverse, with populations from a low hydrothermal level region having higher genetic diversity index values than those from a high hydrothermal level region. An analysis of molecular variation (AMOVA) revealed relatively high levels (>89.83%) of within-population genetic variation. Based on cluster analysis, the 13 studied *A. halodendron* populations can be clustered into two clades. Genetic diversities of all populations have been influenced by many climatic factors, and Nei's genetic diversity (h) is strongly correlated with annual temperature range (ART). These results have important implications for restoration and management of degraded ecosystems in arid and semi-arid areas.

1. Introduction

Artemisia halodendron (Asteraceae) is a climax and dominant sand-fixing semi-shrub species native to the Horqin Sandy Land of northeastern China. It is an important component of vegetation rehabilitation efforts in the Horqin Sandy Land because of several highly valuable ecological traits, which include its high drought tolerance, anti-wind erosion utility, sand burial-resistance (Dong et al., 2000; Li et al., 2002; H.L. Zhao et al., 2006), and status as a key species for plant community establishment and landscape formation (Li, 1991). *A. halodendron* is distributed in mobile, semi-mobile and fixed dunes, and lowlands. A special combination of conditions with respect to water fertility and heat in Inner Mongolia, and the Horqin Sandy Land characterizes the main part of the distribution range (Fu, 1993). The life history traits of *A. halodendron* include long-lived, perennial, wind-pollinated, seed reproduction, vegetative propagation and broad ecological amplitude (Fu, 1993). Previous studies on *A. halodendron* have focused on its population distribution patterns (Chao et al., 1999; Cao et al., 2008), biomass allocation (Li et al., 2005), breeding distribution (Li et al., 2005), morphological characteristics and physiological adaptations (Zhou et al., 1999), root longevity (Huang et al., 2009), and establishment (Li et al., 2002) in the Horqin Sandy Land. The relationship between *A. halodendron* genetic diversity and climatic factors has not yet been reported, however.

The Horqin Sandy Land is located in an agro-pastoral transition zone between the Inner Mongolian Plateau and the Northeast Plains (42°41′–45°45′N, 118°35′–123°30′E). It covers an area of approximately 139,300 km^2, of which about 71,884 km^2 is desertified (Wang, 2003; Zhao et al., 2003). The landscape in this area is characterized by sand dunes alternating with gently undulating lowland areas (Li et al., 2005). The region, which is located in the continental temperate zone, experiences a semi-arid monsoon climate with a mean annual temperature of 3–7 °C and mean annual rainfall of 350–500 mm (Zhao et al., 2003). Over recent decades, this region has undergone severe desertification (Li et al., 2000, 2004), a northward-moving phenomenon affecting

* Corresponding author. Naiman Desertification Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China. Tel.: +86 931 4967178; fax: +86 931 4967219.
E-mail address: huangwenda2008@163.com (W. Huang).

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Soil organic carbon and total nitrogen storage under different land uses in the Naiman Banner, a semiarid degraded region of northern China

Yuqiang Li[1], Juanjuan Han[1], Shaokun Wang[1], James Brandle[2], Jie Lian[1], Yongqing Luo[1], and Fengxia Zhang[3]

[1]Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou, 730000, China (e-mail: liyq@lzb.ac.cn/gsyqli@aliyun.com); [2]School of Natural Resources, University of Nebraska, Lincoln, NE 68583, USA; and [3]School of Environmental and Municipal Engineering, Lanzhou Jiaotong University, Lanzhou, 730070, China.
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Li, Y., Han, J., Wang, S., Brandle, J., Lian, J., Luo, Y. and Zhang, F. 2014. **Soil organic carbon and total nitrogen storage under different land uses in the Naiman Banner, a semiarid degraded region of northern China**. Can. J. Soil Sci. **94**: 9–20. Accurate investigation of soil organic carbon (SOC) and total nitrogen (TN) storage at a regional level is important for detecting changes in the C and N sequestration and emission potentials induced by land-use and cover type changes. In a degraded semiarid region of northern China's Horqin Sandy Land, we selected 208 locations and calculated SOC and TN storage to a depth of 100 cm for the main land-use and cover types. The productive cropland on former grassland had the highest level of SOC and TN storage (6613 g C m^{-2} and 709 g N m^{-2}). The corresponding storage values were 3758 g C m^{-2} and 402 g N m^{-2} in degraded grassland, 3449 g C m^{-2} and 373 g N m^{-2} in afforested dunes, 2674 g C m^{-2} and 320 g N m^{-2} in unproductive cropland on former dunes, and 1109 g C m^{-2} and 129 g N m^{-2} in sand dunes (from mobile to fixed). The average soil bulk density was highest in sand dunes, with a value of 1.59 g cm^{-3}, and lowest in productive cropland on former grassland, with a value of 1.39 g cm^{-3}. The conversion of severely degraded sandy land into other land-use and cover types therefore has considerable potential to partially offset the SOC and TN loss during the past century that has resulted from desertification in the Horqin Sandy Land.

Key words: Land use, soil C and N storage, desertification, Horqin Sandy Grassland

Li, Y., Han, J., Wang, S., Brandle, J., Lian, J., Luo, Y. et Zhang, F. 2014. **Stockage du carbone organique et de l'azote total dans le sol sous différentes vocations des terres dans la ceinture de Naiman, zone semi-aride et dégradée du nord de la Chine**. Can. J. Soil Sci. **94**: 9–20. Il est important d'établir avec précision la capacité de stockage du carbone organique (CO) et de l'azote total (AT) dans le sol à l'échelon régional si on veut déceler les modifications au potentiel de séquestration et de dégagement du C et du N attribuables à un changement dans la vocation des terres ou la couverture végétale. Dans les terres sablonneuses de la région semi-aride de Horqin, dans le nord de la Chine, les auteurs ont sélectionné 208 emplacements et calculé la quantité de CO et d'AT stockée à 100 cm de profondeur en fonction des principaux types de couverture végétale et de vocation des terres. Les cultures poussant sur d'anciennes prairies jouissent du plus fort potentiel de stockage du CO et de l'AT (6 613 g de C et 709 g de N par m^2). Les valeurs correspondantes s'établissent à 3 758 g de C et 402 g de N par m^2 pour les prairies dégradées, à 3 449 g de C et 373 g de N par m^2 dans les dunes boisées, à 2 674 g de C et 320 g de N par m^2 dans les friches agricoles sur les anciennes dunes, et à 1 109 g de C et 129 g de N par m^2 dans les dunes (mobiles et fixes). La masse volumique apparente moyenne du sol atteint son maximum dans les dunes (1,59 g par cm^3) et son point le plus bas dans les anciennes prairies cultivées (1,39 g par cm^3). Le passage des terres sablonneuses très dégradées à une autre vocation ou à un type de couverture végétale différent présente donc le potentiel considérable de compenser partiellement les pertes de CO et d'AT survenues au cours du siècle dernier consécutivement à la désertification des terres sablonneuses de Horqin.

Mots clés: vocation des terres, stockage du C et du N dans le sol, désertification, prairies sablonneuses de Horqin

The biogeochemical cycles of carbon (C) and nitrogen (N) in terrestrial ecosystems have received increasing research attention over the past decade because global atmospheric concentrations of carbon dioxide (CO_2) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750, and these increases have contributed greatly to global warming [Intergovernmental Panel on Climate Change (IPCC) 2007]. Human practices such as agriculture and forestry, which lead to land-use and cover type change, are changing the natural rate of exchange of C between the atmosphere and the terrestrial biosphere. Therefore, it is essential to investigate how C stocks change in response to changing land-use activities (IPCC 2000). On the one hand, emissions of CO_2 due to land uses and land-use change

Abbreviations: **SOC**, soil organic carbon; **TN**, total nitrogen

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Carbon and Nitrogen Cycling are Resistant to Fire in Nutrient-Poor Grassland

Wenjin Li*
State Key Lab. of Grassland Agro-ecosystems
School of Life Science
Lanzhou Univ.
Lanzhou 730000, China

School of Biological Sciences
Univ. of Nebraska
Lincoln, NE, 68588-0118

Johannes (Jean) M. H. Knops
School of Biological Sciences
Univ. of Nebraska
Lincoln, NE, 68588-0118

Xiaoan Zuo
Agriculture and Ecology Research Dep.
Cold and Arid Regions of Environmental and Engineering Research Institute
Chinese Academy of Sciences
Lanzhou, 730000,China

School of Biological Sciences
Univ. of Nebraska
Lincoln, NE, 68588-0118

Ramesh Laungani
Biology Dep.
Doane College
Crete, NE 68333

We used a long-term experiment with four different fire frequencies, annual burns (B1), biennial burns (B2), burn every 4 yr (B4), and no burn (BC) over a 27-yr period. We quantified temporal changes in vegetation dynamics, aboveground and belowground carbon (C) and nitrogen (N) pools, and we examined the cumulative effects of fires on N cycling in a nutrient-poor, old field grassland at Cedar Creek, MN. Compared with fires in fertile grasslands with high productivity, fire in this nutrient-poor and low-productivity old field grassland caused only minor shifts in plant functional groups and did not change net primary productivity (NPP) or N cycling rates. We also found that fire frequency did not affect ecosystem C pools or N pools, and the soil C was accumulating at 28 times of the rate of N accumulation for the period 2000 to 2010. This N accumulation in the soil, combined with the low-productivity and the dominant C_4 grasses, which have relative low litter N concentration and thereby low fire-induced N losses, makes this successional grassland resistant to fire-induced N cycling and C and N pool changes for at least decades after agricultural abandonment.

Abbreviations: NPP, net primary productivity; SOM, soil organic matter.

Fire is a common disturbance and can have significant effects on plant community structure, composition, dynamics (Collins and Wallace, 1990, Magnan et al., 2012), NPP, and carbon (C) and nitrogen (N) cycling (Ojima et al., 1994, Reich et al., 2001, Wardle et al., 2003). Fire frequency and intensity are increasing with global warming and with more frequent extreme climate events worldwide (Piñol et al., 1998). However, in many fire adapted grasslands like the North American prairies, fire frequency has decreased, because of human fire suppression and the fragmented nature of the remaining prairies (Collins and Wallace, 1990).

We used a 27-yr experiment in a grassland at Cedar Creek Ecosystem Science Reserve in Minnesota, USA, with four different fire frequencies to examine the impacts of fire frequency on the structure and functioning of this nutrient-poor old field ecosystem. Several approaches, such as manipulated fire experiments (Shay et al., 2001), observational or gradient studies (Reich et al., 2001), repeated sampling from permanent plots (Dijkstra et al., 2006, Knops, 2006, Li et al., 2013), and modeling studies (Ojima et al., 1994, Thornley and Cannell, 2004) have been used to study ecosystem fire effects. However, ecosystem effects are inconsistent and have shown increases in N mineralization and NPP with decreases in fire frequency (Buis et al., 2009), or no changes in N mineralization (Blair, 1997, Turner et al., 1997, Zhou et al., 2009). Frequent fire can result in lower C and N pools due to elevated N losses (Fynn et al., 2003). However, a meta study showed

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*Corresponding author (wenjinli@163.com).

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Reference Gene Selection for Quantitative Real-Time PCR Normalization in *Reaumuria soongorica*

Xia Yan[1,2☯], Xicun Dong[3☯], Wen Zhang[2], Hengxia Yin[2], Honglang Xiao[1], Peng Chen[4], Xiao-Fei Ma[2]*

1 Key Laboratory of Inland River Ecohydrology, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, P. R. China, **2** Key Laboratory of Stress Physiology and Ecology in Cold and Arid Regions of Gansu Province, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, P. R. China, **3** Department of Radiobiology, Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, P. R. China, **4** Faculty of Plant Science and Technology, Huazhong Agricultural University, Wuhan, P. R. China

Abstract

Despite its superiority for evaluating gene expression, real-time quantitative polymerase chain reaction (qPCR) results can be significantly biased by the use of inappropriate reference genes under different experimental conditions. *Reaumuria soongorica* is a dominant species of desert ecosystems in arid central Asia. Given the increasing interest in ecological engineering and potential genetic resources for arid agronomy, it is important to analyze gene function. However, systematic evaluation of stable reference genes should be performed prior to such analyses. In this study, the stabilities of 10 candidate reference genes were analyzed under 4 kinds of abiotic stresses (drought, salt, dark, and heat) within 4 accessions (HG010, HG020, XGG030, and XGG040) from 2 different habitats using 3 algorithms (geNorm, NormFinder, and BestKeeper). After validation of the ribulose-1,5-bisphosphate carboxylase/oxygenase large unite (*rbcL*) expression pattern, our data suggested that histone H2A (*H2A*) and eukaryotic initiation factor 4A-2 (*EIF4A2*) were the most stable reference genes, cyclophilin (*CYCL*) was moderate, and elongation factor 1α (*EF1α*) was the worst choice. This first systematic analysis for stably expressed genes will facilitate future functional analyses and deep mining of genetic resources in *R. soongorica* and other species of the *Reaumuria* genus.

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* Email: maxiaofei@lzb.ac.cn

☯ These authors contributed equally to this work.

Introduction

Gene expression analysis is increasingly important in many fields of biological research. Understanding gene expression patterns is expected to provide insight into complex regulatory networks and will help to identify which genes are relevant to new biological processes. Recently developed methods to measure transcript abundance have been frequently applied in many model biological systems; however, these approaches require the same normalization procedures as traditional mRNA quantification methods. Real-time quantitative polymerase chain reaction (qPCR) is one of the most common technologies used for gene expression and transcriptome analysis and is characterized by high sensitivity and specificity, good reproducibility, a widely dynamic quantification range, and high-throughput capacity for a limited number of target genes [1–3]. Despite its superiority over other methods available for evaluating gene expression, qPCR remains underused due in part to conflicting results and weak repeatability. Traditional reference genes, such as actin (*ACT*), ubiquitin (*UBQ*), alpha-tubulin (*TUA*), eukaryotic initiation factor 4A-2 (*EIF4A2*), 60S ribosomal protein L2 (*L2*), TIP41-like protein (*TIP41*), elongation factor 1-alpha (*EF1α*), cyclophilin (*CYCL*), histone H2A (*H2A*) and DNAJ-like protein (*DNAJ*), are mostly used in model plants and crops [4–6] and do not always maintain stable expression levels among different tissues, experimental conditions [7–12], or species [7,11–16]. Systematic validations of reference genes have mainly focused on models and important crop species, such as Arabidopsis [17], rice [6], poplar [18], soybean [19], wheat [14], barley [20], tomato [21], grape [22], and potato [5]. However, with the increasing importance of agronomy and ecology, greater numbers of non-model plants are being assessed with molecular functional analyses, and it is crucial to identify proper reference genes for new species. To date, reference gene selection has been performed for some non-model plants like bamboo [23], peach [15], *Caragana intermedia* [12], and eggplant [24], but seldom in desert plants.

Reaumuria (Tamaricaceae) plants are perennial xeric shrubs widely distributed in arid regions in North Africa, Asia, and southern Europe. *R. soongorica* (2n = 22, 778 Mb genome size) [25] is a constructive and dominant species of desert ecosystems in central Asia [26]. It has evolved typical phenotypes of desert plants, such as an extremely thick cuticle; hollow stomata; specialized leaf shape; and a root system that reduces the transpiration rate, increases water use efficiency, and maintains stem vigor to survive desiccation [27,28]. Thus, *R. soongorica* is a good species to study the molecular mechanisms of drought adaptation. Many studies have attempted to elucidate the mechanisms of the adaptation and tolerance of *R. soongorica*

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植物叶片提取物作为添加剂在铝-钢摩擦副下的摩擦学性能

许晓春[①], 夏延秋[①*], 吴浩[①], 陈国雄[②③*]

① 华北电力大学能源动力与机械工程学院, 北京 102206;
② 甘肃省寒区旱区逆境生理与生态重点实验室, 兰州 730000;
③ 中国科学院寒区旱区环境与工程研究所沙坡头沙漠试验研究站, 兰州 730000
* 联系人, E-mail: xiayq@ncepu.edu.cn; guoxiong@lzb.ac.cn

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摘要 为了验证植物叶片提取物作为环境友好型润滑油添加剂的摩擦学性能, 提取球兰、大葱和茄子 3 种植物叶片表面蜡质作为考察对象. 用 MFT-R4000 往复摩擦磨损试验机考察以 PAO 为基础油时, 植物提取物作为添加剂在铝-钢摩擦副下的摩擦学性能, 并采用扫描电子显微镜观察铝块磨斑的表面形貌. 实验结果显示, 不同润滑油添加剂显示了优异的抗磨减摩性能. 摩擦系数大小顺序为: 球兰<茄子<大葱<MoDTC<PAO. 抗磨性能大小顺序为: 茄子>球兰>大葱>PAO>MoDTC. 相比 MoDTC 而言, 3 种植物添加剂表现出优良的抗磨和减摩性能. 这可能与植物蜡质层含有醇、酯和酸等成分有关. 扫描电子显微镜照片显示, 与基础油磨斑相比, 植物叶片提取物作为添加剂润滑的磨斑小且磨斑表面光滑. 为了进一步研究植物添加剂的抗磨减摩机制, 以茄子为例, 通过对铝合金磨痕表面进行 XPS 分析, 结果表明叶片提取物在磨斑表面可能以 Al_2O_3、乙二醇和丙三醇的复合物两种形式存在. 3 种植物叶片提取物在铝-钢摩擦系统中均具有良好的减摩抗磨性能, 是有良好发展前景的环境友好型润滑油添加剂.

关键词
植物叶片提取物
添加剂
摩擦学性能
铝-钢摩擦副
环境友好

铝合金因其优异的耐腐蚀性和良好的导热性以及适度的成本, 近年来已被广泛应用于汽车和航天等工业领域[1]. 但是, 铝合金耐磨和抗擦伤性能差, 特别是在常用的铝-钢摩擦副中, 由于铝和钢之间存在着较大的固溶度, 因而易发生铝向钢的转移, 造成铝件的严重磨损[2], 这使得铝-钢摩擦副在低载荷下也难以润滑. 因此, 研究人员一直致力于铝-钢摩擦副的润滑剂的研究.

Montgomery[3,4]和 St Pierre 等人[5]研究发现极长链化合物, 如脂肪族醇、酯、酸和不饱和碳氢化合物可以有效地减少边界润滑时铝合金的磨损. 万勇等人[2]发现在铝-钢摩擦副中, 含磷添加剂会增加润滑油润滑时铝的磨损, 尤以亚磷酸酯为甚. 刘维民等人[6]发现含磷添加剂, 烷氧基磷酸盐对钢铝副具有优异的减摩和抗磨性能, 可见, 不同的学者对含磷添加剂润滑得出不同的结论, 因此钢铝摩擦副还有待深入研究. 胡丽天等人[7,8]针对添加剂铝合金的相互作用展开了一系列研究, 揭示了常用润滑油含 S, P 及 S 和 P 抗磨添加剂与有机酸等添加剂对铝合金的润滑作用机制及其在铝合金润滑中所能发挥的作用, 极大地推动了铝合金润滑的发展. Hu 和 Liu[9]不仅发现丙三醇是一种良好的铝合金润滑剂, 还进一步研

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Crude Oil Treatment Leads to Shift of Bacterial Communities in Soils from the Deep Active Layer and Upper Permafrost along the China-Russia Crude Oil Pipeline Route

Sizhong Yang[1]*, Xi Wen[2], Liang Zhao[1], Yulan Shi[1], Huijun Jin[1]

1 State Key Laboratory of Frozen Soils Engineering (SKLFSE), Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Sciences, Lanzhou, Gansu, China, **2** College of Electrical Engineering, Northwest University for Nationalities, Lanzhou, Gansu, China

Abstract

The buried China-Russia Crude Oil Pipeline (CRCOP) across the permafrost-associated cold ecosystem in northeastern China carries a risk of contamination to the deep active layers and upper permafrost in case of accidental rupture of the embedded pipeline or migration of oil spills. As many soil microbes are capable of degrading petroleum, knowledge about the intrinsic degraders and the microbial dynamics in the deep subsurface could extend our understanding of the application of *in-situ* bioremediation. In this study, an experiment was conducted to investigate the bacterial communities in response to simulated contamination to deep soil samples by using 454 pyrosequencing amplicons. The result showed that bacterial diversity was reduced after 8-weeks contamination. A shift in bacterial community composition was apparent in crude oil-amended soils with *Proteobacteria* (esp. α-subdivision) being the dominant phylum, together with *Actinobacteria* and *Firmicutes*. The contamination led to enrichment of indigenous bacterial taxa like *Novosphingobium*, *Sphingobium*, *Caulobacter*, *Phenylobacterium*, *Alicylobacillus* and *Arthrobacter*, which are generally capable of degrading polycyclic aromatic hydrocarbons (PAHs). The community shift highlighted the resilience of PAH degraders and their potential for *in-situ* degradation of crude oil under favorable conditions in the deep soils.

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* E-mail: yangsz@lzb.ac.cn

Introduction

Increasing human activities related to petroleum extraction and transport in cold regions can result in the release of crude oil and petroleum products in the environment, and have severe ecological and socioeconomic consequences. Thus, pipeline leakage has been reported to be the main contamination source [1]. For example, over 100,000 tons of crude oil was released to Usinsk (65°N) in the Kolva River Basin from pipeline systems, leading to a massive local biodiversity loss as well as some other long-term environmental impacts [1,2]. Moreover, relatively small amount of oil released by pipeline systems occurs frequently in cold regions, and are generally invisible or difficult to measure [3]. Thus, these contaminants will be present in the cold environment and be subject to *in-situ* degradation by the indigenous microorganisms [4].

Spilled oil can migrate in the active layer when it is unfrozen or thawing. During freeze-thaw cycles, hydrocarbons can migrate ahead of the freezing front and accumulate in the permafrost interface [5]. Even the permafrost is not an impermeable barrier. Thus, hydrocarbons can move through active layer into frozen soil via cracks or fissures or unfrozen pore water [6,7] and oil components were even observed to penetrate into completely ice-saturated soils [5]. Hydrocarbons which are limited to the bottom of active layer can move further downward if the top part of permafrost is thawing. Therefore, this migration is more likely to happen in thermally unstable permafrost area due to climate warming. However, minimal attention has been given to the attenuation of petroleum spillage in permafrost table, owing to the belief that the permafrost is an impermeable barrier, which constrains contaminant transport downward [8].

Wherever petroleum is found in freezing and frozen soils, they can be degraded by hydrocarbon-degrading microorganisms [9–11]. Cold-adapted intrinsic bacteria can be still active in cold regions and have potential to *in-situ* break down petroleum pollutants, even though they are influenced by environmental limitation [11]. Most research has considered hydrocarbon degradation in the active layer, while a substantial number of hydrocarbon degraders have also been detected in permafrost soils [12]. These degraders could use hydrocarbon contaminants which migrate downward in the deep subsurface soils, sustain and enhance number and proportion of hydrocarbon-degrading microbes [4,12–14].

Recently, the China-Russia Crude Oil Pipeline (CRCOP) was built in the permafrost regions in northeastern China. This buried pipeline goes through permafrost-affected forests, wetlands and

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Comparative Reproductive Biology and Pollen Limitation of *Tamarix chinensis* in Wild and Managed Populations in Arid NW China

Min Chen[1*] and Xue-yong Zhao

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Abstract

Tamarix chinensis is ecologically important species in the arid regions of Northwest China. In order to understand its reproductive biology and pollen limitation, flowering dynamics, pollen viability, floral visitors and their behaviors, pollen limitation and breeding system were studied. It was observed that the species show four reproductive characteristics. First, the flower production period and flowering peak were different between wild and managed populations, being longer in the managed. Second, *T. chinensis* can be pollen-limited, pollen limitation appeared to be proportionally more intense in wild populations than in managed. Third, for the wild, *Apis mellifera* being the effective pollinators; for the managed, *Megachile (Amegachile) kagiana* were found to be the most frequent flower visitor. Finally, the pollen ovule rate was 352.3±62.7. We found that out-crossing is dominant in both populations and that self-pollination just played an assistant role to assure production in the breeding system, an informative characteristic that can be used in future reproductive analyses of the both populations.

Keywords: *Tamarix chinensis*, Pollination, Floral visitor, Fruit set, Breeding system

Introduction

The genus *Tamarix* has a Mediterranean origin (Baum 1978). *Tamarix chinensis* is ecologically important plants which are widely distributed in arid and semi-arid regions. They play an important role in the establishment of dryland vegetation due to their lateral spreading root systems and deep taproots which enable them to be very efficient in absorbing water and nutrients from deep soil (Li *et al.* 1990).

For many plant species, pollination is necessary for sexual reproduction. Therefore, pollination affects a variety of evolutionary processes, such as selection on floral attraction and plant mating system (Ashman *et al.* 2004, Ashman and Morgan 2004).

Pollen limitation occurs when plant reproduction is limited by the quantity or quality of pollen received (Byers 1995, Aizen and Harder 2007). The potential consequences of pollen limitation for plant populations have been extensively studied over the last decades (Burd 1994, Larson and Barrett 2000, Knight *et al.* 2006, García-Camacho and Totland 2009). To access pollen limitation most studies have added extra pollen on some plants and comparing the fruit or seed sets with those from control plants exposed to natural pollination methods. In this paper, we improve our understanding of the dynamic interaction between pollen deposition and resource allocation.

Previous studies on *Tamarix* have focused mostly on geographical distribution, biological characteristics, physiological stress and molecular biology (Glenn and Nagler 2005, Milbrath and DeLoach 2006, Whiteman 2006, Hudgeons *et al.* 2007, Moran *et al.* 2009, Orabi *et al.* 2009). This study aimed to investigate the reproductive biology and pollen limitation of two species of *Tamarix* in Northwest Gansu province. In particular, we studied the floral morphology, biology, pollen limitation and breeding system of both populations. First, we examined how the activity of floral visitors in both populations affected pollination. Second, we tested whether pollen limitation is proportionally more intense in wild populations than in managed. Finally, we tested whether out-crossing is dominant in both populations, requiring floral visitors, most probably bees.

Materials and Methods

Species

T. chinensis is endemic to China where it

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China.
[1]University of Chinese Academy of Sciences, Beijing 100049, China
*Corresponding author E-mail: chenmin1360@126.com

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Effects of sand burial on dune plants: a review

Hao Qu [1*], HaLin Zhao [1], RuiLian Zhou [2]

1. *Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China*
2. *School of Life Science, Ludong University, Yantai, Shandong 264025, China*

*Correspondence to: Dr. Hao Qu, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences. No. 320, West Donggang Road, Lanzhou, Gansu 730000, China. E-mail: quhao@lzb.ac.cn

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ABSTRACT

Burial of different growth stages of plants (*e.g.*, adult plants, seedlings and seeds) is frequent in dune ecosystems. The soil micro-environment, which differs from surface conditions, influences the survival and growth of dune plants. To sum up knowledge about the survival mechanisms of plants under sand burial and to promote practical rehabilitation of dune vegetation, we reviewed relevant published literature and concluded that: (1) Focus in recent years has been on impacts of sand burial on seed germination and seedling emergence. Generally, shallow burial increased seed germination and seedling emergence, but deeper burial was negative. Buried at the same depth, large seeds showed higher germination and seedling emergence rates, attributed to larger energy reserves. (2) Survival, growth and reproduction rates of dune plants show plasticity in response to sand burial. Long-term deep burial is fatal because it creates a physical barrier which overcomes the vertical growth of plants, reduces photosynthetic leaf area, and limits oxygen availability to roots. Modest burial, on the other hand, is advantageous for growth and reproduction of many dune plants, due to protection from excessive temperature and drought. (3) There are few reports concerning effects of sand burial on plant physiology, but a limited number of studies indicate that partial burial increases water use efficiency, chlorophyll content, transpiration rate and net photosynthetic rates. The antioxidant protective enzyme system and osmolyte balance were reported to be involved in the mechanisms of dune plant resistance to burial.

Keywords: sand burial; dune plants; survival; growth and reproduction; physiological response

1 Introduction

Sand movement is frequent in inland and coastal dune ecosystems (Maun, 1994; Brown, 1997; Yu *et al*., 2004). As a consequence, seeds, seedlings and adult plants growing in dune ecosystems will suffer from varying degrees of sand burial (Maun, 1998; Yu *et al*., 2004). Sand burial will generate a number of soil conditions which may influence survival and growth of dune plants. For example, temperature, moisture, acidity, oxygen levels, bulk density and nutrient status of soil may change due to wind- or water-induced sand burial (Poulson, 1999). As a consequence, species will be eliminated when sand burial exceeds their threshold of survival, and sand burial has been recognized as a major selective force in the evolution of different growth stages of dune plants (Maun, 1994; Poulson, 1999; Huang and Gutterman, 2000). Therefore, to find effective ways to protect crops and plants in dune ecosystems, it is necessary to understand the effects of sand burial on dune plants and clarify their mechanisms of survival, growth and reproduction strategies under sand burial. Note that we here simply define dune plants and plants growing

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Effects of fertilization on population density and productivity of herbaceous plants in desert steppe

JieQiong Su [1*], XinRong Li [1], HaoTian Yang [1,2]

1. *Shapotou Desert Experimental Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China*
2. *University of Chinese Academy of Sciences, Beijing 100049, China*

*Correspondence to: JieQiong Su, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences. No. 320, West Donggang Road, Lanzhou, Gansu 730000, China. E-mail: sujieqiong@lzb.ac.cn

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ABSTRACT

In order to investigate the impacts of fertilization on population density and productivity on herbaceous plants in desert steppe, nitrogen (N), phosphorus (P), and N-P addition experiments were performed. Each fertilizer treatment included four addition levels, *i.e.*, 0, 5, 10, and 20 g/m^2. The results indicated that population density decreased as fertilization levels increased regardless of the sort of fertilizer. More specifically, total density as well as density of *Artemisia capillaris*, *Allium polyrhizum*, and *Enneapogon brachystachyus* decreased significantly in 20 g/m^2 treated plots, as compared with the control plots. Fertilization effects on aboveground and root biomasses were extremely similar to that found in population density; that is, both total aboveground biomass and aboveground biomasses for *A. capillaris*, *A. polyrhizum*, and *E. brachystachyus* were negatively correlated with increasing fertilization levels, with all determination coefficients (R^2) greater than 0.80. Therefore, in the case of desert regions (annual precipitation <180 mm), fertilization would inhibit population density and productivity of herbaceous plants.

Keywords: desert steppe; herbaceous vegetation; nitrogen fertilizer; phosphorus fertilizer; biomass

1 Introduction

Water and nutrients can co-limit plant growth and reproduction in desert ecosystems (Harpole *et al.*, 2007). Usually, water is believed to be the first factor limiting plant growth in desert ecosystem. However, nitrogen (N) as well as phosphorus (P) has been shown to impact plant growth in consistent ways, due to the increasingly anthropogenic inputs on nutrients to the Earth's ecosystems (Austin *et al.*, 2004; Elser *et al.*, 2007). Herbaceous plants, as an important component and primary producer of the desert ecosystem, is of importance to prevent desertification and protect biodiversity (Hall *et al.*, 2011; Waseem *et al.*, 2011).

Recently, community composition and productivity of herbaceous vegetation are experiencing impacts from altering soil nutrients, and the plant response is more sensitive for herbaceous vegetation relative to woody plants (Boyer and Zedler, 1998, 1999). N and P fertilizers can promote plant growth and increase community productivity in desert ecosystems through either individual (Chen *et al.*, 2004; Qiu *et al.*, 2004; Ma *et al.*, 2007; Zheng *et al.*, 2007) or combined ways (James *et al.*, 2005; Harpole *et al.*, 2007). However, the plant response to fertilizer additions is known to differ both between and within plant communities (Wesche *et al.*, 2007; Xia and Wan, 2008).

It is well known that plant productivity is largely