甘肃省寒区旱区逆境生理与生态重点实验室

2019 年年度总结

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）：生态学

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

实验室主任：李新荣研究员

二、2019 年实验室科研项目进展情况

实验室在研科研项目 107 项：其中中科院 A 类战略性先导科技“美丽中国”专项课题 1 项、泛第三极环境变化与绿色丝绸之路建设子课题 1 项、甘肃省省级引导科技创新发展专项 1 项、科技部基础资源调查专项 1 项、国家重点研发计划专项 1 项、国家重点研发计划战略国际合作项目 1 项、国家自然科学基金委创新群体 1 项、重点基金 2 项、其它国家自然科学基金项目 43 项、中科院战略性先导科技专项子课题 1 项等。重大课题科研工作进展简述如下：

1）干旱区沙化土地生态恢复的关键技术与示范（中科院 A 类战略性先导科技“美丽中国”专项课题）：2019 年进行了示范区现场考察并召开了课题启动会。项目首席丁永建研究员汇同项目监理组、专家组及课题负责人和课题骨干 30 余人分别对黑土退化阻控技术集成示范区（黑龙江省）、农牧交错带生态功能提升与绿色发展示范区（吉林省）和干旱区沙化土地生态恢复关键技术示范区（宁夏回族自治区）开展了现场考察和指导。

2）荒漠化土地植被恢复重建关键技术研发与集成示范（泛第三极环境变化与绿色丝绸之路建设子课题）：2019 年在何明珠研究员的带领下，王进副研究员、张鹏、杨昊天、赵杰才和宋光博士一行对中亚双重内陆国家乌兹别克斯坦的沙漠化现状进行综合考察。考察队员深入一线，对沙漠化区域的气候、土壤、植被和

沙漠化现状进行了综合调查研究，为中亚-西亚荒漠化防治与关键因素调控工作奠定基础。

3）丝绸之路经济带沿线国家流沙固定及植被恢复关键技术研发与示范（国家重点研发计划战略国际合作项目）：与哈萨克斯坦、蒙古和以色列合作，针对合作国的地理区位、自然条件和生态环境现状，确定了适用于不同区域的流沙治理及植被恢复模式 3 套，建成 12ha 流沙治理及植被恢复试验示范基地，培训科研和农牧民 300 余人次。

4）干旱区生态水文学（国家自然科学基金创新研究群体）：研究发现由于结皮群落的种丰富度、多度、盖度和生物量在很大程度上由藓类决定，气候变化导致的结皮群落的这种变化直接降低了结皮对凝结水的捕获，增加了入渗，增大了地表蒸发，减少了表土层含水量，最终改变了原来的水量平衡，限制了草本植物的繁衍和定居，对生态恢复产生不利的影响。

5）生物土壤结皮对沙区土壤生态水文过程响应与反馈机理研究应（国家自然科学基金重点项目）：对腾格里沙漠周边和腹地进行了综合考察，行程 4985 km，重点考察 34 个点，取样 616 个。国家自然科学基金委经同行评议，中期评估优秀。

6）阿拉善干旱荒漠区土壤水－植被互馈关系及其空间异质性机理（国家自然科学基金重点项目）：共完成 252 个调查点的调查及取样工作。调查内容包括灌木调查取样、草本调查取样、土壤取样、标本集采、DNA 条形码样品采集、照片采集（包括植物群落、个体、根、茎、叶、花、果）、无人机照片采集等。

7）西北荒漠-绿洲动态变化过程及其稳定性维持机制（国家重点研发计划-课题 2017YFC0504301）：完成了新疆石河子和阿拉尔绿洲的综合调查，继续开展张掖和阿拉尔土壤水分监测，构建了荒漠-绿洲稳定性评价指标体系，构建了西北干旱区荒漠、绿洲和过渡带动态变化评价技术体系。

8）科尔沁沙地生态产业优化与示范（国家重点研发计划课题）：筛选出产木聚糖酶菌、产漆酶菌和降解木质素菌等 3 种优质菌种，并确定了“C/N 比为 25∶1、初始含水率为 60%、翻堆频率为 2d/次” 的羊粪堆肥最佳工艺条件。引种藜麦

品种 35 个，示范种植 35 亩。已筛选出适宜科尔沁沙地种植的藜麦品种-台红，单产可达 110 公斤/亩。确立了沙地中蒙药材的适宜种类及生长区域，建立了蒙中药材种质资源 1 处，引进种类 16 种，试验示范 30 亩。完成了科尔沁沙地固沙植被饲草化资源调查

9）种养一体化与沙化土地稳定恢复技术集成及产业示范（国家重点研发计划课题）：难治理沙化土地快速修复技术试验, 开展机械固沙、生物固沙、化学固沙等固沙技术和措施的对比研究、集成组装及试验，评价不同类型固沙技术的效果及应用前景。生物固沙措施（种植小叶锦鸡儿、差不嘎蒿）有利于植被盖度快速恢复→生产力较高植物群落；机械沙障（草方格、玉米沙障等）有利于物种快速入侵→物种多样性较高植物群落, 平缓沙丘物种多样性增加快，高大流动沙丘物种多样性增加减缓。

10）生态脆弱区资源环境要素对生态系统演变的驱动机制（国家重点研发计划）：祁连山北坡-河西走廊荒漠带土壤要素特征（剖面 127 个；样品 343 个，动物标本 700 个；微生物样品 270 个）北方农牧交错生态脆弱区近 30 年 SOC 储量变化全国典型生态脆弱区植被 NPP 空间分布特征。

11）农牧交错带农-草-畜-水复合生态工程发展模式及示范（A 类战略性先导科技专项）：生态-经济协调发展模式（托养+订单种植）：农牧户种粮改种饲草、优质饲草增产、牧业收入增加，养殖企业规模化养殖、企业效益提升草料来源稳定；生态治理效果显著放牧压力减轻、植被持续恢复。托养+订单种植模式应用示范：应用示范规模托养基础母牛 768 头、种植青贮玉米 839 亩、青贮产量平均 4.2 吨/亩、退牧草地 5100 亩；社会经济效益退牧区植被盖度增加 25%、农牧民平均收入增加 10%。

12）中国荒漠主要植物群落调查（国家科技基础资源调查专项）：完成 1270 个样点，行程 30000 余公里，调查样方 11430 个，植物样品 6200 份，土壤样品 9890 份，植物标本 460 种；植物 DNA 条形码 600 种。

13）荒漠营养和药用植物种质创新研发中心（甘肃省省级引导科技创新发展专项）：课题在武威、张掖等试验地栽植沙米种质资源圃几十亩，定期观测取样，监测内容开展顺利。

14）柴达木盆地荒漠区地下咸水利用与荒漠化治理技术（国家重点研发计划-课题 2018YFC0406603）：2019 年建立研究样地，筛选抗旱耐盐植物、优化植物配置、合理控制种群密度和群落盖度，探明不同植被-土壤系统的水盐平衡规律。

15）甘肃道地药材病害生物防治关键技术（甘肃省国际科技合作基地）：在定西、陇南地区试验地，通过对微生物与植物相互作用机理、甘肃道地药材主要真菌型病害的鉴定及防治技术开发、土壤改良、生物防治等内容。同时，还就解淀粉微生物菌剂“菌益多“应用作物生长，抗逆微生物技术提高药材产量开展研究。

16）荒漠区退化草地生态恢复技术的研发与示范（国家重点研究计划课题）：目前开展了可降解材料沙障、灌、草、混搭恢复技术，草地稳定恢复的近自然植被维持技术，草地封育恢复和更新复壮及持续利用技术，有机混合物诱导结皮生成的退化植被恢复技术，豆科植物平茬与循环利用技术试验。示范区 3000 亩，发表论文 4 篇。授权专利 1 项，开展相关培训 100 多人次。

17）沙米种群适应分化及种植优化与试验示范（国家重点研究计划课题）：沙米种群发生显著遗传和适应性表型分化沙米种植模式优化与试验示范。目前，已经获得超过 1000 个种质资源，其中有 2 个长穗、1 个密穗优良品系，还有 1 个富含类黄酮和生物碱的药用品系和 1 个高生物量品系，稳定产量>100kg/亩、不与粮争地，不使用除草剂和化肥、穗长 4-6cm，是普通野生型的 3-5 倍、富含药用成分-零抗饲料。后期将完成沙米基因组精细图，对这些优良品系进行分子育种，杂交整合优秀基因资源，创制具有低耗水高抗逆高产的全新沙米品种，推动在我国西北沙漠区域建立“金色粮仓“计划的实施。

18）种养一体化与沙化土地稳定恢复技术集成及产业示范（国家重点研发计划课题）：放牧对不同类型沙丘植被稳定性的影响.选择平缓和高大沙丘草地，通过无人机和 GPS 定位器，动态监测家畜的行动轨迹，分析家畜行动轨迹与牧场微地形的关系，揭示家畜采食行为对不同类型沙丘草地植被结构和格局的驱动作用。

19）寒区动物（牛、羊）脂肪代谢适应机制研究（百人计划项目）：研究进展发现冷应激下阿勒泰羊和湖羊脂肪代谢机制、滩羊营养物质消化代谢机制。

20）甘肃礼县杂交构树扶贫模式试验与示范（中国科学院科技扶贫项目）：2019 年示范栽植 70 亩，预计 2020 年辐射推广 1000 亩。

21）库伦旗草牧业-肉牛养殖一体化脱贫与产业发展模式试验示范（中国科学院科技扶贫项目）：建设完成集雨-节水灌溉温室大棚 2 座（合计 1000 m2），配套节水灌溉农田 60 亩。

22）百合良种繁育：目前繁育食用百合新品种“中百 1 号”脱毒苗 50 万株，鳞片籽球 10 万个，为新品种示范推广奠定了基础。分别指导宁夏种子公司、甘肃三荣公司和甘肃亚盛集团新组建了百合组培快繁中心，在不到一年时间里繁育“中百 1 号”试管苗 400 多万株，培训百合组培快繁技术人员 26 人。

23）百合产业化开发：宁夏农业投资集团拟与实验室联合进行食用百合优质种源繁育、商品百合种植、精深加工产区开发等全产业链开发。2019 年 10 月已与实验室签订了框架协议，合作具体事宜相关工作正在逐步推进。

24）兰州百合专用的包膜型颗粒缓释肥料试制：研发了兰州百合专用包膜型颗粒缓释肥料、开发了食用鲜百合贮藏保鲜技术、开发了百合主要病毒检测试剂盒。百合产量提高了 30%，可溶性糖和 Vc 含量显著提高。在皋兰站和宁夏隆德县等地进行了示范推广，推广面积 1000 亩。

25）植物病害快速检测产品的开发：首次将 3D 打印应用于百合病害检测产品的开发上，研发出了能同时检测百合多种病毒的 3D 打印金标速测卡产品，为解决严重制约百合产业发展的种源退化问题提供技术支撑，助力脱贫致富。

26）道地药材和作物生防菌剂研发。解淀粉芽孢杆菌对危害甘肃道地药材当归、党参、黄芪的根腐病、麻口病和病毒病等进行了病原微生物分离和鉴定，明确了致病微生物的种类。在陇南地区大面积推广试用。生物菌剂科技扶贫的社会效益显著，2019 年在甘肃渭源县临洮、文县等地捐赠颗粒菌剂 250 箱，液体菌剂 20 箱，总计 5 吨多，总价值 30 多万元。

三、科研成果突出亮点

3.1 人工蓝藻结皮在沙化土地治理中的应用研究

比较了机械固沙措施和化学固沙措施对人工蓝藻结皮形成和发育的影响；定量分析了生物和非生物因子对人工结皮形成的贡献；证明了草方格固沙措施可以有效促进人工蓝藻结皮的形成和发育（Zhao et al. 2019, Land Degradation & Development; 2019, Applied Soil Ecology）。

3.2 冠层截留对氢氧稳定同位素组成影响研究

对比分析了降雨、穿透雨和树干茎流的氢氧稳定同位素组成，发现灌木冠层对降水再分配过程中，树干茎流氢氧稳定同位素发生富集，这与冠层蒸发、冠层内外的液-气同位素交换、选择性的冠层存储效应三个机制有关 (Zhang et al. 2019, Science of the Total Environment) 。

3.3 长期施肥对荒漠开垦农田土壤微生物群落结构的影响

研究了荒漠开垦为农田后，持续施用有机肥和无机肥 17 年对土壤微生物群落的影响及其差异。初步阐明了不同肥料类型对农田土壤微生物和作物产量形成的影响机理。确定了不同施肥类型下，影响农田真菌和细菌的关键环境因子；证实了有机肥替代无机肥，显著降低了土壤真菌多样性和丰度，但对制约作物产量形成的细菌群落结构影响不大；中等施用无机肥强度持续 17 年，对微生态环境的影响不足以导致农田土壤质量恶化和作物农艺性状指标衰减（Wang et al. 2019, PeerJ）。

3.4 腾格里格里沙漠生物土壤结皮古菌群落组成及其功能演替研究

以腾格里沙漠东南缘沙坡头人工固沙植被区不同演替阶段生物土壤结皮为研究对象，利用 Illumina Miseq 测序和 GeoChip 5.0 技术对结皮演替过程中古菌群落结构和功能潜力的变化进行研究。结果显示，古菌群落的多样性、绝对丰度和功能潜力均在 5 龄结皮中最高，该群落可能在结皮演替过程的微生物演替阶段扮演先锋种的角色；同时，古菌群落中的优势门 Thaumarcheota、Euryarchaeota 和一个未分类的古菌门在结皮演替的碳、氮、硫和磷循环过程中发挥了重要的作

用；而影响古菌群落结构和功能潜力变化的主要限制因子为土壤 C:N（Zhao et al. 2019, Soil & Tillage Research）。

3.5 纳米复合材料促进生物土壤结皮形成和发育的机理研究

本研究中使用金属有机骨架(MOF)和羧甲基纤维素(CMC)制备了网状结构的纳米复合材料(MC)。MC 具有较大的比表面积和大量的表面基团，对水和营养物质的保持能力高，生物安全性好。富营养化中的蓝藻与纳米复合材料的结合可以为土壤提供适宜的微环境，促进荒漠蓝细菌的生长，促进生物土壤结皮的形成，抑制沙漠化（Li et al., 2019, Science of the Total Environment）。

3.6 明确了荒漠生态系统中低氮含量凋落物分解和混合效应的预测指标

凋落物质量损失与初始碳或氮含量不相关，初始木质素含量对多年生禾本科植物凋落物的混合效应也有显着影响；初始木质素含量为荒漠生态系统中低氮凋落物分解和混合效应的预测指标（Qu et al. 2019, Land degradation &Development）。

3.7 确定了降水对内蒙古荒漠草原生态系统碳收支的影响

明确了降水增减对 GEP 和 Reco 激发作用，生长季降水量增加对 GEP 的激发作用大于 Reco 的，导致 NEP 升高；降水增加会增强荒漠草原的碳固存能力(Zhang et al. 2019, Journal of Geophysical Research-Atmospheres; 2019, Catena)。

3.8 解析了长期极端干旱对不同草原植物群落功能性状及其变异的影响

草原群落性状变异对干旱的敏感性高于性状均值，功能性状的变异比性状均值能更好反映植物群落对干旱的响应能力；干旱地区草原植物群落性状变异对干旱处理的响应能力更强(Luo et al. 2019, Plant and Soil)。

3.9 确定了不同放牧强度下灌木−草本植被的土壤风蚀速率

随着放牧强度的增加，地表粒径有明显粗化显现，可蚀性风蚀物含量明显降低; 随着放牧强度的增加，土壤风蚀速率有明显增大趋势，草本区重度放牧下是对照区 50 余倍 (Du et al. 2019, Agriculture Ecosystems & Environment)。

3.10 研发了荒漠区退化草地的快速修复与合理利用关键技术

集成了荒漠区严重沙化和退化草地的快速治理及持续恢复技术 2 项，研发了荒漠区中度和轻度退化草地的持续恢复及合理利用技术 1 项，建立示范区 4000 亩。

3.11 百合产业化开发合作取得实质性进展

宁夏农业投资集团拟与实验室联合进行食用百合优质种源繁育、商品百合种植、精深加工产区开发等全产业链开发。2019 年 10 月，已与单位签订了框架协议，合作具体事宜相关工作正在逐步推进。

3.12 百合良种繁育

分别指导宁夏种子公司、甘肃三荣公司和甘肃亚盛集团新组建了百合组培快繁中心，在不到一年时间里繁育“中百 1 号”试管苗 400 多万株，培训百合组培快繁技术人员 26 人。

3.13 试制并完善了兰州百合专用的包膜型颗粒缓释肥料

百合产量提高了 30%，可溶性糖和 Vc 含量显著提高。在皋兰站和宁夏隆德县等地进行了示范推广，推广面积 1000 亩。

3.14 植物病害快速检测产品的开发

首次将 3D 打印应用于百合病害检测产品的开发上，研发出了能同时检测百合多种病毒的 3D 打印金标速测卡产品，为解决严重制约百合产业发展的种源退化问题提供技术支撑，助力脱贫致富。

3.15 白藜芦醇减轻脂多糖（LPS）诱导羔羊的全身炎症反应

白藜芦醇通过抑制 IL-1β、IL-6、IFN-γ、TNF-α 等促炎细胞因子和抗炎细胞因子 IL-4 的表达，以及皮质醇的释放和白细胞的减少，减轻 LPS 诱导的羔羊炎症激活。

3.16 生物菌剂科技扶贫的社会效益

2019 年共计捐赠颗粒菌剂 250 箱，液体菌剂 20 箱，总计 5 吨多，总价值 30 多万元。甘肃省渭源县大安乡：1200 亩甘肃省渭源县大安乡：1200 亩甘肃省临洮县站滩乡：150 亩甘肃省文县范坝镇：150 亩。

四、2019 年实验室新增科研项目

2019 年本实验室新增国家级、省部级等各类项目 36 项，总经费 6354.6 万元，目前各课题开展科研启动工作顺利，具体明细如下表。

表一 2019 年实验室新争取课题/项目统计表

序号	课题名称	类 别	主持人	起始年限	总经费(万元)
1	荒漠化土地植被恢复重建关键技术研发与集成示范	泛第三极环境变化与绿色丝绸之路建设”子课题	李新荣	2019-2021	1574
2	干旱区沙化土地生态恢复的关键技术与示范	中科院 A 类战略性先导科技专项课题	张志山	2019-2023	1225
3	东北农牧交错带农-草-畜-水复合生态工程发展模式及示范	中科院 A 类战略性先导科技专项子课题	李玉霖	2019-2023	230
4	荒漠营养和药用植物种质创新研发中心	甘肃省省级引导科技创新发展专项	马小飞	2019-2021	300
5	甘肃礼县杂交构树扶贫模式试验与示范	中国科学院科技扶贫项目	李玉强	2019-2020	75
6	科尔沁沙地农林草畜复合生态产业发展模式与示范	内蒙古科技重大专项	李玉霖	2019-2021	280
7	青藏高原荒漠生态系统植物群落科考	第二次青藏高原科考项目	左小安	2019-2024	600
8	青藏高原荒漠生态系统土壤理化与生物特征	第二次青藏高原综合科考	李玉强	2019-2024	600

9	解芽孢杆菌促进植物抗逆机理研究及道地药材种植用微生物制剂的研制	重点研发计划政府间国际科技创新合作项目	王若愚	2019-2023	292
10	甘肃道地药材病害生物防治关键技术	甘肃省国际科技合作基地	王若愚	2019-2021	50
11	我国沙质草地群落植物多样性对增温和降水减少的响应	国家自然科学基金（面上）	黄文达	2020-2023	62
12	抗旱防御警备在干旱区藓类植物拓殖中的作用及其调控机制研究	国家自然科学基金（面上）	贾荣亮	2020-2023	62
13	流动沙丘先锋植物沙蓬驯化初步研究	国家自然科学基金（面上）	陈国雄	2020-2023	58
14	干旱沙区固沙植被演替进程中土壤微生物功能群和酶活性的生态化学计量研究	国家自然科学基金（面上）	张志山	2020-2023	58
15	沙地生态系统碳平衡及其对氮磷养分添加的响应	国家自然科学基金（面上）	李玉强	2020-2023	58
16	生物土壤结皮微生物铁循环及其对演替的驱动机制	国家自然科学基金（面上）	刘玉冰	2020-2023	61
17	温带荒漠多年生沙生植物物候和生物量分配对增温和降水变化的响应过程和机理研究	国家自然科学基金（面上）	胡宜刚	2020-2023	58
18	干旱荒漠人工植被区风蚀坑形成的生态水文学机理及治理研究	国家自然科学基金（面上）	黄　磊	2020-2023	62
19	石羊河流域千年尺度有机碳库变化及其影响机制	国家自然科学基金（青年基金）	张成琦	2020-2023	26

20	荒漠隐花植物功能性状对环境变化的响应机制研究	国家自然科学基金（青年基金）	宋光	2020-2023	26
21	沙蓬干旱响应相关基因调控网络的适应性分化研究	国家自然科学基金（青年）	钱朝菊	2020-2023	23
22	林草及药材副产物成型饲料产品饲喂技术及质量综合评价	宁夏回族自治区重点研发项目课题子课题	周建伟	2019-2021	15
23	野外生物样本核酸提取纯化储存检测一体机的研制	中国科学院仪器设备功能开发技术创新项目	赵　昕	2019-2021	35
24	兰州百合全产业链开发关键技术研究与示范	中国科学院 STS 项目	谢忠奎	2019-2020	150
25	食用百合新品种选育	宁夏科技厅重点研发项目	谢忠奎	2019-2020	60
26	百合育种联合攻关	甘肃亚盛实业(集团)股份有限公司	郭志鸿	2019-2021	54
27	百合病毒 3D 打印金标速测卡的开发及应用	兰州市人才创新创业项目	张玉宝	2019-2021	40
28	秸秆错位轮还模式下改土新技术	中国科学院 STS 项目（子课题）	杨果	2019-2020	30
29	荒漠营养和药用植物种质创新研发中心	甘肃省引导科技创新转项资金	王若愚	2019-2023	80
30	呼伦贝尔羊和三河牛营养及高效饲喂技术	中国科学院 STS 项目（子课题）	杨果	2018-2019	30
31	经济型牦牛冷季补饲料开发及其应用效果	陇原青年人才创新创业项目	周建伟	2019-2020	4
32	天然草地放牧系统功能优化与管理专家系统研究与应用	青海省科技成果转化专项	周建伟	2019-2021	40

33	荒漠草原温室气体通量对降水变化的响应	西北研究院人才成长基金	岳平	2019-2021	10
34	荒漠草原土壤温室气体通量特征及其驱动机制	中国科学院沙漠与沙漠化重点实验室开放基金	岳平	2019-2021	5
35	巴音温都尔沙漠封禁保护区植被监测项目（二期）	横向项目	曲浩	2019-2023	11.6
36	荒漠隐花植物功能性状权衡关系及其生态适应性研究	中国科学院西北研究院青年人才成长基金	宋光	2019-2021	10
合计					6354.6

五、实验室人才队伍建设

5.1 实验室人员组成

实验室现有研究员 18 名（其中杰青 1 名，中科院—百人计划 7 人，人事部跨世纪百千万人才工程国家级人选 3 人，甘肃省第一层次领军人才 3 人），副研究员 16 名，助理研究员 35 名，支撑系列高级工程师 3 人，工程师 8 人，共 78 人。

5.2 获奖成果

- “风沙灾害防治理论和关键应用技术”获 2018 年获国家科技进步二等奖，李新荣、赵哈林、赵学勇为主要完成人；
- 沙坡头站获得科技部国家野外台站调整梳理评估优秀，奈曼站获得良好。

5.3 科研人员获得奖励

- 李新荣研究员荣获“庆祝中华人民共和国成立 70 周年纪念章”；
- 李新荣研究员荣获中国科学院兰州分院“优秀共产党员”；
- 左小安研究员荣获第九届甘肃青年科技奖；
- 左小安、赵学勇研究员入选甘肃省领军人才；
- 胡宜刚副研究员入选 2019 年宁夏回族自治区国家级学术技术带头人后

备人选；

- 李小军研究员入选 2019 年宁夏回族自治区自治区级学术技术带头人后备人选；
- 张志山研究员当选为中国地理学会“自然地理专业委员会”委员；
- 张玉宝“百合病毒 3D 打印金标速测产品开发及应用”项目获第二届“活力金城”兰州市人才创新创业大赛三等奖，得到了 40 万元的研发补助资金。
- 王少昆获得中国纺织工业联合会科技进步二等奖。

5.4 专利

2019 年授权发明专利 6 项，实用新型专利 3 项，制订地方标准 2 项。

5.4.1 授权发明专利

1) 赵昕, 张继伟, 陈国雄, 赵鹏善. 一种荒漠植物总 DNA 的提取方法. 2019-03-12.中国，ZL201610231035.5.
2) 赵昕，陈国雄，赵杰才. 炒沙米及其制作方法，2019,11,01. 中国 Zl201600051398.4
3) 张玉宝，王亚军，谢忠奎，王若愚，郭志鸿，杨果等. 用三重复合免疫捕获 RT-PCR 同步检测百合三种病毒的方法，2019.09.06，中国, ZL201610210127.5
4) 张玉宝，王亚军，谢忠奎，王乐等.一种兰州百合 PR1 基因定量检测试剂盒及其检测方法. 2019,11.08，中国，ZL201610673491.5
5) 张玉宝，王乐，谢忠奎，王亚军等.一种兰州百合 PR4 基因定量检测试剂盒及其检测方法. 2019,11.08，中国，ZL201610674946.5
6) 张玉宝，王亚军，谢忠奎，王乐等.一种兰州百合 PR5 基因定量检测试剂盒及其检测方法. 2019,11.08，中国，ZL201610673546.2

5.4.2 授权实用新型专利

1) 杨果, 刘虎, 周建伟, 谢忠奎, 张云生, 张玉宝, 段子渊. 一种羊消化代谢笼[P]. 201721392832.8, 2018-05-08.
2) 周建伟, 刘虎, 杨果, 谢忠奎, 张云生, 张玉宝, 段子渊. 一种便携式可控瘤胃液采集装置[P]. 201721392847.4, 2019-01-15.

3) 何钊全, 云建英, 张铜会, 刘新平, 赵学勇, 李玉霖, 李玉强, 左小安, 王少昆, 车力木格. 一种便于 PE 管试验土样砂土装载的装置[P]. 201820723853.1, 2019-03-26.

5.4.3 制订地方标准

1) 沙地生物质固体废物发酵技术规程，奈曼站

2) 防风固沙灌木林生态效益检测技术规程，奈曼站


DB15

内蒙古自治区地方标准

沙地生物质固体废物发酵技术规程


DB15

内蒙古自治区地方标准

防风固沙灌木林生态效益监测技术规程
Technical Regulations for Ecological Monitoring of Windbreak and Sand Fixation Shrub Forest

5.4.4 申请发明专利

1) 赵洋, 李新荣, 张志山, 潘颜霞, 王楠. 一种可机械化的人工蓝藻结皮培养施工工艺.

2) 马小飞;周姗姗;燕霞;朝菊;尹晓月，沙米总黄酮的提取工艺、提取物和应用发明专利 公开 CN201910930623.1

3) 李新荣, 赵洋, 张志山, 潘颜霞, 王楠. 一种利用农作物秸秆提高固沙灌木成活率的器具.

4) 罗亚勇, 赵学勇, 张铜会, 李玉霖, 李玉强. 一种沙化土地道地药材苦参的高产种植方法.

5) 赵丽娜, 刘玉冰, 王增如, 黄文广, 张宇, 王蕾, 罗晓玲. 用于沙区土壤改良的微生物组合物、微生物制剂以及方法.

6) 刘玉冰, 赵丽娜, 王增如, 黄文广, 张宇, 王蕾, 罗晓玲. 特基拉芽孢杆菌及其在荒漠化防治中的应用和方法.

7) 李玉强, 罗永清, 王旭洋, 龚相文, 牛亚毅, 王少昆, 刘新平. 一种风沙风洞的整流装置及其制备方法.

8) 高永平, 宋光, 郭芳, 黄磊, 贾荣亮. 一种试验用苗圃培育床.

9) 高永平, 宋光, 郭芳, 何明珠, 李小军. 一种盆栽苗圃浇水装置.

10) 张玉宝，王若愚，谢忠奎，管青霞等. 一种检测侵染当归 JHMV 病毒的 IC-RT-LAMP 试剂盒及其检测方法. 专利申请号：201910101485.6.

11) 张玉宝，王若愚，谢忠奎，王筠等. 一种特异性检测当归 JHMV 病毒的 IC-RT-LAMP 检测方法. 专利申请号：201910101488.X

12) 张玉宝，王若愚，谢忠奎，张和平等. 一种检测侵染当归 ToMV 病毒的 IC-RT-LAMP 试剂盒及其检测方法. 专利申请号：201910101486.0.

13) 张玉宝，王若愚，谢忠奎，王筠等. 一种特异性检测当归 ToMV 病毒的 IC-RT-LAMP 检测方法. 专利申请号：201910100839.5.

14) 张玉宝，王亚军，谢忠奎，郭志鸿等. 一种检测莴苣坏死黄化病毒的 IC-RT-LAMP 试剂盒及其检测方法. 专利申请号：201910101487.5.

15) 张玉宝，王亚军，谢忠奎，郭志鸿等. 一种特异性检测生菜 LNYV 病毒的 IC-RT–LAMP 检测方法. 专利申请号：201910100840.8.

16) 邱阳, 谢忠奎, 王亚军, 郭志鸿, 何玉惠, 张玉宝. 一种百合浓缩汁及其制备方法与应用. 专利申请号：201910332246.1

17) 周建伟, 杨果, 刘虎, 龙瑞军, 段子渊, 张云生, 谢忠奎. 低蛋白绵羊育肥用配合饲料及其制备方法.专利申请号： 201910043005.5

18) 张玉宝，谢忠奎，王亚军，王若愚，郭志鸿，邱阳，何玉惠. 免疫检测卡. 专利申请号：201930462793.2

5.4.5 申请实用新型专利

1) 苏娜, 冯静, 李玉霖, 云建英, 常宇, 侯晓娟. 一种用于重金属离子的检测装置.

2) 冯静, 苏娜, 李玉霖, 云建英, 侯晓娟. 一种针对土壤全磷全钾消解的聚四氟乙烯管的改良.

3) 周建伟, 杨果, 刘虎, 龙瑞军, 段子渊, 张云生, 谢忠奎. 牛栏结构以及羊栏组.

六、实验室研究生培养

2019 年实验室继续重视人才培养。2019 年新招 9 名硕士研究生、12 名博士研究生；毕业博士生 6 人，硕士生 8 人。目前在读研究生 69 人。

6.1 研究生获个人奖励

1) 博士生王旭洋和张蕊获得中国科学院西北研究院院长奖；
2) 博士生王旭洋获得 2019 届北京市普通高等学校优秀毕业生；
3) 硕士生李云飞、李昭环获得国家奖学金；
4) 博士生王旭洋被评为中国科学院大学 2019 学年“优秀毕业生”；
5) 博士生漆婧华、赵丽娜获得 2018-2019 学年中国科学院大学“优秀学干部”；
6) 博士生漆婧华获得 2018 年度共青团中国科院院兰州分院工委会“优秀学生干部”；
7) 硕士生张甜获得 2018-2019 学年度中国科学院大学“优秀共青团员”;
8) 博士生何钊全获得中国科学院大学 2018-2019 学年“三好学生标兵”；
9) 漆婧华、王炳尧、李云飞等 10 位研究生获得中国科学院大学 2018-2019 学年“三好学生”；
10) 博士生漆婧华获得国科大“优秀学生干部”;
11) 博士生赵丽娜、王艳丽获得朱李月华奖学金。

6.2 毕业答辩博士、硕士研究生记录

1）题目：沙蓬栽培品系筛选及重要性状初步研究

答辩人：张继伟 申请学位：理学博士

导 师：陈国雄 研究员

答辩委员会主席：李新荣 研究员

2）题目：胞外多糖合成基因和果聚糖蔗糖酶基因在解淀粉芽孢杆菌诱导植物抗旱作用中的研究

答辩人：卢 翔 申请学位：理学博士

导 师：王若愚 研究员

答辩委员会主席：李新荣 研究员

3）题目：北方农牧交错带土壤有机碳时空动态及其影响机制

答辩人：王旭洋 申请学位：理学博士

导 师：李玉强 研究员

答辩委员会主席：李新荣 研究员

4）题目：内蒙古地区灌溉玉米节水种植模式及生产潜力评估

答辩人：何钊全 申请学位：理学博士

导 师：张铜会 研究员

答辩委员会主席：李新荣 研究员

5）题目：科尔沁沙质草地植物功能性状与生物量关系及其影响机制

答辩人：张 晶 申请学位：理学博士

导 师：左小安 研究员

答辩委员会主席：李新荣 研究员

6）题目：内蒙古荒漠草原生态系统碳收支对降水变化的响应

答辩人：张 蕊 申请学位：理学博士

导 师：赵学勇 研究员

答辩委员会主席：李新荣 研究员

7）题目：沙区土壤微生物量、酶活性及微生物群落结构对植被恢复的响应

答辩人：马晓俊 申请学位：理学硕士

导 师：李小军 研究员

答辩委员会主席：李新荣 研究员

8）题目：固沙植被演替进程中土壤微生物功能群和酶生态化学计量研究

答辩人：吕星宇 申请学位：理学硕士

导 师：张志山 研究员

答辩委员会主席：李新荣 研究员

9）题目：直插式地下滴灌的土壤湿润体特性及田间应用

答辩人：王炳尧 申请学位：工程硕士

导 师：刘立超 研究员

答辩委员会主席：李新荣 研究员

10）题目：半干旱沙地固沙草本植物生殖生长对降水变化的响应

答辩人：车力木格 申请学位：理学硕士

导 师：刘新平 副研究员

答辩委员会主席：赵文智 研究员

11）题目：凋落物化学组分对土壤有机碳矿化的激发效应及矿质结合态有机碳累积的影响 答辩人：杨红玲 申请学位：理学硕士

导 师：李玉霖 研究员

答辩委员会主席：赵文智 研究员

12）题目：科尔沁地区植被净初级生产力及生态承载力时空动态研究

答辩人：龚相文 申请学位：理学硕士

导 师：李玉强 研究员

答辩委员会主席：赵文智 研究员

13）题目：低温对绵羊营养物质代谢和肌肉组织基因表达的影响

答辩人：姬凯茜 申请学位：理学硕士

导 师：杨 果 研究员

答辩委员会主席：赵文智 研究员

14）题目：生物炭对退化农田土壤的改良作用研究

答辩人：周丽靖 申请学位：工程硕士

导 师：王亚军 副研究员

6.3 实验室研究生年终总结报告

表二 2019 年度研究生开题、中期、考核报告题目

序号	姓名	报告题目	指导老师
1	周媛媛	植物固沙对沙漠生态系统碳通量的影响	李新荣

2	范兴科	北疆红砂多重起源及生态物种形成历史的研究	马小飞
3	王艳莉	砂蓝刺头对沙地生境变化的生活史对策及响应机制	李新荣
4	尹晓月	基于多组学探究沙米局域适应性的分子代谢机制	马小飞
博士三年级			
1	马雄忠	阿拉善高原红砂和珍珠根系特征及生态功能研究	王新平
2	孙靖尧	生物土壤结皮的微尺度空间格局及其机理	李新荣
3	赵丽娜	生物土壤结皮微生物群落组成及其功能演替	李新荣 刘玉冰
4	焦　丹	慢性冷刺激下的绵羊代谢通路分子机制研究	谢忠奎
5	岳　靓	解淀粉芽孢杆菌(Bacillus amyloliquefaciens)诱导植物抗旱的分子机制研究	王若愚
6	张　涛	青藏高原“黑土滩”退化草地中“秃斑块”的水热空洞效应及其对草地退化的作用	谢忠奎
7	CONSTANTINE UWAREMWE	Investigation on Root Rot disease in Wolf berry plants and a systematic study on biological control (a case study of Chinese Wolf berry)	王若愚
博士二年级			
1	李荣麟	西北地区典型植物群落表土植硅体记录及古环境应用	李新荣
2	周珊珊	沙米黄酮含量差异形成的分子代谢调控机制研究	马小飞
3	李昌盛	西北干旱区荒漠、绿洲及过渡带植被与土壤特性及相互作用机制	张志山
4	徐冰鑫	我国北方沙区植被—土壤关系及影响因素	张志山
5	漆婧华	不同类型生物土壤结皮微生物硫磷循环及其对增温的响应	李新荣 刘玉冰
6	刘　洋	解淀粉芽孢杆菌 FZB42 对当归根腐病的微生态机制及抗病促生机理研究	王若愚
7	华翠平	兰州百合根际土壤酚酸类物质累积动态与其病害关系研究	谢忠奎
8	魏海莲	兰州百合多糖功能活性及贮藏环境影响研究	谢忠奎
9	田　原	小分子碳源对 PGPR 在植物根际定殖的作用研究	王若愚

博士一年级			
1	付桐林	区域气候变化与干旱区植被演替的模拟预测	李新荣
2	石亚飞	腾格里沙漠东南缘天然和固沙植被区油蒿种群格局与动态研究	张志山
3	房庭舟	基于群体基因组学的沙蓬进化历史及适应性机理研究	马小飞
4	程天亮	干旱区灌从植被斑块结构特征及其环境效应研究	王新平
5	霍建强	固沙灌木个体形态调整的水力传导机理	张志山
6	张雯莉	生物土壤结皮演替中微生物金属代谢的调控机制	刘玉冰
7	姬凯茜	绵羊肌肉组织对冷胁迫的响应分子机理	谢忠奎
硕士三年级			
1	李云飞	腾格里沙漠东南缘植被恢复对土壤有机碳固存和矿化的影响	李小军
2	许　华	荒漠土壤微生物量碳、氮、磷生态化学计量特征对降水变化的响应	何明珠
3	李昭环	纳米复合材料促进人工生物土壤结皮形成和发展的机理研究	刘立超
4	毛忠超	石羊河流域荒漠-过渡带-绿洲研究	张志山
5	杨利贞	荒漠人工植被区典型植物叶片吸水策略研究	张志山
6	孙沛沛	半干旱区油蒿-差巴嘎蒿群落建成下土壤微生物变化规律	马小飞
7	赵成政	砾石覆盖旱作农田主要生态保育功效研究	王亚军
8	吕文聪	砾石覆盖粒径对土壤生态水文过程的影响研究	谢忠奎
硕士二年级			
1	唐亮	阿拉善荒漠植被空间分布对土壤有机碳、氮储量的响应研究	何明珠
2	王岩松	生物土壤结皮微生物铁循环及其对荒漠土壤演化的驱动机制	刘玉冰
3	张甜	沙坡头固沙植被演替过程中藓类植物种间关系变化研究	贾荣亮
4	杨贵森	固沙植被土壤微生物功能群和酶活性生态化学计量动态变化及机理	黄　磊
5	苏学思	百合南芥菜和车前草花叶病毒的胶体金定量检测技术研究	张玉宝
6	孙冠聪	绵羊 PIK3R1 和 AKT1 的基因多态性及其与脂肪沉积性状的关	杨　果

		联分析	
硕士一年级			
1	谢　婷	沙区生物土壤结皮对表层土壤有机碳组分及矿化的影响	李小军
2	贾谱超	乌玛高速腾格里沙漠段公路防护体系生态与防护效益综合评价	何明珠
3	李晓凤	沙米自然群体种子大小变异的环境与遗传决定因素	赵鹏善
4	刘璐璐	退耕还林对贫困地区农户生计安全及可持续性的影响—以甘肃会宁县为例	李锋瑞
5	杨　琨	西北内陆区城市化过程中失地农民生计问题的实证研究-以兰州市为例	李锋瑞
6	韩亚楠	半干旱区农田生态系统中微生物降解地膜的研究	谢忠奎
7	李文美	兰州百合在干旱胁迫下的适应机制	谢忠奎

七、2019 年实验室发表专著和学术论文

2019 年实验室共发表论文 99 篇，其中 SCI 论文 59 篇。

发表论文目录：

1) Chen JL, Zhao XY, Liu XP, Zhang YQ, Luo YY, Luo YQ, He ZQ, Zhang R. Growth and physiological responses of two psammophytes to precipitation manipulation in Horqin Sandy Land, eastern China. Plants Basel, 2019, 8(7): 244.
2) Chen JL, Zhao XY, Zhang YQ, Li YQ, Luo YQ, Ning ZY, Wang RX, Wang PY, Cong AQ. Effects of drought and rehydration on the chlorophyll fluorescence parameters and physiological responses of Artemisia halodendron. Water, 2019, 11(4): 793.
3) Chen Min and Zhao Xueyong. Impact of floral characters, pollen limitation, and pollinator visitation on pollination success in different populations of Caragana korshinskii Kom. Scientific reports, 2019, 9(1):1-8.
4) Chen Min, Zhao Xueyong, Zuo Xiaoan. Comparative pollen limitation and pollinator activity of *Caragana korshinskii* Kom in natural and fragmented habitats. Science of the Total Environment, 2019, 645: 1056-1063.
5) Chen Min, Zuo Xiaoan. Effect of pollen limitation and pollinator visitation on

pollination success of *Haloxylon ammodendron* (C. A. Mey.) Bunge in Fragmented Habitats. Frontiers in Plant Science, 2019, 10:327.

6) Chen N, Liu XD, Zheng K, Zhang CK, Liu YJ, Lu KL, Jia RL, Zhao CM. Ecohy drological effects of biocrust type on restoration dynamics in drylands. Science of the Total Environment, 2019, 687: 527–534.
7) Cheng Qingping, Gao Lu, Chen Ying, Liu Meibing, Deng Haijun, and Xingwei Chen. Temporal-Spatial Characteristics of Drought in Guizhou Province, China, Based on Multiple Drought Indices and Historical Disaster Records. Advances in Meteorology, 2019, https://doi.org/10.1155/2018/4721269.
8) Cheng Qingping, Gao Lu, Zuo Xiaoan, et al. Statistical analyses of spatial and temporal variabilities in total, daytime and nighttime precipitation indices and of extreme dry/wet association with large-scale circulations of Southwest China, 1961-2016. Atmospheric Research, 2019, 219:166-182.
9) Cheng Qing-ping, Zhong Fang-le. Evaluation of tourism climate comfort in the Grand Shangri-La region. J. Mt. Sci, 2019, 16(6): 1452-1469.
10) Cheng Qingping, Zuo Xiaoan, Zhong Fanglei, et al. Runoff variation characteristics, association with large-scale circulation and dominant causes in the Heihe River Basin, Northwest China. Science of the Total Environment, 2019, 688: 361-379.
11) Cui X, Yue P, Wu W, Gong Y, Li K, Misselbrook T, Goulding K, Liu X. The growth and N retention of two annual desert plants varied under different nitrogen deposition rates. Frontiers in Plant Sciences, 2019, 10: 356.
12) Du Heqiang, Wang Tao, Xue Xian, et al. Estimation of soil organic carbon, nitrogen, and phosphorus losses induced by wind erosion in northern China. Land Degradation & Development, 2019, 30:1006–1022.
13) Du Heqiang, Zuo Xiaoan, Li Sen, et al. Wind erosion changes induced by different grazing intensities in the desert steppe, Northern China. Agriculture, Ecosystems and Environment, 2019, 274:1-13.
14) Guan C, Li XR, Chen N, Zhang P, Zhao CM. Warming effects on soil respiration in moss-dominated crusts in the Tengger Desert, northern China. Plant and Soil, 2019. 443:591–603.
15) Guan C, Li XR, Zhang P, Li CH. Effect of global warming on soil respiration and cumulative carbon release in biocrust-dominated areas in the Tengger Desert,

northern China. Journal of Soils and Sediments, 2019, 19: 1161-1170.

16) He MZ, Hu R, Jia RL. Biological soil crusts enhance the recovery of nutrient levels of surface dune soil in arid desert regions. Ecol Indic, 2019, 106:105497.
17) He Zhaoquan, Zhang Tonghui, Liu Xinping. Study on antioxidant enzymes of affecting greenhouse grape berry under surface mulching. Fresenius Environmental Bulletin, 2019, 28(7):5320-5330.
18) Hu YG, Zhang ZS , Huang L, Qi Q, Liu LC, Zhao Y, Wang ZR, Zhou HK, Lv XY, Mao ZC, Yang YF, Zhou JZ, Kardolh P., Shifts in soil microbial community functional gene structure across a 61-year desert revegetation chronosequence. Geoderma, 2019, 347:126–134.
19) Hua Cui-ping, Xie Zhong-kui, Wu Zhi-jiang, Zhang Yu-bao, Guo Zhi-hong, Qiu Yang, Wang Le and Wang Ya-jun. The Physiological and Biochemical Effects of Phthalic Acids and the Changes of Rhizosphere Fungi Diversity under Continuous Cropping of Lanzhou Lily (*Lilium davidii* var. unicolor). 2019, 54(2):253-261.
20) Huang Wen-Da, Zhao Xue-Yong, zhao Xin, Luo Ya-Yong, Feng Jing, Su Na, and He Yuan-Zheng. Genetic Diversity in Salix gordejevii Populations from Different Environmental Gradients in Horqin Sandy Land, Northern China," Polish Journal of Ecology, 2019. 67(3), 175-185.
21) Hui R, Liu LC, Xie M, Yang HT. Variation in snow cover drives differences in soil properties and microbial biomass of BCSs in the Gurbantunggut Desert - 3 years of snow manipulations. Ecohydrology, 2019, 12:e2118.
22) Hui R, Jia RL, Zhao Y, Song G, Gao YH. Comparative physiological responses o f Microcoleus vaginatus and Bryum argenteum to enhanced UV radiation under field conditions. Functional Plant Biology, 2019, 46(3): 262-274.
23) Jia XH, Wu B, Lu Q, Li XR. Plant restoration leads to divergent sequestration of soilcarbon and nitrogen in different fractions in an arid desert region. Land Degradation & Development, 2019, 30:2197-2210.
24) Jia RL, Chen N, Yu KL, Zhao CM. High rainfall frequency promotes the domina nce of biocrust under low annual rainfall. Plant Soil, 2019, 435: 257–275.
25) Li CS, Zhang ZS. Effects of Ionic Components of Saline Water on Irrigated Sunflower Physiology. Water, 2019, 11(2):183; doi:10.3390/w11020183.

26) Li YQ, Wang XY, Chen YP, Luo YQ, Lian J, Niu YY, Gong XW, Yang H, Yu PD. Changes in surface soil organic carbon in semiarid degraded Horqin Grassland of northeastern China between the 1980s and the 2010s. Catena, 2019, 174: 217-226.

27) Li ZH, Xiao JM, Chen CW, Zhao LN, Wu ZY, Liu LC, Cai DQ. Promoting desert biocrusts formation using aquatic cyanobacteria with the aid of MOF-based nanocomposite, Science of the Total Environment, 2020, 708: 134824.

28) Liang Yanping, Zhou Jianwei, Ji Kaixi, et al. Protective Effect of Resveratrol Improves Systemic Inflammation Responses in LPS-Injected Lambs. Animals, 2019, 9(11): 872, doi:10.3390/ani9110872

29) Liu YB, Wang ZR, Zhao LN, Wang X, Liu LC, Hui R, Zhang WL, Zhang P, Song G, Sun JY. Differences in bacterial community structure between three types of biological soil crusts and soil below crusts from the Gurbantunggut Desert, China. Eur J Soil Sci, 2019, 70:630–643.

30) Luo Wentao, Zuo Xiaoan, et al. Long term experimental drought alters community plant trait variation, not trait means, across three semiarid grasslands. Plant Soil, 2019, 442: 343-353.

31) Luo Yayong, Zuo Xiaoan, Li Yulin et al. Community carbon and water exchange responses to warming and precipitation enhancement in sandy grassland along a restoration gradient. Ecology and Evolution, 2019, 9:10938-10949.

32) Luo YQ, Zhao XY, Ding JP, Li YQ, Liu XP, Wang T, Luo YY. Soil respiration dynamics in a semi-fixed sand dune under the pioneer shrub Artemisia halodendron in the Horqin sandy land, northeastern China. Arid Land Res Manag, 2019, DOI: 10.1080/15324982.2019.1629675.

33) Lv Wencong, Qiu Yang, Xie Zhongkui, Wang Xinping, Wang Yajun, Hua Cuiping. Gravel mulching effects on soil physicochemical properties and microbial community composition in the Loess Plateau, northwestern China. European Journal of Soil Biology. 2019, 94. 103115. 10.1016/j.ejsobi. 2019. 103115.

34) Qian Chaoju, Yan Xia, Shi Yong, Yin Hengxia, Chang Yuxiao, Chen Jun, Ingvarsson Pär K., Nevo Eviator and Ma Xiao-Fei. Adaptive signals of flowering

time pathways in wild barley from Israel over 28 generations. Heredity, 2019, 1-15.

35) Qu Hao, Pan Chencheng, Zhao Xiaoyong, et al. Initial lignin content as an indicator for predicting leaf litter decomposition and the mixed effects of two perennial gramineous plants in a desert steppe: A 5-year long-term study. Land Degradation & Development, 2019, 30: 1645-1654.

36) Shi Y, Yan X, Yin HX, Qian CJ, Fan XK, Yin XY, Chang YX, Zhang CJ, Ma XF. Divergence and hybridization in the desert plant Reaumuria soongarica. J Syst Evol, 2019, https://doi.org/10.1111/jse.12490.

37) Sun ShanShan，Liu Xin Ping， He Yu Hui，Wei Shui Lian，Zhang La Mei，Lv Peng，Bao Chelmeg，Wang Ming Ming，Cheng Li. Responses of annual herb plant community characteristics to increased precipitation and reduced wind velocity in semiarid sandy grassland. Ecology and Evolution. 2019, 9:10654–10664.

38) Wang XY, Li YQ, Gong XW, Niu YY, Chen YP, Shi XP. Storage, pattern and driving factors of soil organic carbon in an ecologically fragile zone of northern China. Geoderma, 2019, 343: 155-165.

39) Wang YL, Li XR, Zhao JC, Song G, Zhou YY. Dormancy and germination strategies of a desert winter annual Echinops gmelini Turcz. in a temperate desert of China. Ecological Research, 2019, 34: 74-84.

40) Wang YL, Li XR, Zhao JC, Liu LC, Yang HT, Zhao YY. Population dynamics of Echinops gmelinii Turcz. at different successional stages of biological soil crusts in a temperate desert in China. Plant Biology, 2019, doi:10.1111/plb.13027.

41) Wang ZR, Liu YB, Zhao LN, Zhang WL, Liu LC. Change of soil microbial community under long-term fertilization in a reclaimed sandy agricultural ecosystem. Peer J, 2019, 7: e6497.

42) Yang HT, Wang ZR, Li XJ, Gao YH. Vegetation restoration drives the dynamics and distribution of nitrogen and phosphorous pools in a temperate desert soil-plant system. Journal of Environmental Management, 2019, 245(9): 200-209.

43) Yue P, Cui X, Gong Y, Li K, Goulding K, Liu X. Fluxes of N2O, CH4 and soil respiration as affected by water and nitrogen addition in a temperate desert. Geoderma, 2019, 337: 770-772.

44) Yue Ping, Cui Xiaoqing, et al. Impacts of precipitation, warming and nitrogen deposition on methane uptake in a temperate desert. Biogeochemistry, 2019, 1-13. DOI:10.1007/s10533-019-00606-0.

45) Yue Xiyuan, Zuo Xiaoan, Q Yuqiang, et al. Response of plant functional traits of Leymus chinensis to extreme drought in Inner Mongolia grasslands. Plant Ecology, 2019, 220: 141-149.

46) Zhang J, Zuo XA, Peng LV, Zhao SL, ZhaoXY. Plant functional trait response to habitat change and grazing in semiarid grassland: unravelling species turnover and intraspecific variation effects. Pol J Ecol, 2019, 67: 62-74.

47) Zhang R, Bai YF, Zhang T, Henkin Z, Degen AA, Jia TH, Guo CC, Long RJ, Shang ZH. Driving factors that reduce soil carbon, sugar, and microbial biomass in degraded alpine grasslands. Rangeland Ecol Manag, 2019, 72: 396-404.

48) Zhang R, Zhao XY, Zuo XA, Degen AA, Shang ZH, Luo YQ, Zhang YG, Chen JL. Effect of manipulated precipitation during the growing season on soil respiration in the desert-grasslands in Inner Mongolia, China. Catena, 2019, 176: 73-80.

49) Zhang R, Zhao XY, Zuo XA, Qu H, Degen AA, Luo YY, Ma XJ, Chen M, Liu LX, Chen JL. Impacts of precipitation on ecosystem carbon fluxes in desert-grasslands in Inner Mongolia, China. J Geophys Res-Atmos, 2019, 124: 1266-1276.

50) Zhang YF, Wang XP, PanYX, Hu R. Relative contribution of biotic and abiotic factors to stemflow production and funneling efficiency: A long-term field study on a xerophytic shrub species in Tengger Desert of northern China. Agricultural and Forest Meteorology, 2020.280: 107781.

51) Zhang YF, Wang XP, PanYX, Hu R. Alteration in isotopic composition of gross rainfall as it is being partitioned into throughfall and stemflow by xerophytic shrub canopies within water-limited arid desert ecosystems. Science of the Total Environment, 2019, 692: 631-639.

52) Zhang YB, Wang YJ, Xie ZK, Wang RY, Yang G, Guo ZH, Qiu Y. A study of viral coat protein accumulation in lily chloroplasts from mixed virus infections of Lily mottle virus and Cucumber mosaic virus. Plant path, 2019, 68:261-268.

53) Zhao LN, Liu YB, Yuan S, Li Z, Sun J, & Li XR. Development of archaeal com

munities in biological soil crusts along a revegetation chronosequence in the Teng ger Desert, north central China. Soil and Tillage Research, 2020,196: 104443. J.1226.2019.00139.

54) Zhao Yang, Wang Jin. Mechanical sand fixing is more beneficial than chemical sand fixing for artificial cyanobacteria crust colonization and development in a sand desert. Applied Soil Ecology, 2019, 140: 115-120.

55) Zhao Y, Jia RL, Wang J. Towards stopping land degradation in drylands: Water-saving techniques for cultivating biocrusts in situ. Land Degradation and Development, 2019, DOI:10.1002/ldr.3423.

56) Zhao Yang, Zhang Zhishan, Tan Huijuan, Hu Yigang, Rain shadow effects of individual shrub related to crown shape in arid desert. Ecohydrology, 2019, 12: e2076.

57) Zhou JW, Guo YM, Kang JP, Degen AA, Titgemeyer EC, Jing XP, Wang WJ, Shang ZH, Li ZP, Yang G, Long RJ. Tibetan sheep require less energy intake than small-tailed Han sheep for N balance when offered a low protein diet. Anim Feed Sci Technol, 2019, 248:85-94.

58) Zhou JW, Wang W J, Jing XP, Degen AA, Guo YM, Kang JP, Shang ZH, Yu Z X, Qiu Q, Guo XS, Ding LM, Yang G, Long RJ. Effect of dietary on digestibilities, rumen fermentation, urinary purine derivatives and serum metabolites in Tibetan and small-tailed Han sheep. J Anim Physiol An N, 2019, DOI:10.1111/jpn.13098.

59) Zuo Xiaoan, Cheng Huan, Zhao Shenglong, Yue Ping, Liu Xinping, Wang Shaokun, Liu Lianxu, Xu Chong, Luo Wentao, KnopsJ.M.H. Medina-Roldánf Eduardo. Observational and experimental evidence for the effect of altered precipitation on desert and steppe communities. Global Ecology and Conservation. 2020,21(3): e00864

60) He YuHui, Xie ZhongKui, XinPing Liu, YaJun Wang, YuBao Zhang, Yang Qiu. 2019. Effects of gibberellic acid on tiller-bulb number and growth performance of *Lilium davidii* var. *unicolor*. Sciences in Cold and Arid Regions, 11(4): 0327-0334.

61) Zhao LN, Li XR, Yuan SW,Liu YB, 2019. Shifts in community structure and fun ction of ammoniaoxidizing archaea in biological soil crusts along a revegetation c hronosequence in the Tengger Desert. Sciences in Cold and Arid Regions, 11(2): 0139−0149. DOI: 10.3724/SP.

62) Zhao X, Wang JF, Wang Yet al., Influence of proximity to the Qinghai-Tibet highway and railway on variations of soilheavy metal concentrations and bacterial community diversity on the Tibetan Plateau. Sciences in Cold and Arid Regions, 2019.11(6): 407−418. DOI: 10.3724/SP. J.1226.2019.00407.

63) 陈娟丽，赵学勇，刘新平，张雅秋，罗永清， 张蕊，张润霞，于海伦. 降雨量对科尔沁沙地 3 种沙生植物生长和生理的影响.中国沙漠，2019, 39(5)：163-173.

64) 段育龙，武发思，汪万福，贺东鹏，卢秀善. 天梯山石窟壁画保存环境中空气细菌的季节性变化. 微生物学通报, 2019, 46(3): 468-480.

65) 段育龙，武发思，汪万福，贺东鹏，马千，董广强. 麦积山石窟赋存环境中空气细菌的时空分布特征. 微生物学报，2019, 59(1): 145-156.

66) 郭俊强，徐晓锋，谢忠奎，杨果. 脂肪酸对羊肉品质的影响研究进展. 中国饲料, 2019, 23:69-75.

67) 黑维高，詹瑾，韩丹，杨红玲，李玉霖. 科尔沁沙地 2 种优势固沙灌木的相容性生物量模型. 中国沙漠, 2019, 39(5):193-199.

68) 姬凯茜, 焦丹, 谢忠奎, 杨果, 段子渊. 棕色脂肪细胞特异基因PRDM16的研究进展与展望.中国生物工程杂志, 2019, 39(04):84-93.

69) 李香云，岳平，郭新新，张蕊，赵生龙，张森溪，王少昆，左小安. 荒漠草原植物群落光合速率对水氮添加的响应. 中国沙漠，2020, 40(1):116-124.

70) 李玉霖, 赵学勇, 刘新平, 李玉强, 罗永清, 连杰, 段育龙. 沙漠化土地及其治理研究推动北方农牧交错区生态恢复和农牧业可持续发展. 中国科学院院刊，2019, 34(7):832-840.

71) 李云飞，都军，张雪，谢婷，李小军. 腾格里沙漠东南缘不同类型生物土壤结皮覆盖下土壤有机碳矿化特征. 生态学报，2020, 40(5) http://kns.cnki.net/kcms/detail/11. 2031.Q.20191217.1016.098.html

72) 李云飞, 谢婷, 石万里, 李小军. 腾格里沙漠东南缘人工固沙植被区表层土壤有机碳矿化对凋落物添加的响应. 中国沙漠, 2019, 39(5): 200-209.

73) 刘璐璐，李锋瑞. 甘肃省会宁县和定西市安定区退耕农户恩格尔系数差异. 中国沙漠. 2019, 39(6):192:199.

74) 刘璐璐，李锋瑞. 黄土高原退耕农户生计资本对生计策略的影响———以甘

肃会宁县为例． 中国沙漠， 2020， 40(1):233－244．

75) 刘艳梅，杨航宇，贾荣亮，李宜轩. 人为踩踏生物土壤结皮对土壤酶活性的影响. 中国沙漠. 2019, 39(4):54-63.

76) 卢翔，王若愚. 干旱对解淀粉芽孢杆菌(Bacillus amyloliquefaciens) FZB42 生物被膜的形成及根际定殖能力的影响. 中国沙漠. 2019, 39(3):199-205.

77) 吕朋, 左小安, 孙姗姗, 张晶, 赵生龙, 程清平, 胡亚. 科尔沁沙地退化植被恢复过程中碳氮化学计量特征的变化. 干旱区地理, 2019, 42(03):606-614.

78) 吕星宇，张志山. 固沙植被区土壤质地与土壤微生物数量的关系.中国沙漠. 2019. 39(5):71-79.

79) 马晓俊, 李云飞. 腾格里沙漠东南缘植被恢复过程中土壤微生物量及酶活性. 中国沙漠, 2019, 39(6): 159-166.

80) 宁志英, 李玉霖, 杨红玲, 张子谦, 张建鹏. 沙化草地土壤碳氮磷化学计量特征及其对植被生产力和多样性的影响. 生态学报, 2019, 39(10):3537-3546.

81) 宁志英, 李玉霖, 杨红玲, 张子谦. 科尔沁沙地优势固沙灌木叶片氮磷化学计量内稳性. 植物生态学报, 2019, 43(01):46-54.

82) 牛亚毅, 李玉强, 王旭洋, 杨欢. 沙地玉米水分利用效率日变化特征. 中国沙漠. 2019, 39(01): 145-151.

83) 漆婧华, 刘玉冰, 李新荣, 赵丽娜, 张雯莉, 王岩松. 沙坡头地区地衣和藓类结皮丛枝菌根真菌多样性研究. 土壤学报. 2020. http://kns.cnki.net/kcms/detail/32.1119.P.20190903.1458.002.html.

84) 孙沛沛, 钱朝菊, 尹晓月, 范兴科, 王进, 燕霞, 李小军, 马小飞, 王涛. 半干旱沙地蒿类植被建成过程中土壤理化性质变化规律. 土壤科学. 2019, 7(3):210-219.

85) 孙姗姗, 刘新平, 魏水莲, 张铜会, 何玉惠, 车力木格, 吕朋, 王明明. 沙地植物幼苗生长对降水和风速变化的响应. 干旱区研究， 2019, 36(4): 870-877.

86) 王炳尧，韦伟，刘立超，王增如. 直插式地下滴灌土壤湿润体特征值变化 规律及灌溉效果分析. 灌溉排水学报. 2019, 38(4):1-10.

87) 王明明,刘新平,何玉惠,张铜会,魏静,车力木格,孙姗姗. 科尔沁沙地封育恢复过程中植物群落特征变化及影响因素. 植物生态学报, 2019, 43(8): 672-684.

88) 王明明, 刘新平, 李玉霖, 车力木格, 罗永清, 孙珊珊, 魏静. 不同植被盖度沙质草地生长季土壤水分动态. 中国沙漠, 2019, (05): 1-8.
89) 王新源, 连杰, 杨小鹏, 赵学勇, 王小军, 马仲武, 龚丞馗, 曲浩, 王彬. 玛曲县植被覆被变化及其对环境要素的响应. 生态学报, 2019, 39(03): 923-935.
90) 王旭洋, 李玉强, 连杰, 罗永清, 牛亚毅, 龚相文. CENTURY 模型在不同生态系统的土壤有机碳动态预测研究进展. 草业学报, 2019, 28(2): 179-189.
91) 许华，何明珠，唐亮，孙岩．荒漠土壤微生物量碳、氮变化特征对降水的响应研究．生态学报，2020．40（4）http://kns.cnki.net/kcms/detail/11.2031.Q.20191120.1536.118.html
92) 杨红玲, 李玉霖, 宁志英, 张子谦. 添加混合凋落物对沙丘草地土壤有机碳矿化的影响. 生态学报, 2019, 39(07): 2510-2519.
93) 杨红玲, 李玉霖, 宁志英, 张子谦. 科尔沁沙地优势固沙灌木叶片凋落物分解的主场效应. 中国沙漠, 2019(05):1-9.
94) 余沛东，陈银萍，李玉强，闫志强，王旭洋，牛亚毅，龚相文. 植被盖度对沙丘风沙流结构及风蚀量的影响. 中国沙漠. 2019, 39(5):29-36.
95) 岳喜元，左小安，常学礼，徐翀，吕朋，张晶，赵生龙，程清平. 内蒙古典型草原与荒漠草原 NDVI 对气象因子的响应. 中国沙漠. 2019, 39(3):25-33.
96) 张蕊, 赵学勇, 王少昆, 左小安, 王瑞雄. 极端干旱对荒漠草原群落物种多样性和地上生物量碳氮的影响. 生态环境学报, 2019, 28(04):715-722.
97) 张蕊, 赵学勇, 左小安, 刘新平, 曲浩, 马旭君, 刘良旭, 陈娟丽, 刘立平. 荒漠草原沙生针茅(*Stipa glareosa*)群落物种多样性和地上生物量对降雨量的响应. 中国沙漠, 2019, 39(02): 45-52.
98) 赵生龙, 左小安, 张铜会, 吕朋, 岳平, 张晶. 乌拉特荒漠草原群落物种多样性和生物量关系对放牧强度的响应.干旱区研究, 2020, 1-11. [2020-01-14]. http://kns.cnki.net /kcms/detail/ 65.1095.X.20191120.1102.004.html.
99) 周丽靖，王亚军，谢忠奎，张玉宝，郭志鸿， 邱 阳，华翠平，赵成政. 生物炭对兰州百合连作土壤的改良作用. 中国沙漠. 2019. 39(2):134-143.

八、学术会议和学术交流活动

8.1 国内学术会议与培训活动

1) 中国科学院西北生态环境资源研究院科技扶贫培训会在库伦旗举办

1 月 28 日，中国科学院西北生态环境资源研究院（简称西北研究院）在库伦旗农牧业局举办科技扶贫培训会。会议由西北研究院科研管理处副处长、库伦旗挂职副旗长、甘肃省寒区旱区逆境生理与生态重点实验室张铜会研究员主持。各苏木乡镇分管领导、相关业务人员，农牧业系统相关领导干部，全旗养殖大户负责人近百人参加培训。

西北研究院甘肃省寒区旱区逆境生理与生态重点实验室王若愚研究员通过对微生物与植物相互作用机理、甘肃道地药材主要真菌型病害的鉴定及防治技术开发、土壤改良、生物防治等内容进行详细讲解。同时，还就解淀粉微生物菌剂“菌益多”应用作物生长，抗逆微生物技术提高青贮玉米、甜高粱等青贮饲料的产量及促进库伦旗草畜产业发展前景等进行了展望。

皋兰生态与农业综合研究站站长助理杨果研究员针对课题组前期在反刍动物营养学的研究进展及大理石花纹雪花牛肉配方研发等方面相关工作作了全面介绍。并就肉牛营养需求、饲料成分与搭配方式、饲料添加剂种类及功能等进行重点讲解。

通辽市畜牧科学研究所韩润英研究员就“基础母牛养殖技术”进行了细致深入地讲解，为库伦旗肉牛养殖规模化发展提供了先进技术和实用经验。会后，与会专家一行先后深入到先进苏木敖海百兴、白音花镇察哈尔、厚很塔本白兴嘎查、库伦镇元宝山、六家子镇杏树洼村、茫汗苏木哈图嘎查养殖合作社和养殖大户，实地调研肉牛规模养殖情况和设施农业，现场为种养殖户提供技术指导。

8.2 国际合作交流

1) 沙坡头站荒漠化防治人员考察乌兹别克斯坦

4 月 16 日，在沙坡头站何明珠研究员的带领下，王进副研究员、张鹏、杨昊天、赵杰才和宋光博士一行正对中亚双重内陆国家乌兹别克斯坦的沙漠化现状进行综合考察。本次考察基于中国科学院 A 类先导专项“泛第三极环境变化与绿色丝绸之路建设”子课题“荒漠化土地植被恢复重建关键技术研发与集成示范”而开展。考察队员深入一线，对沙漠化区域的气候、土壤、植被和沙漠化现状进行了综合调查研究，为中亚-西亚荒漠化防治与关键因素

调控工作奠定基础。

2) 5 月 12-18 日植物病毒课题组张玉宝高级工程师和王亚军副研究员参加在韩国首尔举办的第 14 届国际植物病毒流行学研讨会，并提交了题为“Developing virus assays to improve lily crop production in northwest, China”的论文摘要 1 篇，宣读了论文，促进了国际合作与交流。

8.3 举办国内外项目/学术会议

1) 中国荒漠主要植物群落特征调查项目年度总结会顺利召开

为了总结项目进展，凝练成果和发现问题，中国基础资源调查专项《中国荒漠主要植物群落特征调查》项目于 2019 年 3 月 21-24 日在西安召开了 2018 年年度总结会议。在陕西师范大学的鼎力协助之下，会议取得了圆满成功。22 日进行了项目内部交流，23 日进行了项目与课题的进展汇报。会议邀请项目咨询专家傅伯杰院士与潘伯荣、董治保、雷加强和陈世龙研究员及中国科学院前沿局娄治平主任参加。

2018 年，项目先后开展了《中国荒漠主要植物群落特征调查项目实施技术手册》的修订、调查点的踏查、校正及调查。项目调查行程 10 万多公里，覆盖了包括新疆荒漠区、青藏高原荒漠区、阿拉善-河西走廊荒漠区、西鄂尔多斯-阴山北麓荒漠区和毛乌素沙地、浑善达克沙地、科尔沁沙地与呼伦贝尔沙地，完成 1300 多个调查点的取样，采集植物标本 2000 多号，调查土壤剖面 1300 个、采集土样 5000 多份，测定了 380 多种荒漠植物的 DNA 条形码，完成了项目任务的 60%-62%。

项目进展汇报得到了专家组的充分肯定，也得到了专家组的宝贵意见。专家组认为尽管项目经历了沙尘暴、洪水、炙热和寒冷等严苛的自然条件的考验，也经历了加班、加点和远离单位与家人等的艰苦与孤独，项目总体进展顺利，取得了预期成果。专家组也建议进一步加速包括植物命名、鉴定、标准化等方面的工作，同时建议加紧凝练成果，宣传成果，把项目任务完成得更好。近 60 名专家学者和研究生参加了本次会议。

2) 国家重点研发计划战略性国际科技创新合作重点专项“丝绸之路经济带沿线国家流沙固定及植被恢复关键技术研发与示范”项目进展汇报会召开

3 月 28 日至 29 日，国家重点研发计划战略性国际科技创新合作重点专

项“丝绸之路经济带沿线国家流沙固定及植被恢复关键技术研发与示范”项目进展汇报会在北京召开。中科院微生物研究所魏江春院士、中科院前沿科学与教育局段晓男处长、中科院西北生态环境资源研究院（简称西北研究院）党委书记、副院长冯起等相关负责人和专家，项目首席西北研究院王新平研究员及各课题负责人、项目研究骨干共 30 余人参加会议。会议由中国农业大学康绍忠院士主持。

会上中科院国际合作局业务主管黄赛首先介绍了项目立项背景和意义，希望加强项目在相关国家的示范推广。冯起代表项目主持单位对科技部、中科院及各参与单位给与的支持和贡献表示感谢。中科院微生物研究所副所长向华代表会议承办单位致欢迎辞。随后，王新平对项目整体情况进行了介绍；各课题负责人及项目骨干分别从课题概况、考核指标完成情况、主要研究成果、研究成果创新性、成果示范推广和人才培养组织管理情况等方面进行了详细介绍。咨询专家组认真听取了项目各课题的进展汇报，并对项目的后期执行提出了建设性意见和建议。康绍忠强调，要聚焦目标、提炼关键技术，突出国际合作需求，为项目的下一步实施指明方向。针对专家建议，项目组成员进一步完善了实施方案，制定了详细的研究计划，以期为科技部项目中期考核筹划准备。

3) 中科院先导 A 类“美丽中国”专项“生态脆弱区绿色发展途径和区域综合示范”项目示范区考察暨课题启动会顺利召开

5 月 26 日-6 月 1 日，中国科学院先导 A 类“美丽中国”专项“生态脆弱区绿色发展途径和区域综合示范”项目进行了示范区现场考察并召开了课题启动会。项目首席丁永建研究员汇同项目监理组、专家组及课题负责人和课题骨干 30 余人分别对黑土退化阻控技术集成示范区（黑龙江省）、农牧交错带生态功能提升与绿色发展示范区（吉林省）和干旱区沙化土地生态恢复关键技术示范区（宁夏回族自治区）开展了现场考察和指导。

6 月 1 日下午，课题 2、课题 3 和课题 7 启动会在中科院沙坡头国家站召开。项目首席科学家丁永建、专项监理组刘国彬、项目专家组李新荣、宁夏回族自治区中卫市林业和草原局李宏然和唐希明、课题负责人及课题组主要成员参加了会议。会议由项目负责人丁永建研究员主持。

会上宁夏回族自治区中卫市林业和草原局李宏然副局长首先对各位专家的到来表示了热烈欢迎，对课题的启动表示祝贺，并充分肯定了课题实施的重大意义，希望能够将课题研究成果产出在宁夏进行推广和应用，建设“美丽中国”的同时，也为“美丽宁夏”和“美丽中卫”的建设提供支撑，并预祝课题取得优异成绩。李宏然指出中卫市林业和草原局将全力配合课题实施，将在人力、财力、物力等各方面给予大力支持。

随后 3 位课题负责人对各自负责课题 2019 年工作计划和工作进展进行了汇报。听取报告后，专家们就课题工作计划和工作进展进行了深入研讨交流，并提出诸多建设性意见和建议。课题负责人表示将对专家意见梳理、准确凝练、扎实落实，确保高质量完成本年度研究任务。

8.4 实验室人员学术交流活动记录

1) 1 月 8 日，李新荣研究员参与完成的“风沙灾害防治理论与关键技术应用”获国家科学技术进步奖二等奖。
2) 1 月 21 日，李新荣获得 2018 中国科学院年度先锋人物。
3) 2 月 13 日，《中国科学报》深入报道 2018 年中国科学院年度先锋人物李新荣研究员，报道题目：锁住“沙龙”绿大地 ——记中科院沙坡头沙漠研究试验站站长李新荣。
4) 3 月 22-24 日，6 位科研人员在甘肃永靖参加《中国沙漠志》编纂、腾格里沙漠卷编委会议暨启动会
5) 3 月 29 日，《中国绿色时报》深入报道李新荣研究员科研经历和研究内容，报道题目：沙漠中的“全科大夫”李新荣：给风沙以赤诚。
6) 4 月 19 - 21 日，左小安研究员、王少昆副研究员，岳平助理研究员在大连参加了国家重点研发计划“典型脆弱生态修复与保护研究”重点专项项目“荒漠化退化草地治理技术及示范” 年度研究进展及学术报告会。左小安研究员做了题为“北方荒漠草原植被对降水变化响应的观测与模拟实验对比研究”的学术报告；王少昆副研究员做了题为“微生物有机混合物对退化土地的快速修复技术原理及试验示范”的学术报告；岳平博士做了题为“温带沙质荒漠温室气体通量对水分、温度和氮沉降响应”的学术报告。
7) 4 月 21 日，《兰州微传媒》深入报道甘肃省寒区旱区逆境生理与生态重点实

验室王若愚研究员研究工作，报道题目：中科院西北生态环境资源研究院王若愚团队在渭源县种下试验田。

8) 4 月 28 日，甘肃省科学技术协会第八次代表大会隆重召开。中国科学院西北生态环境资源研究院左小安研究员荣获第九届甘肃青年科技奖。

9) 5 月 25 日 王少昆博士在兰州参加了兰州交通大学青年科学家论坛，并做了题为“沙漠化土地的恢复及其面临的挑战——以科尔沁沙地为例”的学术报告。

10) 5 月，张玉宝和王亚军参加了在韩国举办的第 14 届国际植物病毒流行学研讨会，宣读了论文，促进了国际合作与交流。

11) 6 月 13-14 日，王新平等 4 人在蒙古参加第二届国际环境科学与技术大会。

12) 6 月 22－25 日，新疆乌鲁木齐举行“第十届西部地区植物科学与资源利用研讨会”，马小飞研究员应邀做了《沙米的生态适应性》的报告。

13) 6 月 28 日，应站长李玉霖研究员邀请，全国人大代表、中国科学院西北生态环境资源研究院王涛院长在奈曼站做题目为《中国沙漠与沙漠化研究》的学术报告。报告由李玉霖站长主持，奈曼站 20 余位在站师生参加本次活动。

14) 7 月 1 日，中国科学院野外站网络重点科技基础设施建设项目“中国北方沙区水量平衡自动模拟监测系统—Lysimeter 群”在沙坡头站建成竣工并通过验收。这是中国科学院野外站网络首个完成的重点科技基础设施建设项目。经过 3 年（2016—2018 年）建设，我国首个规模最大的水量平衡自动模拟监测系统-Lysimeter 群在沙坡头站建设完成。

15) 7 月 5-7 日, 沙坡头站 6 人在银川参加《中国沙漠志》编纂、腾格里沙漠卷编委第二次会议。

16) 7 月 25 日, 苏洁琼在北京参加 “美丽中国生态文明建设科技工程”先导专项财务、档案管理培训会。

17) 7 月 25 日，《中国科学报》深入报道中国北方沙区水量平衡自动模拟监测系统，报道题目：把沙漠戈壁装进实验室——我国规模最大水量平衡自动模拟监测系统建成。

18) 7 月 26-28 日，张志山研究员在西宁参加“自然地理学与山区生态文明建设学术研讨会”，主持“山地水土要素时空耦合”专题分会场 ，并做“固沙灌木的

冠层截留及雨影效应”学术报告。

19) 7 月 27 - 30 日，马旭君博士在吉林省长春市参加第十四届全国菌根学术研讨会。

20) 7 月，郭志鸿和王亚军参加了在北京举办的第四届中国百合论坛，并做了会议报告。

21) 7 月 28 日-8 月 1 日，王新平在乌鲁木齐参加第六届干旱区生态系统可持续管理与环境演变会议

22) 7 月 29 日，马小飞研究员参加甘肃省遗传学会常务理事会会议。

23) 8 月 2 - 12 日王少昆博士前往哈萨克斯坦参加“丝绸之路经济带沿线国家流沙固定及植被恢复关键技术研发与示范”国际合作项目，在 Birlik 试验示范基地和 Aral Sea 考察了哈萨克斯坦土地退化情况以及合作项目在哈萨克斯坦的试验示范情况，并在植物生物学和生物技术学研究所（Institute of Plant Biology and Biotechnology）参加了学术讨论，做了题为“An Ecological Approach in Degraded Land Restoration—using Microbial Organic Compound”的学术报告。

24) 8 月 8 日，曲浩博士和岳平博士参加了乌拉特后旗林业局组织的“荒漠草原区林业生态博士科研工作站”相关工作汇报会。

25) 8 月 25-27 日，宋光、贾荣亮、张亚峰在兰州参加第五届陆地生态系统青年论坛。

26) 8 月 24-31 日 沙坡头站 4 位科研人员前往澳大利亚参加第四届生物土壤结皮国际会议。

27) 9 月 10-12 日，李新荣、王增如在北京参加中国气候与生态环境演变和新疆气候变化科学评估。

28) 9 月 23-30 日, 李新荣研究员等在南非参加 2019 国际恢复生态学大会。

29) 10 月 12-14 日 沙坡头站 2 位科研人员在乌鲁木齐参加中-乌生态、环境与区域可持续发展双边论坛研讨会。

30) 10 月 16-18 日，李新荣、贾荣亮在北京参加创新研究群体项目“干旱区生态水文学”中评会。

31) 10 月 26-27 日，第三届自然杂交与生物多样性学术研讨会在中国科学院昆明植物研究所成功举办，马小飞研究员应邀做了《荒漠植物红砂的种内分化和杂交历史》的报告。

32) 10 月 28-31 日，胡宜刚、虎瑞在长沙参加第 4 届青年论坛暨首届国际微生物生态前言研讨会

33) 11 月 1-3 日，王新平、虎瑞、张亚峰、潘颜霞、何明珠、杨昊天在北京参加中国地理学大会

34) 11 月 8 日-9 日，由生物学杂志社、安徽师范大学生物信息研究所和安徽大学生命科学学院共同主办的“生物科学之生物信息学学术沙龙”在安徽大学召开。马小飞研究员做了《利用多组学挖掘植物抗逆基因资源及其对生态物种形成的启示》的特邀报告。

35) 11 月 8 -9 日，由生物学杂志社、安徽师范大学生物信息研究所和安徽大学生命科学学院共同主办的“生物科学之生物信息学学术沙龙”在安徽大学召开。钱朝菊助研应邀参加沙龙讨论。

36) 11 月 15-18 日，钱朝菊助研参加广西南宁召开的“全国蔬菜产业高质量发展暨蔬菜绿色标准化生产新技术交流会”。

37) 11 月 21-23 日，9 人在北京参加 CERN30 年年会。

38) 11 月 28-30 日，实验室主任李新荣带队实验室 20 人在昆明参加中国生态学大会。其中孙靖尧、赵丽娜和王艳莉三名博士研究生围绕干旱区生态学主题，在大会今年第一次设立的全国生态学研究生论坛上作口头报告。赵丽娜作了题为生物土壤结皮微生物群落组成及其功能演替的学术报告，荣获大会研究生论坛优秀报告奖。

39) 2019 年 12 月 9 日-13 日，李新荣研究员和杨昊天博士参加了中亚干旱区荒漠化防治国际研讨会，共有来自乌兹别克斯坦、蒙古、哈萨克斯坦、埃及以及中国的 60 余名国内外相关专家参加会议。

九、大事记

1) 4 月 10 日，在奈曼旗邬君明副旗长、科协主席韩巴特尔以及通辽市科协相关领导的陪同下，内蒙古自治区科协主席赵吉一行 9 人到奈曼站考察调研。

2) 4 月 24 日，中国科学院沈阳应用生态研究所乌兰敖都荒漠化防治生态试验站站长刘志民研究员和副站长阿拉木萨研究员一行 5 人来奈曼站参观访问。

3) 5 月 8 日，中卫市组织部部长刘晓燕带领中卫市委党校教一师行 30 余人赴中国科学院沙坡头沙漠研究试验站考察。

4) 5 月 16 日，应马小飞研究员邀请，华中农业大学陈鹏教授来我院交流访问，并做题为“小 RNA 修饰核苷和核苷修饰基因在植物逆境调控中的机理初探”报告

5) 5 月 20-21 日，武汉外国语学校师生 26 人组成的地理实践活动小组到达中国科学院沙坡头沙漠研究试验站学习实践。

6) 5 月 21 日，中卫市委副书记、市长李晓波一行考察沙坡头站。

7) 5 月 24 日，宁夏回族自治区政府副主席杨培君一行 20 余人赴中国科学院沙坡头沙漠研究试验站考察，中卫市副市长蔡菊、中卫市旅游发展委员会主任范家宏等陪同考察。

8) 5 月 23 - 24 日，中国农科院曹远博博士和王杰博士来乌拉特站开展实验，在快速生成生物结皮的试验平台进行了植被调查和土壤取样。

9) 5 月 25 日，中央电视台《塞上江南》纪录片导演赴中国科学院沙坡头沙漠研究试验站进行调研。

10) 5 月 25 日，国家林业和草原局监测总站副总站长郭文辉、国家林业和草原局西安专员办副专员及调研员贾永毅、朱志文等一行 16 人赴中国科学院沙坡头沙漠研究试验站进行考察。

11) 5 月 24 - 25 日，宁夏大学刘任涛教授一行 4 人来沙坡头站做实验，主要对长期放牧试验平台土壤动物组成进行调查和取样。

12) 5 月 29 日，国家统计局宁夏调查总队一行 20 余人到沙坡头站参观。

13) 5 月 31 日，中国科学技术大学宁夏海原支教 20 年回访团一行 12 人赴中国科学院沙坡头沙漠研究试验站参观考察。

14) 6 月，受杨果研究员邀请，比利时让布鲁农业大学教授 Pierre Dardenn 来西北院进行学术交流。

15) 6 月 28 - 30 日，应乌拉特站站长左小安邀请，中国科学院新疆生态与地理研

究所柳妍妍博士和公延明博士一行 2 人到乌拉特站进行学术交流。柳妍妍博士做了题为“养分添加抑制高寒草原甘肃马先蒿入侵”的学术报告。公延明博士作了题为“荒漠植物功能性状和谱系结构对水盐胁迫的响应”的学术报告。

16) 6 月 29 日，内蒙古农业大学仲举和党晓宏教授一行 9 人来乌拉特站开展学术交流。党晓宏教授了题为“西鄂尔多斯地区荒漠灌丛生态系统碳汇/源问题探讨”的学术报告。

17) 6 月 18 日，中国科学院植物研究所王仁忠研究团队一行 4 人来乌拉特站布设了碳同位素的试验。

18) 6 月 28 - 30 日，应乌拉特站站长左小安邀请，中国科学院新疆生态与地理研究所柳妍妍博士和公延明博士一行 2 人到乌拉特站进行学术交流。柳妍妍博士做了题为“养分添加抑制高寒草原甘肃马先蒿入侵”的学术报告。公延明博士作了题为“荒漠植物功能性状和谱系结构对水盐胁迫的响应”的学术报告。

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20) 7 月 10 日 - 7 月 13 日，鲁东大学常学礼教授一行 9 人来乌拉特站开展学术交流。

21) 7 月 10 日- 7 月 13 日，山东农业大学常学礼教授一行 9 人来乌拉特站开展学术交流。

22) 7 月 17 日- 8 月 20 日，来自西北农林科技大学、内蒙古民族大学、甘肃农业大学、河套学院 20 多名本科学生来乌拉特站完成暑假实习。通过本次实习，学生们掌握了生态学野外调查和取样、实验室样品处理和分析等原理和方法，不仅让学生们提高了生态学理论知识和实验技能，同时为乌拉特站的实验顺利完成提供了保障。

23) 7 月 19 日，中国科学院沈阳应用生态所刘雪华老师一行 4 人来乌拉特站开展学术交流。

24) 7 月 1 日，澳大利亚学者 David Eldridge 到沙坡头站学术交流

25) 7 月 13 日，中科院国际合作局邱华盛到沙坡头站参观交流。

26) 7 月 3 日，中国科学院党组副书记、副院长侯建国赴内蒙古调研科技扶贫工作。

27) 7 月 3-4 日，兰州大学资源与环境学院暑期实践小分队一行 7 人赴中国科学院沙坡头沙漠研究试验站进行参观学习。

28) 7 月 6 日，东南大学网络空间安全学院本科生一行 5 人赴中国科学院沙坡头沙漠研究试验站进行参观学习。

29) 7 月 7-8 日，北京市海淀区 101 中学 80 余名师生赴中国科学院沙坡头沙漠研究试验站开展研学科考活动。

30) 7 月 7-8 日，西华师范大学国土资源学院地理科学专业本科生一行 210 人赴中国科学院沙坡头沙漠研究试验站进行教学实习。

31) 7 月 8 日，西北工业大学学生社会实践活动“探秘沙海”一行 8 人赴中国科学院沙坡头沙漠研究试验站进行参观学习。

32) 7 月 9 日，全国政协组织以港澳委员为主体的社团青年代表一行 46 人赴中国科学院沙坡头沙漠研究试验站参观考察。

33) 7 月 11 日，山西师范大学地理科学学院师生一行 82 人赴中国科学院沙坡头沙漠研究试验站进行本科生教学实习。

34) 7 月 17 日，在奈曼旗邬君明副旗长等相关领导的陪同下，内蒙古中医药研究所教授、国家蒙医药加工技术研发中心主任李旻辉，内蒙古民族大学包金花、周立业和贾俊英教授等一行近 20 余人到奈曼站参观调研。

35) 7 月 17 日，中山大学地理科学专业师生 30 余人到中国科学院沙坡头沙漠研究试验站进行综合自然地理学课程野外实习。

36) 7 月 13-17 日，银川唐徕回民中学高一师生一行 53 人来中国科学院沙坡头沙漠研究试验站进行暑期社会实践活动。

37) 7 月 17 日，中国工程院院士张福锁、中科院水保所黄土高原土壤侵蚀与旱地农业国家重点实验室常务副主任李世清研究员等一行人到沙坡头沙漠研究试验站考察。

38) 7 月 17 日，中国科学院原国际合作局副局长邱华盛和联合国防治土地荒漠化公约亚太地区协调处原处长杨有林到沙坡头沙漠研究试验站访问考察。

39) 7 月 20-21 日，北京海淀区科普教育协会师生一行 15 人来中国科学院沙坡头

沙漠研究试验站进行暑期社会实践活动。

40) 7 月 21-22 日，中科院银川中心师生 14 人来中国科学院沙坡头沙漠研究试验站进行暑期研学活动。

41) 7 月 22 日，中国科学院兰州分院小学师生 30 余人到中国科学院沙坡头沙漠研究试验站参观学习。

42) 7 月 22 日，华中科技大学光学与电子信息学院学生 10 余人来到中国科学院沙坡头沙漠研究试验站开展暑期社会实践活动。

43) 7 月 23 日，南京大学生物科学专业学生 10 余人到中国科学院沙坡头沙漠研究试验站开展暑期课程实习。

44) 7 月 24 日，宁夏回族自治区农科院沙漠化防治国际研修班 44 人赴中国科学院沙坡头沙漠研究试验站进行考察学习。

45) 7 月 25 日，西南大学和西安建筑科技大学学生一行余人到沙坡头站开展暑期社会实践调研活动。

46) 7 月 27 日，中国科学院监审局副局长袁东、监审局审计室张会芳处长，以及库伦旗农牧系统党组书记王凤富和科技局局长梁晓蕾等一行 10 人到奈曼站考察调研。

47) 7 月 28 日-7 月 29 日，中国科学院沈阳应用生态所宋琳老师一行 10 人来乌拉特站开展学术交流。

48) 7 月 28 日，在通辽市委组织部副部长李海林和奈曼旗人大常委会副主任白额尔敦巴特等相关领导的陪同下，内蒙古自治区人社厅综合处副处长高国青和教育厅人事处主任张晓莺等一行 10 余人到奈曼站考察调研。

49) 8 月 2 日，中国科学院秦大河院士到沙坡头站做学术报告

50) 8 月 2 日，中央电视台农业频道播出关于王若愚研究员的《盐碱地治理有新意》。

51) 8 月 2 日，科技日报全国记者一行 46 人参观沙坡头站。

52) 8 月 5 日，国家重点研发计划《沙区生态产业技术推广模式及政策研究》项目组李金花和吕艳丽老师等一行 15 人到奈曼站参观调研。

53) 8 月 6 日-8 月 8 日，内蒙古自治区草原生态保护修复调研小组在乌拉特后旗、乌拉特中旗境内开展调研。8 月 7 日上午，调研组组长内蒙古自治区草原勘

察规划院院长刘爱军率调研组一行十余人来到乌拉特站参观考察。乌拉特站工作人员曲浩及在站学生对来访人员进行了接待，并简要介绍了乌拉特站自建站以来的科研成果及与地方政府的合作情况。

54) 8 月 5 日，国家重点研发计划《沙区生态产业技术推广模式及政策研究》项目组李金花和吕艳丽老师等一行 15 人到奈曼站参观调研。

55) 8 月 19 日，浙江大学杨小平教授等一行 14 人到奈曼站参观调研。

56) 8 月 23 日，瑞典隆德大学的 Ronny Berndtssonn 教授到沙坡头站开展学术交流

57) 8 月 24 日，奈曼旗副旗长刘宁到奈曼站参观调研，与库伦旗挂职副旗长张铜会研究员进行了座谈。

58) 8 月 30-31 日，内蒙古林科院纪蒙所长一行 4 人到站考察交流。参观了室内实验室及室外试验观测场，岳平向其介绍了研究站相关情况。

59) 8 月 31 日，中国人与生物圈国家委员会与内蒙古自治区政协联合专家组在内蒙古科尔沁沙地进行生态综合考察。由国家委员会王丁秘书长带队，桂建芳院士领街专家组一行，深入中国科学院西北生态环境资源研究院奈曼站，了解基层科研单位的一线工作。

60) 9 月，王若愚研究员邀请深圳大学生命与海洋科学学院蒋中浩博士来实验室进行学术交流，并作学术报告。

61) 9 月 5 日，清华大学杨云峰教授到沙坡头站访问，做学术报告。

62) 9 月 3 日，民进通辽总支朱瑞莲主委一行 5 人到奈曼站参观调研。

63) 9 月 9 日，巴彦淖尔市林业研究所张宏武老师一行 3 人到站商讨项目合作事宜。

64) 10 月 16 日，湖南卫视播出《新闻大求真》专题片，报道王若愚研究员的生物菌剂诱导植物自身抗病能力。

65) 11 月 26 日，应左小安研究员邀请，西交利物浦大学 Eduardo Medina Roldan 博士到实验室进行学术交流，并作学术报告。

66) 11 月 4 日，国家自然资源部部长、国家自然资源总督察陆昊，宁夏回族自治区自然资源厅厅长马波及相关领导和中卫市地方领导一行视察中国科学院

沙坡头沙漠研究试验站。

67) 12 月 15 日，内蒙古林科院王晓江所长及其团队参观分子生物学实验室。

plants

MDPI

Article

Growth and Physiology of Two Psammophytes to Precipitation Manipulation in Horqin Sandy Land, Eastern China

Juanli Chen [1,2,3,*], Xueyong Zhao [1,3,*], Xinping Liu [1,3], Yaqiu Zhang [4], Yayong Luo [1,3], Yongqing Luo [1,3], Zhaoquan He [1,2,3] and Rui Zhang [1,2,3]

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Abstract: The availability of water is the critical factor driving plant growth, physiological responses, population and community succession in arid and semiarid regions, thus a precipitation addition-reduction platform with five experimental treatments, was established to explore the growth and physiology of two psammophytes (also known as psammophiles) to precipitation manipulation in Horqin Sandy Land. Changes in coverage and density were measured, and antioxidant enzymes and osmoregulatory substances in both of the studied species were determined. Investigation results showed that the average vegetation coverage increased with an increasing precipitation, and reached a maximum in July. Under the −60% precipitation treatment, *Tribulus terrestris* accounted for a large proportion of the area, but *Bassia dasyphylla* was the dominant species in the +60% treatment. *T. terrestris* was found to have higher a drought stress resistance than *B. dasyphylla.* From days 4 to 7 after rainfall, *B. dasyphylla* under precipitation reduction showed obvious water stress. The malondialdehyde (MDA) content of *B. dasyphylla* was higher than that of *T. terrestris*, but that of *B. dasyphylla* had the lower relative water content (RWC). The MDA content in the precipitation reduction treatments of the two studied species was higher than that in the precipitation addition treatments from days 4 to 10. Peroxidase (POD) and superoxide dismutase (SOD) activity and the soluble proteins and free proline content of *T. terrestris* were higher than those of *B. dasyphylla*. The free proline content of *T. terrestris* and *B. dasyphylla* increased with increasing drought stress. Our data illustrated that *T. terrestris* had a higher drought stress resistance than *B. dasyphylla*, which was correlated with the augmentation of some antioxidant enzymes and osmoregulatory substance. The adaptive mechanism provides solid physiological support for an understanding of psammophyte adaptation to drought stress, and of community succession or species manipulation for desertified land restoration.

Keywords: Horqin Sandy Land; precipitation addition; precipitation reduction; growth; physiological response

1. Introduction

Water is a key driving factor in arid and semi-arid sand ecosystems. Plant growth and physiological processes are closely correlated with water availability. Precipitation is the most important source

water

MDPI

Article

Effects of Drought and Rehydration on the Physiological Responses of *Artemisia halodendron*

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Abstract: *Artemisia halodendron* is a widely distributed native plant in China's Horqin sandy land, but few studies have examined its physiological responses to drought and rehydration. To provide more information, we investigated the effects of drought and rehydration on the chlorophyll fluorescence parameters and physiological responses of *A. halodendron* to reveal the mechanisms responsible for *A. halodendron*'s tolerance of drought stress and the resulting ability to tolerate drought. We found that *A. halodendron* had strong drought resistance. Its chlorophyll content first increased and then decreased with prolonged drought. Variable chlorophyll fluorescence (*Fv*) and quantum efficiency of photosystem II (*Fv*/*Fm*) decreased, and the membrane permeability and malondialdehyde increased. When plants were subjected to drought stress, superoxide dismutase (SOD) activity degraded under severe drought, but the activities of peroxidase (POD) and catalase (CAT) and the contents of soluble proteins, soluble sugars, and free proline increased. Severe drought caused wilting of *A. halodendron* leaves and the leaves failed to recover even after rehydration. After rehydration, the chlorophyll content, membrane permeability, SOD and CAT activities, and the contents of the three osmoregulatory substances under moderate drought began to recover. However, *Fv*, *Fv*/*Fm*, malondialdehyde, and POD activity did not recover under severe drought. These results illustrated that drought tolerance of *A. halodendron* resulted from increased enzyme (POD and CAT) activities and accumulation of osmoregulatory substances.

Keywords: Horqin sandy land; hydration-dehydration; chlorophyll fluorescence; lipid peroxidation; antioxidant enzyme activity; solute accumulation

1. Introduction

About one-third of the world's area is arid or semi-arid, but nearly half of China's terrestrial area belongs to arid or semi-arid regions [1]. Drought seriously affects plant growth and development, crop yield, and gene expression because of the importance of water in biochemical process [2–4]. As a result of global climate change, drought is becoming a more frequent and increasingly severe problem [5,6]. Since native plants are frequently subjected to water stress in drought-prone regions,

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ORIGINAL RESEARCH
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Effect of Pollen Limitation and Pollinator Visitation on Pollination Success of *Haloxylon ammodendron* (C. A. Mey.) Bunge in Fragmented Habitats

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Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

Haloxylon ammodendron (C. A. Mey.) Bunge is an ecologically important species in arid regions. Pollen limitation may decrease plant reproduction due to low levels of pollen transfer and inadequate pollen receipt. In arid regions, pollen limitations of many plant species may be influenced by habitat fragmentation. However, whether pollen limitation and pollinator visitation affect the pollination success of *H. ammodendron* (Amaranthaceae) in fragmented habitats still needs further study. In this study, we calculated the pollen limitation in natural and fragmented habitats to estimate the effect of habitat fragmentation on pollen limitation. In different habitats, we investigated the relationship between the number of open flowers and pollinator visiting frequency. In addition, we examined how habitat fragmentation affects pollination success through the influence of pollinator visitation rate on seed set. Our results indicated that pollen limitation was the important limiting factor for seed set in fragmented and natural habitats. The results showed higher pollinator visitation rates resulted in a higher percentage of seeds in both habitats. In *H. ammodendron*, *Apis mellifera* was found to be the dominant pollinator. These results may support the assertion that plants evolve traits to attract pollinators and pollinators increase their visiting frequency to better exploit the floral resources. We also determined that outcrossing was dominant in the breeding system and that wind pollination played an important role in pollination success. This study aims to contribute to a better understanding of how environmental heterogeneity affects pollen limitation, pollinator visitation, and pollination success in arid regions.

Keywords: habitat fragmentation, pollen limitation, pollinator, pollinator visitation rate, seed set

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INTRODUCTION

In many flowering plants, a large proportion of flowers do not develop into fruits and seeds (Stephenson, 1981; Larson and Barrett, 2000). Many hypotheses have been presented to explain this phenomenon, and one prominent hypothesis is that pollen limitation may result in low fruit and seed set (Burd, 1995; Chen et al., 2015). Over the past decade, there has

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Comparative pollen limitation and pollinator activity of *Caragana korshinskii* Kom in natural and fragmented habitats

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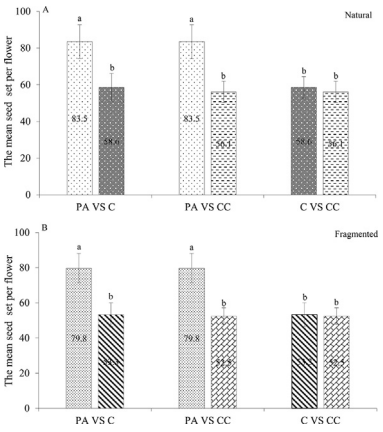
HIGHLIGHTS

- Pollen supplementation significantly increased seed set.
- There is a negative correlation between pollinator visitation frequency and PL index.
- *A. Mellifera* was the dominant pollinator.
- Fragmented habitats are more significantly affect pollinator visitation than natural habitats.
- Insect pollination played a critical role in outcrossing.

GRAPHICAL ABSTRACT



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ABSTRACT

In many flowering plants, fragmented habitats may affect pollen limitation, pollinator behavior, and plant-pollinator interactions. Pollen limitation may decrease plant reproduction due to low levels of pollen transfer and inadequate pollen receipt. However, how fragmented habitats affect the pollen limitation and pollinator activity of *Caragana korshinskii* Kom. still needs further study. We designed a pollen supplementation treatment to understand how pollen limitation affects seed set. We calculated the visiting patterns and frequency of pollinators in different habitat types (natural and fragmented) to determine the effect of fragmented habitats on pollinator activity and on the pollination success of a desert-grassland shrub. Our results demonstrated that pollen supplementation was found to significantly increase seed set per flower, which is pollen-limited in the studied species. Moreover, the pollen limitation index in fragmented habitats was increased compared to that of natural habitats. *Apis mellifera* was found to be the dominant pollinator, with more pollinators and a higher visitation frequency of *A. mellifera* found in natural habitats compared to fragmented habitats. Our results showed that pollen limitation intensity was significantly correlated with the pollinator visitation frequency in the both habitats. Outcrossing was dominant in the breeding system, and insect pollination played a critical role in outcrossing. We found that fragmented habitats could affect pollinator activity, which might reduce pollen dispersal among flowers and the probability of outcrossing in the studied habitats.

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Impact of floral characters, pollen limitation, and pollinator visitation on pollination success in different populations of *Caragana korshinskii* Kom

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Min Chen & Xue-yong Zhao

Caragana korshinskii **Kom. has a significant function in desert-grassland revegetation in arid regions. Plant reproduction in arid regions can be restricted due to inadequate pollen receipt and reduced pollen transfer. An assessment of pollination success as a result of pollen limitation and pollinator visitation in various *C. korshinskii* populations is presently lacking. We thus tested three different treatments (pollen addition, control, and procedural control) to elucidate how pollen limitation affects seed numbers per flower in *C. korshinskii*. We also determined the effect of pollinator visit frequency on seeds per flower. Our results demonstrated that there was a higher proportion of open flowers and mature fruits in the managed population than in the natural population. Pollen addition significantly increased seed number per flower, and pollen limitation was determined to be a significant limiting factor in seed production. Furthermore, *Apis mellifera* was determined to be the principal pollinator, and pollinator visitation frequency was significantly correlated with open flower number. Our findings also demonstrated that pollinator visitation rate and seed production were positively correlated. Management and pollinator visitation could affect seed production, which may explain the higher seeds per flower in the managed population compared with the natural population.**

As plants are immobile, they therefore depend on abiotic or biotic vectors to facilitate pollen transfer for sexual reproduction[1], which has shaped floral attraction and plant mating systems[1]. Many studies have indicated that pollinator visits and behavior could affect the pollination success of plants[2,3]. Pollinator limitation can occur because flower visitors are either erratic or exhibit a preference for more attractive flowers[1,2].

The pollination success of a plant can be hampered by an inadequate or insufficient supply of pollen, called "pollen limitation"[4]. There are both ecological and evolutionary determinants and consequences for pollen limitation[1]. In addition, many studies have measured the scale of pollen limitation based on the pollen limitation index (PL index) for each reproductive component[4,5]. There has been particular focus on pollen limitation because low pollen transfer and resource availability can impact seed production[1]. Pollen limitation is a widely-observed phenomenon that is typically interpreted as an indication of insufficient pollinator visitation in arid areas[6,7]. There is abundant evidence of pollen limitation due to insufficient pollinator services, particularly in animal-pollinated plants[8,9].

Changes in habitat that cause increases or decreases in plant density may consequently alter pollinator availability and thus the pollination success of plants[10]. Human impacts on landscapes as well as grazing can also negatively influence pollinator visitor frequency[6]. Numerous plant species that rely on less effective pollinators may be subject to significant decreases in pollination success if pollinator activity is influenced by severe environmental conditions or climate change[11].

Caragana korshinskii Kom. (Leguminosae: Ammopiptanthus) has an important function in the establishment of arid vegetation[12]. The aims of the present study were to (1) assess the floral trait differences between natural and managed populations, (2) establish the potential impact of pollen limitation on seeds per flower in both natural

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Ecohydrological effects of biocrust type on restoration dynamics in drylands

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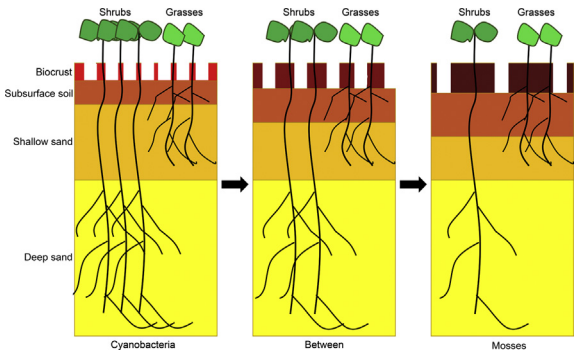
HIGHLIGHTS

- Biocrust in early-stage succession can support high cover for both grasses and shrubs.
- Biocrust in late-stage succession maintains high grass cover, while not shrub cover.
- Biocrust cover increases gradually as biocrust type shifting from early- to late-stage.
- We explored ecohydrological mechanisms to interpret the changes in vegetation cover.
- Climate change may influence dryland restoration in a way of altering biocrust type.

GRAPHICAL ABSTRACT



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ABSTRACT

Global climate change influences not only vascular plants, but also biological soil crusts (biocrusts), which play important roles in dryland vegetation dynamics by redistributing rainfall in soils. Different types of biocrusts, spanning a spectrum from cyanobacteria-dominated and moss-dominated, have distinct roles in rainfall redistribution patterns, but the ecohydrological effects of different biocrust types on dryland ecosystem dynamics remain largely unclear. This study developed an ecohydrological model with biocrust as a system state variable to explicitly explore the effects of different biocrust types on dryland vegetation dynamics in Shapotou region in northern China, particularly after restoration. The results indicated that both cyanobacteria- and moss-dominated biocrusts could support high grass cover (approximately 40%) after restoration. Cyanobacterial, but not moss biocrusts, could also maintain a high level of shrub cover (13 and 3%, respectively). Shifting from cyanobacteria to mosses gradually increased the biocrust cover from approximately 40% to 80%. The biocrust's water-holding capacity (the volume of water it can intercept per unit area) is likely be able to explain the dynamics of biocrust and shrub cover (with correlation efficiency of $R^2 = 0.972$ and 0.987, respectively), but not grass cover ($R^2 = 0.224$). The findings suggest that biocrust type may significantly affect coverage of biocrusts and shrubs, but not grass coverage, and global climate change may influence dryland restoration by altering biocrust types.

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Research Article

Temporal-Spatial Characteristics of Drought in Guizhou Province, China, Based on Multiple Drought Indices and Historical Disaster Records

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Guizhou Province, China, experienced several severe drought events over the period from 1960 to 2013, causing great economic loss and intractable conflicts over water. In this study, the spatial and temporal characteristics of droughts are analyzed with the standard precipitation index (SPI), comprehensive meteorological drought index (CI), and reconnaissance drought index (RDI). Meanwhile, historical drought records are used to test the performance of each index at identifying droughts. All three indices show decreasing annual and autumn trends, with the latter particularly prominent. 29, 30, and 32 drought events were identified during 1960–2013 by the SPI, CI, and RDI, respectively. Continuous drought is more frequent in winter–spring and summer–autumn. There is a significant increasing trend in drought event frequency, peak, and strength since the start of the 21st century. Drought duration indicated by CI shows longer durations in the higher-elevation region of central and western Guizhou. The corresponding drought severity is high in these regions. SPI and RDI indicate longer drought durations in the lower elevation central and eastern regions of Guizhou Province, where the corresponding drought severity is also very strong. SPI shows an increasing trend in drought duration and drought severity across most of the regions of Guizhou. In general, SPI and RDI show an increasing trend in the western Guizhou Province and a decreasing trend in central and eastern Guizhou. Comparing these three drought indices with historical records, the RDI is found to be more objective and reliable than the SPI and CI when identifying the periods of drought in Guizhou.

1. Introduction

Drought, a water shortage phenomenon caused by natural precipitation anomalies, is one of the most serious natural disasters, causing economic losses globally. The American Meteorological Society classified droughts into four types: meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought [1]. Meteorological drought refers to water shortages caused by an imbalance in precipitation and evaporation. Drought disasters are a product of the coupling of the natural environmental and socioeconomic systems under specific time and space conditions [2]. Among different types of natural disasters, drought disasters are among those with the highest frequencies, widest

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Statistical analyses of spatial and temporal variabilities in total, daytime, and nighttime precipitation indices and of extreme dry/wet association with large-scale circulations of Southwest China, 1961–2016

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ABSTRACT

The spatial and temporal variabilities of total precipitation (TP), daytime precipitation (DP), nighttime precipitation (NP), and their corresponding extremes in Southwest China (SWC) were investigated based on daily precipitation records from 112 meteorological stations obtained during 1961–2016. The standardized precipitation index was used to analyze extreme dry/wet events, and correlations with climate indices were detected using cross-wavelet analysis. The results indicated that on annual and seasonal scales, the majority of meteorological station records displayed downward trends for TP, DP, and NP (except in spring), which were particularly evident in autumn. Spatially, on both annual and seasonal timescales, higher values of TP and NP were found in southwestern parts of the Hengduan Mountains (HDM), southern and eastern parts of the Yunnan–Guizhou Plateau (YGP), and in southwestern and southeastern areas of the Sichuan Basin (SCB). The occurrences of dry/wet events in SWC were found correlated particularly well with ENSO. Furthermore, extreme dry/wet events were found to occur during El Niño and La Niña years, whereas the frequency of extreme dry events was found higher than extreme wet events during both El Niño and La Niña years since 2001. The findings of this study suggest that TP (TPd), DP (DPd), and NP (NPd) all showed decreasing trends, while extreme precipitation showed an increasing trend, indicating that both the intensity and the concentration of precipitation are increasing. Therefore, the risks of heavy precipitation and flooding are likely to increase in SWC, particularly in the SCB and that extreme events might be strengthened in certain seasons.

1. Introduction

Global mean annual land precipitation exhibited a trend of slight increase of approximately 1.1 ± 1.5 mm decade^{-1} between 1901 and 2005 (Trenberth et al., 2007). Atmospheric precipitation is a vital water resource, the availability of which over the continents is important for human health, economic activity, ecosystem function, and geophysical processes (Milly et al., 2002, 2005; Mooney et al., 2005; Mishra and Singh, 2010; Mishra and Liu, 2014; Yang et al., 2016). Meanwhile, the saturation vapor pressure of water in air is highly sensitive to temperature, perturbations in the global water cycle are expected to accompany climate warming (Allen and Ingram, 2002). In addition, precipitation change related to human activity is another important factor (Milly et al., 2002) that might contribute to increasingly intense extreme precipitation events (Qian et al., 2009; Min et al., 2011; Fu and Dan, 2014; Ma et al., 2017a). Previous studies appear to show that heavy/extreme precipitation events have increased (Wang and Zhou, 2005; Goswami et al., 2006; Allan et al., 2010; Westra et al., 2013; Lu et al., 2014; Fu and Dan, 2014; Ma and Zhou, 2015; Cui et al., 2018) and will increase in both intensity and frequency on regional and global scales in the future (Kharin et al., 2007; Li et al., 2013;Wang et al., 2014; Wang et al., 2016; Wang et al., 2017a; Shrestha et al., 2017; Gao et al., 2017; Xiao et al., 2017; Li et al., 2018). Specifically extreme precipitation in the monsoon regions is projected to further intensify with warming (Kitoh et al., 2013; Freychet et al., 2015). The study carried out by Zhang et al. (2018) suggested that the area and

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Evaluation of tourism climate comfort in the Grand Shangri-La region

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Abstract: The Grand Shangri-La (GSL) region has strong international tourist appeal. GSL has considerable international eco-tourist potential as well as being attractive for leisure, vacation, health, explorative, and scientific research activities in addition to high-end tourism experiences. These factors could promote the development of its regional tourism. GSL has been identified as a key area for tourism development in China. In this study, we investigated tourism climate conditions in GSL from 1980 to 2016 using a tourism climate index (TCI). We found that through global warming, the number of annual and monthly good-weather days, as assessed with the TCI, showed an increase over most of GSL; that trend was especially true for very good, excellent, and ideal days. The optimal travel period was May–October. We obtained the same result using cluster heat maps, in which we categorized 31 studied meteorological stations into eight types. However, heavy rainfall tended to occur during that optimal period, and it was concentrated at certain times. The annual total number of comfortable days greater than 300 was mainly located in southern GSL. We observed significant correlations between monthly and annual excellent and ideal days with latitude and elevation; in particular, we identified a significant nonlinear correlation between excellent (and ideal) days and elevation.

Keywords: Grand Shangri-La region; Evaluation; Tourism climate comfort; Cluster heat maps; Temperature; Precipitation

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Introduction

Globally, tourism is a major economic sector: in 2017, it accounted for roughly 10.4% of global GDP and 313 million jobs, i.e., 9.9% of total employment (WTTC 2018). Today, there are over 1.2 billion international tourists, and that number is estimated to rise to 1.8 billion by 2030 (UNWTO 2016). Climate is a major factor in tourism development (Saarinen 2014): it affects tourists' choice of destination (Mieczkowski 1985; Ridderstaat et al. 2014; Olya et al. 2015). The weather and climate of destinations can also be attractions in themselves, e.g., various tourism products are designed based on climate (Gómez Martín 2005; Grillakis et al. 2016a). Surveys have shown that climate information is a primary or secondary deciding factor for tourists when choosing a travel destination (Hamilton et al. 2005; Lin et al. 2006). Many factors affect the

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Runoff variation characteristics, association with large-scale circulation and dominant causes in the Heihe River Basin, Northwest China

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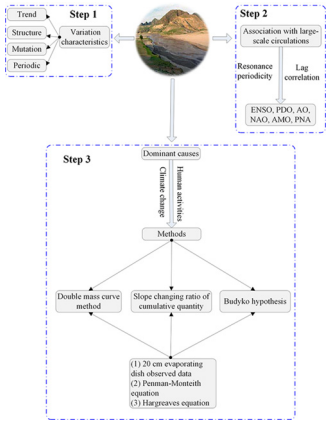
HIGHLIGHTS

- Monthly runoff with climate indices had a significant resonance periodicity and Spearman's lag correlation in Ylx and Zyx
- In low-flow season, human activities had a greater impact on UHRB, while climate had a greater impact on MHRB
- E_0 had different effects for separate the impacts of climate changes and human activities to the runoff variation

GRAPHICAL ABSTRACT



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ABSTRACT

The water resources in arid and semi-arid regions are critical to providing reliable sources of water for food production and ecosystem functioning. In this study, continuous wavelet transform and wavelet coherence were used to analyse the runoff periodicity and relationship with climate indices, respectively. Additionally, the double mass curve (DMCD), the slope changing ratio of cumulative quantity (SCRCQ) and the Choudhury–Yang equation (Budyko-CY) methods for different potential evapotranspiration data (E_0(E_0-20 cm, E_0-PM, E_0-H)) were used to separate the impacts of climate changes and anthropogenic activities on runoff variations. The results demonstrated that the flow regimes in high and low flow seasons were not obvious shifts, and that after implementation of the Ecological Water Diversion Project (EWDP), ecosystems were gradually restored in the downstream portion of the Heihe River Basin (DHRB). Periodicities of 1–7 years and 1–5.8 years were detected in Yingluoxia and Zhengyixia, respectively. Additionally, on a 1–148.2 month timescale, the monthly runoff with AO, NAO, PDO, and AMO had significant resonance periodicity and a 1–48 month Spearman's lag correlation. On the annual and

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frontiers in Plant Science

ORIGINAL RESEARCH
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The Growth and N Retention of Two Annual Desert Plants Varied Under Different Nitrogen Deposition Rates

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Nitrogen (N) partitioning between plant and soil pools is closely related to biomass accumulation and allocation, and is of great importance for quantifying the biomass dynamics and N fluxes of ecosystems, especially in low N-availability desert ecosystems. However, partitioning can differ among species even when growing in the same habitat. To better understand the variation of plant biomass allocation and N retention within ephemeral and annual species we studied the responses of *Malcolmia Africana* (an ephemeral) and *Salsola affinis* (an annual) to N addition, including plant growth, N retention by the plant and soil, and N lost to the environment using ^{15}N (double-labeled $^{15}NH_4{}^{15}NO_3$ (5.16% abundance) added at 0, 0.8, 1.6, 3.2, and 6.4 g pot^{-1}, equivalent to 0, 15, 30, 60, and 120 kg N ha^{-1}) in a pot experiment. Higher N addition (N120) inhibited plant growth and biomass accumulation of the ephemeral but not the annual. In addition, the aboveground:belowground partitioning of N (the R:S ratio) of the ephemeral decreased with increasing N addition, but that of the annual increased. The N input corresponding to maximum biomass and ^{15}N retention of the ephemeral was significantly less than that of the annual. The aboveground and belowground retention of N in the ephemeral were significantly less than those of the annual, except at low N rates. The average plant–soil system recovery of added ^{15}N by the ephemeral was 70%, significantly higher than that of the annual with an average of 50%. Although the whole plant–soil ^{15}N recovery of this desert ecosystem decreased with increasing N deposition, our results suggested that it may vary with species composition and community change under future climate and elevated N deposition.

Keywords: desert plants, annual, ephemeral, ^{15}N tracer, biomass, ^{15}N retention, N deposition

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RESEARCH ARTICLE

WILEY

Estimation of soil organic carbon, nitrogen, and phosphorus losses induced by wind erosion in Northern China

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Abstract

The loss of nutrients induced by wind erosion causes serious land degradation. Northern China suffers from severe wind erosion that causes massive amounts of soil nutrients to be lost and results in land degradation. To thoroughly comprehend the mechanisms of land degradation in Northern China, the spatiotemporal distribution of nutrients losses induced by wind erosion must be considered. Therefore, in this study, a wind erosion model was employed to obtain the PM10 emissions in Northern China from 2001 to 2014, and the quantities of soil organic carbon (SOC), total nitrogen (TN), and total phosphorus (TP) entrained by PM10 were obtained using the integrated soil database of China. The results showed that the losses of SOC, TN, and TP induced by wind erosion were 0.894, 0.184, and 0.123 Tg/a, respectively, and the spatial distributions of these three nutrients differed from one another. According to the Moderate Resolution Imaging Spectroradiometer land-cover data, the nutrients lost from desert ecosystems contributed the largest fractions of the total nutrients lost in Northern China, and the fractions of SOC, TN, and TP losses from the desert ecosystems all exceeded 50%. Following the desert ecosystems, the grassland ecosystems also had higher fractions of nutrients losses. The farmland ecosystems, which were the most severely impacted by human activities, contributed to less than 10% of the total nutrients losses.

KEYWORDS

PM10, SOC, TN, TP, wind erosion

1 | INTRODUCTION

Soils are the main terrestrial reservoir of nutrients, including nitrogen (N), phosphorus (P), and organic carbon. The potential impact of soil redistribution on the biogeochemical cycling of nutrients remains one of the great uncertainties in our knowledge base (Davidson & Janssens, 2006; Heimann & Reichstein, 2008). Since the pioneering work of Stallard (1998), scientists have become increasingly aware that soil erosion fluxes are of key importance in the global carbon cycle (Quinton, Govers, Van Oost, & Bardgett, 2010; Van Oost et al., 2007). These research results indicated that soil erosion preferentially removed the fine, nutrient-rich fractions of topsoil and the nutrients entrained by eroded sediment were transported to other sites. These processes changed the composition and structure of the soil surface, which resulted in changes in the soil albedo, soil moisture-holding capacity, soil fertility, and soil productivity (Quinton et al., 2010). For example, erosion-induced lateral and vertical fluxes of carbon, nitrogen, and phosphorus can cause serious soil degradation at the erosion site and excessive element accumulation at the deposition site. According to the estimation of Lal (2003), under the assumption of a delivery ratio of 10% and soil organic carbon (SOC) content of 2–3%, there were about 4.0- to 6.0-Pg/year total carbon that were displaced by erosion; with 20% emission due to mineralization of the displaced carbon, erosion-induced emission might be 0.8- to 1.2-Pg

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Wind erosion changes induced by different grazing intensities in the desert steppe, Northern China

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ABSTRACT

Desert steppes are fragile ecosystems, which generally suffer severe wind erosion hazards, especially when they experiencing external disturbances such as grazing. Therefore, the effects of grazing on the wind erosion process are very important for improving our understanding of the effects of the stocking rate on grassland degradation and enacting reasonable grazing strategies in grasslands. However, few studies have discussed the wind erosion changes induced by different grazing intensities thus far. Herein, a series of grazing experiments was carried out in a desert steppe in Urad Back Banner, Inner Mongolia. These experiments included 2 types of grasslands that are shrub dominated grassland (SDG) and grass dominated grassland (GDG). Each grassland type had 3 grazing rate treatments: no grazing as the control (CK), moderate grazing (MG), and heavy grazing (HZ). After the grazing experiments lasting for 4 years, sand traps were set in the grazing plots to detect the horizontal sand flux at different grazing intensities. In addition to the wind erosion observed, the vegetation and soil particles were also surveyed and sampled. Our results showed that the vegetation cover (VC) and aboveground biomass (AGB) in the MG and HG plots all had obvious differences compared to the CK plot, regardless of whether it was SDG or GDG. The soil particle analysis showed that the fractions of erodible particles (60–200 μm) in the MG and HG plots decreased significantly. In the GDG, the soil particles exhibited a coarsening trend from CK to HG plots for the sorting action of the wind. Suffering a grazing disturbance, the wind erosion in a desert steppe exhibited significant changes. For instance, in the SDG, the horizontal sand flux in the MG and HG plots were 1.78 and 2.06 times the sand flux in the CK plots, respectively, and, in the GDG, they were 17.86 and 56.53 times the flux in the CK plots, respectively. Except in the MG and HG plots of the GDG, the saltation height of sand was generally lower than 20 cm. In the SDG, the particle size of the entrained sand mainly ranged from 80 to 200 μm, and, in the GDG, it ranged from 80 to 300 μm. This finding also indicated the validity of Shao's sand entrainment equation. We also found that particle size of saltating sand increased with their saltation height for the tough surface of the MG and HG plots in the GDG. Based on the different fractions of horizontal flux in different directions, we also discussed the threshold wind velocity for sand entrainment, and we confirmed that the threshold wind velocities for no grazing in SDG and GDG were approximately 16.5 $m \cdot s^{-1}$ and 15 $m \cdot s^{-1}$, respectively. Using our previous wind erosion model, we estimated the dust emission in the total desert steppe of China and found that different grazing scenarios would change the magnitude and distribution of dust emissions.

1. Introduction

Wind erosion is a major topic of concern worldwide for approximately 28% of the global land area is experiencing wind erosion hazards (Oldeman, 1994; Callot et al., 2000; Prospero et al., 2002; Webb et al., 2006). Wind erosion is a major contributing factor to soil degradation by changing the soil texture and nutrient content through the entrainment of fine particles (Warren et al., 2005; Wang et al., 2006; Berhe et al., 2018). In addition, the dust generated by wind erosion has a negative effect on the environment (Sharratt et al., 2007) and impacts the global biogeochemical cycle by its characterized long-distance transport capacity and its rich nutrient content compared to

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REGULAR ARTICLE

Warming effects on soil respiration in moss-dominated crusts in the Tengger Desert, northern China

Chao Guan · Xinrong Li · Ning Chen · Peng Zhang · Changming Zhao

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Abstract

Background and aims Despite the important role of biological soil crusts in the soil carbon cycles of desert ecosystems, the responses of soil respiration in biological soil crust-dominated areas to warming are not well understood. The goal of this study was to investigate the expected increases in temperature on soil respiration both diurnally and seasonally in biological soil crust-dominated areas.

Methods We used open-top chambers to simulate warming in the Shapotou region in the Tengger Desert, northern China. An automated soil respiration system was used to measure the soil respiration rates in moss-dominated crusts. The measured environmental variables included the precipitation, volumetric soil water content, air temperature and soil temperature at depths of 0, 5, 10, 20, and 50 cm.

Results The response of soil respiration to warming is a function of soil moisture following rainfall in desert ecosystems. Our results showed that 1.5 °C of simulated warming significantly decreased soil respiration, indicating that the inhibition of soil respiration was likely due to the reduction in soil water content at a relatively high temperature. Over daily cycles, hourly soil respiration rates have commonly been related to hourly temperatures. The observed diel hysteresis between hourly soil respiration and temperature resulted in semielliptical hysteresis loops, and the temperature often lagged behind soil respiration for several hours. The lag times between soil respiration and temperature were significantly and positively related to the depth of the soil temperature measurements. The proximate reason for the diel hysteresis between soil respiration and temperature was likely a mismatch between the depth of CO_2 production and the depth of the temperature measurements.

Conclusions Our results indicate that warming increases the response of soil respiration to soil water availability in biological soil crust-dominated desert ecosystems. Therefore, the accelerated drying effect of warming on soil respiration and diel soil respiration patterns between soil respiration and temperature at different depths should be considered in future soil carbon cycle models for biological soil crust-dominated desert ecosystems.

Keywords Soil respiration · Biological soil crust · Warming · Temperature · Diel hysteresis

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SOILS, SEC 1 • SOIL ORGANIC MATTER DYNAMICS AND NUTRIENT CYCLING • RESEARCH ARTICLE

Effect of global warming on soil respiration and cumulative carbon release in biocrust-dominated areas in the Tengger Desert, northern China

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Abstract

Purpose Global warming is expected to have profound effects on terrestrial carbon (C) fluxes, consequently influencing future climate. Biocrusts are important sources of C in the C cycle of desert ecosystems, where vascular plants are restricted by limited soil moisture. This study was conducted in order to evaluate the expected increases in temperature on soil respiration in biocrust-dominated areas.

Materials and methods In a field warming experiment, we evaluated the impact of increased temperature on soil respiration in biocrust-dominated (moss-crusted and lichen-crusted) areas in Shapotou, China. In addition, the impacts of precipitation, soil temperature, and moisture on soil respiration were investigated.

Results and discussion The effect of warming on soil respiration varied with soil water availability. Our results showed that soil respiration in moss-crusted and lichen-crusted areas in the warming treatment was significantly lower than that in the control. The observed inhibition of soil respiration by the increase in soil temperature was likely due to the reduction in soil moisture caused by the increased water evaporation rate under higher soil temperature. Warming also decreased cumulative C release in moss-crusted and lichen-crusted areas. Moreover, cumulative C release showed marked seasonal variations, with the highest C release occurring in summer and the lowest in winter. Over the seasonal cycle, soil respiration rates were positively correlated with precipitation, soil temperature, and volumetric soil water content.

Conclusions The results of this study indicate that warming may increase the sensitivity of soil respiration to water availability in biocrust-dominated areas in desert ecosystems, suggesting that biocrust should be considered in projections of future C budget.

Keywords Biological soil crust · Precipitation · Seasonality · Soil respiration · Stimulated warming · Cumulative C release

1 Introduction

Biological soil crusts (biocrusts) are widely distributed communities comprising cyanobacteria, green algae, lichens, mosses, and other microorganisms that live within or immediately on the top of the uppermost millimeters of the soil surface. Biocrusts develop widely on the soil surface in desert regions, where no vascular plants grow, and are often a substantial component of the total terrestrial surface (Belnap and Lange 2003). Due to their environmental sensitivity, biocrusts serve as indicators of environmental changes in temperature and soil moisture, and they can influence ecological processes, including seed germination and plant establishment (Li et al. 2010). Biocrusts also play an important role in carbon (C) cycling in terms of C uptake and release C to the atmosphere

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Biological soil crusts enhance the recovery of nutrient levels of surface dune soil in arid desert regions

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Cyanobacteria-lichen crusts
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ABSTRACT

Revegetation, an effective method for restoring desertified lands, helps enhance the colonization and development of biological soil crusts (BSCs) and improves the nutrient conditions of desert soils. This study aims to shed light on the changes of elemental concentrations and their enrichment in fixed surface soil of sand dunes over a 50-year revegetation chronosequence linked to BSCs of different successional stages in the Tengger desert of China. We investigated the elemental levels of K, Na, Ca, Mg, Mn, Zn, Cu, and Fe in surface soil covered by cyanobacteria-lichen crusts, moss crusts and subsoil. Nutrient enrichment of BSCs and soils were analyzed to reflect the nutrient changes in the revegetated desert ecosystem. Concentrations of K, Na, Ca, Mn, Zn, and Cu in cyanobacteria-lichen crusts were significantly higher than in mobile sand dunes. Nutrient enrichment rate (except for Na) exhibited unimodal patterns, and year 31 was a key turning point after which the rate switched from increasing to decreasing over time. Our long-term study indicated that both cyanobacteria-lichen crusts and moss crusts can effectively improve nutrient accumulation and promote edaphic conditions, which is beneficial to the development and nutrient cycling of desert ecosystems.

1. Introduction

In the context of global warming and intensified human activities, desertification has had a deteriorative influence on most infrustructure of windy desert regions, resulting from shifting dune movement and transportation of sand without vegetation protection (CCICCD, 1997; Diallo, 2008). Most lands in arid and semi-arid regions of China are suffering from desertification; therefore, a series of ecological engineering construction projects have been implemented since the 1950s (Li et al., 2006). After fixing mobile sand dunes, revegetation through planting xeric shrubs is an effective method of ecosystem restoration and can significantly enhance the biodiversity and stability of revegetated ecosystems, in addition to increasing nutrient levels in soil environments (Li et al., 2004). After dune surface fixed by revegetation, biological soil crusts (BSCs) begin to colonize and develop, ultimately becoming an indispensable part of the ecosystem (Bowker, 2007; Li et al., 2006; Xiao et al., 2015). Generally, pioneer cyanobacteria with long and highly mobile filaments, such as *Microcoleus*, are the first colonizers, which are then, gradually replaced by other desert algae, lichens and mosses (Belnap, 2006; West, 1990). Previous studies revealed that BSCs play several different roles in ecological restoration. These roles include enhancing dust trapping through increased surface roughness (Fearnehough et al., 1998; Reynolds et al., 2001); increasing the levels of plant-essential nutrients (Belnap and Harper, 1995); improving carbon and nitrogen fixation (Evans and Lange, 2001; Kidron et al., 2015; Yang et al., 2014); enhancing nitrogen mineralization and availability (Delgado-Baquerizo et al., 2013; Hu et al., 2015); strengthening soil stability and physical structure (Felde et al., 2017); and adjusting hydrologic processes in arid ecosystems (Li, 2012). The nutrient enrichment that occurs in BSCs plays a vital role in biogeochemical cycles, soil fertility, and plant nutrient availability. Although nutrient enrichment in BSCs has been studied (e.g., Reynolds et al., 2001; Geesey and Jang, 1990; Lange, 1974), relatively little is known regarding the elemental composition and how it changes in BSCs over a long-term chronosequence in revegetated ecosystems.

To date, most studies involving elemental composition analysis have focused on vascular plant species, as well as on BSCs. Elemental composition also determines the species composition and physiological function of BSCs. For example, in the Colorado Plateau highland and the Sonoran Desert lowland, Beraldi-Campesi et al. (2009) indicated that BSCs showed coincident trends of enrichment in biogenic elements (e.g., C and N) and depletion of non-biogenic elements (e.g., Ca, Cr, Mn, Cu, Zn, As, and Zr). These elemental patterns might help scientists identify the ancient microbial communities at a site. Macro- (C, N, P,

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STUDY ON ANTIOXIDANT ENZYMES OF AFFECTING GREENHOUSE GRAPE BERRY UNDER SURFACE MULCHING

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ABSTRACT

A field trial was designed by five mulching approaches (TS, coarse sand mulching; TJ, straw mulching; TBJ, straw mulching with white plastic film; THJ, straw mulching with black plastic film; TK, no mulching) for determination of main physiological factors affecting greenhouse grape berries, and mastery of how the grape berry was influenced particularly by antioxidant enzymes. Main results showed that: (1) the first eigenvalues of the three main factors in all treatments were above 1, which corresponded with the variance ratio of TK>TJ>TS>TBJ>THJ, wherein TK was up to 95.634%, and THJ was 91.567%. In TS, higher load of 0.926, 0.834, and 0.638 occurred in catalase (CAT), Pro content in leaves and superoxide dismutase (SOD) activity of berries, of which correlation coefficient in principal component expression was 0.542, 0.526, and 0.618, respectively, serving as main component factors; (2) determination coefficient (R^2) of berry diameter was in range of 0.970-0.970, with high reliability. Based on linear regressions between the berry diameter and principal component factors, the interpretation degree of these principal components factors to the grape berry was 82.90%, 78.40%, 66.60%, 77.00% and 70.30% in TS, TJ, TBJ, THJ and TK, respectively. Our conclusions suggested that under coarse sand mulching, the high level of CAT activity reduced the effect of variational proline (Pro) content and SOD activity on grape berry. The complementary synergy effect of CAT, SOD and Pro promoted the grape berry growth; after straw mulching, the Pro content in grape leaves and berries kept at an unstable status in the middle phase of growing season, weakened the ability of maintaining leaf osmotic potential, led to grape berry was controlled by the malondialdehyde (MAD) accumulations; under straw mulching with black film, combining the higher SOD activity which was not affected by the growing season with more Pro content maintained the defensive capability of membrane system, furthermore, MAD with a gentle decrease in earlier growing season enhanced the resistance of grapevines.

KEYWORDS:
Surface mulching, Grape berry, Antioxidant enzyme activities, Principal component analysis, Regression analysis

INTRODUCTION

Surface mulching technology plays a prominent role in soil management and crop cultivation [1, 2]. For example, straw mulching can increase the number of microorganisms in soil [3], and the mulching amount is in direct proportion to the inhibition of germination rate and emergence rate of crop seeds [4]. However, less mulching is not conducive to increasing production, and when the coverage is larger, the yield does not increase or even decrease [5, 6]. In addition, surface mulching can improve the utilization rate of surface water and groundwater [7, 8], and its effect of water storage at a stable temperature and production increase is obvious [9]. Liu et al. [10] studied the effect of straw mulching and the amount of straw mulching on winter wheat, and concluded that the average moisture content of 0-200cm soil layer increased by 19.20%, 12.90% and 8.80%, respectively, compared with no mulching, after the mulching amount of 9000, 6000 and 3000kg·hm^{-2} in the whole growth period, which confirmed the favourable storage capacity of straw mulching. Xia et al. [11] found that straw mulching can reduce the surface soil temperature, while plastic film mulching can increase the surface soil temperature. Yun et al. [12] studied the reflection characteristics of millet on mulching, and found that the photosynthetic physiological indexes under mulching increased to different degrees, while the white film mulching could significantly promote the development process of millet, black film mulching can greatly increase yield, water utilization and input-output ratio, which is beneficial to crop growth. Further studies showed that organic matter, available nitrogen and phosphorus contents in soil significantly increased after years of continuous mulching [13, 14]. For example, Kar et al. [15] studied that straw mulching dramatically improved potato biomass and soil fertility. Kasperauer et al. [16] and Locascio et al. [17] found that red film

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Shifts in soil microbial community functional gene structure across a 61-year desert revegetation chronosequence

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ABSTRACT

Vegetation and soil properties are crucial in shaping soil microbial communities. However, little is known about temporal changes in the functional structure of soil microbial communities to managed revegetation in desert ecosystems. Here, we adopted GeoChip 5.0-180 K, a functional gene array, to investigate the succession of soil microbial functional genes structure and potential across a 61-year revegetation chronosequence in the Tengger Desert, China. The abundance of bacterial, fungal and archaeal genes generally increased during succession. However, variation in α-diversity of microbial functional genes and signal intensity of most C-, N- and P-cycling related genes showed hump-shaped patterns along the successional gradient. Although microbial functional structure changed during succession, these revegetation sites shared a high percentage of functional genes and nestedness-resultant component dominantly determined β-diversity. Furthermore, microbial functional structure significantly correlated with crustal and shrub coverage, thickness and mass of crusts, soil fine particles, total C, total P and the ratios of C to N and C to P. The canonical correspondence analysis (CCA) and CCA-based variation partitioning analysis showed that environmental variables explained 56.6% and 85.3% of the variance in overall microbial functional genes, respectively. These results indicate that vegetation development, especially the colonization and development of soil crusts together with changes in soil abiotic properties, play key roles in driving the functional shifts in soil microbial community structure after desert revegetation.

1. Introduction

Deserts occupy about a quarter of the global land surface and are characterized by low plant cover, bare soil and aeolian sandy conditions. Biological soil crusts (BSCs), a complex of cryptogams and microorganisms cemented with soil particles, are a major component of desert ecosystems, covering as much as 70% of the surface area in the Mojave Desert (Zaady and Bouskila, 2002; Belnap and Lange, 2003). Due to the key functions in C cycling, N-fixation, eco-hydrological processes and stabilization of deserts (Eldridge and Greene, 1994; Belnap and Lange, 2003; Elbert et al., 2012), BSCs play important roles in driving vegetation succession and soil development in desert ecosystems (Li et al., 2007a, 2007b). According to previous studies in a revegetated region of the Tengger Desert, China, BSCs colonize and establish in the first several years after revegetation, thereby stabilizing the soil surface and enhancing further ecosystem succession. Many changes in plant community composition and soil properties occur in the following decades (Li et al., 2004, 2007a). After 50 years of succession, BSCs make up > 80% of the sandy surface and shift from cyanobacteria-dominated crusts to moss and lichen-dominated crusts (Li et al., 2006). These changes in the composition of BSCs result in improvement of soil nutrient levels and alteration of plant community structure, such as the establishment of herbaceous plants and a decrease in the abundance of shrubs (Li et al., 2007b).

Microorganisms play integral and unique roles in driving soil biogeochemical cycles of carbon (C), nitrogen (N), phosphorus (P), sulfur

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The Physiological and Biochemical Effects of Phthalic Acids and the Changes of Rhizosphere Fungi Diversity under Continuous Cropping of Lanzhou Lily (*Lilium davidii* var. *unicolor*)

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Additional index words. continuous cropping, Lanzhou lily (*Lilium davidii* var. *unicolor*), physiological, biochemical, fungi diversity, edible bulb

Abstract. **The autotoxicity of root exudates and the change of rhizosphere soil microbes are two important factors that affect the quality and yield of Lanzhou lily (*Lilium davidii* var. *unicolor*). Phthalic acid (PA) is a major autotoxin of the root exudates in Lanzhou lily. In this study, we treated plants with different concentrations of PA from the Lanzhou lily root exudates and then analyzed the effects of autotoxins on fresh weight, shoot height, root length, and Oxygen Radical Absorbance Capacity in root. The diversity of soil fungi in Lanzhou lily soil was analyzed using MiSeq. The results showed that PA induced oxidative stress and oxidative damage of Lanzhou lily roots, improved the level of the membrane lipid peroxidation, reduced the content of antioxidant defense enzyme activity and the nonenzymatic antioxidant, and eventually inhibited the growth of the Lanzhou lily. We found that continuous cropping of Lanzhou lily resulted in an increase in fungal pathogens, such as *Fusarium oxysporum* in the soil, and reduced the size of plant-beneficial bacteria populations. The results in this study indicate that continuous cropping would damage the regular growth of Lanzhou lily.**

Lanzhou lily (*Lilium davidii* var. *unicolor*) is an important economic crop in northwest China's Ningxia and Gansu provinces; however, continuous cropping has seriously affected the yield and quality of Lanzhou lily bulbs. *Fusarium oxysporum* is the main pathogenic fungus of Lanzhou lily. *Fusarium moniliforme, Fusarium tricinctum,* and *Fusarium solani* can also result in wilt disease (Shang et al., 2014). In addition to the impact of microorganisms, the toxic effects of root exudates cannot be ignored. Many studies have shown that the autotoxicity of root exudates is an important obstacle to continuous cropping. Different concentrations of root exudates have a significant effect on the growth of seedlings of Lanzhou lily. The low-concentration root exudates promote seedlings, whereas high-concentration root exudates repress seedlings (Chen et al., 2016). Studies have shown that PA can accumulate in soil with the increase in duration of monoculture, and PA may be one of the major factors inducing continuous cropping obstacles in Lanzhou lily (Wu et al., 2015). The aim of this study was to investigate the effects of continuous cropping on soil-borne disease and the crop autotoxicity in Lanzhou lily cultivation.

Material and Methods

Experimental materials and sample plot profiles. A total of 100 Lanzhou lily seed bulbs used in physiological experiments were purchased from lily dealers (Xiguoyuan of Lanzhou City, Gansu Province, China). The seed bulbs were dormancy broken through refrigeration for 60 d at 4 °C. PA was purchased from Tianjin Kexin Chemical Company (Tianjin, China). The test soils were obtained from the surface soil (0 to ≈15 cm) where lilies were grown. After removing the stones of soils by sieving through a 4-mm mesh screen, the soil was mixed evenly and used as the growth medium for Lanzhou lily.

Soil samples for fungal diversity analysis were collected from sites in Xiguoyuan of Lanzhou City, Gansu Province, China (lat. 35°98'N, long. 103°78'E) that had grown lily for many years. Test soils came from different sites, including sites that planted lily for a year (RS1), 2 years (RS2), 3 years (RS3), and a site that was planted with lily and idle for a year (RS0). The experimental plot size was 100 × 100 cm, and there were 36 bulbs per plot. All plots were adjacent to each other to eliminate the variation of soil properties caused by spatial differences. There were three replicate plots in every site. We collected rhizosphere soil from four plants in every plot. Meanwhile, the fertilization program and the planting management measures were consistent in all plots.

Experimental designs. At the beginning of April, we used a pot experiment to investigate the effect of PA on growth of Lanzhou lily. Lily bulbs were immersed in Imazalil for 1 h to sterilize the surface, and then rinsed with tap water several times before planting;

Continuous cropping can cause soil-borne disease and crop autotoxicity, resulting in a decline in crop quality. Succession cropping leads to the changes of physical and chemical properties in soil that crops need to grow (Dou et al., 2016). In addition, changes in microbial community composition and the residue of the toxic substances following continuous cropping are also important factors causing the continuous cropping obstacle (Kennedy and Smith, 1995; Zhang et al., 2008). One of the obvious signs of soils with continuous cropping is that the soil is transformed from ''bacterial'' to ''fungal,'' and fungi are the main pathogens of plant disease (Ibekwe et al., 2002), including *Fusarium*, *Rhizoctonia*, *Pythium*, *Cylindrocarpon*, and *Phytophthora* (Mazzola, 1998).

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Genetic diversity in *Salix gordejevii* populations from different environmental gradients in Horqin Sandy Land, Northern China

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ABSTRACT

Salix gordejevii (Salicaceae) is a climax and dominant sand-fixing shrub species native to the northern China. We assessed *S. gordejevii* population genetic variation in different environmental gradients in Horqin Sandy Land, Northern China using inter-simple sequence repeat (ISSR) markers, and investigated the possible existence of relationships between genetic diversity and environmental gradients. The results showed that *S. gordejevii* populations in general have high genetic diversity. An analysis of molecular variation (AMOVA) revealed relatively high levels (> 89.91%) of within-population genetic variation. Based on cluster analysis, the 12 studied *S. gordejevii* populations can be clustered into three clades. Genetic diversity and differentiation of *S. gordejevii* populations are affected from different environmental gradients. Genetic diversity of all populations was affected by habitat environment change, and was well-correlated with the humidity gradients. These results have important implications for restoration and management of degraded ecosystems in arid and semi-arid areas.

INTRODUCTION

More than one third of Earth's land surface area is classified as arid and semi-arid ecosystems (Collins *et al*. 2008). The environment plays an important role in evolutionary processes in arid and semi-arid areas. The directional and continuous environmental changes, such as increasing temperature, reducing rainfall and habitat destruction, affected the dynamics of species, even in those with high potential for gene flow (Hamrick 2004). In turn, making a population more suited for survival in various environmental, genetic adaptations are achieved through gene frequency changes across generations (Koski *et al*. 1997). The genetic diversity of individuals within a population can also be affected by a range of environmental gradients. The interaction between genetic diversity and environmental gradients has been assessed in many population-level studies in plants, for example *Pistacia lentiscus* (Nahum *et al*. 2008) and *Salvia s*pecies (Al-Gharaibeh *et al*. 2016).

Horqin Sandy Land is located in the agro-pastoral transition zone between the Inner Mongolian Plateau and the Northeast Plains. It has 139,300 km^2 in area and located in the east of Inner Mongolia of China (Wang 2003, Zhao *et al*. 2003). It belongs to a typical

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RESEARCH ARTICLE

WILEY

Variation in snow cover drives differences in soil properties and microbial biomass of BSCs in the Gurbantunggut Desert—3 years of snow manipulations

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Abstract

Variations in snow cover (as specific precipitation) can have an important effect on development of biological soil crusts (BSCs) in arid and semiarid regions, where water is the principal limiting factor for microorganisms. However, there is still limited knowledge available regarding the effects of snowfall on soil properties and microbial biomass in BSCs. To examine these effects of snow cover, three types of BSCs (cyanobacteria-dominated, lichen-dominated, and moss-dominated crusts) were collected and exposed to five snow depths for 3 years. The results indicated that most of the soil properties and soil microbial biomass were significantly ($p < .05$) affected by 3 years of snow manipulation in three types of BSCs. In BSCs, the values of most soil properties and microbial biomass were higher in the increased snow depth treatments relative the snow removal treatments. Moreover, there were variations in soil properties and microbial biomass among BSC types. In short, increases/decreases in snow cover had different effects on three types of BSCs after 3 years of manipulation. Moreover, increases in snow cover had a positive influence on soil properties and microbial biomass, but negative effects were observed in all BSCs following snow removal and snow reduction. Thus, variations in snow cover can drive differences in soil properties and microbial biomass of BSCs, which may further affect development and succession of BSCs in arid and semiarid regions.

KEYWORDS

biological soil crusts (BSCs), snow cover, soil microbial biomass, successional stages, water availability

1 | INTRODUCTION

Arid and semiarid regions share 33–52% of the terrestrial land surface in the world (Elbert, Weber, Büdel, Andreae, & Pöschl, 2009), where many vascular plants are restricted because of deficiencies in precipitation, but biological soil crusts (BSCs) are widespread. BSCs are consortia of cyanobacteria, green algae, lichens, mosses, and other organisms associated with soil particles that play integral roles in arid and semiarid regions (Belnap & Lange, 2003; Li, 2012; West, 1990), including stabilizing soil surfaces against water and wind erosion (Gao et al., 2017), enriching the soil in carbon and nitrogen (Johnson, Neuer, & Garcia-Pichel, 2007; Li, Zhang, Su, & Jia, 2012), influencing the colonization and development of vascular plants (Langhans, Storm, & Schwabe, 2009; Li, Jia, Long, & Zerbe, 2005), and supplying habitats for other microorganisms and protozoa (Liu, Xing, & Yang, 2017). Because BSCs are usually located within the uppermost millimetres of the soil surface, they are more likely to be influenced by environmental factors, including soil water, soil nutrients, temperature, and radiation intensity (Grote, Belnap, Housman, & Sparks, 2010; Hui et al., 2013; Miralles, Trasar-Cepeda,

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Comparative physiological responses of *Microcoleus vaginatus* and *Bryum argenteum* to enhanced UV-B radiation under field conditions

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Abstract. UV-B radiation is an important environmental factor affecting the composition and function of biological soil crusts (BSCs). The aim of this study was to compare the effects of enhanced UV-B radiation on BSCs from Tengger Desert, north-western China, which are dominated by the cyanobacterium *Microcoleus vaginatus* Gom. and moss *Bryum argenteum* Hedw. The BSCs were exposed to four UV-B supplemental treatments, including 2.75 (control), 3.08, 3.25, and 3.41 W m^{-2}, for 40 days under field condition. In both the studied organisms, UV-B radiation significantly affected the physiological properties (total flavonoids, soluble proteins, soluble sugars, and proline contents). While marginally enhanced UV-B radiation for a short period favoured the growth of *M. vaginatus* and *B. argenteum*, excessively high and prolonged UV-B radiation suppressed the physiological properties of the two organisms. Moreover, response index revealed that UV-B radiation had more detrimental effects on *B. argenteum*, suggesting that *B. argenteum* is more sensitive to UV-B radiation than *M. vaginatus*. The findings of this study could help to predict and evaluate the possible changes in the structure and function of desert ecosystems, based on the variation in physiological responses of *M. vaginatus* and *B. argenteum* to enhanced UV-B radiation.

Additional keywords: biological soil crusts, detrimental effects, physiological properties, response index, sensitivity, UV-B radiation.

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Introduction

In arid and semiarid regions, vascular plant cover is sparse. Nevertheless, the interspace surfaces are usually covered with organic complexes of specialised organisms, including fungi, algae, cyanobacteria, lichens, and mosses, together with topsoil, which are the major components of biological soil crusts (BSCs), and constitute up to 70% of the living ground cover (Eldridge and Greene 1994; Belnap and Lange 2003). BSCs play major ecological functions in desert ecosystem by forming microhabitats, and reduce soil erosion by water or wind, affect surface hydrological processes, contribute to carbon assimilation and nitrogen fixation, influence the establishment and development of vascular plants, and provide favourable habitats for other microorganisms and protozoa (Grote *et al*. 2010; Li 2012; Zhang and Belnap 2015; Guan *et al*. 2018). The physiological properties and ecological functions of BSCs are directly related to various environmental factors, including precipitation, temperature and UV-B radiation (Zelikova *et al*. 2012; Hui *et al*. 2013; Yin and Zhang 2016). In particular, depletion of the stratospheric ozone layer resulting in increased levels of UV-B radiation at the earth's surface is a major concern (Agrawal and Rathore 2007). UV-B (280–315 nm) constitutes only a small portion (1.5%) of the total solar spectrum, but can be absorbed by biomacromolecules, causing major impacts on terrestrial organisms and ecosystems (Arróniz-Crespo *et al*. 2011).

Despite controlling a diverse array of regulatory processes in plants, it is well known that increased UV radiations may cause harmful effects on many plants such as cryptogams and spermatophytes (Urban *et al*. 2006). Previous studies have shown that photosynthetic system (photosynthetic apparatus (PA), plastoquinones (Q_A, Q_B), D1 and D2 proteins, and enzyme Rubisco) is the primary target affected by high doses of UV-A or UV-B (Babu *et al*. 1999; Asada 2006; Kreslavski *et al*. 2016). The efficiency and stability of photosynthetic system is important for the functioning of PA, which may further affect photosynthesis rates and plant growth and development (Haapala *et al*. 2010). As plants may experience oxidative stresses caused by the generation of reactive oxygen species as a result of exposure to UV radiation (Kumari and Agrawal 2010), they have developed several defence systems (such as induction of enzymes and UV-absorbing substances) to minimise oxidative injury, including lipid peroxidation, protein degradation, and DNA damage (Singh *et al*. 2009).

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REGULAR ARTICLE

High rainfall frequency promotes the dominance of biocrust under low annual rainfall

Rongliang Jia · Ning Chen · Kailiang Yu · Changming Zhao

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Abstract

Aims Global climate change may greatly alter the structure and stability of drylands, creating an urgent need to recover their functions and services. Biological soil crust (biocrust), an interface between the soil and atmosphere, plays a crucial role in ecohydrological processes, and thus in influencing the restoration dynamics of dryland ecosystems. Previous studies have generally investigated the influences of biocrust on ecohydrological processes as an exogenous factor. However, it remains unclear how biocrusts, as an integral part of many ecosystems (i.e., as a system state variable), will change under global climate change.

Methods This study developed a new ecohydrological model with biocrust cover as a system state variable, and explored the response of dryland ecosystems to altered rainfall regimes.

Results Biocrust cover responded with an inverted U-shaped curve relationship to increasing annual rainfall and linearly to increasing rainfall frequency. Vascular plant (grass and shrub) cover showed an increasing trend with increasing annual rainfall and a decreasing trend to increasing rainfall frequency. Therefore, biocrust usually dominated over vascular plants (i.e., high biocrust cover and low vascular plant cover) under low annual rainfall. Furthermore, an increasing rainfall frequency would amplify the range of environmental (rainfall) conditions dominated by biocrust from an annual rainfall 0–100 mm under a rainfall frequency of 0.025 day^{-1} to 0–500 mm under a rainfall frequency of 1 day^{-1}.

Conclusions This study developed a model framework to predict dryland dynamics for surfaces covered by biocrust under global climate change. We suggest that restoration efforts could target at biocrust-dominated state in deserts, especially in a (future) drier climate.

Keywords Biological soil crust · Rainfall frequency · Global climate change · Drylands · Ecohydrological model · Layered soils

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Introduction

Drylands are the largest terrestrial biome of the Earth covering around 40% of the terrestrial land surface and

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RESEARCH ARTICLE

WILEY

Plant restoration leads to divergent sequestration of soil carbon and nitrogen in different fractions in an arid desert region

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Abstract

Soil organic carbon (OC) and nitrogen (N) associated with particle size fractions can be used as sensitive indicators to evaluate impacts of land use change on soil total OC (TOC) and total N (TN) pools. Aeolian sandy-soils were collected from seven sites in the Tengger Desert, representing a 56-year chronosequence of plant restoration at decadal intervals in an arid desert region. Bulk soils were separated into silt + clay (<53 μm), fine sand (53–100 μm), and coarse sand (>100 μm) fractions. TOC and TN concentrations of bulk soil and their levels associated with particle size fractions were analyzed. Results showed that plant restoration promoted C and N sequestration in both topsoil and subsoil layers over time, as indicated by elevated levels of OC and N associated with silt + clay and sand fractions. TOC and TN concentrations of 56-year restored topsoil respectively increased by 31- and 43-fold than did the control (moving dunes); corresponding levels associated with silt + clay or coarse sand fraction respectively increased by more than 30- and 20-fold, whereas less than 15-fold increases were found in fine sand fraction. In the early stages of plant restoration, both C and N sequestration primarily resulted from finer particle size fractions. In the later stages, increased C sequestration was principally derived from coarse sand fraction, whereas N sequestration was mainly derived from silt + clay fraction. The results highlight that plant restoration stage and soil textural change are key factors leading to divergent soil C and N sequestration in the arid desert region.

KEYWORDS

arid desert, plant restoration, sand fraction, silt and clay fraction, soil nitrogen, soil organic carbon

1 | INTRODUCTION

Land use change such as plant restoration has profound impacts on soil organic matter storage in terrestrial ecosystems (Gelaw, Singh, & Lal, 2015; He, Liang, Han, Wang, & Liu, 2016; Köchy, Don, van der Molen, & Freibauer, 2015; Liu, Dang, Tian, Wang, & Wu, 2017; Xiong et al., 2014). Soil organic matter represents a major pool of organic carbon (OC) and nitrogen (N) characterized by distinct inherent levels of turnover and stability (Six, Conant, Paul, & Paustian, 2002), and OC and N accumulations exhibit diverse patterns across various types of soils due to different mineralogical, textural, and microbial characteristics (Cai, Feng, Zhang, & Xu, 2016; Liang et al., 2009). Among total OC (TOC and OC of bulk soil), OC associated with sand particles (>53 μm) is a less stable fraction as it contains physically unprotected plant debris with faster turnover; by contrast, OC bound to silt and clay particles is considered as a major sink for C storage because it is relatively resistant to microbial mineralization (Ahrens, Braakhekke, Guggenberge, Schrumpf, & Reichstein, 2015; Canarini, Mariotte, Ingram, Merchant, & Dijkstra, 2018; Cotrufo, Wallenstein, Boot, Denef, & Paul, 2013; Feng, Plante, Aufdenkampe, & Six, 2014). Due

water

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Article

Effects of Ionic Components of Saline Water on Irrigated Sunflower Physiology

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Abstract: The characteristics of ions in saline water can be significantly different along the water salinity gradient. The physiologic processes of plants that are irrigated with this kind of water are remarkably influenced. Based on the field sampling data, the chemical components of irrigation water were studied, and their influence on sunflower nutrient uptake, water content, and dry weight were evaluated. The results demonstrated that irrigation water salinity was mainly controlled by Na, SO_4, Mg, and Cl concentrations and the ionic characteristics changed as soon as water becomes saline. The concentrations of Na, Ca, Mg, and N in sunflower leaves changed slightly with increasing irrigation salinity, whereas the concentration of leaf C decreased steadily. The ions in irrigation water had significantly different effects on leaf nutrient uptake. The Ca and Cl concentrations in irrigation water significantly influenced the Ca-related ionic exchange and C- and N-assimilation processes in sunflower leaves. The water content in the stem rose positively with irrigation salinity, whereas we observed little response in the leaves, fruits, and roots, although they were all mainly affected by the concentrations of Ca, Cl, Na, NO_3, and SO_4 in irrigation water. The biomass in leaves, stems, flower discs, and seeds all significantly reduced with irrigation salinity increase, and a loss of about 25% in stem biomass was detected. The concentrations of Na, Ca, Mg, K, Cl, and SO_4 in irrigation water influenced the dry weight of different organs. The results presented here demonstrate that the ionic effects of irrigation water on plant physiologic processes are complex, which is concerning in terms of improving plant salt tolerance and managing saline water resources.

Keywords: saline water; chemical component; plant nutrient; water content; dry weight

1. Introduction

The worldwide freshwater shortage and the need for agricultural irrigation have motivated farmers to explore new water resources while compromising water quality. Therefore, saline water irrigation has become a well-established practice in both industrialized and developing countries [1]. However, the types of saline water vary with region and location. The chemical composition of saline water differs throughout the world [2]. Even under the same salinity levels, different ionic components are usually found. As such, the chemical interactions between the active components (e.g., Na, Ca, Mg, Cl and SO_4) in saline water might change significantly, which affect the performance of plants that are irrigated. Thus, we need to understand the influence of the chemical composition of saline water on irrigated plant physiology, which may reveal the mechanism of salt tolerance in plant, and thus be useful in engineering plants that are more salt tolerant.

Numerous studies have examined the effects of salinity on various aspects of plant life. Alvarez and Sanchez-Blanco [3] discussed the effect of salinity on plant quality, water relationships,

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Changes in surface soil organic carbon in semiarid degraded Horqin Grassland of northeastern China between the 1980s and the 2010s

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ABSTRACT

Soil organic carbon (SOC) plays an important role in the global carbon cycle and in mitigating climate change. The Horqin Grassland is one of the largest grasslands in China and has undergone serious aeolian desertification in recent decades. We conducted the largest field inventory to date, with the highest density of soil sampling, and explored changes in SOC in the region over the 30-year gap between the 1980s and the 2010s. Our results indicated that the mean SOC density to a depth of 20 cm decreased from 2.58 to 2.21 kg C m^{-2}, while the total SOC storage decreased from 311.11 to 266.70 Tg C, at an average of 12.29 g C m^{-2} yr^{-1}. We ranked the SOC densities by ecosystem as woodland > grassland > cropland > sandy land. The decreased SOC storage in the Horqin Grassland can be ascribed to a combination of increasing temperature, decreasing precipitation, an expansion of the areas of extremely severely desertified land and cropland, and shrinkage of the grassland area. Our results provide an important updated regional baseline for quantifying how SOC storage will respond to future climate change and anthropogenic activities. Our results will also help policy makers determine how to achieve sustainable development of agriculture, forestry, and animal husbandry based on carbon sequestration.

1. Introduction

Soil is the largest reservoir of organic carbon in terrestrial ecosystems, as it holds about three times the amount stored in living vegetation (Lal, 2004a). It is therefore essential to understand changes in soil organic carbon (SOC) as well as its role in the global carbon cycle (Post and Kwon, 2000; Scharlemann et al., 2014). SOC accounts for approximately two-thirds of the carbon involved in active exchanges with the atmosphere in terrestrial ecosystems (Post et al., 1982). The amount of SOC represents the long-term net balance between photosynthesis and total respiration (Schlesinger, 1990). Many studies (Jobbágy and Jackson, 2000; Smith et al., 2008; Muñoz-Rojas et al., 2015; Valtera and Šamonil, 2018; Wang et al., 2018) have documented the link between SOC dynamics and the build-up of atmospheric carbon dioxide (CO_2), and the soil's potential to act as a carbon sink for mitigating climate change.

The SOC pool is highly dynamic, reactive, and sensitive to land use, climate change, and management. Deforestation, degradation of natural ecosystems, and conversion of natural ecosystems into cultivated fields and grazing land have generally decreased SOC (Guo and Gifford, 2002; Smith et al., 2016), whereas afforestation and reforestation, re-establishing grasslands, and implementing conservation tillage can sequester SOC (FAO, 2004; Cantarello et al., 2011; Deng and Shangguan, 2017; Lu et al., 2018). Climate change can significantly affect the SOC level through the ability of changes in temperature, rainfall patterns, and CO_2 concentrations to influence carbon inputs and outputs from soils (Cao and Woodward, 1998; Soleimani et al., 2017).

Lal (2004b) reported that depletion of the global SOC pool, primarily due to land misuse and soil mismanagement, has contributed 78 ± 12 Pg of C to the atmosphere since the industrial revolution, versus global potential SOC sequestration that could reach 0.9 ± 0.3 Pg C yr^{-1} if we adopted restorative land use practices and improved management practices. Kirschbaum (2000) created a model in which a decrease of just 10% in SOC storage would be equivalent to all the anthropogenic CO_2 emitted in the previous 30 years. Bellamy et al. (2005) and Yang et al. (2009) summarized numerous findings from small-scale laboratory incubations, field experiments, and modeling studies that suggested climate warming is likely to be inducing

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Promoting desert biocrust formation using aquatic cyanobacteria with the aid of MOF-based nanocomposite

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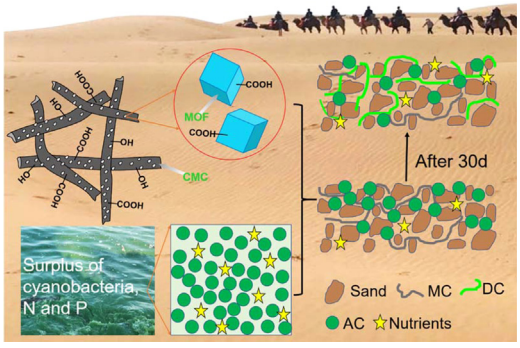
HIGHLIGHTS

- A nanocomposite (designated as MC) was fabricated based on MOF.
- MC possesses excellent retaining performance on water and nutrients.
- Cyanobacteria-containing water and MC promote biocrusts formation on sand surface.
- MC possesses a good biosafety.
- This technology can relieve desertification and eutrophication simultaneously.

GRAPHICAL ABSTRACT



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ABSTRACT

Desertification and eutrophication are two global environmental problems human beings face. Inoculating cyanobacteria to form biocrusts is considered an effective technology to inhibit desertification. The main limitation of biocrust formation is the lack of propagules and nutrients in deserts. A possible low cost source of propagules and nutrients is eutrophic water containing aquatic cyanobacteria (AC), nitrogen and phosphorus. In this study, we fabricated a network-structured nanocomposite (designated as MC) using a metal-organic framework (MOF) and carboxymethyl cellulose (CMC). MC, with a large specific surface area and numerous surface groups, had a high retention capacity for water and nutrients and good biosafety. The combination of AC-containing water (ACW) and MC could provide a suitable microenvironment in the soil, promote the growth of desert cyanobacteria (DC), formation of biocrusts and inhibition of desertification. This study provides a novel approach to simultaneously relieve desertification and eutrophication.

1. Introduction

Desertification, a global challenge facing human being in the environmental field, can result in dust storms, loss of biodiversity, low soil productivity, and economic losses (Reynolds et al., 2007; Xu et al., 2006). Biocrusts are estimated to cover 12% of Earth's terrestrial surface under natural conditions (Rodriguez-Caballero et al., 2018; Elbert et al., 2012) and can effectively prevent and repair desertification soil (Lan et al., 2013). Biocrusts are very complex photosynthetic assemblages formed by cyanobacteria, lichens, mosses and microorganisms in the top millimeters of soil, and are

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animals

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Article

Protective Effect of Resveratrol Improves Systemic Inflammation Responses in LPS-Injected Lambs

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Simple Summary: China's livestock industry has been transforming from traditional extensive systems to highly intensive systems. Highly intensive livestock production often causes immune stress to animals, which makes them more susceptible to infections. The aim of this study was to examine whether resveratrol alleviates inflammation in lambs. Results showed that resveratrol attenuated the LPS-evoked inflammatory responses in lambs by suppressing expression levels of inflammatory cytokines and blocking *NF-κB* and MAPK signaling pathways. Based on these studies, resveratrol has the potential to be a promising therapeutic reagent for multiple inflammatory illnesses caused by immune stress.

Abstract: Highly intensive livestock production often causes immune stress to animals, which makes them more susceptible to infections. The aim of this study was to examine whether resveratrol (Res) alleviates inflammation in lambs. In Experiment 1, 16 male lambs were injected with lipopolysaccharides (LPS) at an initial dose of 0.25, 1.25, and 2.5 μg/kg body weight (BW) for 9 days. Average daily gain and blood parameters were measured and clinical symptoms were recorded. In Experiment 2, 20 male lambs were injected intravenously with LPS (0 mg/kg) + Res (0 mg), LPS (2.5 μg /kg) + Res (0 mg, 82.5 mg, 165 mg, 330 mg), 4 h after LPS injection. Jugular blood was collected from each lamb to determine white blood cell (WBC) counts and the expression of inflammatory genes. In Experiment 1, all LPS-treated lambs showed clinical signs of sickness including rhinorrhea, lethargy, and shivering, and systemic inflammatory responses of increased inflammatory genes levels and cortisol concentration. The lambs had increased respiratory and heart rates and rectal temperature and decreased average daily gain and feed intake. In Experiment 2, resveratrol significantly reduced WBCs and the expression levels of several genes associated with inflammation response (*TLR4*, *NF-κB*, *c-jun*) and inhibited the signaling cascades of *NF-κB* and MAPKs by down-regulating the expression levels of inflammatory cytokines (*IL-1β*, *IL-4*, *IL-6*, *TNF-α*, *IFN-γ*) induced by LPS. Resveratrol attenuated the LPS-evoked inflammatory responses in lambs by suppressing expression levels of inflammatory cytokines, and blocking *NF-κB* and MAPK signaling pathways.

Keywords: resveratrol; lipopolysaccharide (LPS); inflammation responses; cytokines; lamb

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ORIGINAL ARTICLE

Differences in bacterial community structure between three types of biological soil crusts and soil below crusts from the Gurbantunggut Desert, China

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The scarcity of knowledge on differences in the microbial assemblage between biological soil crusts (BSCs) and soil below crusts (SBCs) limits our understanding of the contribution of different layers of topsoil to desert ecosystems. This study used Illumina MiSeq sequencing to determine whether differences in bacterial communities among different types of BSCs (algae, lichen and moss dominated) are greater than those between BSCs and their corresponding underlying soils (0–5 cm) in the Gurbantunggut Desert, China. Alpha and beta diversity of bacterial communities showed that richness and diversity were greater in SBCs than in BSCs, but the absolute bacterial abundance was larger in BSCs than in soils. Differences were mainly in the phyla *Cyanobacteria*, *Actinobacteria*, *Chloroflexi* and *Acidobacteria*. *Cyanobacteria* were concentrated in BSCs, especially in algae-dominated BSCs. The relative abundances of *Actinobacteria*, *Chloroflexi* and *Acidobacteria* in SBCs were more than twice those in BSCs, and they were also abundant in the lichen- and moss-dominant crusts. The number of sample-specific genera was larger in BSCs, but there were more shared genera among SBCs. These results, combined with the principal coordinate analysis and the predicted function profiles, showed that differences in microbial community structure and function in desert ecosystems were greatest between BSCs and the underlying soils, followed by differences among the three types of BSCs, and differences were smallest between the soils below different crusts. These differences might be closely related to the soil chemical properties, especially to pH and fertility. Our study indicated that microbial communities tended to converge in SBCs of different microhabitats.

Highlights

- We studied bacterial community composition in different types of BSCs and SBCs.
- Differences in bacterial community were greatest between BSCs and SBCs.
- BSC components contributed to small-scale microbial heterogeneity in SBCs.
- Surface soil bacterial communities were strongly stratified even at the centimetre scale from BSCs.

KEYWORDS

bacterial community composition, bacterial abundance, Illumina MiSeq sequencing, soil below crusts, biological soil crusts

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REGULAR ARTICLE

Long term experimental drought alters community plant trait variation, not trait means, across three semiarid grasslands

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Abstract

Background and aims Grasslands are expected to experience droughts of unprecedented magnitude and duration in this century. Plant traits can be useful for understanding community and ecosystem responses to climate extremes. Few studies, however, have investigated the response of community-scale traits to extreme drought on broad spatial/temporal scales, with even less research on the relative contribution of species turnover vs. intraspecific trait variation to such responses.

Methods We experimentally removed ~66% of growing season rainfall for three years across three semi-arid grasslands of northern China and tracked changes in community functional composition, defined as the community mean and variation of several leaf economic traits.

Results Community trait variations were more sensitive to drought than community trait means, which suggests this component of functional composition may be a better indicator of initial community drought responses than trait values themselves. The greatest change in trait variation was observed at the high aridity site and was driven largely by intraspecific trait variability. Apart from specific leaf area, trait variability increased with

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ORIGINAL RESEARCH

Community carbon and water exchange responses to warming and precipitation enhancement in sandy grassland along a restoration gradient

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Abstract

Temperature increasing and precipitation alteration are predicted to occur in arid and semiarid lands; however, the response mechanism of carbon and water exchange at community level is still unclear in semiarid sandy land. We investigated the responses of carbon and water exchanges to warming and precipitation enhancement along a sand dune restoration gradient: mobile sand dunes (MD), semifixed sand dunes (SFD), and fixed sand dunes (FD). The average net ecosystem productivity (NEP) and evapotranspiration (ET) between May and August increased by 98% and 59%, respectively, from MD to SFD, while they had no significant differences between FD and the other two habitats. Warming inhibited ecosystem NEP, ET, and water use efficiency (WUE) by 69%, 49% ($p < .001$), and 80%, respectively, in SFD, while it nearly had no significant effects in MD and FD. However, precipitation addition by 30% nearly had no significant effects on community NEP, ET, and WUE, except for warming treatment in FD. In general, precipitation addition of 30% may still not be enough to prevent drought stress for growth of plants, due to with low water holding capacity and high evaporation rates in sandy land. Temperature increase magnified drought stress as it increased evapotranspiration rates especially in summer. In addition, community NEP, ET, and WUE were usually influenced by interactions between habitats and temperature, as well as the interactions among habitats, temperature, and precipitation. Species differences in each habitat along the restoration gradient may alter climate sensitivity of sandy land. These results will support in understanding and the prediction of the impacts of warming and precipitation change in semiarid sandy grassland.

KEYWORDS

net ecosystem productivity, precipitation, sandy grassland, warming

ARID LAND RESEARCH AND MANAGEMENT
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Soil respiration dynamics in a semi-fixed sand dune under the pioneer shrub *Artemisia halodendron* Turcz. ex Bess. in the Horqin sandy land, northeastern China

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ABSTRACT

Soil respiration is a major pathway by which carbon dioxide (CO_2) fixed by terrestrial plants returns to the atmosphere. Studies of the dynamics of soil respiration in sandy land are rare and the contribution (R_c) of plant root respiration to the total soil respiration (R_t) is not well known. In this study, R_t in a semi-fixed dune planted with *Artemisia halodendron* was separated into autotrophic (root) respiration (R_a) and heterotrophic respiration (R_h) by the root-exclusion method. R_t and its two components were measured or calculated during 2013 on seven dates during the growing season when variation during the day was measured. Both R_a and R_h showed similar dynamics, with the maximum rates observed in July and with large daily variability observed on the earlier dates. R_c ranged from 39.3% to 53.1% during the growing season and exhibited a single peak in early August. Soil temperature at a depth of 20 cm was significantly correlated with soil respiration. R_a was more sensitive to soil temperature than R_h and the temperature sensitivity coefficients (Q_{10}) were 3.39, 2.52, and 2.79 for R_a, R_h, and R_t, respectively. In summary, *A. halodendron* roots contributed an average of 46% to the total soil respiration, although this contribution varied during the growing season.

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KEYWORDS
Artemisia halodendron; Horqin sandy land; root contribution; root respiration; seasonal variation; total soil respiration

Introduction

Artemisia halodendron is a typical sub-shrub in the Horqin Sandy Land and Hulun Buir grassland of eastern Inner Mongolia, China. It is well adapted to mobile and semi-mobile sand dunes, showing high tolerance against drought, wind erosion, and sand burial (Huang et al. 2011; Liu, Liu, and Guan 2008), and the species has a high ability

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Color versions of one or more of the figures in this article can be found online at www.tandfonline.com/uasr
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Gravel mulching effects on soil physicochemical properties and microbial community composition in the Loess Plateau, northwestern China

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ABSTRACT

Gravel mulch has been used as an agricultural water conservation measure for over three hundred years in China's semiarid regions. In this study, a 3-year gravel mulch experiment on slopes in the northwestern Loess Plateau was conducted to evaluate the impact that different sized gravel mulch and natural rainfall has on surface runoff, soil physicochemical properties and microbial communities. The following three treatments were investigated: small-sized gravel mulch (AG, 2–5 mm particle size), large-sized gravel mulch (BG, 40–60 mm particle size), and no gravel mulch as a control (CK). We found that gravel mulch could effectively control surface rainwater runoff, especially in the AG treatment. AG treated soil was typically oligotrophic compared to BG treated soil with higher soil carbon and nitrogen content.

PCR-amplified 16S rRNA genes and internal transcribed spacer (ITS) sequencing showed that soil bacterial and fungal communities in the AG treatment differed from the BG treatment or the CK treatment, and soil bacterial and fungal richness and bacterial diversity changed significantly after mulching. The relative abundance of Acidobacteria, Actinobacteria, Ascomycota and *Bacillus* significantly increased and the relative abundance of Proteobacteria and Bacteroidetes significantly decreased in the AG treatment compared to the CK treatment. Furthermore, the relative abundance of *Bacillus* was significantly increased in the AG treatment and was slightly increased (not significant) in the BG treatment compared to the control. Redundancy analysis (RDA) revealed that soil carbon and available nutrients were important driving factors for changes in microbial communities. Overall, the capacity of runoff production suppression and soil bacterial diversity and richness were higher in the AG treatment than the other treatments. Therefore, small-sized gravel mulching is recommended for arid and semiarid areas.

1. Introduction

The Loess Plateau region in northwestern China is characterized by an extremely fragile ecological environment and severe soil erosion between 4400 and 7600 t km^{-2} per year [1]. Soil erosion on the Loess Plateau is accompanied by a significant loss in soil nutrients, which destroys the overall soil microenvironment with adverse effects on soil quality [2]. Under such conditions, local residents have developed a unique farming method regionally referred to as “sand farmland,” which involves mulching farmland with gravel that is derived from fluvial deposits of the Yellow River and which is mainly composed of silica [3]. This technology is becoming popular in arid regions of China, as increasing numbers of Chinese farmers are recognizing the positive effects that gravel mulch provides in protecting farmland from soil erosion. By the late of 2016, 72,327 ha of gravel-sand mulched farmland fields were distributed in Gansu Province according to the “Gansu Rural Yearbook” (2017).

Gravel mulch can reduce evaporation and rainwater runoff, improve water-use efficiency, and provide a more suitable environment for plant growth [4–8]. In addition, mulch can be used to increase the average soil temperature [9]. In fact, there is a close relation between this temperature effect and the thickness of the mulch layer [6]. Furthermore, mulch can retain soil water, thereby increasing the water use efficiency and yield of crops [7]. It has been reported that a 7–8 cm thick mulch layer is most suitable for maintaining high crop yields [8].

Our previous research indicated that gravel mulch characteristics (i.e., thickness, particle size and coverage degree) greatly influence rain fall interception [10] and water retention (data not published). Our results also showed that the size of the gravel particles is of importance in reducing the surface runoff, which consequently should also reduce

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ARTICLE

Adaptive signals of flowering time pathways in wild barley from Israel over 28 generations

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Abstract

Flowering time is one of the most critical traits for plants' life cycles, which is influenced by various environment changes, such as global warming. Previous studies have suggested that to guarantee reproductive success, plants have shifted flowering times to adapt to global warming. Although many studies focused on the molecular mechanisms of early flowering, little was supported by the repeated sampling at different time points through the changing climate. To fully dissect the temporal and spatial evolutionary genetics of flowering time, we investigated nucleotide variation in ten flowering time candidate genes and nine reference genes for the same ten wild-barley populations sampled 28 years apart (1980–2008). The overall genetic differentiation was significantly greater in the descendant populations (2008) compared with the ancestral populations (1980); however, local adaptation tests failed to detect any single-nucleotide polymorphism (SNP)/indel under spatial-diversifying selection at either time point. By contrast, the WFABC (Wright–Fisher ABC-based approach) that detected 54 SNPs/indels was under strong selection during the past 28 generations. Moreover, all these 54 alleles were segregated in the ancestral populations, but fixed in the descendent populations. Among the top ten SNPs/indels, seven were located in genes of *FT1* (*FLOWERING TIME LOCUS T 1*), *CO1* (*CONSTANS-LIKE PROTEIN 1*), and *VRN-H2* (*VERNALIZATION-H2*), which have been documented to be associated with flowering time regulation in barley cultivars. This study might suggest that all ten populations have undergone parallel evolution over the past few decades in response to global warming, and even an overwhelming local adaptation and ecological differentiation.

Introduction

Overwhelming evidence supports the hypothesis that the climate has been changing rapidly since the early twentieth century (IPCC 2001; Jones and Osborn et al. 2001). Under different scenarios of greenhouse gas emission, the mean global temperature is predicted to increase by 1.8–4.0 °C by

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RESEARCH ARTICLE

WILEY

Initial lignin content as an indicator for predicting leaf litter decomposition and the mixed effects of two perennial gramineous plants in a desert steppe: A 5-year long-term study

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Abstract

Leaf is the main component of litter that often exists in mixed forms in nature. However, the mixed effects of leaf litter decomposition in desert ecosystems remain unclear. To reveal the mixed effects and the influence of litter quality on leaf litter decomposition in desert ecosystems, a 5-year long-term study was conducted to compare the observed and expected leaf litter mass loss in single-species and mixed (equal proportions and natural proportions) litters of two typical perennial gramineous plants (*Stipa klemenzii* and *Achnatherum splendens*) in a desert steppe in Northern China. The relationship between litter mass loss and litter qualities was also analysed. The results showed that (a) after 5 years of decomposition, the mass losses of mixed litter in natural proportions and *S. klemenzii* litter were significantly higher than those of mixed litter in equal proportions and *A. splendens* litter; (b) the mixed effects of two litters in different ratios varied with time, and the synergistic effect only appeared in the second year when an easily decomposed litter (*S. klemenzii*) was mixed with a slowly decomposing litter (*A. splendens*); and (c) litter mass loss was not correlated with the initial carbon or nitrogen content but was negatively correlated with the initial lignin content, and the initial lignin content also had a significant effect on litter mixed effects of these two perennial gramineous plant litters. These results can suggest that the initial lignin content is an indicator of predicting decomposition and mixed effects of litter with low nitrogen content.

KEYWORDS

antagonistic effects, litter quality, mixed litter, nonadditive effects, synergistic effects

1 | INTRODUCTION

Litter decomposition is not only an important biogeochemical cycle of ecosystems but also a key link to the material circle and energy flow within ecosystems, and it plays a decisive role in the physical and chemical properties of soil, soil fertility, and plant productivity (Kripal et al., 2016; Zhang, Schaefer, Chan, & Zhao, 2013). As the most important component of litter, leaf litter accounts for more than 60% of the total amount of litter, and its decomposition rate is faster than other parts of the litter due to its high nutrient content (Huysen, Harmon, Perakis, & Chen, 2013). Even small changes in leaf litter decomposition rates can significantly affect the balance of soil carbon, soil fertility, and land–atmosphere carbon exchange (Currie et al., 2010), which is of great significance for the maintenance of

Hao Qu and Chengchen Pan are co-first authors and contributed equally to the study.

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Research Article

Divergence and hybridization in the desert plant *Reaumuria soongarica*

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Abstract Speciation is widely accepted to be a complex and continuous process. Due to complicated evolutionary histories, desert plants are ideal model systems to understand the process of speciation along a continuum. Here, we elucidate the evolutionary history of *Reaumuria soongarica* (Pall.) Maxim., a typical desert plant that is wildly distributed across arid central Asia. Based on variation patterns present at nine nuclear loci in 325 individuals (representing 41 populations), we examined the demographic history, patterns of gene flow, and degree of ecological differentiation among wild *R. soongarica*. Our findings indicate that genetic divergence between the ancient western and eastern lineages of *R. soongarica* occurred approximately 0.714 Mya, probably due to the Kunlun–Yellow River tectonic movement and the Naynayxungla glaciation. Later, multiple hybridization events between the western and eastern lineages that took place between 0.287 and 0.543 Mya, and which might have been triggered by the asynchronous historical expansion of the western and eastern deserts, contributed to the formation of a hybrid northern lineage. Moreover, despite continuing gene flow into this population from its progenitors, the northern lineage maintained its genetic boundary by ecological differentiation. The northern lineage could be an incipient species, and provides an opportunity to study the continuous process of speciation. This study suggests that two opposite evolutionary forces, divergence and hybridization, coexisting in the continuous speciation of the desert plant *R. soongarica* in a short time. Moreover, we provide evidence that this continuous speciation process is affected by geological events, climatic change, and ecological differentiation.

Key words: arid central Asia, ecological speciation, glaciation, hybrid speciation, Quaternary, speciation continuum.

1 Introduction

Speciation is a continuous and complex process rather than an instantaneous event (Darwin, 1859; Mallet, 2008; Via, 2009), and reproductive isolation is a critical component of the speciation process, which allows one species to split into two or more derived species. However, before reproductive isolation is complete, species can occupy many positions along the speciation continuum (Coyne & Orr, 2004; Nosil et al., 2009; Baack et al., 2015). Geographic isolation and/or ecological differentiation can initiate genetic divergence, which can facilitate reproductive isolation (Mayr, 1963; Barraclough & Vogler, 2000; Coyne & Orr, 2004; Hendry, 2009). The level of reproductive isolation, from minor to complete isolation, can be enhanced by natural selection (Hendry et al., 2009). However, hybridization, a ubiquitous force opposing divergence, plays an important role in regulating the speciation process (Mallet, 2007). Moreover, more evidence of hybridization in plant speciation has been found than previously thought (Grant, 1981; Rieseberg et al., 1993; Abbott et al., 2013). Hybridization occurs when, due to incomplete reproductive isolation, differentiated lineages come into contact and produce crossbreed offspring (Lexer et al., 2003; Arnold, 2004; Rieseberg & Willis, 2007; Abbott et al., 2013). Divergence and hybridization act together to ensure that speciation is a continuous process that cannot be divided into distinct stages. Up to the present, many studies of speciation have supported a continuous model of speciation, and this interpretation is now widely accepted (Coyne & Orr,

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ORIGINAL RESEARCH

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Responses of annual herb plant community characteristics to increased precipitation and reduced wind velocity in semiarid sandy grassland

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Abstract

Changes in precipitation regimes and wind velocity tend to alter structure and composition of the annual herb plant community, with consequent effects on ecological functioning and biodiversity maintenance. We examined the effects of increased precipitation and reduced wind velocity on annual herb plant community characteristics via a manipulative experiment from the middle of April to middle of August, 2016. There was significant increment in species richness with increased precipitation from June to August, and there were interactive effects between increased precipitation and reduced wind velocity especially in June and the end of July. From June to August, increased precipitation, reduced wind velocity as well as their interaction stimulated sandy plant community development. There was considerable elevation in plant coverage with increased precipitation, and also there was an interactive effect of increased precipitation with 20% reduced wind velocity. However, reduced wind velocity caused more significant stimulation ($p < .01$) in plant height. Moreover, dominant plants, *Salsola collina*, *Bassia dasyphylla*, and *Setaria viridis*, contributed equally to the elevated community coverage with increased precipitation, whereas *S. collina* occupied a much larger proportion on the augment of community height compared with the other two species under the increased precipitation and reduced wind velocity. Elevated Shannon–Wiener index was detected with increased precipitation in June and July. Furthermore, increased precipitation and reduced wind velocity enhanced aboveground and belowground biomass, respectively. These species traits-in structuring and composing plant community were suggested to be conducive to deep understanding the plant functioning and dynamics under global changing precipitation regimes and atmospheric wind velocity scenarios.

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Storage, pattern and driving factors of soil organic carbon in an ecologically fragile zone of northern China

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Correlation

ABSTRACT

Knowledge of the spatial pattern of soil organic carbon (SOC) and its influencing factors is important for understanding the carbon cycle. We investigated the SOC density (*SOCD*) to a depth of 30 cm from ground surface at 644 sites in an agro-pastoral ecotone of northern China that covered 654,564 km^2. SOC storage to a depth of 30 cm was 2360 Tg, and *SOCD* averaged 3.78 $kg{\cdot}m^{-2}$ for the entire study area. *SOCD* to a depth of 20 cm and from 20 to 30 cm showed strong and moderate spatial dependence, with a nugget to sill ratio of 0.7% and 43.5%, respectively. Overall, *SOCD* increased from southwest to northeast, it was more strongly correlated with latitude than with longitude. Forest and sandy land had the highest and lowest *SOCD*, at 6.28 and 1.76 $kg{\cdot}m^{-2}$, respectively. The *SOCD* ($kg{\cdot}m^{-2}$) of grassland decreased with decreasing vegetation cover: high (4.42) > medium (3.62) > low (2.50). For the common soils in the study area, the highest mean *SOCD* was 9.31 $kg{\cdot}m^{-2}$ in Grey Forest Soils, versus 1.75 $kg{\cdot}m^{-2}$ in Brown Pedocals. In the study area, temperature appears to be the dominant factor that influences SOC, and *SOCD* decreased with increasing temperature. However, topographic factors (elevation, slope, and aspect) had a weaker effect on SOC. Our results provide a valuable baseline for future research on the long-term evolution of *SOCD*.

1. Introduction

Soil organic carbon (SOC) plays a crucial role in the global carbon cycle, as the SOC pool is 2.5 to 3 times the size of the vegetation and atmospheric carbon pools in the world's terrestrial ecosystems (Lal, 2004). Therefore, even a small change in SOC pools could have a large influence on the atmospheric carbon dioxide (CO_2) concentration, which in turn will affect global climate change (Were et al., 2015). In addition, SOC affects the physical, chemical, and biological properties of soils, and this in turn affects soil fertility and plant productivity (Maia et al., 2010). Hence, research on carbon cycling has aroused widespread scientific attention in recent years (Gelaw et al., 2014; Maia et al., 2010; Scharlemann et al., 2014; Tashi et al., 2016).

Precise estimates of SOC storage are essential to formulate effective policies for carbon management and climate change mitigation, and also improve the parameterization of carbon cycle models that are being used to simulate SOC on large scales (Scharlemann et al., 2014; Schrumpf et al., 2011). Research on SOC and its assessment have been conducted at regional (Chen et al., 2017; Gelaw et al., 2014; Li et al., 2018; Sheikh et al., 2009), national (Martin et al., 2014; Matsuura et al., 2012; Meersmans et al., 2015; Yang et al., 2007), and global (Post et al., 1982; Scharlemann et al., 2014; Tashi et al., 2016) scales. However, due to inconsistent methods and limited data, estimates of SOC for a given study area differ greatly. For example, the SOC storage of China's terrestrial ecosystem was estimated as ranging from 50 to 180 Pg (Yu et al., 2007), versus 62.1 to 99.3 Pg for the contiguous United States (Kern, 1994). Estimates of global SOC storage to a depth of 100 cm range from 504 to 3000 Pg (Scharlemann et al., 2014). This high degree of uncertainty makes it difficult to obtain detailed regional-level estimates of SOC storage. This requires in situ sampling through field investigation to obtain the most accurate possible estimates of SOC. However, soils are a non-uniform continuum, and the finite

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WILEY ECOLOGICAL RESEARCH

ORIGINAL ARTICLE

Dormancy and germination strategies of a desert winter annual *Echinops gmelini* Turcz. in a temperate desert of China

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Abstract

Echinops gmelini Turcz. is an annual Asteraceae species widely distributed in the desert habitats of northern China. However, little is known about how this species adapts to harsh desert habitats. In this study, *E. gmelini* germination behaviors were observed in a natural population at the southeastern edge of the Tengger Desert. In addition, the effects of temperature, light, hydration–dehydration (H–D) cycles and different storage conditions on seed germination were tested in the laboratory. *E. gmelini* behaves as a winter annual, and its seeds germinate during the summer and early autumn in the field. Fresh seeds have non-deep physiological dormancy (PD). A 15-day dry storage treatment under laboratory conditions was required to break PD. Non-dormant seeds can germinate rapidly and at a high rate in light at 30/20°C. Dry storage with seasonal temperature changes had little effect on seed germination and dormancy. However, under natural field conditions, greater and faster germination at a wide range of temperatures was observed after seeds were stored for 1–2 months, which allows seeds to germinate during short periods of moisture availability; seeds were induced into secondary dormancy after storage for 3 months which may prevent germination in autumn. Furthermore, seed germination was reduced and became faster after exposure to four or more H–D cycles. Our results suggest that precipitation is the key factor in determining *E. gmelini* seed germination time in natural habitats, and they provide information about the strategies that annual plants need to adapt to climatically unpredictable environments in temperate deserts.

KEYWORDS

dormancy, *Echinops gmelini* Turcz., germination, temperate desert, winter annual

1 | INTRODUCTION

Seed dormancy and germination are critical elements of the plant life cycle, and the responses of these processes to environmental conditions are crucial for successful recruitment (Commander, Golos, Miller, & Merritt, 2017). This is particularly true for annual plants, for which seeds provide the only link to future years. Many species have mechanisms that allow seeds to remain dormant to overcome climate constraints (Baskin & Baskin, 2000). This strategy likely allows for dispersal of the germination risk over time and ensures that some seeds germinate when the conditions are favorable for germination and seedling survival (Adondakis & Venable, 2004; Baskin & Baskin, 2000; Cohen, 1966; Venable, 2007). Thus, dormancy is crucial in the formation of soil seed banks, and long-lived seed banks maintained by annual desert plants are often regarded as evolutionary bet-hedging strategies against unpredictable environmental variations or harsh climatic regions (Gutiérrez & Meserve, 2003; Mott, 1974; Venable, 1985; Went, 1948). For instance, the available rainfall varies substantially among years in both amount and timing and acts as the primary limiting factor for seed germination in desert areas (Gutterman, 1993). The temperature is another environmental factor determining

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RESEARCH PAPER

Population dynamics of *Echinops gmelinii* Turcz. at different successional stages of biological soil crusts in a temperate desert in China

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ABSTRACT

- The effects of biological soil crusts (BSC) on vascular plant growth can be positive, neutral or negative, and little information is available on the impacts of different BSC successional stages on vascular plant population dynamics.
- We analysed seedling emergence, survival, plant growth and reproduction in response to different BSC successional stages (*i.e.* habitats: bare soil, cyanobacteria, lichen and moss crusts) in natural populations of *Echinops gmelinii* Turcz. in the Tengger Desert of northwest China. The winter annual *E. gmelinii* is a dominant pioneer herb after sand stabilisation.
- During the early stages of BSC succession, the studied populations of *E. gmelinii* were characterised by high density, plant growth and fecundity. As the BSC succession proceeded beyond moss crusts, the fecundity decreased sharply, which limited seedling recruitment. Differences in seedling survival among the successional stages were not evident, indicating that BSC have little effect on survival in arid desert regions. Moreover, *E. gmelinii* biomass allocation exhibited low plasticity, and only reproductive allocation was sensitive to the various habitats. Our results further suggest that the negative effects of BSC succession on population dynamics are primarily driven by increasing topsoil water-holding capacity and decreasing rain water infiltration into deeper soil.
- We conclude that BSC succession drives population dynamics of *E. gmelinii*, primarily *via* its effect on soil moisture. The primary cause for *E. gmelinii* population decline during the moss-dominated stage of BSC succession is decreased fecundity of individual plants, with declining seed mass possibly reducing the success of seedling establishment.

INTRODUCTION

Biological soil crusts (BSC) typically consist of a mixture of mosses, lichens, algae, cyanobacteria, bacteria, fungi and micro-fauna, and are a common and widespread feature of arid and semiarid landscapes worldwide (West 1990; Belnap 2003). BSC play significant roles in desert ecosystems, including stabilising the soil surface, providing fertility (Eldridge & Leys 2003; Li *et al.* 2004; Belnap *et al.* 2008; Zhang *et al.* 2009), altering soil moisture patterns by affecting rainfall infiltration, increasing topsoil water-holding capacity and altering evaporation (West 1990; Eldridge *et al.* 2000; Li *et al.* 2010; Kidron & Tal. 2012; Xiao *et al.* 2016). These activities may be especially important in regions where water is the main limiting factor for plant growth (Noy-Meir 1973; Zhuang *et al.* 2015). Furthermore, BSC perform vital ecosystem services that differ in function with different developmental and successional BSC (Lan *et al.* 2013). Compared with early successional cyanobacterial crusts, later successional lichen or moss crusts have higher topsoil nutrition and water-holding capacities, and water and wind erosion protection ability (Zhang *et al.* 2009; Li *et al.* 2010; Lan *et al.* 2013).

In arid and semiarid ecosystems, BSC potentially influence the establishment and growth of associated vascular plants, particularly annuals, because these crusts modify resource availability near the soil surface, where roots are concentrated (Defalco *et al.* 2001). Studies have revealed the interactions between BSC and vascular plants, and such studies have mainly focused on germination, survival and growth (Li *et al.* 2005; Godínez-Alvarez *et al.* 2011). In most cases, a negative effect on plant germination is detected (Zaady *et al.* 1997; Serpe *et al.* 2006; Su *et al.* 2006). Although BSC have been shown to facilitate plant growth by providing surface stability, water and nitrogen (Belnap 2002; Kidron 2014a), the effect of BSC on vascular plants can also be neutral or negative, depending on the plant species, stage of the population recruitment process and crust type (St Clair *et al.* 1984; Zaady *et al.* 1997; Belnap 2003; Godínez-Alvarez *et al.* 2011). Most relevant research has focused on the effects of one dominant BSC type, such as cyanobacteria-dominated (Prasse & Bornkamm, 2000), lichen-

Change of soil microbial community under long-term fertilization in a reclaimed sandy agricultural ecosystem

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ABSTRACT

The importance of soil microbial flora in agro-ecosystems is well known, but there is limited understanding of the effects of long-term fertilization on soil microbial community succession in different farming management practices. Here, we report the responses of soil microbial community structure, abundance and activity to chemical (CF) and organic fertilization (OF) treatments in a sandy agricultural system of wheat-maize rotation over a 17-year period. Illumina MiSeq sequencing showed that the microbial community diversity and richness showed no significant changes in bacteria but decreased in fungi under both CF and OF treatments. The dominant species showing significant differences between fertilization regimes were Actinobacteria, Acidobacteria and Ascomycota at the phylum level, as well as some unclassified genera of other phyla at the genus level. As expected, soil organic matter content, nutrient element concentrations and bacterial abundance were enhanced by both types of fertilization, especially in OF, but fungal abundance was inhibited by OF. Redundancy analysis revealed that soil enzyme activities were closely related to both bacterial and fungal communities, and the soil nutrient, texture and pH value together determined the community structures. Bacterial abundance might be the primary driver of crop yield, and soil enzyme activities may reflect crop yield. Our results suggest a relatively permanent response of soil microbial communities to the long-term fertilization regimes in a reclaimed sandy agro-ecosystem from a mobile dune, and indicate that the appropriate dosage of chemical fertilizers is beneficial to sandy soil sustainability.

Subjects Microbiology

Keywords Soil microbial communities, Long-term fertilization, Microbial abundance, Soil enzyme activity, Crop yield, Soil physicochemical properties

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INTRODUCTION

A growing global demand for agricultural crops is one of the main challenges in the 21st century. The pursuit of high productivity, long-term sustainability and optimal resource use efficiency without negative effects in the restricted land available for agricultural cultivation has led to the emergence of a variety of management practices (*Xin & Li, 2018*). Because of the low level of soil nutrients, the productivity of sandy land agro-ecological systems in arid areas is mainly dependent on intensive agricultural management. Generally, controlling

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Research article

Vegetation restoration drives the dynamics and distribution of nitrogen and phosphorous pools in a temperate desert soil-plant system

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ABSTRACT

The role vegetation restoration and succession play in regulating Nitrogen (N) and Phosphorous (P) pools remains unexplored and poorly understood. To examine the effects of vegetation restoration and succession from a shifting sand dune to restored vegetation at different ages (23, 33, 50, and 58 years) on the dynamics and distribution of N and P pools in a soil-plant system, a comprehensive field investigation was conducted and N(P) concentrations and densities of soil, shrubs (including leaves, new branches, aging branches, and roots), and grass (including aboveground, roots, and litter) at each site were analyzed and quantified. We found that total N (TN) and total P (TP) density for the plant-soil system, in live shrub biomass as well as soil TN (STN) density in subsoil (10–100 cm), decreased between 23 and 50 years, and then increased from 50 to 58 years. STN and soil TP (STP) densities in topsoil (0–10 cm), and N and P densities of herbage and dead shrubs, continued to increase with restoration. N and P were primarily stored in soils and accounted for 89.83%–92.06% and 99.33%–99.48% of the TN and TP pools, respectively. In the first 23 years, live shrubs made up the second largest N and P pools, however, herbage made up the second largest N and P pools after 23 years. The ratios of N and P in herbage to TN and TP density increased from 3.71% to 6.31%, and 0.33%–0.43%, gradually approaching the native site (6.39% and 0.46%). The ratios of N and P in live shrubs to TN and TP density in the soil-plant system decreased from 4.55% to 1.08% and from 0.33% to 0.13%. Our results indicated that the restored ecosystem was a N(P) source from 0 to 50 (0–23) years, and a N(P) sink from 50 to 58 (23–58) years, with strong potential for accumulating more N (147.18 g m^{-2}) and P (102.67 g m^{-2}) to reach the natural site levels. These results suggest that vegetation restoration and succession may profoundly alter N and P geochemical cycles through N(P) redistribution in a temperate desert plant-soil system. Proper N and P addition at the initial stage of vegetation restoration may promote the recovery of desertified land.

1. Introduction

Nitrogen (N) and phosphorus (P) are two of the most important nutrients for all living organisms. They are key components of amino and nucleic acids and cannot be replaced in most biological functions (Marschner and Rengel, 2007). The alteration of these two elements has the potential to profoundly affect ecosystem structure, function, and key ecological processes, such as plant growth, community structure, species diversity, net primary productivity, and global carbon cycles (Vitousek and Howarth, 1991; Gruber and Galloway, 2008; Xia and Wan, 2008; Yu et al., 2010; Vitousek et al., 2010). N and P are limiting nutrients in many terrestrial ecosystems, especially deserts (Crawford and Gosz, 1982; Schlesinger and Raikes, 1996; Elser et al., 2007; Lebauer and Treseder, 2008). Hence, their dynamics are considered to be important factors in the assessment of the biological and biogeochemical states of terrestrial ecosystems.

Nutrients are always cycling among various pools in an ecosystem. Desert ecosystems cover approximately 20% of the earth's land surface (Whitford, 2002), and the most important nutrient pools include soil, live shrubs, dead shrubs, live grass, and litter. Identifying and quantifying the dynamics of all pools in a soil-plant system can provide insights into geochemical and biological processes and play an important role in desert ecosystem management (Delgado-Baquerizo et al., 2013). Considering the high spatial heterogeneity of nutrients in arid regions and a lack of long-term experimental conditions without external interference, there may be greater uncertainty about the estimation of N and P in dryland ecosystems (Hartley et al., 2007). There have been extensive studies on N and P content, pools, inputs, mineralization, and soil loss (Feng et al., 2016), but few on the dynamics of N and P pools in soil-plant systems. To reduce this uncertainty, a more accurate

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Impacts of precipitation, warming and nitrogen deposition on methane uptake in a temperate desert

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Abstract Desert soils are a significant global sink for methane (CH_4). However, it remains unclear how CH_4 uptake in temperate deserts could respond to elevated precipitation, nitrogen (N) deposition and warming. An in situ field experiment was conducted to investigate these effects on CH_4 uptake in the Gurbantunggut Desert, northwest China, from September 2014 to August 2017. This desert was a weak sink for CH_4 (0.83 kg C ha^{-1} $year^{-1}$) over this period, with the non-growing season (November–March) accounting for 30.5% of the annual CH_4 uptake. Pulse CH_4 uptake was found to result from increased water addition (by 30% or 60 mm $year^{-1}$) and low N deposition (30 kg N ha^{-1} $year^{-1}$) which enhanced annual CH_4 uptake by 62.3 and 52.6%, respectively. However, no significant impact of high N deposition (60 kg N ha^{-1} $year^{-1}$) was found. Warming in open topped chambers (OTCs) had a variable effect on CH_4 uptake, which mainly depended on variation in soil moisture. The response in CH_4 uptake to the interaction between water and N addition was less than that for the individual factors, except under conditions of warming. In addition, CH_4 uptake was significantly positively correlated to water-filled pore space (WFPS), differing from observations in forest and grassland ecosystems. Structural equation

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Fluxes of N_2O, CH_4 and soil respiration as affected by water and nitrogen addition in a temperate desert

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ABSTRACT

An experiment was conducted to investigate the effect of precipitation and N deposition on N_2O and CH_4 fluxes and soil respiration (R_s) in the Gurbantunggut Desert from September 2014 to August 2015. The desert was a weak sink for CH_4 (-0.92 kg C ha^{-1} yr^{-1}) and a small source of N_2O ($+0.13$ kg N ha^{-1} yr^{-1}) and the annual rate of R_s was 874 kg C ha^{-1}. Our work confirmed a relatively strong sink for CH_4 in desert soils. Significant impacts on N_2O, CH_4 fluxes and R_s were found by increasing precipitation, with pulses of CH_4 uptake and R_s accounting for 79.1% and 33.2% of annual CH_4 uptake and R_s, respectively. N_2O and CH_4 fluxes were significantly enhanced by 7.8–109.6% by N addition, but it had no significant effect on R_s. Statistical significant interactions of precipitation and N addition on N_2O and CH_4 fluxes were found, and on R_s was lower than any single factor. Our results indicate that the Gurbantunggut Desert is a weak sink for CH_4 and a small source of N_2O, and is sensitive to elevated precipitation and N deposition.

Desert soils, as a net sink of greenhouse gases (GHGs) (Zhuang et al., 2013), are profoundly affected by precipitation patterns and nitrogen (N) deposition (Huang et al., 2015). However, the impacts of precipitation and N deposition on N_2O, CH_4 and soil respiration (R_s) are uncertain largely in desert soils. Previous studies (Zhang et al., 2008; Huang et al., 2015) investigating precipitation and N addition impacts on GHGs have primarily focused on the effect of single factor in grassland and forest, while the interaction effects in desert soils are very scarce.

Temperate desert, covering approximately one third of the global land area, is dynamically sensitive to precipitation and N deposition (Li et al., 2015). Climate change in Northwest China is for an increase in precipitation of 30%, with an increases of 3–5 mm yr^{-1} since 1979 (Li et al., 2015), and N deposition has increased significantly since 1980 to total deposition of 35.2 kg N ha^{-1} yr^{-1} (Song, 2015). These changes are important for soil biological processes because of the extreme limits of soil N and water in such deserts (Huang et al., 2015). However, information on the responses of N_2O, CH_4 fluxes and R_s to precipitation and N deposition in this ecosystem is scarce and merits research.

We therefore conducted an experiment from September 2014 to August 2015 in the Gurbantunggut Desert (44°26′–43°65′N, 84°31′–90°00′E). Weather and soil conditions are shown in Fig. 1(a, b). N addition rates were 0 (N0), 30 (N1) and 60 (N2) kg N ha^{-1} yr^{-1}. Precipitation was 'natural' (W0) and 'natural' plus 60 mm yr^{-1} (equivalent to 30% of annual precipitation) (W1). There were six treatments: W0 N0 (the control), W0 N1, W0 N2, W1 N0, W1 N1 and W1 N2. Four plots were established for each treatment, each plot 10 m × 10 m with a 5 m-wide buffer zone; a total of 24 plots. The enhanced precipitation was sprayed onto the plots as an extra 10% (i.e. 20 mm) in Autumn (September), Spring (April), and Summer (July) in four doses of 5 mm per week in September, April and July using a petrol-driven, single-nozzle spray. Nitrogen was applied as NH_4NO_3 directly (in W0 N1 and W0 N2) or just after the extra precipitation (in W1 N1, W1 N2) in all treatments.

N_2O, CH_4 fluxes and R_s were measured using static chambers in all 24 plots. Gas samples were collected from the headspace of each static chamber at 0, 10, 20 and 30 min after closing the chamber between 10:00 and 12:00 (GMT + 8). Gas samples were collected once or twice a week. Samples were measured using a gas chromatograph (GC; Agilent 7890A, Agilent Technologies, Santa Clara, CA). Fluxes were calculated according to Chen et al. (2013). Effects of precipitation and N deposition on R_s, N_2O and CH_4 fluxes were analyzed by two-way

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Response of plant functional traits of *Leymus chinensis* to extreme drought in Inner Mongolia grasslands

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Abstract Understanding the effects of climate change, in particular, climate extremes on plant functional traits can provide a mechanistic basis for predicting how plant communities may be altered in the future. Here, we focused on a dominant species in Inner-Mongolia typical temperate steppe, *Leymus chinensis* (Trin.) Tzvei, to examine the responses of plant functional traits to experimentally imposed extreme drought at three sites along an aridity gradient. When comparing the driest (high aridity) to the wettest sites (low aridity), plant height, leaf dry matter content and $\delta^{13}C$ (water use efficiency) were increased at the intermediate and low aridity sites, whereas specific leaf area and leaf nitrogen content were reduced at the high-aridity site. When extreme drought ($\sim$ 66% reduction in the growing season precipitation) was experimentally imposed at all sites, plant height decreased and $\delta^{13}C$ of *L. chinensis* increased at the intermediate and low aridity sites. The extreme drought of 66% precipitation reduction also increased leaf dry matter content in high- and low-aridity sites. Compared to the control (ambient precipitation), extreme drought increased the strength of the positive association between plant height and $\delta^{13}C$, as well as the negative associations of specific leaf area with plant height and leaf dry matter content. Thus, extreme drought altered key functional traits of

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Plant functional trait response to habitat change and grazing in a semiarid grassland: unravelling species turnover and intraspecific variation effects

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intraspecific variation
grassland habitat change
grazing

ABSTRACT

Plant community assembly is determined by species turnover and intraspecific trait variations (ITV) controlled by environment changes. However, little is known about how species turnover and ITV affect the responses of plant community to habitat changes and grazing disturbance in semiarid grasslands. Here, we measured five functional plant traits in four typical grassland habitats under fencing and grazing disturbance in a semiarid grassland, Northern China, including plant height, specific leaf area (SLA), leaf dry matter content (LDMC), leaf nitrogen content (LNC) and leaf carbon: nitrogen ratio (C:N). We also calculated the community weighted means (CWM) and non-weighted means (CM) of all traits and examined the relative roles of species turnover and ITV in affecting the responses of community traits to habitat changes and grazing disturbance. Our results showed that the CWM and CM values of five functional traits differed with grassland habitat changes. As compared to other grasslands, the *Stipa* steppe had the higher plant height, the sandy grassland had the higher SLA and lower LDMC, and the meadow had the lower LNC and higher C:N. Grazing decreased plant height across grassland habitats, as well as decreased SLA and increased LDMC in meadow. The responses of all community-level traits to habitat changes were driven by species turnover, while the responses of phenotypic traits (height, SLA and LDMC) to grazing were determined by both species turnover and ITV. So, we argue that ITV should be considered when understanding plant community assembly under grazing disturbance regime in semiarid grasslands.

INTRODUCTION

Plant community assembly are mainly determined by environmental changes (Cochard *et al.* 2017). Numerous studies have shown that the trait-based methods can provide the new insight to understand the mechanism of how plant community structure and composition respond to environmental changes (Stubbs and Wilson 2004, Webb *et al.* 2010). The environment filtering hypothesis suggests that plant community compositions are caused by the species turnover and intraspecific competitions induced by environment changes (Weiher and Keddy 1995). So, the variations of community-level traits in response to environmental changes are mainly driven by the species turnover and

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Effect of manipulated precipitation during the growing season on soil respiration in the desert-grasslands in Inner Mongolia, China

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ABSTRACT

The dynamics of soil respiration are crucial in understanding carbon cycling and its feedback to climate change. However, little information exists regarding the response of soil respiration to precipitation variation. To examine the response of soil respiration to precipitation variation through biogeochemical regulation, a manipulative field experiment was conducted along a precipitation gradient (−60%, −40%, −20%, CK = natural precipitation, +20%, +40% and +60%) in a native desert grassland ecosystem in Inner Mongolia. Plant biomass, total soil carbon and soil respiration were determined across the precipitation treatments during the growing season (from late May to early October) in 2017. Above-ground biomass tended to increase but total soil carbon varied little with an increase in precipitation. Soil respiration exhibited a unimodal curve diurnally in all precipitation treatments, peaking between 09:00 and 13:00, but showed irregular patterns seasonally. Both the daily and seasonal average soil respirations increased with an increase in precipitation (diurnal Rs ranged from 0.37 μmol $m^{-2} s^{-1}$ to 0.75 μmol $m^{-2} s^{-1}$; seasonal Rs ranged from 0.43 μmol $m^{-2} s^{-1}$ to 0.66 μmol $m^{-2} s^{-1}$). Soil respiration was correlated positively with precipitation-induced change in above-ground plant biomass, but was correlated negatively with precipitation-induced change in total soil carbon. It was concluded that carbon released from the soil increases with an increase in precipitation.

1. Introduction

Soil respiration (Rs) represents CO_2 released from the soil to the atmosphere and plays a key role in regulating the responses of ecosystem and global carbon cycling to natural and anthropogenic perturbations. Rs comprises the second largest terrestrial ecosystem carbon flux, with a range of 68 to 98 Pg C yr^{-1} (Raich and Schlesinger, 1992; IPCC, 2001; Xu and Wan, 2008; Bondlamberty and Thomson, 2010; Zhao et al., 2017). This carbon flux originates from the soil carbon pool, which is the largest carbon reservoir in terrestrial ecosystems (Batjes, 2014), containing at least twice as much carbon as in the atmosphere (Tarnocai et al., 2009).

Rs has been used as an indicator of metabolic activity, persistence and decomposition of plant biomass input in soil, and the transformation of soil carbon to atmospheric CO_2 (Mukhopadhyay and Maiti, 2014; Guo et al., 2017). Consequently, Rs plays a crucial role in regulating atmospheric CO_2 concentration, climatic dynamics (Luo and Zhou, 2006) and the soil carbon pool in terrestrial ecosystems. The rate of Rs is affected largely by major factors of global climate change such as increased N deposition, elevated CO_2 and precipitation variation (Cardon et al., 2001; Deng et al., 2010; Harper et al., 2005; Zhou et al., 2014). Small changes in soil carbon storage can have considerable effects on the atmospheric CO_2 concentration and produce large feedbacks to the global carbon cycle (Black et al., 2017). Therefore, the pattern of diurnal and seasonal Rs, as well as factors that affect the patterns, are important in understanding the long-term relationship

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Water-soil-air-plant-human nexus: Modeling and observing complex land-surface systems at river basin scale

Impacts of Precipitation on Ecosystem Carbon Fluxes in Desert-Grasslands in Inner Mongolia, China

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Abstract The frequency and amount of precipitation exert profound impacts on plants and the soil subsystem in dryland ecosystems. To quantitatively assess the effect of precipitation on ecosystem carbon fluxes during the growing season, a field experiment was carried out in a native desert-grassland ecosystem in Inner Mongolia to determine the dynamics of ecosystem carbon fluxes along a precipitation gradient (−60%, −40%, −20%, CK, +20%, +40%, and +60%; CK is natural precipitation). The net ecosystem productivity (NEP) and gross ecosystem productivity (GEP) exhibited a single peak, whereas ecosystem respiration (Reco) exhibited a bimodal peak across all precipitation treatments. Reco reached its highest value at the beginning of August, whereas NEP and GEP reached their highest values at the end of August. Mean values of carbon fluxes increased with an increase in precipitation (from NEP: 0.06 μmol · m^{-2} · s^{-1}, Reco: 0.37 μmol · m^{-2} · s^{-1}, GEP: 0.42 μmol · m^{-2} · s^{-1} at −60% to NEP: 1.25 μmol · m^{-2} · s^{-1}, Reco: 0.93 μmol · m^{-2} · s^{-1}, and GEP: 2.18 μmol · m^{-2} · s^{-1} at +60%). Increased precipitation stimulated GEP more so than Reco during the growing season, resulting in an enhanced NEP, and decreased precipitation reduced GEP more so than Reco, leading to a reduced NEP. We concluded that the carbon sequestration capacity was enhanced by increased precipitation in the desert-grassland ecosystem.

Key Points:
- Ecosystem carbon flux increased with precipitation increase
- Carbon sequestration capacity was enhanced by increased precipitation in the desert-grassland ecosystem

Supporting Information:
- Figure S1
- Table S1

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1. Introduction

Terrestrial ecosystems absorb CO_2 from the atmosphere through plant photosynthesis (gross ecosystem productivity, GEP) and release CO_2 into the atmosphere by ecosystem respiration (Reco; Dijk & Dolman, 2004; Lasslop et al., 2010; Law et al., 2002; Yu et al., 2013). Net ecosystem productivity (NEP) represents the balance between GEP and Reco (Oberbauer et al., 2007; Xia et al., 2009), which is an indicator of the carbon sink or source in terrestrial ecosystems. Positive and negative NEP values denote carbon uptake from the ambient environment and release to the atmosphere by the ecosystem, respectively (Li et al., 2017).

The role of the terrestrial ecosystem in regulating carbon exchange between the atmosphere and the biosphere has long been a subject of great debate (Bonal et al., 2008). Photosynthesis and respiration are sensitive to temperature change and water regime (Woodwell et al., 1983). As ecosystem carbon release is enhanced more than carbon uptake with an elevation in air temperature (Illeris et al., 2004), there is a decrease in NEP with climate warming and drought. In addition, water availability mediates the responses of carbon fluxes in arid and semiarid grasslands in northern China (Niu et al., 2008). In a 9-year study in semiarid grasslands, it was reported that GEP increased more than Reco with an increase in precipitation during the growing seasons, leading to an enhanced NEP (Li et al., 2017).

Most aspects of terrestrial ecosystem structure, including species diversity, and of function, including biomass and carbon fluxes, are vulnerable to a higher frequency of extreme precipitation. Among terrestrial ecosystems, grasslands are the most responsive to precipitation variation, and the greatest responses occur in more arid regions (Knapp et al., 2002). Carbon fluxes in desert-grasslands are sensitive to precipitation change because water availability determines plant growth and carbon uptake and release (Knapp et al., 2002; Niu et al., 2008; Weltzin et al., 2003). There are many studies on carbon fluxes in alpine meadows (Peng et al., 2014), permafrost regions (T. Zhang et al., 2017), temperate peatlands (Aslan-Sungur et al., 2016), and temperate steppes (Xia et al., 2009); however, responses of GEP, ecosystem respiration (Reco),

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Driving Factors That Reduce Soil Carbon, Sugar, and Microbial Biomass in Degraded Alpine Grasslands☆

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ABSTRACT

Soil carbon and sugars play key roles in carbon (C) cycling in grassland ecosystems. However, little is known about their changes in quantity and composition in degraded alpine meadows in the Tibetan plateau. We compared vegetation C density, soil organic carbon (SOC) density, and soil sugars in nondegraded (ND), degraded (DA; following artificial restoration), and extremely degraded (ED) grasslands and analyzed the relation among these parameters by redundancy analysis (RDA) and structural equation models (SEMs). Belowground biomass, soil microbial biomass C, soil microbial biomass nitrogen (N), belowground biomass C density, SOC density, and soil sugars were lower in DA and ED grasslands than in ND grasslands. In addition, the ratio of belowground biomass to aboveground biomass (BAR) decreased with an increase in degradation. The ratio of belowground biomass to aboveground biomass was identified as the main indirect driving force of ecosystem C density by affecting total vegetation C and SOC densities. Soil dissolved organic carbon (DOC), microbial biomass carbon (SMBC), neutral sugars (NS), and total nitrogen (TN) were identified as main direct driving forces. The ratio of belowground biomass to aboveground biomass altered DOC, SMBC, NS, and TN and, consequently, was the primary driving force for the alpine meadows' ecosystem C density. It was concluded that land management in alpine meadows should include practices that maintain a relatively high BAR in order to curb degradation and increase ecosystem C density.

Introduction

Grasslands, one of the most widespread vegetation types worldwide, are an important part of the terrestrial ecosystem carbon (C) cycle, accounting for approximately 35% of the total terrestrial C (Scurlock and Hall, 1998; Tian et al., 2016). Soil C and nitrogen (N) contents, as well as their changes, reflect soil quality and ecosystem productivity and influence C and N cycling and storage (Wen et al., 2013).

Soil carbohydrates, including neutral sugars (NS), amino sugars (AS), sugar alcohols, and sugar acids, are the most abundant organic compounds in the biosphere and the most important C and energy sources for soil microorganisms (Zhang et al., 2007; Gunina and Kuzyakov, 2015). Neutral sugars are the major components in dissolved total saccharides and form the basic units of plant cells, whereas amino sugars are associated with structural polysaccharides or glycolipids. It has been suggested that amino sugars can be used as biomarkers for organic matter sources (Glaser et al., 2004).

The Tibetan plateau, with an average elevation of > 4 000 m, is regarded as the world's "third pole" and the headwater region of Asia. Alpine meadows constitute 46% of the vegetation on the Tibetan plateau (Xie et al., 2003; Shang et al., 2016) and are used principally for raising yaks and Tibetan sheep (Harris, 2010). The alpine grasslands have a huge capacity for C storage, accounting for approximately 49% of all

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Relative contribution of biotic and abiotic factors to stemflow production and funneling efficiency: A long-term field study on a xerophytic shrub species in Tengger Desert of northern China

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ABSTRACT

Stemflow production has been reported to be influenced by a suite of biotic and abiotic factors. Nevertheless, relative contributions of biotic and abiotic factors to stemflow production and funneling efficiency were largely unclear due to complex interactions among those factors. In this study, stemflow of nine xerophytic shrubs of *Caragana korshinskii* were measured in nearly nine growing seasons from 2010 to 2018 within a desert area of northern China, accompanying with observing on six biotic variables (shrub morphological attributes) and ten abiotic variables (meteorological conditions). We performed boosted regression trees (BRT) model to evaluate the relative contribution (θ) of each biotic and abiotic variable to stemflow volume (SF_v), stemflow percentage (SF_p), and funneling ratio (FR), associating with partial dependence plots (PDPs) to visualize the effects of individual explanatory variables on SF_v, SF_p, and FR, respectively. Generally, we observed that larger shrubs generated more SF_v, while had lower SF_p and FR. BRT analysis demonstrated that biotic variables outweighed abiotic variables by 1.5-fold as to their contribution to SF_v, whereas abiotic variables prevailed for SF_p and FR, respectively. Differences in θ between variables for SF_v (CV = 146%) were much pronounced than for SF_p (CV = 57%) and FR (CV = 26%), with the foremost three influential variables for SF_v ranking in descending orders of θ by rainfall amount (33.2%), basal area (20.9%), projected canopy area (15.1%), and that for SF_p by projected canopy area (13.2%), rainfall amount (13.0%), and air temperature (11.1%), and that for FR by antecedent dry period (9.1%), rainfall amount (8.4%), and wind speed (8.3%). The quantitative and mechanistic explanations regarding the effects of biotic and abiotic variables on three stemflow parameters from the present study are expected to be applicable to other shrub species within arid and semi-arid ecosystems.

1. Introduction

Stemflow represents a comparatively small fraction of incident precipitation (mostly < 10%) funneling down the trunks/stems (Magliano et al., 2019a; Van Stan and Gordon, 2018) in comparison to that part of intercepted rainfall loss to evaporation (13 − 22%) as interception loss (Miralles et al., 2010) and that part of rainfall reaching the under-canopy soil as throughfall by penetrating and/or dripping from vegetative canopies (approximately four-fifths) (Levia and Frost, 2006). Nonetheless, the eco-hydrological and biogeochemical importance of stemflow is increasingly acknowledged and a dramatic increase of stemflow studies can be found in recent years (e.g., Johnson and Lehmann, 2006; Levia and Frost, 2003; Levia and Germer, 2015). Stemflow has been documented to be closely related to a suite of eco-hydrological processes, including spatial distribution pattern of soil moisture (Liang et al., 2015; Schwarzel et al., 2012), surface runoff (Bui and Box, 1992; Cattan et al., 2007), soil erosion (Herwitz, 1988; Keen et al., 2010), groundwater recharge and perched water development (Germer, 2013; Taniguchi et al., 1996), the distribution of understory vegetation and epiphytes (Van Stan and Pypker, 2015), and a potential streamflow generation process (Herwitz, 1986). Stemflow also serves as an vector for the transport of inorganic nutrient ions (Van Stan et al., 2017; Whitford et al., 1997; Zhang et al., 2016), dissolved organic matter (Stubbins et al., 2017; Van Stan et al., 2017), small metazoans (Ptatscheck et al., 2018), and bacterial fluxes from the tree surfaces/phyllosphere down to the pedosphere (Bittar et al., 2018). In water-limited areas, the highly localized nutrient-enriched stemflow may create islands of soil moisture and nutrients by infiltrating into deep soil layers through preferential pathways such as roots, thereby playing a crucial role in sustaining the

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Alteration in isotopic composition of gross rainfall as it is being partitioned into throughfall and stemflow by xerophytic shrub canopies within water-limited arid desert ecosystems

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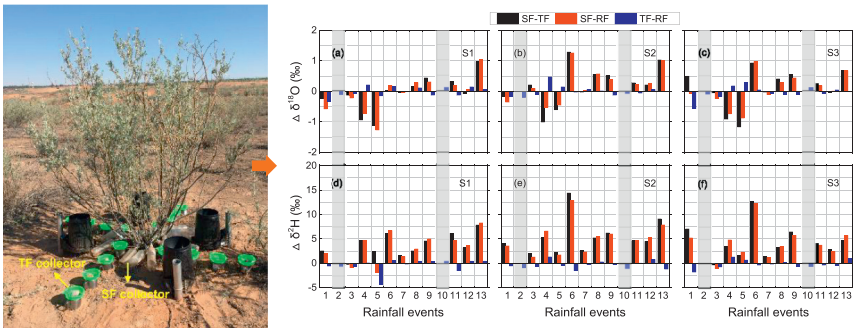
HIGHLIGHTS

- We found a general isotopic enrichment in stemflow than in gross rainfall.
- We found a general isotopic depletion in throughfall than in gross rainfall.
- We detected the pronounced "amount effect".
- Mechanisms affecting alteration in isotopic composition were discussed.
- Factors reflecting evaporative demand were well related to isotopic composition.

GRAPHICAL ABSTRACT



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ABSTRACT

Isotopic composition of gross rainfall has been extensively used as a conservative tracer to track water movement and other hydrological processes in vegetated ecosystems. Recent studies from forest ecosystems, however, demonstrated that vegetation canopies can alter the isotopic composition of rainwater during rainfall partitioning into throughfall and stemflow, likely leading to errors and biases in aforementioned studies. No known studies, to date, had investigated this topic in shrub-dominated arid and semi-arid ecosystems where water is typically the driving factor in ecological, hydrological and biogeochemical processes. In this study, event-based gross rainfall, the throughfall and stemflow induced by shrubs of *Caragana korshinskii* were measured and samples were collected within a water-limited arid desert ecosystem of northern China, and their water stable isotopes (^{18}O and ^{2}H) were also analyzed in the laboratory. We mainly aimed to investigate whether there is an isotopic enrichment or depletion in stemflow and throughfall in comparison to gross rainfall, and to evaluate the possible underlying mechanisms. Our results indicated an enrichment of both isotopes in stemflow, while a general more depletion in throughfall than in gross rainfall, which is presumably affected by a combinative effects of canopy evaporation, isotopic exchange, and selective canopy storage. Deuterium excess of stemflow were found to be significantly higher ($P < 0.05$) than that of gross rainfall and throughfall. Moreover, we detected the pronounced "amount effect", with a significant ($P < 0.05$) negative relationship between isotopic composition and the amount of gross rainfall, throughfall, and stemflow, respectively. Our study is expected to contribute to an improved understanding of physical processes and water routing in shrub canopies within vast arid desert ecosystems.

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A study of viral coat protein accumulation in lily chloroplasts from mixed virus infections of *Lily mottle virus* and *Cucumber mosaic virus*

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Two viruses that frequently occur in many *Lilium* species are *Lily mottle virus* (LMoV) and *Cucumber mosaic virus* (CMV), which usually co-infect lilies causing severe disease symptoms. Recent reports have revealed that the viral coat protein (CP) affects chloroplast ultrastructure and symptom development. This study used western blot analysis to confirm that in leaves infected by mixed virus infections of LMoV and CMV, CPs of both viruses were accumulated in lily chloroplasts. Immunogold labelling further demonstrated that both the LMoV CP and CMV CP were localized in the stroma and the thylakoid membranes of the chloroplasts. In addition, it was found that CPs of both viruses were rapidly transported into isolated, intact chloroplasts (*in vitro*), and their transport efficiencies were positively related to CP concentrations. The lowest transmembrane concentration of CMV CP decreased from 38 μg mL^{-1} recorded in the single CMV CP import system to 10 μg mL^{-1} in the mixed import system of LMoV CP and CMV CP. CPs of both viruses exhibited species selection in their transmembrane transport into chloroplasts. This is the first report that the CPs from two viruses (LMoV and CMV) are simultaneously present in lily chloroplasts. Accumulation of high levels of LMoV CP and CMV CP inside the chloroplast appears to contribute to a synergistic interaction inducing the development of mosaic symptoms.

Keywords: chloroplast, coat protein, *Cucumber mosaic virus*, *Lilium* spp., *Lily mottle virus*, mixed virus infections

Introduction

Lily (*Lilium* spp.) is an important economic crop in the floricultural industry. Additional value is obtained from growing *Lilium davidii* var. *unicolor* bulbs, which are edible and have medicinal properties. Almost all lilies are propagated vegetatively, and virus-infected bulbs used for forcing may propagate diseases from one generation to the next. Viruses cause quantitative and qualitative yield reduction of lily worldwide. Two frequently occurring viruses in many *Lilium* species are *Lily mottle virus* (LMoV; genus *Potyvirus*, family *Potyviridae*) and *Cucumber mosaic virus* (CMV; genus *Cucumovirus*, family *Bromoviridae*). Generally, lilies infected with LMoV exhibit symptoms of leaf mottle, leaf mosaic, reddish-brown necrotic spots, vein clearing, chlorosis and yellow streaking, leaf curling and narrowing (Zhang *et al.*, 2016). Leaves infected with CMV initially display chlorotic, or yellow spotting, interveinal striping or vein-clearing, occasional leaf malformation, followed by the development of grey or brown necrotic spots (Ryu *et al.*, 2002). In the field, mixed infections of LMoV and CMV have been confirmed in various lily species, resulting in more severe disease symptoms than those produced by single infections (Zhang *et al.*, 2014; Lim *et al.*, 2016).

Most plant viruses usually cause plants to exhibit mosaic symptoms. Studies have revealed that viral factors, especially the coat protein (CP), affect chloroplast ultrastructure and symptom development (Zhao *et al.*, 2016). Many hypotheses have been proposed about the pathogenesis of mosaic viruses, the most popular of which is that the interaction between the viral CP and chloroplasts is a major cause of the mottled symptoms of the host (Reinero & Beachy, 1989; Xu *et al.*, 2017). Earlier research confirmed that *Tobacco mosaic virus* (TMV) CP and CMV CP accumulate in the respective chloroplasts of systemically infected tobacco and cucumber leaves, and the severity of the symptoms is positively related to the amount of CPs in the host chloroplasts (Reinero & Beachy, 1989; Zhu & Francki, 1992). Subsequently, CPs of *Turnip mosaic virus* (TuMV), *Potato virus Y* (PVY), *Potato virus X* (PVX) and *Rice stripe virus* (RSV) were similarly found to accumulate in the chloroplasts of host plants (Fu *et al.*, 2004; Feki *et al.*, 2005; Qiao *et al.*, 2009; Cheng *et al.*, 2011).

Plants infected with LMoV and CMV exhibit symptoms of leaf mosaic. However, to date there is a lack of knowledge about the pathogenesis in the mixed

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Development of archaeal communities in biological soil crusts along a revegetation chronosequence in the Tengger Desert, north central China

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Successional stage of BSCs

ABSTRACT

Archaea are major contributors to biogeochemical cycles and energy metabolism among soil microorganisms under extremely acidic and high-temperature conditions, however, the biodiversity and ecological function of archaea in biological soil crusts (BSCs) of desert ecosystems are not fully understood. Here, we used Illumina MiSeq sequencing and microbial functional gene array (GeoChip 5.0) to test the following hypotheses: (1) the composition and function related to biogeochemical cycles of the archaeal community would change significantly in the development process of BSCs; and (2) the key factors driving these changes may be soil biogeochemical properties. The results showed that the diversity, abundance, and functional potential of the archaeal community showed their highest levels in 5-year-old BSCs. The dominant phyla were Thaumarchaeota, Euryarchaeota, and an unclassified phylum in the archaeal community during BSC succession. The functional genes of the archaeal community were mainly involved in carbon (C) and nitrogen (N) cycles, and the functions of the three dominant phyla were complementary in these cycles. Moreover, redundancy analysis showed that soil biogeochemical properties were negatively related to the composition and function of the archaeal community during BSC succession, and the soil C:N ratio might be the major limiting factor. These results provided evidences for our hypotheses and revealed that the archaeal community played an important ecological role in the early development stage of BSCs, and might be pioneer species of soil microbial communities during BSC succession.

1. Introduction

Biological soil crusts (BSCs) are assemblages of microscopic (cyanobacteria, algae, fungi, and bacteria) and macroscopic (lichens, mosses, and micro arthropods) organisms combined with surface soil particles, and make up to 40% of the living cover of desert ecosystems and can even exceed 70% in some unique soil habitats (Belnap and Lange, 2003; Eldridge and Greene, 1994; Weber et al., 2016). Being considered as the desert ecosystem engineers, BSCs have many important ecological functions in arid and semi-arid areas, such as fixing dune surfaces (Li et al., 2010a, b, 2012), reducing soil erosion (Warren and Eldridge, 2001), enhancing soil fertility (Belnap and Gardner, 1993; Li, 2005), influencing soil nutrient cycling (Belnap and Lange, 2003; Li et al., 2002), regulating soil moisture (Belnap and Lange, 2003; George et al., 2003), affecting the germination and establishment of vascular plants (Godínez-Alvarez et al., 2012; Li et al., 2005), and establishing a favorable living environment for other organisms (Neher et al., 2009). The formation of BSCs is generally regarded as a process in which the dominance of pioneer cyanobacteria is subsequently replaced by lichens and mosses with corresponding improvement in soil environments (Neher et al., 2009). As environmental changes can result in rapid variation in the microbial communities in BSCs (Cong et al., 2015; Han et al., 2007; Harris, 2009; López-Lozano et al., 2013), microbial communities are often used as sensitive bio-indicators for predicting the degradation and restoration of BSCs (Emmerling et al., 2001; Fernandes et al., 2005; Liu et al., 2017a, b).

With the recent development of high-throughput sequencing technology, research on the composition and function of bacterial and fungal communities in BSCs has become in-depth and comprehensive (Bates and Garcia-Pichel, 2009; Bates et al., 2010a; Green et al., 2008; Gundlapally and Garcia-Pichel, 2006; Maier et al., 2014; Wang et al., 2015). It has been reported that the dominant bacteria in BSCs are

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Mechanical sand fixing is more beneficial than chemical sand fixing for artificial cyanobacteria crust colonization and development in a sand desert

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ABSTRACT

The incubation of biological soil crusts (BSCs) can potentially determine a decrease in abiotic stress levels, which can then shift the state of the ecosystem and combat desertification due to their key ecological roles in drylands. Stabilized sand soil surface is the primary factor for natural and induced BSCs successful establishment in harsh dryland environments. Mechanical sand fixing, such as straw checkerboard barriers and chemical sand fixing are two effective ways to stabilized sandy soil surface. The impacts of these two sand fixing methods on artificial cyanobacteria colonization have not been frequently been compared in the field. In this study, five cyanobacteria, *Anabaena* sp., *Nostoc* sp., *Phormidium* sp., *Scytonema* sp. and *Tolypothrix* sp. were isolated and cultured. The straw checkerboard method was represented mechanical sand fixing and W-OH (modified water-borne polyurethane) method was used to test chemical sand fixing. Coverage, thickness and biomass of artificial cyanobacterial crust as well as wind erosion intensity and dust deposition were measured after 16 months of inoculation. Results show that the highest coverage, thickness and biomass of artificial cyanobacterial crust was in the straw checkerboard mechanical method, with cyanobacteria measuring higher than other treatments ($p < 0.05$) at 28.3%, 3.01 mm and 0.24 mg cm^{-2}, respectively, and showed both positive relationships with dust deposition and herb coverage, but negatively with wind erosion intensity ($p < 0.05$). Thus, mechanical sand fixing was more beneficial to artificial cyanobacterial crust incubation in field conditions rather than chemical sand fixing, due to sustaining increase in dust deposition to sand surface stability. In addition, mechanical sand fixing uses lessees water than chemical sand fixing. Our results also indicated that annual herb coverage should be closely managed during the artificial cyanobacterial crust incubation in field conditions.

1. Introduction

Land degradation/desertification occurs widely and is one of the most important global social, economic and environmental issues caused by climate change and anthropogenic activities. It has reduced land productivity and seriously affected the livelihood and health of many people as well as been major cause of biodiversity loss; these factors make it a major obstacle to the sustainable development of arid and semi-arid regions (Gisladottir and Stocking, 2005; Reynolds et al., 2007; Zhang et al., 2017). Therefore, control and rehabilitation of degraded and desertified lands are a major challenge facing approximately 41.0% of the land surface of the world and affect > 38.0% of the total global human population of 6.5 billion (Reynolds et al., 2007; Wang et al., 2015).

Biological soil crusts (BSCs) are complex communities composed of different proportions of cyanobacteria, green algae, bryophytes lichens and microfungi. These communities are capable of substantially affecting the stability and quality of soils in arid and semiarid regions, and more importantly aid in resisting land degradation and desertification (Assouline et al., 2015; Belnap and Lange, 2003; Li, 2012; Su et al., 2013; Xiao and Veste, 2017). Due to their key ecological roles in drylands, the “construction” or incubation of BSCs can potentially determine a decrease in abiotic stress levels, shifting the state of the ecosystem. Thus a new method to restore desertified areas is to use artificial BSCs (Bu et al., 2018; Park et al., 2017; Rossi et al., 2017). The most frequently reported rapid and successful restorations have occurred due to the cultivation of cyanobacteria and moss crusts on sand or disturbed soil surfaces in both laboratory and field conditions (Bu

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RESEARCH ARTICLE

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Towards stopping land degradation in drylands: Water-saving techniques for cultivating biocrusts in situ

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Abstract

In recent years, inoculating sand surfaces with biocrust organisms has become one of the most promising biotechnological strategies for controlling and reversing land degradation in drylands. To fully exploit this biotechnology on a large scale in drylands, researchers must explore water-saving techniques to incubate biocrusts in situ. To achieve this aim, we tested three methods—broadcasting dried cyanobacteria, spraying fresh cyanobacteria, and broadcasting natural biocrust fragments—to culture biocrusts in situ on the Tengger Desert in Northern China. The cover of incubated biocrust increased during the first 2 months after inoculation (from 6% to more than 20.0% in treatments using biocrust fragments); biocrust cover declined but persisted after 12 months of incubation (13.8% cover in the best treatment, natural cyanobacteria fragments). The cover of cyanobacteria was higher than the cover of lichen in our natural cyanobacteria-lichen crust fragment treatment (NCL; $p < .05$) after incubating for 12 months. We highlight that cyanobacteria should be selected for biocrust incubation during the initial stages of dryland restoration. Accumulated rainfall was positively related to the cover of incubated biocrust. However, wind speed and wind erosion intensity were both negatively related to the cover of incubated biocrust. In conclusion, broadcasting biocrust fragments is a rapid, efficient, and water-saving biotechnique to cultivate biocrusts in situ. Actions to reduce wind speed and wind erosion, such as mechanical sand fixing, can help stabilize soils and improve crust cultivation.

KEYWORDS

cyanobacteria, eco-friendly biotechnique, ecology restoration, water-saving

1 | INTRODUCTION

Land degradation is an important global social, economic, and environmental problem in drylands, where it can trigger a desertification process (Reynolds et al., 2007; Schlesinger et al., 1990). Land degradation has reduced land productivity and seriously affected the livelihood and health of many people. It has also been a major cause of biodiversity loss. These factors make it a major obstacle to the sustainable development of drylands (Gisladottir & Stocking, 2005; Reynolds et al., 2007). Finding a viable approach to reverse degradation has become an urgent problem for humanity (Gisladottir & Stocking, 2005; Reynolds et al., 2007; Singh & Ajai, 2019).

Biological soil crust (biocrust) are primo-colonizers, especially in areas with low vegetation cover, and they play key roles in the structure and function of dryland ecosystems, where they may help to fight against land degradation (Assouline et al., 2015; Bowker, Reed, Maestre, & Eldridge, 2018). Attempts to restore disturbed soil surfaces, particularly in drylands, by applying cultivated biocrusts thus may be an important way to benefit ecosystem recovery (Bowker, 2007; Rossi, Li, Liu, & De Philippis, 2017). Recently, many publications have shown that inoculation with biocrust organisms, such as cyanobacteria, lichen, or moss, is a promising, eco-friendly biotechnological tool to rapidly increase soil stability, resist erosion of degraded soils, and stimulate land rehabilitation in drylands (Chiquoine, Abella, &

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Rain shadow effects of individual shrub related to crown shape in arid desert

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Abstract

Rain shadow effects of individual shrubs (RSEISs) during wind-influenced rain events influence the redistribution of net rainfall, which is especially important in water-limited ecosystems. Two shrub species, *Caragana korshinskii*, which has an inverted conical shape and large crown size, and *Artemisia ordosica*, which has a hemispheroidal shape and small crown size, were selected for study in the southeast edge of the Tengger Desert of Northern China. Throughfall was measured at 12 different positions around each shrub (four distances from the trunk in each of three directions) during each of the 210 rain events occurring over a 10-year period; wind speed during each rain event and various crown properties of the shrubs were also measured. RSEISs were quantified using coefficient of variation of throughfall. Thoughfall was most variable for *C. korshinskii* near the trunk and under the crown, and for *A. ordosica*, at the edge of the crown and within the space between plants. The coefficient of variation in thoughfall at each distance from the trunk ($CV_{Distance}$) for *C. korshinskii* positively related to plant height and the plant area index (PAI; $p < 0.05$), whereas the $CV_{Distance}$ for *A. ordosica* was positively related to height, PAI, crown area, and volume ($p < 0.01$). RSEISs were structured by interspecific crown shape rather than crown size and branch density of a given plant. In conclusion, RSEIS lead to different local hydrologic budgets, which may have relevant implications in maintenance of the patchy pattern of vegetation in water-limited ecosystems.

KEYWORDS

crown size, desert shrub, distance from trunk, throughfall, wind-influenced rainfall

1 | INTRODUCTION

Rain shadow effects refer to the influence of plant morphological structures on the net rainfall occurring beneath and around the plant crown during a wind-influenced rain event (Herwitz & Slye, 1995; Storey & Wilm, 1944). Rain shadow effects can be seen in the redistribution of rainfall to the ground, which significantly decreased rain amount in the rain shadow zone or even significantly increased in the windward zone (Grier & Running, 1977; Huning & Margulis, 2017; Manzano et al., 2017). The redistribution of water by the

Abbreviations: $CV_{Direction}$, Coefficient of variation in throughfall amongst positions in the same direction from the trunk but at different distances, %; $CV_{Distance}$, Coefficient of variation in throughfall amongst positions at the same distance from the trunk but in different directions, %; CV_{Total}, Coefficient of variation of total throughfall, %; GR, Gross rainfall in an individual rain event, mm; PAI, Plant area index, m^2/m^2; RD, Rainfall duration, h; $T_{Direction}$, Throughfall across the crown at positions in the same direction from the trunk but at different distances, mm; $T_{Direction}/GR$, Percentage of gross rainfall that occurs as throughfall in a given direction from the trunk, %; $T_{Distance}$, Throughfall across the crown at positions the same distance from the trunk but in different directions, mm; $T_{Distance}/GR$, Percentage of gross rainfall that occurs as throughfall at a given distance from the trunk, %; T_{Total}, Total throughfall over the entire crown, mm; T_{Total}/GR, Percentage of gross rainfall that occurs as throughfall across the shrub crown, %; WS, Wind speed within a rainfall event, m/s

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Effect of level of oat hay intake on apparent digestibility, rumen fermentation and urinary purine derivatives in Tibetan and fine-wool sheep

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ABSTRACT

Tibetan sheep are indigenous to the Qinghai-Tibetan Plateau and are raised at an altitude between 3000–5000 m. In contrast, the crossbred fine-wool sheep were introduced to the plateau and are raised at an altitude between 2600 to 3500 m. Tibetan sheep graze grassland all year round while fine-wool sheep require feed supplements during the long cold season. Tibetan sheep were able to utilize dietary nutrients more efficiently than fine-wool sheep when offered adequate energy and protein diets. We questioned whether the responses would still favour Tibetan sheep with limited energy and protein intakes, as is often the case on the Qinghai-Tibetan Plateau. To answer this query, apparent nutrients digestibilities, rumen fermentation characteristics and urinary purine derivatives (PD) were compared between Tibetan and fine-wool sheep when fed oat hay at below maintenance levels: 0.3, 0.5, 0.7 and 0.9 voluntary intake. Five wethers of each breed of similar age and body weight (BW) were used in two concurrent 4 × 4 Latin square designs. Dry matter (DM), organic matter (OM) and neutral detergent fiber (NDF) digestibilities were higher in Tibetan than fine-wool sheep ($P < 0.05$), but were not affected by the level of oat hay intake ($P > 0.10$). As feed intake increased, ruminal pH decreased ($P < 0.01$) and total volatile fatty acid (VFA) concentration increased, both linearly ($P < 0.001$). Moreover, ruminal total VFA concentration ($P < 0.05$), ruminal soluble protein nitrogen (N) and saliva urea-N concentrations ($P < 0.01$) were higher in Tibetan than fine-wool sheep. Urinary total PD and its fractions increased linearly with feeding level ($P < 0.01$). Estimated microbial N synthesis was greater in Tibetan than fine-wool sheep ($P < 0.05$) and increased linearly with the level of oat hay intake ($P < 0.001$). It was concluded that both energy and protein metabolism were used more efficiently in Tibetan than in fine-wool sheep when offered below maintenance intakes, which would allow Tibetan sheep to cope better with the harsh, winter foraging conditions of the Qinghai-Tibetan Plateau.

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; BW, body weight; CP, crude protein; DE, digestible energy; DM, dry matter; N, nitrogen; NDF, neutral detergent fiber; OM, organic matter; PD, purine derivatives; VFA, volatile fatty acid; VI, voluntary intake

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Effect of dietary energy on digestibilities, rumen fermentation, urinary purine derivatives and serum metabolites in Tibetan and small-tailed Han sheep

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Abstract

Tibetan sheep are indigenous to the Qinghai–Tibetan Plateau, graze the grassland all year round without supplementation and are well-adapted to the harsh conditions. Small-tailed Han sheep were introduced to the plateau and are raised mainly in feedlots. Based on their different backgrounds, we hypothesized that the ability to cope with poor diets would be better in Tibetan than in Han sheep. To test our prediction, we examined the effect of dietary energy on apparent digestibilities, rumen fermentation, urinary purine derivatives and serum metabolites by using a 4 × 4 Latin square design in each sheep breed. Four diets were formulated to be low in crude protein (~7%) but to differ in metabolizable energy concentration. Average daily gain was greater in Tibetan than in Han sheep ($p < 0.01$) and increased linearly with an increase in energy intake ($p < 0.001$). The digestibilities of dry matter, organic matter, gross energy, and neutral and acid detergent fibres were greater in Tibetan than in Han sheep ($p < 0.05$). Ruminal pH was lower ($p < 0.05$), while volatile fatty acids (VFAs), urea-N, ammonia-N and soluble protein-N concentrations were higher ($p < 0.05$) in Tibetan than in Han sheep. As a molar proportion of total VFA, acetate decreased ($p < 0.001$) with an increase in dietary energy whereas propionate and butyrate increased ($p < 0.05$). Urinary purine derivative excretion was greater in Tibetan than in Han sheep ($p < 0.01$), as was microbial nitrogen production; both parameters increased with dietary energy ($p < 0.01$). Serum concentrations of glucose, insulin and insulin-like growth factor-1 increased ($p < 0.05$) as energy level increased, while non-esterified fatty acids and growth hormone decreased ($p < 0.05$). It was concluded that Tibetan sheep were better able to cope with low-protein, low-energy diets and, consequently, our prediction was supported.

KEYWORDS
apparent digestibility, dietary energy level, rumen fermentation, Tibetan sheep, urinary purine derivatives

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Original Research Article

Observational and experimental evidence for the effect of altered precipitation on desert and steppe communities

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ABSTRACT

Changes in precipitation pattern are likely to affect the community structure and ecosystem function in drylands. Observational and experimental studies can provide insight into how plant community in desert and grassland ecosystems responds to precipitation changes, however, the studies combining both approaches are rare. Here, we reported the results of altered precipitation effects on desert-shrub community and steppe-grass community from both a natual precipitation gradient and an experiment manipulating precipitation in Inner Mongolia, northern China. We found that precipitation changes along the natural gradient could well explain species richness and aboveground plant biomass (AGB), inducing their positive relationships in shrub- or grass-dominated community. In the manipulative experiment, 40% and 60% increased precipitation increased species richness and Shannon's diversity in grass-dominated community, and 60% increased precipitation increased AGB in grass-dominated community, while 60% reduced precipitation decreased plant density and AGB in shrub and grass-dominated communities. Species richness, Shannon's diversity, plant density and AGB were positively related to increased precipitation in the manipulative experiment. The positive relationship between species richness and AGB in the grass-dominated community could be shaped by the manipulative precipitation gradient, but no significant relationship was found in the shrub-dominated community in the experiment. Our study highlights that species richness and AGB in desert and steppe community consistently respond to altered precipitation along the natural gradient and in experiment. Extreme drought or high precipitation-induced shifts of the composition and production of herbaceous plants in the shrub-dominated community can contribute to shape the positive associations of community structure and function with precipitation changes. The high vulnerability of grass-

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Effects of gibberellic acid on tiller-bulb number and growth performance of *Lilium davidii* var. *unicolor*

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ABSTRACT

Lilium davidii var. *unicolor* (Lanzhou lily) is an important economic crop in the northwest cold and arid regions of China. Effective regulation of tiller-bulb development and plant growth is the key to improving yield and quality of the lily. This study attempted to evaluate the effect of gibberellic acid (GA_3) on tiller-bulb development and plant growth of Lanzhou lily by applying GA_3 at various concentrations (0 mg/L, 10 mg/L, 30 mg/L, 60 mg/L, and 100 mg/L) before planting and in the seedling period. Results showed that the 60-mg/L GA_3 application had an inhibiting effect on tiller-bulb formation and increased the ratios of single and double bulbs but decreased the ratios of bulbs with three or more tiller bulbs, as compared to the control (CK) and other GA_3 treatments. The difference in flower number did not reach significant levels among the treatments. The tillering-related endogenous hormones IAA (indole-3-acetic acid) and Z (zeatin) content decreased, while IAA/Z increased with the 60-mg/L GA_3 treatment during tiller initiation. And also, the shoot-bulb number and total daughter-bulb number decreased significantly with the 60-mg/L GA_3 treatment. Furthermore, the 10-mg/L GA_3 application promoted growth of Lanzhou lily significantly and resulted in an increase in plant height; bulb diameter; bulb circumference; and biomass of shoots, bulbs, fibrous roots, and the whole plant. Therefore, GA_3 application is promising as a new regulation method for inhibiting tiller-bulb development and promoting bulb growth in Lanzhou lily production.
Keywords: Gibberellic acid; tiller bulb; endogenous hormone content; height; biomass

1 Introduction

Lilium davidii var. *unicolor* (Lanzhou lily) is a native variant in China; and it is an important economic bulb crop that is distributed mostly in Gansu, Ningxia, and neighboring northwest cold and arid regions of China (Qiu *et al*., 2018). It is the best edible lily as well as a traditional medicinal plant due to its abundant nutrient substances and nourishing effect (Li *et al*., 2014). Besides, it also has ornamental value and gardening uses for its flaming and flamboyant color (Wang *et al*., 2010). In Lanzhou lily production, the formation of new daughter bulbs from a mother bulb is a common way of commercial bulb production; but too many tiller bulbs seriously influence lily quality, commodity value, and, to some extent, nutrition (Lü *et al*., 2009; Yang *et al*., 2011). Tillering regulation has important physiological, ecological, and agricultural significance. And also, the single-bulb lily is easy to process and convenient for commercialization. Studies have shown that reducing ineffective tillers (or branches) is directly related to increasing crop yield; cultivating crops with few tillers has always been one of the main objectives of crop domestication (Yang, 2015). In recent years, tiller-bulb numbers have increased and bulb quality has deteriorated continuously, becoming the main problems in Lanzhou

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Shifts in community structure and function of ammonia-oxidizing archaea in biological soil crusts along a revegetation chronosequence in the Tengger Desert

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ABSTRACT

Metagenomic studies have demonstrated the existence of ammonia-oxidizing archaea (AOA) and revealed they are responsible for ammoxidation in some extreme environments. However, the changes in compositional structure and ammonia-oxidation capacity of AOA communities in biological soil crusts (BSCs) of desert ecosystems remain poorly understood. Here, we utilized Illumina MiSeq sequencing and microbial functional gene array (GeoChip 5.0) to assess the above changes along a 51-year revegetation chronosequence in the Tengger Desert, China. The results showed a significant difference in AOA-community richness between 5-year-old BSCs and older ones. The most dominant phylum during BSC development was Crenarchaeota, and the corresponding species were *ammonia-oxidizing_Crenarchaeote* and *environmental_samples_Crenarchaeota*. Network analysis revealed that the positive correlations among dominant taxa increased, and their cooperation was reinforced in AOA communities during BSC succession. Redundancy analysis showed that the dominant factor influencing the change in AOA-community structure was soil texture. GeoChip 5.0 indicated that the *amoA* gene abundances of AOA and ammonia-oxidizing bacteria (AOB) were basically the same, demonstrating that AOA and AOB played an equally important role during BSCs development. Our study of the long-term succession of BSC demonstrated a persistent response of AOA communities to revegetation development in desert ecosystems.

Keywords: ammonia-oxidizing archaea; biological soil crusts; GeoChip 5.0; network analysis

1 Introduction

Biological soil crusts (BSCs) are assemblages of macroscopic and microscopic organisms, including mosses, lichens, algae, archaea, bacteria, fungi, and other organisms that bind together with surface soil particles, forming a cohesive horizontal layer of a few centimeters deep (Belnap *et al*., 2016). BSCs are widespread in semiarid and arid areas, making up as much as 70% of the living cover of some unique soil habitats (Belnap *et al*., 2016) and performing a variety of ecological functions, such as fixing dune surfac-

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Influence of proximity to the Qinghai-Tibet highway and railway on variations of soil heavy metal concentrations and bacterial community diversity on the Tibetan Plateau

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ABSTRACT

An understanding of soil microbial communities is crucial in roadside soil environmental assessments. The 16S rRNA sequencing of a stressed microbial community in soil adjacent to the Qinghai-Tibet Highway (QTH) revealed that the accumulation of heavy metals (over about 10 years) has affected the diversity of bacterial abundance and microbial community structure. The proximity of a sampling site to the QTH/Qinghai-Tibet Railway (QTR), which is effectively a measure of the density of human engineering, was the dominant factor influencing bacterial community diversity. The diversity of bacterial communities shows that 16S rRNA gene abundance decreased in relation to proximity to the QTH and QTR in both alpine wetland and meadow areas. The dominant phyla across all samples were *Actinobacteria* and *Proteobacteria*. The concentration of Cr and Cd in the soil were positively correlated with proximity to the QTH and QTR (MC/WC sampling sites), and Ni, Co, and V were positively correlated with proximity to the QTH and QTR (MA/WA sampling sites). The results presented in this study provide an insight into the relationships among heavy metals and soil microbial communities, and have important implications for assessing and predicting the impacts of human-induced activities from the QTH and QTR in such an extreme and fragile environment.

Keywords: Qinghai-Tibet Highway (QTH); Qinghai-Tibet Railway (QTR); soil bacterial community; alpine wetland; alpine meadow; heavy metal

1 Introduction

As the geographical unit with the highest elevation on earth, the Qinghai−Tibet Plateau (QTP) is referred to as the "Third Pole" and has an important role in regulating climate change and water resources in

降雨量对科尔沁沙地 3 种沙生植物生长和生理的影响

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摘要： 对降水格局变化的响应是植物适应环境的重要方面。通过野外增减雨试验，研究了降水变化对科尔沁沙地 3 种沙生植物生长特性和生理特征的影响。结果表明：(1) 6 月植被平均密度最大，7 月平均盖度最大，降雨量增加 60%时，植被盖度最大，为 58.0%。(2) 增雨区的主要植物为雾冰藜(*Bassia dasyphylla*) 和猪毛菜(*Salsola collina*)，减雨区主要植物为蒺藜(*Tribulus terrestris*)，降雨量减少 60%时，蒺藜在 6、7、8 月密度分别为 70%、80%、79%，显著高于其他植物。(3) 降雨量减少时，3 种沙生植物的相对含水量(RWC) 减少，而细胞膜透性增加；蒺藜 RWC 高于雾冰藜和猪毛菜，但是丙二醛(MDA) 正好相反；蒺藜的耐脱水能力和细胞膜的耐伤害程度强于雾冰藜和猪毛菜。(4) 随着降雨量的增加，3 种植物的光能转化效率(F_v/F_m、ΦPSⅡ) 逐渐增加，但随干旱天数的增加而减小。

关键词： 沙生植物；降雨量增减；生长特性；叶绿素荧光特性；抗氧化酶

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0 引言

全球约有 1/3 的面积为干旱和半干旱区，中国国土面积的 1/2 属于干旱半干旱区[1]。在干旱半干旱环境中，水分主要来源于降水，植物定植、发育繁衍和群落物种组成及物种演替均受到降水的影响[2]，植物的光合蒸腾特征、抗氧化酶活性和渗透调节物质含量等与降水密切相关[3]。水分是影响干旱半干旱区植物生存和生长的重要因子。不同植物的抗旱能力有很大差异。干旱环境下，耐旱植物存活而不耐旱植物可能被淘汰，从而改变了群落组成[4]。物种丰富度在年降水量较小年份极度减少，一年生草本植物种在群落中的定植或消失随降水量的增加或减少而发生改变[5]。

随着干旱的加剧，杠柳[6]和沙地云杉[7]叶片叶绿素含量先增加后降低，而决明叶绿素含量下降[8]。干旱胁迫后云杉[7]和膜荚黄芪[9]的光能转化效率(F_v/F_m、ΦPSⅡ) 均降低。在人工控制水分条件下，沙米和芦苇叶片抗氧化酶活力随干旱胁迫程度的增加而增加[10-11]。蒙古岩黄芪在中度和重度干旱胁迫下抗氧化酶活力、丙二醛(MDA) 含量和细胞膜膜透性均增加[12]。乌丹蒿的膜透性随胁迫时间的延长而增加[13]。干旱复水后差不嘎蒿和白草的相对含水率(RWC) 增加，MDA 含量和细胞膜透性降低[10]。在土壤反复人工干旱复水处理后，杠柳、狗尾草和马唐的抗氧化酶活力随干旱程度的增加而增加，复水后降低[14-15]。沙生植物抗御恶劣自然条件的能力与其细胞具有较强的抗氧化能力密切相关[16]。

目前对沙生植物的抗旱性多集中于用人工模拟的方法对土壤水分进行短期调控，很难系统地反映自然状态下植物的响应机制[17]。科尔沁沙地位于内蒙古东部半干旱半湿润地区过渡带，当地多年平均降雨量低，并且不同年份间差异较大，地下水位下降，年降水量呈现减少趋势[18-19]。植物的种类、密

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Research Article 研究报告

麦积山石窟赋存环境中空气细菌的时空分布特征

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摘要：【目的】空气微生物沉降及污染与文化遗产的微生物退化密切相关，本文对世界文化遗产地麦积山石窟赋存环境空气中细菌浓度和群落结构的季节性变化特征进行了系统研究，为石窟环境监测预警和文物预防性保护提供依据。【方法】利用生物气溶胶采样器，在 2016 年春、夏、秋和冬季分别采集空气样品；基于传统培养方法获得空气中细菌浓度及纯培养菌株；通过提取基因组 DNA、扩增细菌 16S rRNA、测序和系统发生树等分子技术研究细菌群落时空动态变化规律；结合环境监测数据，分析影响遗产地空气细菌变化的主要因素。【结果】监测期内，空气细菌浓度在(281.20–1409.20) CFU/m^3 之间，最高浓度出现在 MJ4 处的夏季，最低浓度出现在 MJO 处的春季；具有明显季节性变化特征，在空间层位分布上有所差异，但不显著(P>0.05)。培养的细菌菌株经鉴定属于 4 个门 11 个属，芽孢杆菌属(*Bacillus*)、*Paenarthrobacter*、节杆菌属(*Arthrobacter*)、薄层菌属(*Hymenobacter*)和考克氏菌属(*Kocuria*)等为优势属。【结论】麦积山石窟空气细菌群落结构具有明显的季节性和空间分布动态变化特征；在石窟不同层位，空气中细菌群落分布与相对湿度、温度与降雨量相关；部分细菌种属如芽孢杆菌属、微球菌属(*Micrococcus*)，为壁画及彩塑生物腐蚀的潜在病害菌；麦积山石窟及周边环境空气细菌的监测可为石窟保护和旅游开放管理提供重要参考。

关键词：石窟寺，空气细菌，群落组成，时空变化，监测预警

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研究报告

天梯山石窟壁画保存环境中空气细菌的季节性变化

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摘　要：【背景】微生物侵蚀是古代壁画常见生物病害，影响壁画的长久保存和安全陈展。空气微生物作为壁画病害菌的主要来源，近年在文物赋存环境监测和预防性保护中引起广泛重视。【目的】对天梯山石窟壁画的 2 处保存地，即天梯山原址和武威西夏博物馆壁画保存环境中的空气细菌浓度、群落结构及其季节变化规律进行分析。【方法】利用生物气溶胶采样器，在 2016 年春、夏、秋、冬 4 季分别采集各位点空气样品；基于传统培养方法获得空气中细菌浓度及纯培养菌株；通过提取细菌基因组 DNA、扩增其 16S rRNA 基因、测序和系统发生关系分析等技术研究不同位点细菌群落时空动态变化规律；结合环境监测数据，分析影响文化遗产地空气细菌群落变化的主要因素。【结果】空气可培养细菌的总浓度在 16.7−1 451.8 CFU/m^3 范围内变动。原址第 18 窟和第 13 窟，各季节细菌浓度无显著性差异，且呈明显季节性变动规律，总体特征为夏秋季低，冬春季高。西夏博物馆外空气细菌浓度在各季节均高于库房内，冬季最高。本研究共鉴定出 19 个细菌属，隶属于 4 个门；其中不动杆菌属(*Acinetobacter*)、节杆菌属(*Arthrobacter*)、芽孢杆菌属(*Bacillus*)、考克氏菌属(*Kocuria*)、短波单胞菌属(*Brevundimonas*)、肉食杆菌属(*Carnobacterium*)、*Pseudoclavibacter* 和薄层菌属(*Hymenobacter*)为优势属。【结论】天梯山石窟空气细菌群落结构具有明显的时空分布特征；相对湿度、温度及季节性降水均会影响其变化；鉴定得到部分种属具备引起壁画生物腐蚀的潜势；本研究可为当地开展遗址和馆藏环境中文物预防性保护提供本底资料。

关键词：空气细菌，群落特征，古代壁画，监测预警

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脂肪酸对羊肉品质的影响研究进展

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[摘要] 脂肪酸是动物生长发育和维持健康的重要营养因素之一，动物体内脂肪酸的分布和组成，在一定程度上影响着肉品质以及消费者的健康。脂肪酸的来源和含量对肉品质具有重要影响。鉴于此，本文针对羊肉中脂肪酸的类别、功能以及对肉品质的影响进行综述，以期对未来建立高品质羊肉生产体系提供一定参考。

[关键词] 脂肪酸；羊肉；肉品质

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随着人们物质生活水平的不断提高，高品质羊肉产品已越发成为人们饮食需求的重要组成部分之一，由于其具备人类必需的营养物质，包括必需微量营养素、铁、锌以及 B 族维生素等(Boada，2016)，被广大消费者所喜爱。据统计，中国居民对羊肉的需求逐年在升高，2015 年我国羊肉人均需求量为 3.38 kg/人，现以年均 1.39%的速度增长(沈辰和孟阳，2016)。将从 2015 年的 440.80 万 t 增加到 2020 年的 502 万 t。羊肉的物理化学特性决定着消费者对肉品的可接受性。目前市面上羊肉普遍缺乏多不饱和脂肪酸(PUFA)，而且在羊肉生产加工的过程中，肉品中的脂肪酸分布和特性的差异也会引起羊肉品质的变化(吴建平，2000)。鉴于此，本文针对不同脂肪酸对改善羊肉品质的作用进行综述，以期为生产高品质羊肉提供一定参考。

1　脂肪酸的分类

脂肪酸是脂肪的主要组成部分，而羊肉中的脂肪酸种类繁多，其主要按碳链的饱和程度分为两类，即饱和脂肪酸(SFA)和不饱和脂肪酸(UFA)。不饱和脂肪酸又被分为：单不饱和脂肪酸(MUFA)和多不饱和脂肪(PUFA)。单不饱和脂肪酸是指在碳链中仅具有一个双键的脂肪酸，包括肉豆蔻油酸(Myristic oleic acid)、棕榈油酸(Palmitoleic)、油酸(Oleic acid)、反式油酸(Trans oleic acid)、蓖麻油酸(Ricinoleic acid)以及神经酸(Cis-15-Tetracosenoic acid)等；多不饱和脂肪酸根据其从甲基末端到第一个双键的位置分为：第三个碳原子上的远端双键称为 ω-3 PUFA（主要包括亚麻酸、DHA、EPA），在第六个碳原子上称为 ω-6 PUFA(主要有亚油酸、γ-亚麻酸和花生四烯酸等)(王柏辉，2014)。按照碳链长度可分为：短链(含 4 ~ 6 个碳原子)脂肪酸；中链(含 8 ~ 14 个碳原子)脂肪酸；长链(含 16 ~ 18 个碳原子)脂肪酸和超长链(含 20 个或更多的碳原子)的脂肪酸。

随着反刍动物营养学的不断完善与发展，羊肉中不同脂肪酸的营养价值也变得越来越明晰。目前研究较多的主要包括 ω-3 族 PUFA 和 ω-6 族 PUFA，这些脂肪酸的分布以及对肉品质的影响与人类健康有着密切的关联，大量研究表明，PUFA 不仅能维护生物膜结构和功能，提高机体免疫功能，而且还能促进生长发育，调节脂类代谢和相关基因的表达等，同时还能减少血栓的形成，降低心血管疾病发病率，抵抗癌症等(Patterson 等，2012；Habermann 等，2010；Petrik 等，2000)。

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科尔沁沙地 2 种优势固沙灌木的相容性生物量模型

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摘要：基于现有的灌木生物量模型存在各组分与总量不相容问题，以半干旱区科尔沁沙地 2 种优势固沙灌木小叶锦鸡儿(*Caragana microphylla*)和黄柳(*Salix gordejevii*)为对象，通过对大样本的相关形态指标及生物量实测数据进行非线性回归和非线性误差变量联立方程组的计算，建立了 2 种灌木叶片、新枝、老枝和地上生物量的独立模型及与各组分相容的生物量模型，并通过决定系数 R^2、估计值的标准差 *SEE*、总相对误差 *TRE*、平均系统误差 *MSE*(*ASE*)、平均预估误差 *MPE* 和平均百分标准误差 *MPSE* 对模型进行评价。结果表明：非线性加权回归使得两种灌木各组分的独立模型拟合效果优化，而生物量相容模型与独立模型相比，由于抽样误差的存在拟合效果不佳，相关评价指标较低。

关键词：固沙灌木；生物量模型；相容性；半干旱区沙地

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0 引言

生物量反映植物在一段时间内积累的有机物质和能量，是整个生态系统的能量基础和营养物质来源，体现了生态系统的生产力[1-2]。灌木作为自然界中广泛存在的重要生态系统组成，地上多分枝的茎和近地面的树冠表现出较强的防风固沙和保持水土的能力，地下根系分布较深，有较强的抗旱性[3]，特别是在年降雨量 400 mm 以下的干旱半干旱风沙区，灌木所占面积达到总造林面积的 70%以上[4]，已成为生态建设和退化生态系统修复中防风固沙、保持水土和维持生态平衡的关键植物。

灌木生物量已成为灌木群落及生态系统研究的重要对象，不仅反映灌木与其他植物的竞争能力，还反映出灌木对周边生态环境的适应程度[5]。由于灌木根系分布的特殊性，在测定灌木生物量时，一般忽略地下根系生物量的观测，采用直接收割法进行测定，但仍会对干旱半干旱风沙区生态环境产生破坏。因此通过建立生物量和灌木形态指标之间的关系来估测灌木的生物量，是目前实际生产中较为有效的方法。曾伟生等[6]通过柠条(*Caragana korshinskii*)和山杏(*Armeniaca sibirica*)的株高、丛生枝数和植冠面积建立了地上生物量预测模型；罗永开等[7]基于对山西芦芽山地区 14 种常见灌木的各器官(根、茎和叶)、地上和总生物量及基径、树高、冠幅的测定，建立了各器官、地上及总生物量的最优估算模型；曹萌等[8]以植株地径和植株高度为指标，建立并筛选出松山自然保护区内 5 种灌木最优生物量模型。综合分析以往研究，以地上生物量模型居多，地上各部分生物量都是各组分独立估计得到，并不满足各组分生物量估计值之和等于总量这一潜在逻辑关系。单木总生物量等于各分项生物量之和，是定量研究单木不同组分生物量分配及生长过程的基础，所以，在构建叶片、新枝、老枝和地上部分的生物量模型的同时，必须保证各个方程之间是相互兼容或相加的[9-10]，即模型的相容性。

科尔沁沙地由于脆弱的生态环境及强烈的人类活动，已成为中国北方农牧交错带沙漠化严重地区，在过去的几十年中，约 80%的土地发生了不同程度的沙漠化[11]，建植防风固沙灌木林是有效遏制该地区土地沙漠化和生态治理的重要措施[12]。小叶锦鸡儿(*Caragana microphylla*)和黄柳(*Salix gordejevii*)是科尔沁沙地固沙灌木林的主要建群种[13]，关于它们的生物量模型建立依旧存在不相容问题。因此，

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棕色脂肪细胞特异基因 *PRDM16* 的研究进展与展望*

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摘要 PR 结构域蛋白 16(PR domain-containing 16,PRDM16)是棕色脂肪细胞分化过程的重要转录因子,其对维持棕色脂肪细胞的特殊形态特征及细胞功能具有重要的作用。PRDM16 不仅能调控棕色脂肪细胞的分化,而且可能是脂肪细胞和肌细胞相互转化的"开关",还与白色脂肪细胞的米色化过程相关。研究发现,人和家畜的 *PRDM16* 基因具有丰富的 SNPs 位点,这些 SNPs 位点与人类疾病和家畜生产性状之间存在着一定的相关性。鉴于 PRDM16 在脂肪分化和人类健康等方面的重要性,综述了近十几年来国内外研究者在 *PRDM16* 基因与 PRDM16 蛋白的结构与功能、该基因与疾病和家畜经济性状的相关性等方面的研究成果,并展望了 PRDM16 的未来研究方向与在人类疾病治疗和动物性状改良方面的应用前景。

关键词 PR 结构域蛋白 16 蛋白质结构 生物学功能 调控机制 多态性

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哺乳动物体内存在 3 种类型的脂肪细胞:白色脂肪细胞、棕色脂肪细胞和米色脂肪细胞。白色脂肪细胞是能量储存的场所;棕色脂肪细胞因其含有丰富的线粒体,成为能量释放的场所;米色脂肪细胞可能是由在特定条件(冷暴露、β_3-肾上腺素受体激动剂)刺激下的白色脂肪细胞转化而来的,米色脂肪细胞内也有线粒体,也具备能量释放的功能。其中棕色脂肪细胞和米色脂肪细胞的产热机制是线粒体内膜富含的解偶联蛋白 1(UCP1)能够运输质子跨过线粒体内膜破坏氧化磷酸化,使用于合成 ATP 的能量以热能形式散失,所以棕色脂肪细胞和米色脂肪细胞对维持能量平衡和机体内稳态具有重要的意义。棕色脂肪细胞分化过程受许多基因(*MYF5*、*PPAR-α/β*、*CEBP-β*、*PGC1-α/β* 和 *UCP1*)调控,PRDM16 被发现是其中一种重要的转录调控因子。

PRDM16 为 PR 结构域家族的第 16 个成员,人类 *PRDM16* 基因首次是在一例因 1 号染色体与 3 号染色体部分区域相互易位 t(1;3)(p36;q21)所引发白血病的患者中发现的,其基因序列定位于 1 号染色体上,因其氨基酸序列与亲嗜性病毒整合位点 1 或 PR 结构域蛋白 3(EVI1/PRDM3)具有高度的相似性,PRDM16 又被称为类骨髓增生异常综合征 1/亲嗜性病毒整合位点 1 基因 1[MEL1(MDS1/EVI1-LIKE GENE 1)][1-2]。近几年来许多研究证实了 PRDM16 是棕色脂肪细胞分化过程中的转录调控因子,对维持棕色脂肪细胞的特殊形态(包括脂滴和线粒体的形成)、促进相关基因的表达并最终发挥其产热功能具有重要的作用[3-4]。因而 PRDM16 结构的改变与多种疾病的发生有关,PR 结构域的缺失可能与骨髓增生异常综合征(MDS)、白血病相关[5-8],PRDM16 的变异也与癌症[9-10]、心肌病[11]、肥胖[12]等具有相关性。在家畜(羊、牛)、家禽(鸡)的研究中发现,PRDM16 与家畜家的生产性状也具有相关性。鉴于 PRDM16 的重要性,本文从 PRDM16 的蛋白质结构、生物学功能及相关的调控机制等方面加以综述,并对 *PRDM16* 基因未来的研究方向与应用前景进行了展望。

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李香云，岳平，郭新新，等.荒漠草原植物群落光合速率对水氮添加的响应[J]. 中国沙漠，2020，40(1)：116-124.

荒漠草原植物群落光合速率对水氮添加的响应

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摘要： 氮沉降和降水格局改变对草原生态系统的结构、功能及关键过程具有重要影响。依托内蒙古乌拉特荒漠草原研究站的全球变化实验平台，研究了氮添加和增减雨(+50%、-50%)及其交互作用对荒漠草原植物群落光合速率和植被特征的影响，分析了荒漠草原植物群落光合速率与植被特征的关系。结果表明：(1)短期氮添加对荒漠草原植物群落光合速率和植被特征没有显著影响($P>0.05$)；(2)降水格局改变显著影响荒漠植物群落光合速率($P<0.05$)，减雨50%显著降低了荒漠草原植物群落光合速率和优势种植物高度($P<0.05$)，而降水增加50%没有改变群落光合速率和植被特征，降水改变下的土壤水分能很好地解释群落光合速率；(3)氮添加和增加降水的交互效应显著提高了群落的光合速率和优势种植物高度($P<0.05$)，而减少降水与氮添加没有显著影响；(4)荒漠草原植物群落盖度、优势种盖度、优势种平均高度与群落的光合速率呈现出指数增加关系，解释率为40%～58%。干旱极大地抑制荒漠草原植物群落光合速率，而氮沉降则依赖于降水增加来提高群落的光合速率，荒漠草原植物群落光合速率与水肥处理下的植物生长特征具有密切的关系。

关键词： 荒漠草原；植物群落；光合速率；氮沉降；降水格局改变

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0　引言

氮沉降和降水格局是全球变化的重要内容，全球变化对陆地生态系统的影响及其反馈一直是研究焦点[1-2]。化石燃料燃烧、氮肥施用、畜禽养殖等人为活动，致使过去的1个世纪内大气活性氮化合物增加了约3倍[3]。1980—2010年，中国总的氮沉降量平均以每年0.4 kg·hm^{-2}的速率持续增加，并且随着经济、农业等的进一步发展，氮沉降量可能还会继续升高[4-5]。在全球变化的背景下，全球降水格局也有着显著变化，降水量、降水频度、极端暴雨干旱事件都在变化[6]。据预测，全球气候变化将导致中国北方地区在未来100年内降水增加30～100 mm[7]，同时还有小降水事件减少和极端降水事件增加的趋势[8]。由于大气氮沉降有相当部分是伴随降水的，因此两者同时改变可能会对草地生态系统结构和功能有着复杂的影响[9]。

全球氮沉降加剧是改变陆地植物群落结构的重要驱动因子[10-11]。随着干旱、半干旱地区的工业和农牧业的发展，排放到大气中的氮素增加很快，导致沉降在附近荒漠生态系统的氮素大量增加[12]，进而导致土壤中可利用氮及植物体内的氮积累增加[13]。可利用氮的增加能够改变植物生长状态、降低植物群落多样性、改变生态系统的功能[14-16]。氮添加能够增加草本植物的盖度，并使得植物优势度降低，从而改变植物群落的结构[17]；叶片氮含量会影响叶片中光合色素含量和核酮糖1,5-二磷酸羧化酶的含量和活性，并进一步影响植物光合作用[14,18]。氮含量在一定范围内时，植物酶活性、浓度以及叶绿素的含量提高，进而使光合作用得到加强，而氮含量超过一定值后，植物体内的营养均衡被打破，营养失衡对光合作用不利，表现为高浓度氮沉降会抑制植物的光合速率[13]。目前，有关氮沉降对于植物个体光合速率影响的研究较多[13,19-23]，但有关氮沉降是如何

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沙漠化土地及其治理研究推动北方农牧交错区生态恢复和农牧业可持续发展

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摘要　土地沙漠化问题在我国北方农牧交错区尤为突出。中国科学院西北生态环境资源研究院奈曼沙漠化研究站（以下简称“奈曼站”）围绕北方农牧交错带典型区科尔沁沙地的土地沙漠化治理和农牧业经济持续发展，长期开展荒漠生态系统协同保护和合理利用的机理研究、过程监测、技术试验与示范等工作，取得了卓有成效的成绩。经过30多年的发展，奈曼站已经成为我国农牧交错地带荒漠化土地治理的野外观测研究平台，提出的“奈曼沙漠化土地综合整治模式”及其相关理论和技术不仅被国内同类沙漠化地区的生态治理实践广泛采用和借鉴，还被联合国环境规划署（UNEP）、联合国开发计划署（UNDP）以及联合国其他相关机构作为长期培训教材和科普推广内容；同时，奈曼站坚持研发农牧业经济可持续发展的关键技术并示范应用，引种适地丰产作物及林草果蔬植作物品种，提高农牧民的经济收入和生活质量，为农牧交错带土地沙漠化趋势“初步得到遏制和整体呈现逆转态势”作出了贡献。1998年，奈曼站获得联合国环境署和粮农组织联合颁发的“拯救干旱区土地成功业绩奖”。随着全球气候变化及社会经济发展带来的土地利用压力持续增加，该区域出现了可利用水资源减少、区域生态资源过度开发、得到治理的沙漠化土地再次退化等新问题。针对新的问题，奈曼站的观测与研究工作将重点围绕水资源制约的关键因子开展植被-土壤系统协同演变机理研究，研发水分、土壤与生物资源有效利用和区域农牧业持续发展的关键技术与模式，构建新的符合区域生态环境建设、可持续土地利用与管理以及社会发展的科技支撑体系。

关键词　农牧交错区，土地沙漠化，农牧复合生态系统，生态建设，可持续发展

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沙漠化是在干旱、半干旱（包括部分半湿润）地区，由于人类过度且不可持续的经济和发展活动，导致原本脆弱的生态平衡被破坏，使原有的非沙漠地区出现了以风沙活动为主要特征的土地退化过程。沙漠

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李云飞,都军,张雪,谢婷, 李小军.腾格里沙漠东南缘不同类型生物土壤结皮覆盖下土壤有机碳矿化特征.生态学报,2020,40(5): - .
Li Y F, Du J, Zhang X, Xie T, Li X J.Carbon mineralization of soil covered by different types of biological crusts in the southeastern fringe of the Tengger Desert.Acta Ecologica Sinica,2020,40(5): - .

腾格里沙漠东南缘不同类型生物土壤结皮覆盖下土壤有机碳矿化特征

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摘要:生物土壤结皮(BSCs)是荒漠生态系统的重要组成部分,是该区土壤碳循环及碳平衡的关键影响因素。研究了腾格里沙漠东南缘不同类型生物土壤结皮覆盖下土壤碳矿化过程及其对温度(10℃、25℃和35℃)和水分(土壤含水量10%和25%)变化响应特征,分析了土壤碳矿化过程与土壤理化性质的关系。结果表明:(1)结皮的形成和发育显著影响土壤有机碳矿化过程,藻类、地衣和藓类结皮覆盖的土壤碳矿化速率和 CO_2-C 累积释放量均显著高于去除结皮的土壤,不同类型 BSCs 覆盖土壤和去除结皮土壤之间均表现为藓类结皮土壤>地衣结皮土壤>藻类结皮。(2)含结皮层土壤的平均和最大矿化速率均随温度升高和水分增加而逐渐增大,有结皮覆盖的土壤和去除结皮的土壤对温度和水分变化的响应规律相同。(3)有结皮土壤和去除结皮土壤碳矿化速率的温度敏感性(Q_{10})与结皮类型密切相关,均表现为藓类结皮>地衣结皮>藻类结皮。本研究结果表明生物土壤结皮由以藻类为主向以藓类为主的演变进一步促进了土壤碳矿化过程,结皮对土壤碳循环的调控作用受水热等环境因子的共同影响。

关键词:生物土壤结皮;土壤有机碳矿化;Q_{10};水分;腾格里沙漠

Carbon mineralization of soil covered by different types of biological crusts in the southeastern fringe of the Tengger Desert

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Abstract: Biological soil crusts (BSCs) are the association of soil organisms including algea, cyanobacteria, bacteria, fungi, lichen and moss and soil particles, which cover as much as 70% of the interspaces between vegetation and are the key component of arid and semiarid ecosystems. They play a significant role in the process of soil formation and biogeochemical cycling of carbon and nitrogen. Although the functions of BSCs in soil carbon cycling in drylands have been extensively described in the literature, previous research has primarily focused on the effects of BSCs on soil carbon sequestration and respiration. Knowledge is rather poor regarding their effects on soil organic carbon mineralization which is the major part of global carbon cycling and an important process of carbon loss from soils in terrestrial ecosystem.

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腾格里沙漠东南缘人工固沙植被区表层土壤有机碳矿化对凋落物添加的响应

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摘要： 土壤有机碳矿化是调控土壤碳库时空格局、土壤碳收支平衡和植物养分供应的重要过程，植物残体和凋落物分解释放 CO_2 直接影响着土壤有机碳矿化。研究了不同类型凋落物对腾格里沙漠东南缘建植于 1956 年的人工固沙植被区土壤有机碳矿化过程及其对水分和温度的响应特征。结果表明：凋落物添加显著促进了有机碳矿化，添加柠条锦鸡儿(*Caragana korshinskii*)、油蒿(*Artemisia ordosica*)、小画眉草(*Eragrostis minor*)凋落物后，CO_2-C 最大矿化速率分别增大了 6.94、5.17、3.46 倍，0~5 cm 层土壤是 5~10 cm 层土壤的 1.09、1.55、1.22 倍；CO_2-C 累积释放量分别增加了 3.73、3.38、2.34 倍，0~5 cm 层土壤是 5~10 cm 层土壤的 1.17、1.30、1.57 倍。凋落物对有机碳矿化的促进作用与温度和水分密切相关，25 ℃时，CO_2-C 平均释放速率、最大释放速率、累积碳释放量分别是 10 ℃的 2.21、3.60、2.21 倍，而含水量 10%时，CO_2-C 平均释放速率、最大释放速率和累积碳释放量分别是含水量 5%时的 1.25、1.20、1.25 倍。相关性分析表明，凋落物碳氮含量、碳氮比、木质素比氮和土壤有机碳以及全氮是影响有机碳矿化的主要因子。凋落添加土壤后潜在可矿化碳表现为柠条锦鸡儿>油蒿>小画眉草>对照。凋落物添加显著促进了有机碳矿化过程及碳周转，植被恢复过程中草本植物凋落物的输入更有利于土壤碳固存，凋落物对土壤碳库的调控作用受土壤理化性质和水热等环境因子的共同作用影响。

关键词： 凋落物；有机碳矿化；腾格里沙漠；土壤温度；土壤水分
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0 引言

植被恢复与重建是干旱半干旱区退化土地修复最为有效的途径[1-2]，也是改善土壤水热状况、质地、养分有效性、微生物群落结构组成和酶活性等物理、化学及生物属性的重要手段[3-6]。植被恢复过程中，输入土壤中的凋落物数量和质量不断变化。凋落物的输入和分解是改善和维持土壤生态环境的关键过程，并驱动陆地生态系统和大气碳交换[7]。目前，日益加剧的全球变化对陆地生态系统的初级生产力和物种多样性产生深刻影响，势必改变进入土壤的凋落物数量和种类，最终影响陆地生态系统的碳循环过程和碳库时空格局。

土壤有机碳矿化是土壤碳循环的重要组成部分[8]，是反映土壤质量和土壤有机碳稳定性及周转的关键指标[9-10]。全球每年 CO_2 碳通量的 70%以上来自于土壤有机碳矿化[11]。而陆地生态系统植被生物量最终多以凋落物的形式进入土壤，凋落物分解释放 CO_2 和向土壤中输入有机碳是影响土壤碳矿化的关键因素，凋落物化学性质差异直接影响土壤有机碳矿化分解[12-13]。添加凋落物会显著改变土壤微生物群落、多样性和酶活性及土壤有机碳矿化过程等土壤生理生化属性和过程[13-16]。然而，由于不同类型生态系统的气候、植被和土壤质地等差异以及人类活动等因素的影响，凋落物添加对土壤有机碳矿化的影响存在较大差异，这给准确估算陆地生态系统土壤碳库动态带来很大的不确定性。而且土壤有机碳矿化受微生物调控的过程[17]，对水分、温度和土壤质地等环境的变化异常敏感。因此，针对特定区域或特定气候条件研究优势植物凋落物添加对土壤有机碳矿化过程的影响，对于准确预测陆地生态系统对全球变化的贡献以及土壤碳库的变

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甘肃省会宁县和定西市安定区退耕农户恩格尔系数差异

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摘要： 测度退耕还林农户的恩格尔系数并分析其显著影响因素及差异性，对于完善退耕还林政策、巩固退耕还林成果、改善退耕农户贫困状况具有重要的现实意义。选取位于黄土高原丘陵沟壑区的会宁县和定西市安定区退耕户跟踪数据，基于收入、政策、家庭因素等多个层面构建相关经济指标，揭示两个区域退耕户恩格尔系数呈现的基本特征、显著影响因素及其差异性。结果表明：首先，由于自然地理环境和区位相近，会宁县和安定区退耕户恩格尔系数呈现出较为一致的高位波动趋势，消费需求弹性较弱是主要影响因素；其次，退耕还林户补贴率对会宁县恩格尔系数有显著的负向影响，说明退耕还林政策对当地居民经济生活具有显著影响，安定区退耕还林户补贴率对恩格尔系数有显著的正向影响，主要原因是退耕还林补贴额在家庭收入中所占比重较少；最后，会宁县和安定区农户退耕率对恩格尔系数有显著影响，这意味着退耕户的主要收入来源于农业收入。

关键词： 恩格尔系数；退耕还林；农户
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0 引言

恩格尔系数指食品消费支出与家庭所有生活消费支出的比值。由恩格尔系数进一步衍生出恩格尔定律。恩格尔定律指出，生存需求中最基本的是食品需要，随着收入的增加食品支出占总支出比会不断下降，意味着消费结构的改变与居民生活水平的提高。联合国粮农组织于 20 世纪 70 年代中期将恩格尔系数作为评价国家富有或地区生活水平的重要标准。恩格尔系数是衡量居民生活水平的重要指标，相对于收入和消费指标而言更有综合性[1]。

近年来，中国中央政府非常重视“三农”问题，并取得了良好的政策效果。但是在经济欠发达的西部地区，农村贫困问题相当突出。这一地区的农村贫困率仍在 5%～10%，低收入群体占该地区人口的比例高于 10%[2]。测度居民生活水平的恩格尔系数可以作为测度贫困程度的重要方法[3]。值得关注的是，在西部地区的退耕还林区域，自然环境更加恶劣，农村贫困问题更加突出。统计数据表明，退耕还林农户的人均收入低于相同区域的非退耕还林户。精确测度退耕还林户的贫困程度及其显著影响因素是完善退耕还林政策、巩固退耕还林成果的关键环节。因此，基于恩格尔系数，利用西部地区退耕还林户数据考察农村贫困问题显得更为必要。

目前，国内大量文献主要关注农村居民的恩格尔系数变化情况。总体而言，中国农村恩格尔系数呈现下降趋势。甘健胜等[4]运用分型分析方法对近年来中国恩格尔系数变动情况进行拟合，认为中国居民恩格尔系数下降速度放缓。张哲晰等[5]指出恩格尔系数自 2002 年起降速放缓，并有几年出现不降反增现象，而农村居民恩格尔系数虽降幅大于城镇居民，但始终保持高位。

由于中国区域经济发展水平差异加大，学者们对特定区域如经济欠发达地区的农村居民恩格尔系数更加关注[3,6-10]。多数学者认为中国经济欠发达地区的恩格尔系数亦呈现下降趋势。范贤广[6]指出中国贵州省农村居民恩格尔系数呈逐年下降的趋势。夏热古丽·穆力达坤等[7]以北疆 3 个典型牧区为例，发现 3 个典型牧民定居点在牧民定居后恩格尔系数下降。另有部分学者关注了恩格尔定律具体表现。陈强强等[8]初步测算了甘肃省城乡居民恩格尔系数，认为甘肃省农村居民生活状况

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黄土高原退耕农户生计资本对生计策略的影响
——以甘肃会宁县为例

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摘要: 探索贫困地区退耕农户的生计资本与生计策略关系,对实现精准扶贫、乡村振兴战略具有重要意义。基于甘肃会宁县退耕农户调查数据,构建了具有区域特色的生计资本指标体系,采用熵值法测算生计资本,运用Logistic回归模型探讨了退耕农户生计策略选择问题。结果表明:(1)研究区退耕农户拥有的生计资本中人力资本指数最低,且各生计资本值存在差异;(2)金融资本中的现金收入可以显著增加退耕农户选择非农型生计策略的概率,而自然资本中的平地面积、物质资本中的耐用消费品价值和金融资本中的资金获得渠道会显著降低退耕农户选择非农型生计策略的概率;(3)对于不同退耕程度的农户,现金收入依旧可以显著增加选择非农型生计策略的概率,而抑制两类农户选择非农型生计策略的生计资本指标则存在差异。基于此,提出改善退耕农户的金融资本的多项措施,进而提高农户的非农生计意愿,更好地解决贫困问题。

关键词: 退耕还林;贫困地区;生计策略;生计资本;可持续生计

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0 引言

退耕还林工程是一项兼具生态保护和地区发展的综合项目,在实施过程中,巩固退耕还林成果的目标逐渐演变成为解决生态脆弱区生态恢复及生态协同扶贫[1-3]。中国西部退耕还林地区的自然环境更恶劣,农村贫困问题更加突出,现阶段最迫切需要从根本上找到解决退耕农户生计贫困等经济问题的原因,使退耕农户具有不依赖于自然资源及退耕补贴的可持续生计能力,避免出现返耕现象。因此,研究退耕农户生计资本对生计策略的影响,对提高农户生计水平及巩固退耕还林工程成果具有重要意义。

近年来,国家将生态文明建设放在突出位置,生态与可持续发展的重要性逐渐凸显,生态工程得到迅速发展,以此为背景的可持续研究明显增多[4-7]。这些研究多以生计资本对生计策略影响的角度,来阐释如何构建可持续的生计方式[8-10],并将生计策略作为可持续生计评估的重点内容[11],指出生计策略的多样性能够实现生计的可持续[12-14]。目前国内学者对退耕还林工程可持续性研究主要在生态环境、经济社会等宏观角度,而以退耕农户生计视角对退耕还林工程可持续性的研究较少,特别对于自然环境更为恶劣、农村贫困问题更加突出的西部退耕区的农户生计策略的研究更缺乏。

鉴于此,本文以地处西部黄土高原丘陵沟壑典型生态脆弱区的会宁县为研究对象,依据英国国际发展署的可持续生计框架[15],结合研究区域特征,构建了具有区域特色和针对性的指标评价体系。进一步地,本文将退耕农户的生计策略分为以农业为主和以非农为主两类[12],采用二分类反应变量的Logistic回归模型,结合调查问卷数据及相关统计资料,就如何促进退耕农户以生计资本为资源、生计策略由农业型向非农型转化进行量化分析,甄别影响农户生计策略转化的关键因子,旨在分析出在生态脆弱和生计贫困地区实施退耕还林政策后,参与农户生计资本如何对退耕农户生计非农化及生计可持续性产生影响。这对于完善政策及促进农户生计可持续性具有重要的理论和现实意义。

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人为踩踏生物土壤结皮对土壤酶活性的影响

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摘要: 土壤酶活性是衡量荒漠区生态恢复程度的重要生物学指标。为揭示人为踩踏生物土壤结皮对土壤质量的影响，分别采集腾格里沙漠植被固沙区未踩踏、中度踩踏和重度踩踏结皮下 0~5 cm 和 5~15 cm 土样并测定土壤脲酶、转化酶、过氧化氢酶、脱氢酶、碱性磷酸酶和蛋白酶的活性，通过土壤酶活性反映人为踩踏对荒漠区土壤质量的影响。结果表明: 人为踩踏藻-地衣和藓类结皮可导致土壤脲酶、转化酶、过氧化氢酶、脱氢酶、碱性磷酸酶和蛋白酶活性的降低，且这些土壤酶活性与踩踏程度呈线性负相关。除踩踏程度外，土壤酶活性也受结皮发育阶段和土壤深度的影响; 人为踩踏的藓类结皮下 6 种土壤酶的活性显著高于踩踏藻-地衣结皮($P<0.05$)，表明演替晚期的藓类结皮比早期的藻-地衣结皮具有更强的抗踩踏干扰能力; 踩踏生物土壤结皮下 0~5 cm 土层的土壤酶活性显著高于 5~15 cm 土层($P<0.05$)。此外，无论季节更替，土壤酶活性均表现为未踩踏>中度踩踏>重度踩踏，且踩踏或未踩踏结皮下土壤酶活性均表现明显的季节变化，夏季最高、秋季次之、春季再次之、冬季最低。腾格里沙漠人工植被区和天然植被区人为踩踏生物土壤结皮可降低土壤酶活性，表明踩踏生物土壤结皮可导致土壤质量下降和荒漠生态系统的退化。保护荒漠区的生物土壤结皮将有利于该区土壤及荒漠生态系统的恢复。

关键词: 生物土壤结皮; 人为踩踏; 踩踏程度; 结皮发育阶段; 土壤酶活性

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0 引言

生物土壤结皮是由隐花植物(藻类、地衣和苔藓等)和土壤微生物及其他生物体通过繁殖体和一些代谢物等与土壤表层颗粒胶结在一起形成的非常复杂的复合体。由于高温缺水、土壤营养贫瘠和高 pH 等非生物因子的胁迫，荒漠区地表不可能支撑连续分布的大面积维管束植物群落，这些维管束植物群落呈现斑块状分布，而正是这种分布格局为生物土壤结皮的定殖提供了空间，生物土壤结皮的盖度已占荒漠区地表活体生物面积的 40%以上[1-3]。作为荒漠地区的生态系统“工程师”，生物土壤结皮发挥着提高土壤稳定性、改良土壤理化性状、调节土壤生态水文过程、促进维管束植物种子的萌发、定居和生长及提高土壤生物多样性等多重功能[2,4]。人为踩踏、火烧、车辆碾压等典型的干扰事件已对生物土壤结皮的结构和功能产生了重要的影响，进而影响到土壤性质和整个荒漠生态系统的稳定性[5-8]，中国荒漠区生物土壤结皮可能面临最大干扰事件之一——人类活动(如生产、旅游等)的增加所带来踩踏的干扰，因此，踩踏干扰对生物土壤结皮的影响逐渐成为研究者关注的焦点问题。

土壤酶是土壤中最活跃的有机成分，在水分受限的荒漠地区，主要来自土壤微生物分泌。土壤酶参与土壤有机物质转化的全过程，影响着土壤的生物化学反应，进而影响生态系统的物质循环[9-10]。因而，可用土壤酶活性表征人为踩踏对荒漠区土壤质量的影响。荒漠区生物土壤结皮的定殖能提高土壤酶的活性[11]。那么踩踏干扰生物土壤结皮能否影响土壤酶的活性？而且，这种影响是否因结皮的发育阶段而有所差异？在寒冷沙漠车辆碾压生物土壤结皮可降低结皮中固氮酶的活性，且固氮酶的活性因干扰结皮的发育阶段而有所差异[12-13]；严重踩踏生物土壤结皮可降低腾格里沙漠东南缘植被区土壤碱性磷酸酶、蛋白酶和纤维素酶的活性[14]；人为干扰生物土壤结皮可降低土壤微生物的数量和活

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干旱对解淀粉芽孢杆菌(*Bacillus amyloliquefaciens*) FZB42 生物被膜的形成及根际定殖能力的影响

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摘要: 解淀粉芽孢杆菌(*Bacillus amyloliquefaciens*) FZB42 是一种植物根际促生菌(PGPR),能够促进植物生长,提高植物抵抗病害、干旱和盐胁迫的能力。但关于干旱胁迫下解淀粉芽孢杆菌 FZB42 自身生物被膜形成能力及根际定殖能力的研究鲜见报道。利用 PEG-6000 模拟干旱胁迫,进行渗透势分别为-0.05、-0.50、-1.48、-2.95 MPa 的干旱胁迫处理,测定分析此胁迫条件对解淀粉芽孢杆菌 FZB42 的生长、生物被膜的形成、根际定殖能力以及胞外多糖产量的影响,为进一步阐明解淀粉芽孢杆菌 FZB42 对提高植物的抗干旱能力提供理论依据。结果表明:(1) 高浓度的 PEG-6000 能够显著抑制解淀粉芽孢杆菌 FZB42 的生长、生物被膜的形成及在拟南芥(*Arabidopsis thaliana*) 根际的定殖能力。当添加 15% PEG-6000 时,生物被膜吸光度(OD_{600}) 和根际定殖数量达到最低值,分别为 1.542 和 1 500 cfu·mm^{-1}。(2) 解淀粉芽孢杆菌 FZB42 的胞外多糖分泌量随 PEG-6000 浓度的增加而增加。不添加 PEG-6000 时,胞外多糖含量最低为 150.2 mg·L^{-1}。当添加 15% PEG-6000 时,胞外多糖的产量最高为 568.8 mg·L^{-1}。

关键词: 干旱; 解淀粉芽孢杆菌(*Bacillus amyloliquefaciens*) FZB42; 生物被膜; 根际定殖; 胞外多糖

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0 引言

目前世界范围内干旱区域约占陆地面积的 40%,且仍在不断扩张[1-2]。干旱是限制农业生产力的主要因素,每年在全球范围内造成的经济损失高达千亿美元[3]。干旱胁迫可以引起植物组织脱水,进而引发一系列影响植物正常生长发育的生理生化反应,包括气孔关闭、光合作用降低、呼吸作用增强等[4-6]。因此,如何提高植物对干旱胁迫的耐受性是亟待解决的科学问题。根际促生菌(PGPR)不仅可以促进植物的生长、发育,而且可以通过引发系统诱导性防御机制来提高植物的抗旱能力,如枯草芽孢杆菌(*Bacillus subtilis*)、绿针假单孢菌(*Pseudomonas chlororaphis*)、多粘类芽孢杆菌(*Paenibacillus polymyxa*) 等[7-9]。

生物被膜的形成能提高微生物对各种生物胁迫(抗生素) 及非生物胁迫(干旱、低温、盐等) 的耐受性[10]。在自然环境中,生物被膜通常由胞外多糖、蛋白质及 DNA 组成,并以多细胞聚集的形式存在[11]。如荧光假单孢菌(*Pseudomonas fluorescens*)、农杆菌(*Agrobacterium*)、巴西固氮螺菌(*Azospirillum brasilense*) 等[12-13]。生物被膜的形成不仅是根际促生菌附着并定殖到植物表面的重要因素,而且在根际促生菌促进植物生长、诱导植物抗逆性方面起到重要作用[14-16]。当根际促生菌形成生物被膜并在植物根际定殖后,可以通过提高植物抗氧化物酶活性、可溶性糖含量以及调控脱落酸(ABA)、水杨酸(SA)、茉莉酸(JA) 和乙烯(ET) 等植物激素的含量来提高抗胁迫能力[17-19]。

解淀粉芽孢杆菌(*Bacillus amyloliquefaciens*) FZB42 属于革兰氏阳性菌,能够定殖于植物根际,促进植物生长以及对矿质营养元素的吸收和利用,并产生大量抑制有害微生物的次级代谢产物,提高植物抗胁迫能力[18-19]。

目前关于解淀粉芽孢杆菌 FZB42 提高植物抗性的研究大部分集中于抗生物胁迫,如抗病害能力,对促进植物抗非生物胁迫如干旱胁迫和盐胁迫的研究也有报道,但对干旱胁迫下解淀粉芽孢杆菌

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科尔沁沙地退化植被恢复过程中碳氮化学计量特征的变化①

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摘 要: 为研究沙地退化植被恢复过程中碳氮化学计量特征的变化,分别于2011年、2013年和2015年8月中旬对流动、半固定、固定沙丘和草地进行植被调查,并测定植被—土壤系统的碳氮化学计量特征。结果表明:(1) 随着沙地退化植被的恢复,地上植物、凋落物和根系的C、N含量及C/N比波动变化,土壤(0~10 cm)C和N含量及C/N比显著增加($P<0.05$)。(2) 沙地4种生境上的地上植物、凋落物、根系、土壤的C、N含量及C/N比年际间变化显著($P<0.05$)。(3) 沙地退化植被恢复过程中地上植物、凋落物、土壤的C/N比与物种丰富度呈正线性关系($P<0.01$)。沙地退化植被恢复过程中优势植物演替导致植被—土壤系统中C、N化学计量特征的变化,植被恢复过程中植物的氮素利用效率也在逐渐增强,而封育时间的增加能够促进沙地土壤中N的积累。

关 键 词: C、N含量; C/N比; 退化植被恢复; 恢复年限; 科尔沁沙地

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生态化学计量特征现已成为国际生态学研究的热点问题之一,是度量植物利用养分和土壤养分供给能力的主要指标。近年来,国内外生态学家对生态化学计量学开展了多方面的研究,主要集中在全球气候变化[1]、放牧[2]对生态化学计量特征的影响以及不同生态系统[3-5]、不同研究尺度[6]的碳氮化学计量特征等方面。退化植被恢复过程中,植被—土壤系统的C、N化学计量特征发生明显变化。刘梦云[7]的研究指出,退化植被不同恢复阶段土壤有机碳及总碳存在显著差异,退化植被恢复较大程度上提高了土壤的碳含量。秦海[8]的研究表明,随着退化植被恢复,植物叶片N含量显著增加,植物叶片C/N比变化不显著。近年来,对退化植被恢复过程中C、N化学计量特征的研究主要集中在植被恢复对土壤C、N化学计量特征的影响[9-11]。生态化学计量学不仅在群落的结构以及动态研究[12-14]中具有重要作用,而且在生态系统的养分循环以及供求关系的平衡[15-16]、全球的生物地球化学循环[17]等方面也发挥着重要作用。

近年来,由于人类不合理的活动导致科尔沁沙地的植被遭到严重破坏,进而发生了不同程度的沙漠化[18]。但该地区的水热耦合条件较为良好,同时又具有可观数量的天然种源,随着围栏封育、退耕还草等保护性措施的实施,原有的退化植被逐渐恢复、流动沙丘逐渐固定,沙漠化进程得到有效遏制并呈现出整体逆转的趋势[19]。沙漠化的逆转不仅改变了沙地的植被类型及其群落组成,也影响了土壤的发育、植被与土壤之间的碳氮循环过程及其生态效应。在科尔沁沙地退化植被恢复过程中,有关生态化学计量特征的研究较少,主要集中在植物的C、N、P含量的变化等方面[20-21]。尽管国内外生态学家对生态化学计量学进行了大量的研究,但有关沙漠化地区植被—土壤系统碳氮化学计量特征的时空动态基础数据仍然缺乏。国内学者对植物、根系、土

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固沙植被区土壤质地与土壤微生物数量的关系

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摘要： 土壤微生物是荒漠生态系统的重要组分，参与成土过程与生物地球化学循环，其数量反映土壤质量，是判别退化生态系统恢复程度的重要指标。选取沙坡头固沙植被区土壤中的真菌、细菌、放线菌数量进行研究，分析了其时空分布、恢复特征及影响因子。结果表明：土壤微生物数量随固沙年限增加而增加，随土层深度增加而减少，夏秋季显著大于冬春季。三大类群微生物数量恢复曲线均呈现 S 型，在固沙植被建立 18～24 a 后恢复速率达到峰值，24～36 a 后数量能够达到天然植被区的 31.6%～83.7%。土壤微生物数量恢复过程主要受土壤细物质含量的影响，土壤 pH 是限制因子。土壤微生物对土壤状况与覆被变化敏感，能较早且敏感地指示生态系统功能的变化。

关键词： 固沙植被；微生物数量；恢复；时空格局；通径分析

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0 引言

中国干旱区约占全国陆地面积的 25%，环境严酷、脆弱[1]。荒漠化是该地区主要的环境问题，影响社会经济发展和生态安全[1-2]。植被重建是干旱区生态恢复的主要措施，在干旱沙漠地区得到了广泛应用，也是荒漠化防治的有效方法[2]。在生态恢复过程中，成土环境的改善、生物地球化学循环过程的加强、生物作用特别是根系分泌物及有机残体的积累，使土壤理化性质改善，流动风沙土向地带性土壤方向演替[3]。

土壤微生物作为土壤中的活跃因素，参与土壤有机质分解、腐殖质形成、养分转化和元素循环等土壤形成和改良过程，其种类和数量与土壤的通气性、水分状况、养分状况及有机质含量有密切联系，可以反映土壤的质量状况[4]。土壤微生物的数量和活性反映了土壤质量，可用来判别退化生态系统的恢复程度[5]。近年来，植被重建后生态恢复过程中的土壤微生物数量及活性引起了学者们的广泛关注[6-8]。然而，针对干旱沙区固沙植被建立后的土壤微生物数量恢复研究还存在不足，缺乏微生物恢复如何响应生物和环境因素变化的研究。因此，本研究采用时空互代的方法，研究干旱沙区固沙植被演替过程中土壤微生物数量恢复特征，揭示植被重建对改善土壤生态环境的作用机制，旨在为沙区土壤质量管理与荒漠生态系统的恢复与重建提供科学依据。

1 材料和方法

1.1 研究区概况

研究区位于腾格里沙漠东南缘的宁夏沙坡头地区(37°32′N，105°02′E)，处于草原化荒漠与荒漠化草原过渡带，气候干旱而多风，海拔 1 300 m，年均气温 9.6 ℃，低温极值-25.1 ℃，高温极值 38.1 ℃，年日照时数 3 264.7 h，年降水量 186.4 mm，年蒸发量 3 000 mm，年均风速 2.9 m·s^{-1}，年均沙暴 59 d。自 1956 年起，中国科学院等单位在沙坡头地区铁路沿线设置了“以固为主、固阻结合”的无灌溉人工植被固沙防护带。即在防护带内流动沙丘表面扎设 1 m × 1 m 草方格沙障，选择较适宜的固沙植物栽植在沙障内，并在固沙带的风沙前沿采用立式阻沙栅栏，拦积外来流沙[9]。并于 1964、1981、1987、1990 年扩建人工植被固沙防护带，形成了“绿色走廊”[10]。人工植被建立后经过 50 余年的演变，植物种除了人工种植的灌木柠条(*Caragana korshinskii*)、花棒(*Hedysarum scoparium*)、中间锦鸡儿(*Caragana intermedia*)、沙木蓼(*Atraphaxis bracteata*)、油蒿(*Artemisia*

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腾格里沙漠东南缘植被恢复过程中土壤微生物量及酶活性

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摘要： 土壤微生物量和酶活性是反映土壤功能的关键指标，也是土壤恢复和环境变化的指示器。以流动沙丘为对照，研究了腾格里沙漠东南缘人工固沙植被区表层 0~5、5~10、10~20 cm 土壤微生物量碳氮和酶活性随植被恢复的变化特征。结果显示：土壤微生物碳氮含量和脲酶、多酚氧化酶、碱性磷酸酶、过氧化氢酶、淀粉酶、纤维素酶、蔗糖酶活性均随植被恢复年限延长而增大，随土层深度增加而减小，不同年代植被区及不同土层间差异均显著($P<0.05$)。其中 0~5 cm 土层变化最明显，经过 62 年植被恢复后土壤微生物碳氮量和脲酶、多酚氧化酶、碱性磷酸酶、过氧化氢酶、淀粉酶、纤维素酶、蔗糖酶活性分别增加了 16.44、8.79、3.99、3.01、2.54、19.35、0.77、0.65、16.61 倍，年平均变化速率分别为 1.55、0.21 $mg \cdot kg^{-1}$ 和 6.14×10^{-4}、1.25×10^{-2}、9.32×10^{-4}、6.05×10^{-2}、8.22×10^{-5}、9.07×10^{-5}、$4.24\times10^{-3}mg \cdot g^{-1} \cdot h^{-1}$。土壤微生物量和酶活性与土壤理化性质高度相关，除与沙粒、容重呈负相关关系外，与土壤粉粒、黏粒、pH、电导率、有机碳、无机碳、全氮、碱解氮、速效磷和速效钾含量呈正相关关系。这表明种植旱生灌木能够有效促进沙地土壤功能恢复并改善沙区环境。

关键词： 土壤微生物量；土壤酶；植被恢复；腾格里沙漠

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0 引言

干旱区约占中国陆地总面积的 25%，生态环境严酷脆弱。受气候变化及不合理的土地利用管理的共同影响，该区大部分发生了以荒漠化为主要特征的土地退化[1]。植被恢复与重建是干旱沙区土地荒漠化防治和社会经济可持续发展的有效途径[1-2]。随着植被恢复，土壤碳氮不断积累，理化性质日益改善[2-5]。这一过程引发的土壤理化性质变化被广泛应用于生态恢复效应的评价，但对土壤微生物属性的研究较少[1,6]。土壤微生物量碳氮和酶活性等微生物属性比理化性质更敏感，能有效指示生态系统功能早期的变化[7-8]。土壤微生物量碳氮及酶活性与植被恢复过程中土壤的发育、养分周转及肥力特征密切相关，是土壤功能恢复的关键驱动因素[7-9]。

土壤微生物参与土壤中有机质的分解、腐殖质的形成和土壤养分的转化循环等代谢过程，是土壤有机质中最活跃的组分[9]。土壤酶是土壤有机体的代谢动力，推动土壤中的生物化学过程，其活性可以反映土壤有机质与养分转化的强弱[7-8,10]。多酚氧化酶和过氧化氢酶活性的增加可以改善土壤氧化还原条件[11]，对有机质分解起调节作用[12]；而土壤蔗糖酶、脲酶和磷酸酶活性的增加分别加强了土壤碳、氮和磷的周转[13]。因此，研究土壤微生物量及酶活性对于植被恢复和提高土壤肥力具有重要的生态学意义[7-10]。Cao 等[14] 发现，经过 28 年的植被恢复，土壤养分含量、电导率、净初级生产力及凋落物量显著增加，继而提高了土壤微生物量及酶活性。Zhang 等[15] 研究表明在植被恢复区，土壤过氧化氢酶、脲酶、脱氢酶和蔗糖酶活性显著高于流动沙丘。石万里等[16] 发现植被恢复 31 年后土壤微生物量碳氮显著增加。尽管上述研究报道了植被恢复过程中土壤微生物量或酶活性的变化情况，但长时间序列的研究较缺乏，而这正是揭示植被恢复的长期生态学效应的可靠途径[17]。另一方面，本研究区的原生景观是以草本植物为优势的沙质草地，而旱生灌木是该区植被恢复的过渡阶段[18]，灌木植被是否能有

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沙化草地土壤碳氮磷化学计量特征及其对植被生产力和多样性的影响

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摘要:沙化草地土壤碳(C)、氮(N)、磷(P)化学计量特征及其对植被生产力与多样性的影响对于认识草地沙漠化过程中土壤与植被的互馈关系,以及沙漠化发展的生态学机理具有重要的意义。通过对科尔沁沙地 75 个沙化样地的野外调查,研究了科尔沁沙地不同程度沙化草地的表层土壤 C、N、P 化学计量特征及其与生产力和多样性的相关关系。结果表明:1)科尔沁沙地沙化草地表层土壤具有较低的有机 C、全 N、全 P 含量及 C∶N、N∶P 和 C∶P,平均值分别为 1.39 mg/g、0.117 mg/g、0.079 mg/g 和 7.50、2.22、16.91;草地沙漠化过程中,土壤有机 C、全 N、全 P 含量显著降低的同时,C∶N、N∶P 和 C∶P 亦显著降低,表明土壤有机 C、全 N、全 P 在沙漠化过程中的损失是不同步的;2)科尔沁沙地沙化草地表层土壤有机 C、全 N、全 P 元素间均呈显著正相关,具有一定的耦合关系,且土壤有机 C 和全 P 间的耦合关系不随沙漠化的发展而发生改变;3)草地沙化过程中,土壤养分的损失限制着草地生产力,而土壤 N∶P 较全 N、全 P 含量更能反映土壤养分对生产力的限制作用;4)沙化草地土壤全 N 含量与物种丰富度间具有显著正相关关系,而土壤全 P 含量与其无显著相关性;多样性指数与全 N、全 P 含量间均具有显著正相关关系;相对于土壤全 N、全 P 含量,N∶P 能更好地反映养分平衡对物种多样性的影响作用。

关键词:科尔沁沙地;生态化学计量学;土壤;生产力;物种多样性

Stoichiometry and effects of carbon, nitrogen, and phosphorus in soil of desertified grasslands on community productivity and species diversity

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Abstract: Information on the stoichiometry of carbon(C), nitrogen, (N) and phosphorus (P) in soils and its effects on community productivity and species richness in desertified grassland is essential to understanding the interactive relationship between soil and vegetation in the process of grassland desertification, and reveals the ecological mechanisms of land desertification. In this study, we measured organic C, total N, total P concentrations, and C∶N, N∶P, C∶P in the topsoil of different desertified grasslands in the Horqin sandy land, and statistically analyzed the correlations among C, N, and P stoichiometry, community productivity, and species diversity. The results showed that the concentrations of organic C (1.39 mg/g), total N (0.117 mg/g), and total P (0.079 mg/g), and the C∶N (7.50), N∶P (2.22), and C∶P (16.91) ratios in the topsoil of desertified grasslands remained at relatively low levels in contrast to the results nationwide or worldwide. It

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科尔沁沙地优势固沙灌木叶片氮磷化学计量内稳性

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摘 要 为科学认识科尔沁沙地优势固沙灌木的生态适应性和固沙植被演变规律, 该研究对科尔沁沙地流动沙丘、半固定沙丘、固定沙丘和丘间低地的优势固沙灌木小叶锦鸡儿(*Caragana microphylla*)和盐蒿(*Artemisia halodendron*)进行野外调查, 研究了这两种固沙灌木的叶片氮(N)、磷(P)化学计量特征、灌丛土壤养分状况以及内稳性特征。结果表明: 1)与盐蒿相比, 灌木小叶锦鸡儿具有较高的叶片N含量及N:P, 而P含量仅为盐蒿的1/2; 2)两种优势固沙灌木灌丛下土壤的全N、全P含量及速效N、速效P含量高于该地区土壤的平均水平, 小叶锦鸡儿灌丛下土壤养分含量显著高于盐蒿灌丛下土壤; 3)盐蒿叶片N、P化学计量内稳性指数(*H*)表现为$H_P > H_{N:P} > H_N$, 说明盐蒿更易受土壤N的限制; 小叶锦鸡儿叶片N、P化学计量内稳性指数表现为$H_{N:P} > H_N > H_P$, 意味着小叶锦鸡儿更易受土壤P的限制。在N含量较低的沙化草地, H_N较高的固沙灌木小叶锦鸡儿比盐蒿更具生长优势, 对于该地区生态恢复及保护具有不可替代的作用。然而, 小叶锦鸡儿额外吸收的N, 使其生长过程可能易受P的限制, 因此在沙地恢复过程中应注意土壤P的供应。

关键词 科尔沁沙地; 灌木; 叶片; 土壤; 化学计量内稳性

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Nitrogen and phosphorus stoichiometric homoeostasis in leaves of dominant sand-fixing shrubs in Horqin Sandy Land, China

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Abstract

Aims Sand-fixing shrubs play an irreplaceable role in ecological restoration and eco-environmental protection in arid and semiarid regions of northern China. Determination of the stoichiometric homoeostasis of dominant sand-fixing shrubs along soil nutrient gradients could provide insights into ecological adaptability and pattern of changes of sand-fixing vegetation in Horqin Sandy Land.

Methods We measured N and P concentrations in leaves of two dominant sand-fixing shrubs *Caragana microphylla* and *Artemisia halodendron,* and the total and available N and P concentrations in soils beneath the canopy of each shrub. The differences between the two shrubs in N and P concentrations and N:P of leaves and soils as well as in stoichiometric homoeostasis were examined.

Important findings *Caragana microphylla* had higher leaf N concentration and lower leaf P concentration, thereby higher leaf N:P, than *A. halodendron*. Soils beneath the shrub canopies, regardless of the species, had higher total and available N and P concentrations relative to soils outside the canopy cover. Moreover, the total and available N and P concentrations in soils beneath the *C. microphylla* canopy were higher than that beneath the *A. halodendron* canopy. The stoichiometric homoeostasis indexes (*H*) were ranked in the order of $H_P > H_{N:P} > H_N$ in *A. halodendron* and $H_{N:P} > H_N > H_P$ in *C. microphylla,* respectively, suggesting N limitation in *A. halodendron* and P limitation in *C. microphylla*. Therefore, *Caragana microphylla* could be used as nursing plants in degraded N-limiting soil because of high H_N. However, due to excessive uptake of N, *Caragana microphylla* might suffer from P limitation, and adequate P supply should be considered during the restoration process in sandy land.

Key words Horqin Sandy Land; shrub; leaf; soil; stoichiometric homoeostasis

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沙地玉米水分利用效率日变化特征

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摘要： 以科尔沁沙地玉米农田生态系统为研究对象，利用涡度相关技术和便携式光合作用测定系统(LI-COR6400)同步观测玉米(郑单 958)主要生育期(苗期、拔节期、抽穗期、灌浆期和成熟期)群体和叶片尺度瞬时 CO_2 交换及水汽交换速率，并分析其水分利用效率的日变化特征。结果表明：各生育期玉米群体尺度瞬时 CO_2 交换速率分别为-2.205、-26.113、-26.118、-8.201、-3.672 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$，叶片尺度光合速率分别为 27.57、59.55、24.38、22.03、20.09 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$。各生育期群体水分利用效率($WUE_C$)的日动态呈现“L”型，峰值出现在日出后(约 06:00)，分别为 0.025、0.039、0.088、0.058、0.191 $gCO_2 \cdot g^{-1}H_2O$，叶片尺度瞬时水分利用效率(WUE_L)的日动态呈“~”型，峰值出现在 06:00—10:00，分别为 0.029、0.041、0.017、0.019、0.024 $gCO_2 \cdot g^{-1}H_2O$。玉米各生育期群体及叶片尺度瞬时 CO_2 交换速率和水分利用效率均存在明显差异。

关键词： 玉米；叶片；群体；日动态；瞬时水分利用效率
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0 引言

位于内蒙古东部的科尔沁沙地，是中国北方农牧交错带沙漠化影响最剧烈的区域之一[1-3]，玉米是该区域的重要栽培作物，播种面积占农田总面积的 70%以上[4-5]。玉米是高杆作物，对水分需求量大，水分是其产量的主要限制因素[6]。科尔沁沙地脆弱的生态环境、不平衡的降水以及频繁的人类活动，使得该地区近地面河流、湖泊日渐枯竭，当地农作物生长发育所需水分大部分来源于地下水，造成地下水位逐年下降，再加上不合理的人为利用方式，水资源日渐紧缺，已经成为制约该地区农业发展的主要条件之一[2,6]。如何提高作物的水分利用效率，利用有限的水资源保障较高的作物产量，已经成为节水高效农业的核心问题[7-8]。

在农学领域，作物耗水与干物质生产之间的关系用作物的水分利用效率(WUE)来表示，是评价作物生长状态的综合生理生态重要参数之一[9-10]。根据研究尺度的不同，作物的 WUE 的研究通常分为叶片、群体和产量 3 个水平[10]。关于作物 WUE 的研究，集中在环境因子对作物叶片和产量水平生理生态机制的影响方面[11-14]，对于群体水平的研究由于受到观测方法的限制，多数利用模型模拟的方法来测定[15]。而针对作物群体和叶片水平瞬态 WUE 的平行对比观测研究较少[16-17]。本研究利用 LI-COR6400 便携式光合作用测定仪和涡度相关技术，同步观测了科尔沁沙地夏玉米主要生长期叶片及群体尺度 WUE 的日变化特征，并对净光合速率和 CO_2 通量之间的关系进行了初步的探讨，进行该方面的研究有助于了解作物光合及蒸腾作用的空间尺度效应，对于提高水资源的利用效率和有效的保护当地有限的水资源具有重要的意义。

1 研究区与研究方法

1.1 研究区概况

研究区位于内蒙古通辽市奈曼旗境内，地处科尔沁沙地腹地，依托中国科学院奈曼沙漠化研究站(42°55′N、120°42′E，海拔 345 m)来开展试验，属于温带大陆性半干旱气候，年均气温 6.4 ℃，≥10 ℃

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沙坡头地区地衣和藓类结皮丛枝菌根真菌多样性研究*

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摘 要 丛枝菌根真菌（Arbuscular mycorrhizal fungi, AMF）是自然界分布最广的一类植物共生真菌，可与生物土壤结皮（Biological soil crust, BSC）的隐花植物形成共生体，对荒漠植被的恢复和演替具有重要意义。目前针对不同类型 BSC 的 AMF 群落结构及其多样性研究较少，限制了 AMF 群落对 BSC 发育的作用和对荒漠生态系统贡献的理解。利用高通量测序技术，对腾格里沙漠东南缘沙坡头固沙植被区地衣和藓类结皮及其下层土壤 AMF 群落组成与多样性进行研究，分析不同结皮类型 AMF 群落结构的差异。结果发现，AMF 群落丰富度和多样性表现为：藓类结皮下层土壤>地衣结皮下层土壤>藓类结皮>地衣结皮。地衣和藓类结皮及其下层土壤 AMF 均属于球囊菌门、球囊菌纲，以球囊霉属、类球囊霉属、盾巨孢囊霉属、巨孢囊霉属和一种未分类属为优势，且地衣和藓类结皮 AMF 群落在属水平差异显著。主成分分析结果显示，藓类结皮下层土壤中 AMF 群落物种组成与其他各组有显著差异，表明随着结皮的发育，AMF 群落多样性增加，结皮演替与 AMF 群落多样性之间具有相互促进的作用。

关键词 生物土壤结皮；丛枝菌根真菌；高通量测序技术；群落结构和多样性

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荒漠生态系统是全球陆地生态系统的重要组成部分。在荒漠生态系统中，生物土壤结皮（Biological soil crust, BSC）占荒漠生态系统活体盖度的40%~70%。BSC是指隐花植物与土壤中的细菌、真菌等微小生物通过与土壤颗粒“胶结”形成的荒漠地表的一种生物覆盖体[1] 。作为寒区、旱区严酷荒漠生境地表组成和景观的重要特征[1]，BSC扮演了“生态系统工程师”的重要角色，能够有效地改善地表微生境，对荒漠生态系统的能流、物流、养分循环以及维管束植物的萌发、定居和繁衍等具有重要作用[2] 。

丛枝菌根真菌（Arbuscular mycorrhizal fungi, AMF）是陆地生态系统最重要的土壤微生物之一，能与约80%的陆生高等植物根系形成寄生—共生统一体[3]。AMF从宿主植物获得碳水化合物，同时帮助其吸收水分和养分，促进植物的生长，提高植物对干旱、盐渍、重金属以及极端温度的耐受性[4-5]。AMF主导的菌根共生系统已成为应对全球变化的一种新型生物修复主体[6-7] 。从生物进化的角度看，荒漠植物与AMF建立共生关系是适应水分和资源极度匮乏的荒漠生态系统双赢的重要生存策略[8]。

国内外对于荒漠生态系统AMF群落多样性已经进行了大量研究[9-11]，在荒漠生境中已发现

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Keywords

Semi-Arid Area, Physical and Chemical Properties, Vegetation Construction, Sandy Soil

半干旱沙地蒿类植被建成过程中土壤理化性质变化规律

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摘　要

半干旱区沙地生态恢复是我国生态文明建设的主战场之一，最近几十年来生态恢复成绩显著，但遗憾的是，之前的研究多局限于通过植被覆盖率和物种丰富度等指标反映生态恢复的效果，而忽视了植被恢复演替早期阶段土壤理化性质变化规律的系统研究。本研究选取了典型的半干旱沙地科尔沁沙地和毛乌素沙地生态恢复早期阶段的建群种油蒿－差巴嘎蒿群落，调查了不同发育程度的生物土壤结皮理化性质的变化规律。结果表明：两沙地中土壤随植被建成下理化性质变化规律为：1) 总碳、总氮、含水率和电导率均表现为藓类结皮 > 藻类结皮 > 少量物理结皮 > 流动沙丘；2) 全磷表现为藓类结皮 > 藻类结皮 > 流动沙丘 > 少量物理结皮；3) pH值从流动沙丘到藓类结皮的整个过程中变化不显著。土壤理化性质随土层深度的变化规律为：1) 总氮和总碳的含量变化分别为发育前期：中层和底层 > 表层，发育后期：中层和表层 > 底层；2) 电导率和全磷含量则表现为随着深度的增加而逐渐降低。这些结果为我们理解半干旱沙地植被建成过程中的土壤演化规律提供了重要参考。

关键词

半干旱区，理化性质，植被建成，沙地土壤

1. 引言

植被群落演替是土壤质量条件改善和生态环境恢复的有效途径之一[1] [2]。研究表明，在受干扰条件

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沙地植物幼苗生长对降水和风速变化的响应①

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摘 要： 为研究沙地植物幼苗生长对降水和风速变化的响应过程，于2016年4月中旬利用40个2 m×2 m×2 m的混凝土样方池，通过人工增雨及遮风网降低风速的方法开展模拟控制实验。结果表明：① 风速、降水以及两者的协同作用对萌发物种数无显著影响（$P>0.05$）。风速降低20%和降水增加60%使种子萌发物种数与对照相比分别增加4.9%和1.3%；风速降低20%条件下，自然降水和降水增加60%均可使种子萌发物种数增加7.2%。② 不同降水处理会使植物幼苗密度大幅度降低、高度波动变化；风速降低可以较显著地促进沙地植物幼苗生长高度，特别是优势植物猪毛菜（*Salsola collina*）、大果虫实（*Corispermum macrocarpum*）的生长高度（$P<0.01$）。在自然风速条件下，降水增加30%明显促进猪毛菜幼苗高度生长，降水增加60%则相反；风速降低20%条件下，降水增加60%可以大幅度的促进雾冰黎（*Bassia dasyphylla*）幼苗的生长高度；风速降低40%与降水增加30%和60%的协同作用使雾冰黎、猪毛菜和大果虫实幼苗的生长高度均明显降低。③ 不同风速和降水处理对植被的Simpson优势度指数（D）、香浓－威纳多样性指数（H）、Pielou均匀度指数（J）无显著影响（$P>0.05$）。以上研究结果表明：降水增加30%对种子萌发阶段物种丰富度的抑制作用较大；与降水相比，风速是沙地植物幼苗生长高度的主要影响因素，并且自然降水条件下，风速降低40%可以使沙地植物幼苗生长高度最大限度地增加；沙地植被物种多样性指数对降水及风速的变化不敏感，这说明科尔沁沙地生态系统群落结构相对较为稳定。

关键词： 沙地植物；降水；风速；幼苗生长；科尔沁沙地

在干旱与半干旱地区，水是限制植物定居、生存和生长的关键因子[1-2]。降水是干旱、半干旱生态系统重要的水分来源，是不同时空尺度各种生物过程的重要驱动因子[3]，同时也是沙地植物正常生长和退化植被恢复重建的重要限制因子。降雨量对沙地植物生长和生物量有显著影响[4]，可直接影响植被的分布格局[5]，并且降雨量及降水时间分布对沙地植物定殖、生长以及物种结构组成有至关重要的作用[6]。降水减少促进植物成熟，减少干物质积累；降水增加能为植物提供充足的水源，有利于植物营养生长和植被生产力的提高。风是影响植物生长的一个重要的环境因子[7]，而且对植物生长的影响较其他因子复杂。风对植物生长有直接和间接作用[8]，直接作用是指风对植物的机械刺激影响植物的生理活动，间接作用则是指风引起叶环境（湿度、温度、气体浓度等）发生变化而产生的作用。风对植物生长、发育和繁衍的整个过程都有重要影响[9]。随着全球及区域气候变化的日益加剧，气候暖干化趋势明显[10]，而且全球范围内平均风速有下降趋势[11]，特别是在我国北方干旱、半干旱地区。降水格局的改变会影响植物生长、改变种间关系[12-13]，同时降水、风速变化会对这些地区植被资源的稳定和可持续发展利用产生重要的影响[14]。近年来，关于不同生态因子（单因子水平、双因子协同水平）对植物生长特征和生理特性等方面的研究成果较多。在干旱、半干旱区域的沙地生态系统中，种子萌发的时间和地点对于植物的定居和存活具有关键作用。朱选伟等[15]在研究中指出，小叶锦鸡儿

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直插式地下滴灌土壤湿润体特征值变化规律及灌溉效果分析

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摘 要：【目的】了解2种典型干旱区土壤（砂土、砂黏土）中直插式地下滴灌的灌水效果。【方法】以实测的土壤湿润锋在垂直向上、向下和水平3个方向的运移距离为基础，建立了土壤湿润锋运移距离与直插式地下滴灌滴头流速和灌水时间之间的函数关系，依据此量化关系结合土壤含水率求得了直插式地下滴灌的微灌技术参数，并评价了直插式地下滴灌在干旱区砂土、砂黏土中的灌水效果。【结果】在2种土质条件下，湿润锋不同方向上的运移距离与滴头流速和灌水时间之间的量化关系式R^2＞0.95，验证方程R^2＞0.95，表明模型可行；在砂土中，灌溉水储存系数、灌水均匀系数及土壤湿润比均小于0.6，而在砂黏土中均高于0.8，表明直插式地下滴灌在砂土中灌水效果比砂黏土差。【结论】幂函数可准确描述砂土、砂黏土中直插式地下滴灌湿润峰运移距离、滴头出流速度和灌水时间之间的关系；垂直向上湿润距离与滴头流速负相关，与灌水时间正相关，水平与向下湿润距离与流速、灌水时间均正相关；在本试验条件下，流速为1.25 L/h灌水效果最好。

关 键 词：干旱区；直插式地下滴灌；湿润体；湿润锋；运移距离；微灌技术参数
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0 引 言

地下滴灌是一种高效节水灌溉技术[1]，与其他灌溉方法相比，地下灌溉具有节水增产、性能稳定、耐用、水分利用效率高等显著优点[2-4]，但存在检修困难、施工复杂、渗水管易堵塞、灌水均匀性差等诸多不足[5-7]。因此，许多学者提出了新的地下灌溉技术，如陈新明等[8]提出的无压滴灌，孙三民等[9]针对稀植作物提出的间接地下滴灌等。直插式地下滴灌[10]，是地下滴灌的一种，与竖管地下灌溉[11]类似，其原理是将直插式地下滴灌滴头垂直置入一定深度的土壤中，上端连接供水管，通过滴头边壁或底端出水[12]，以实现土壤的越层灌溉。该滴头对比其他地下滴灌滴头在达到优良灌水效果的同时结构简单、布设方便、防堵塞，更适合应用于灌溉果树等多年生深根疏植型作物[13-15]。但新技术往往意味着新的灌溉系统设计参数，因此基于土壤湿润体特征值[16-20]、土壤水分入渗特性[11]以及土壤水分运动模型[17,21-22]等方面的研究对新型地下滴灌技术的推广应用意义重大。湿润体特征值，即土壤湿润体体积、水平与垂直方向湿润锋运移的最大距离，是微灌系统设计的重要依据之一[2]。近年来，对湿润体特征值的研究集中在数值模拟[17,23-25]、试验验证[12,26]等方面，并在研究中均将土壤湿润体近似为规则形状进行数值模拟，如球体[3]、圆柱体[17]、椭球体[20]等，但实际应用中由于土壤质地等原因湿润体不规则并呈上小下大[27]，因此如何精确计算地下滴灌土壤湿润体特征值，并掌握其变化规律成了亟待解决的问题。

为了将地下滴灌技术进一步推广应用，研究人员以枣树[9]、棉花[26]、葡萄[27]等作物为研究对象开展了大量

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科尔沁沙地封育恢复过程中植物群落特征变化及影响因素

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摘 要 封育是退化沙地植被恢复与生态重建的重要措施, 理解长期处于封育状态下不同类型沙地植物群落特征变化及其影响因素有利于沙地植被恢复和生态重建。该文基于对科尔沁沙地长期封育的流动沙丘(2005年封育)、固定沙丘(1985年封育)和沙质草地(1997年封育)连续多年(2005–2017年)的植物群落调查, 结合土壤种子库、土壤养分以及气象数据, 分析了植物群落特征变化及其对环境变化的响应。研究结果表明流动沙丘植被盖度显著增加, 群落生物量和物种多样性年际间波动变化, 但无明显趋势; 固定沙丘植物群落存在逆行演替趋势, 具体表现为群落生物量、灌木和半灌木以及豆科优势度显著下降, 而一年生和多年生杂类草优势度显著增加; 沙质草地群落物种丰富度和多年生禾草优势度存在降低趋势, 并且一年生杂类草优势度明显高于其他功能群, 群落存在退化现象。3类沙地土壤种子密度变化不显著, 而种子丰富度在流动沙丘显著增加, 在固定沙丘和沙质草地有下降趋势, 土壤养分仅有有效氮和有效磷含量增加。回归分析结果表明气温和降水是影响年内生物量积累的主要因素, 但对年际间群落生物量和物种丰富度变化影响不大。除趋势对应分析结果显示土壤种子库与植物群落之间存在很高的相似性, 典型相关分析结果表明沙质草地植物群落与土壤养分紧密相关, 而固定沙丘群落主要与土壤水分紧密相关。综合以上结果可知, 封育33年的固定沙丘群落和封育21年的沙质草地群落都存在退化现象, 而封育11年的流动沙丘群落正在缓慢恢复, 因此封育年限的设定对退化沙地植被恢复至关重要, 封育时间过长不仅不利于植物群落恢复, 反而会使群落发生逆行演替, 建议封育年限的设定应综合考虑植被退化程度、土壤养分状况、土壤种子库基础以及气候条件等因素的影响。

关键词 沙地; 封育; 植被恢复; 群落特征; 影响因素

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How enclosure influences restored plant community changes of different initial types in Horqin Sandy Land

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Abstract

Aims Enclosure is one of the important measures for vegetation restoration of degraded sandy land. Understanding the plant community change of different initial types in long-term state of enclosing is vital for us to understand the vegetation restoration process or re-vegetation in sandy land. This paper aims to analyze the changes of plant communities and its comparative responses to long-term enclosure (2005–2017) of mobile dunes (enclosed in 2005), fixed dunes (enclosed in 1985) and sandy grassland (enclosed in 1997), in relation to soil seed bank, soil nutrient and precipitation and air temperature.

Methods The species composition, height, coverage and above-ground biomass were measured by quadrats in

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不同植被盖度沙质草地生长季土壤水分动态

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摘要： 水分是干旱半干旱沙地生态系统最大的限制因子，研究植被盖度和土壤水分之间的关系有助于沙地生态恢复和保护。基于生长季科尔沁沙质草地不同植被盖度下土壤水分动态和降水的观测试验，分析了沙质草地植被盖度和土壤水分的耦合关系。结果表明：在土壤剖面上土壤水分存在明显的分层结构，依次为水分剧变层(0~40 cm)、缓变层(40~100 cm)和稳定层(100~180 cm)；植被盖度对土壤水分有很大影响，不同植被盖度下土壤含水量存在显著差异，土壤水分与盖度之间呈倒“V”型关系，土壤水分状况在28%的盖度下最优；不同的植被盖度下土壤水分对降水的响应也存在差异，在13%盖度下响应最敏感，28%和46%的盖度下响应微弱，后二者的土壤水分也相对稳定。在沙地生态恢复建设过程中合理的植被盖度配置可提高降水利用效率，并能使土壤水分和植被达到一种良好的平衡状态，从而有利于生态系统的稳定。

关键词： 沙质草地；植被盖度；土壤水分；动态特征

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0 引言

沙地生态系统是干旱半干旱地区的主要生态系统类型，具有对气候变化敏感、生产力年际波动大的特点，对维持区域生态系统的稳定性至关重要[1]。在干旱半干旱沙地生态系统中，水分是最主要的限制因子，主导着许多生态水文过程，其中土壤水是沙地生态系统运转的核心，推动着土壤-植被-大气连续体中物质的流动和循环，直接影响根系对土壤水分和养分的吸收，在很大程度上决定着生态系统中植被的物种组成、形态结构和生理特性，对沙地土壤的发生、演化和土地生产力也起着关键作用[2-4]。土壤水分是将气候、土壤和植被对水文过程的影响与水文过程对植被格局的动态影响综合起来的关键因子，综合反映了生态系统的水文过程和生态过程，更是沙地生态系统中生态过程和水文过程的核心。深入了解沙地生态系统与土壤水分关系和相互作用机理，对理解草地生态系统与土壤水分之间的耦合关系具有重要的科学意义[5]。

土壤水分的动态变化除了受沙土矿物、机械组成、地形、地下水、气温及降水等环境因素的影响，也与地表植被覆盖变化关系密切[6-9]。大尺度上关于地表覆盖变化的研究表明，土地利用覆盖变化导致的水热传输变化是影响区域气候变化的重要因素[10]。在流域尺度上的研究表明，流域特性微小的改变会引起径流很大的变化，其中植被盖度的变化是影响流域径流变化的关键因素[11-12]；植被和土壤水分关系的回归模型分析也表明，植被盖度和叶面积指数对水分剧变层土壤水分的变化有很高的贡献率[13]。在小区域尺度上植被影响土壤水分平衡关系，由于植物生长过程中耗水量的差异，在不同的土壤水分条件下要求不同的植被覆盖率，反过来不同植被覆盖导致不同的土壤水分平衡关系[6,14]；小区域尺度上植被覆盖的变化对土壤水分格局也有一定的影响，如植被重建增强了沙地土壤水分的水平和垂直格局的异质性[15]。另外，沙地植物种类、地下水埋深及固沙植物的生长状况也对土壤水有显著的影响，如地下水埋深和植被生态型的分布之间存在

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王新源,连杰,杨小鹏,赵学勇,王小军,马仲武, 龚丞嵩,曲浩,王彬.玛曲县植被覆被变化及其对环境要素的响应.生态学报,2019,39(3):923-935.
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玛曲县植被覆被变化及其对环境要素的响应

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摘要:植被覆被变化是气象要素和人类活动综合作用的结果,能够反映区域内生态系统的演替趋势。玛曲高寒生态区作为黄河上游重要的水源涵养和补给区,具有维持区域生物多样性和生态安全,保障经济社会健康发展的重要作用,因此厘清该区域植被变化与气候及人类活动等环境要素的相互关系有助于为玛曲县生态治理与恢复提供科学参考。鉴于此,以 2000—2015 年 MODIS/NDVI 数据为基础,结合同期气象与人类活动数据,应用趋势分析法、相关分析以及通径分析等方法,分析了玛曲县植被 NDVI 的时空变化规律,并详细探讨了气象要素和人类活动对植被覆被变化的影响。结果表明:(1)2000—2015 年玛曲县 NDVI 呈波动上升趋势,上升速率为 0.01015/10a;各土地利用/覆被类型中,增加幅度由大到小依次为高山稀疏植被、湿地、沙化草甸、山地疏林地、高寒草甸、亚高山硬叶灌丛、亚高山阔叶灌丛和高寒草原; 增加面积占相应地类总面积比例由大到小分别是高山稀疏植被(75.57%)、山地疏林地(71.45%)、沙化草甸(71.18%)、湿地(70.66%)、高寒草甸(68.15%)、亚高山硬叶灌丛(66.96%)、亚高山阔叶灌丛(66.24%)和高寒草原(66.05%);(2)气象要素中,气温与 NDVI 间具有显著正相关($P<0.05$),是影响植被覆被的决定性因子,利于植被的生长与发育;降水与 NDVI 间相关不显著($P>0.05$),对植被覆被的影响较小;(3)人类活动要素中,与放牧强度密切相关的大牲畜存栏数和羊存栏数是植被生长的主控因子,其中大牲畜存栏数呈显著的抑制作用($P<0.05$),羊存栏数具有较强的促进作用($P<0.05$);(4)通径分析发现,气温、大牲畜存栏数和羊存栏数的决定系数依次为 0.3005,-0.0563 和 0.0128,说明气温对 NDVI 的综合作用强度最高、大牲畜存栏数次之,羊存栏数最低;此外,剩余通径系数为 0.53。该数值较大,表明仍有部分对 NDVI 增加存在影响的环境要素未考虑到,需在今后的研究中给予关注。

关键词:MODIS/NDVI;玛曲县;气象要素;人类活动要素;通径分析

Variation in vegetation and its response to environmental factors in Maqu County

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Abstract: Change in vegetation coverage, which can reflect the direction of regional succession in ecosystems, is the result of the combined action of meteorological factors and human activities. As an important water conservation and recharge area in the upper reaches of the Yellow River, the alpine ecological zone of Maqu County plays an important role in maintaining regional biodiversity and ecological security, and also in ensuring the healthy development of human economy and society. Clarification of the relationships among vegetation change and climatic conditions and human activities or other environmental factors in this region would thus make an important contribution to ecological management and restoration in

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王旭洋，李玉强，连杰，等. CENTURY 模型在不同生态系统的土壤有机碳动态预测研究进展. 草业学报，2019，28(2)：179－189.
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CENTURY 模型在不同生态系统的土壤有机碳动态预测研究进展

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摘要：CENTURY 模型是国际上著名的生物地球化学模型之一。本研究系统介绍了 CENTURY 模型的运行机理及过程，分析和总结该模型在草地、农田、森林生态系统中土壤有机碳(SOC)的研究成果，并归纳了影响其模拟精度的主要因素。结果表明，土壤质地和土壤养分是影响 CENTURY 模型在草地生态系统应用的关键因素，且该模型在荒漠草原生态系统的适应性较高；不同农业管理模式是影响 SOC 模拟精度的因素之一，间作农业模式下模拟 SOC 的精度较高；CENTURY 模拟森林生态系统的枯枝落叶层的有机质时存在结构缺陷，这导致 CENTURY 模型在草地和农田系统的模拟效果优于森林生态系统。由于 CENTURY 模型最初是基于草地生态系统而开发，其模型参数在不同地域的草地生态系统的普适性较高；过多的人为干预增加了 CENTURY 模型在农田生态系统模拟的不确定性，从而会出现模拟结果不稳定的现象；通过调查掌握详细的农田历史管理制度和方式，准确控制模拟进程，可以有效提高模拟精度；森林生态系统的模拟结果可以服务于管理措施的制定，CENTURY 模型结合 GIS 可以实现单点模拟向区域模拟的转变。

关键词：CENTURY 模型；土壤有机碳；生态系统

*Progress in application of the CENTURY model for prediction of soil carbon levels in different ecosystems

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Abstract: The CENTURY model, designed to predict soil C, N, P, and S dynamics in a range of ecosystems, is one of the most famous biogeochemical models in the world. The research reported here systematically examines the operating mechanisms and processes of the CENTURY model, and research data on results of soil organic carbon were analyzed and collated for grassland, farmland and forest ecosystems using this model. It was found that soil texture and soil nutrient levels are key factors influencing the application of the CENTURY model in grassland ecosystems, and that the model has high predictive accuracy in desert grassland. Agricultural management is one of the factors most strongly affecting soil organic carbon (SOC) simulation accuracy. The SOC simulation accuracy was higher in intercrop systems than in monocrop scenarios. CENTURY had structural defects in simulating soil organic matter in the litter layer of forest ecosystems; hence the CENTURY model

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荒漠土壤微生物量碳、氮变化特征对降水的响应研究

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摘要:以腾格里沙漠东南缘的典型荒漠植被为研究对象,通过遮雨棚和滴灌系统设置 5 个降水梯度,即极端干旱处理、中度干旱处理、对照、增水处理 I 和增水处理 II,研究了荒漠土壤微生物量碳(MBC)、氮(MBN)和微生物碳氮比(MBC/MBN)对季节、降水和土壤深度的响应规律,以期为极端降水事件影响干旱荒漠区土壤微生物量碳、氮及其循环规律的深入研究提供科学依据。结果表明:(1)MBC、MBN 和 MBC/MBN 对降水处理的响应存在差异,三者的变化范围为:230.14—272.87 mg/kg,13.82—17.58 mg/kg,19.78—36.06。其中,降水处理对 MBC、MBN 的影响显著,对 MBC/MBN 的影响不显著,在极端干旱处理下,MBC、MBN 均显著高于其他降水处理;(2)两年间的 MBC、MBN 和 MBC/MBN 差异显著,2017 年较 2016 年 MBC、MNB 显著减少,MBC/MBN 显著增加;(3)MBC、MBN 和 MBC/MBN 变化均表现季节性差异,变化范围分别为:153.31—337.09 mg/kg,7.89—22.29 mg/kg,14.82—46.04,其中 MBC、MBN 为春季最高、秋季最低,MBC/MBN 为夏季最低、冬季最高;(4)MBC、MBN 和 MBC/MBN 在土壤 0—20 cm 的变化范围为:232.57—265.15 mg/kg,14.00—17.93 mg/kg,24.37—32.07,其中土壤表层(0—5 cm)MBC、MBN 显著高于中层土壤(5—10 cm)和下层土壤(10—20 cm),而不同土壤深度的 MBC/MBN 差异不显著。因此,在极端降水事件频发的全球气候背景下,极端干旱将影响荒漠生态系统 MBC、MBN 水平,进而对碳、氮平衡和循环过程产生影响,对这一问题的确切回答尚需长期系统监测研究。

关键词:荒漠土壤;微生物量;季节变化;极端干旱;碳、氮循环

Response of changes of microbial biomass carbon and nitrogen to precipitation in desert soil

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Abstract: The change of global precipitation pattern has a great impact on the arid ecosystem. As an indicator of change of soil quality, soil microbes could reflect the material circulation ability, soil fertility, and plant productivity of the ecosystem. Soil microbial biomass carbon (MBC) and nitrogen (MBN) were very sensitive to precipitation changes. The typical desert vegetation on the southeast edge of Tengger Desert was selected as research object in this study. We aimed to provide the scientific basis for further study of microbial carbon and nitrogen and their cycling mechanism in desert ecosystem in the context of global climate change with extreme precipitation events. By using rain shelter and drip systems, five precipitation

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杨红玲,李玉霖,宁志英,张子谦.添加混合凋落物对沙丘草地土壤有机碳矿化的影响.生态学报,2019,39(7):2510-2519.
Yang H L, Li Y L, Ning Z Y, Zhang Z Q.Effects of mixed litter on organic carbon mineralization in a dune grassland.Acta Ecologica Sinica,2019,39(7):2510-2519.

添加混合凋落物对沙丘草地土壤有机碳矿化的影响

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摘要:土壤有机碳矿化是调节温室气体排放、土壤有机质形成以及土壤生物和植物营养供应的重要过程,植物残体分解释放 CO_2 对土壤有机碳矿化有着重要影响。通过对科尔沁沙地沙丘草地 4 种优势植物叶凋落物的混合培养试验,测定了凋落物培养过程中 CO_2 释放速率及其累积释放量,比较了混合凋落物 CO_2 释放量实测值与预测值的差异,分析了凋落物化学成分和物种多样性(包括物种丰富度和物种组成)与土壤有机碳矿化的相关关系,以期解释添加混合凋落物对土壤有机碳矿化的影响。结果表明,混合凋落物物种丰富度对土壤有机碳矿化的影响不显著,而凋落物一些化学性质与土壤有机碳矿化紧密相关;所有混合组合处理中,80%的凋落物组合处理对土壤有机碳矿化产生显著($P<0.05$)的非加和效应;氮含量较高的豆科植物达乌里胡枝子凋落物与禾本科植物凋落物混合后土壤有机碳矿化表现极显著($P<0.001$)的协同非加和效应,而禾本科植物凋落物交互混合后土壤有机碳矿化产生显著拮抗非加和效应,这可能是凋落物化学成分相似或凋落物叶片的空间异质性引起的。

关键词:外源有机物;凋落物化学成分;物种多样性;非加和效应

Effects of mixed litter on organic carbon mineralization in a dune grassland

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Abstract: The mineralization of organic carbon in soil is an important process that regulates greenhouse gas emissions, soil organic matter formation, and nutrient availability for soil biota and plants. The decomposition and release of CO_2 from plant residue are important processes that affect soil organic carbon mineralization, and many studies have explored the changes in soil organic carbon following litter addition; however, these studies focus on the effects of single type of litter addition and failed to consider the effects of mixed litter. In both natural and managed ecosystems, plant litter, with different chemical compositions, generally become mixed by the influence of wind, water, or humans, and animals influence the degradation process of organic matter in the soil. Hence, examining the effects of the chemical traits of litter mixtures and litter species diversity on the mineralization of soil organic carbon is of considerable importance. In this study, litters of typical plants *Setaria viridis*, *Phragmites communis* Trin, *Cleistogenes squarrosa*, *Lespedeza davurica*, and sandy soil from the Horqin dune grassland was collected and incubated in a laboratory for 95 days. In order to explain the effects of mixed-species litter on soil organic carbon mineralization, four single litter species and their mixtures, consisting of all possible 2-, 3- and 4-species combinations, were added to soil in jars. We described the dynamics of organic carbon mineralization rates and calculated the cumulative release of CO_2 for all treatments and the difference between measured and predicted effects for the litter mixture. We also explored the effects of chemical traits and species diversity on soil organic carbon mineralization. The

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科尔沁沙地优势固沙灌木叶片凋落物分解的主场效应

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摘要： 在气候变化和人类活动的影响下，科尔沁沙质草地中灌木植物种增加，导致沙质草地逐渐向灌木地转变。选取该地区优势固沙灌木差不嘎蒿(*Artemisia halodendron*)和小叶锦鸡儿叶(*Caragana microphylla*)凋落物及其混合凋落物开展交互移置培养试验，分析了培养过程中 CO_2 释放和干物质损失量以及混合凋落物 CO_2 释放量实测值与预测值的差异，辨析主场效应产生的原因及其驱动机制，以期为将主场效应纳入到凋落物分解模型提供理论基础。结果表明：与高质量的小叶锦鸡儿叶凋落物相比，质量较低的差不嘎蒿叶凋落物分解具有更强的主场效应；其次，引起叶凋落物分解的主场效应归因于土壤微生物的特化作用，而不是土壤动物的搬运或贮藏行为。此外，混合凋落物主场效应与其分解生境中长期输入的凋落物的质量相似性紧密相关，质量相似性越大，主场效应越强，这也是本研究中混合凋落物分解在差不嘎蒿灌丛土壤下具有较强主场效应的原因。

关键词： 科尔沁沙地；灌丛；凋落物质量；土壤生物；混合凋落物

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0 引言

自然生态系统中，植被净初级生产量的绝大部分最终通过凋落物的形式回归到生态系统。凋落物作为植被和土壤之间的一个重要通量，其矿化过程是生态系统碳素周转和矿质养分循环的重要过程[1-2]。由于微生境中土壤温度、水分和土壤微生物以及凋落物自身化学性质等的差异[3-7]，不同植物种凋落物分解速率存在明显差异[8]。生物地球化学模型能够很好地模拟凋落物分解过程并且可以解释 70%的分解变异，但是剩余 30%的分解变化仍然存在争议[7]，不同物种凋落物之间的相互作用、UV 辐射及土壤微生物多样性等都可能发挥作用。Ayres 等[2]认为，主场效应是控制凋落物矿化分解过程的第二因子(凋落物质量和环境因子是第一因子)，可影响凋落物分解模型模拟精度的 10%。自此，凋落物分解主场效应引起越来越多学者的广泛关注。

据统计，在 35 个关于主场效应的研究中，77%的叶凋落物在主场比在客场分解快，主场效应强度均值达到 8%[3]。实际上凋落物分解的主场效应并不一定总是表现为正效应，有研究发现草本和乔木之间会产生负效应，而混合凋落物之间存在零主场效应，这与土壤微生物、凋落物质量和环境因素等有关。土壤微生物对同生境植被凋落物的特化作用是凋落物分解主场效应产生的根本原因[4]。不同生境中植物叶凋落物质量(N、木质素、C/N、木质素/N)差异显著[4]，导致土壤生物多样性也存在差异。土壤生物在分解凋落物的同时从中吸取养分和能量，因此土壤生物之间存在着对这些养分的竞争关系，使土壤微生物特化而专门分解源于同生境植被的凋落物，产生主场效应[5]。然而，如果土壤微生物丰度较低或者殖民化一个立地时，土壤微生物群落可能会根据凋落物质量迅速调整组成及丰度，表现出比较弱的主场效应。细菌的短暂世代间隔和真菌菌丝的快速增生能力，都有助于土壤微生物群落组成的调节[6]，削弱主场效应。凋落物质量较低是主场效应产生的必要条件，高质量凋落物含有较多的易分解物质，大多数土壤生物群落都包含可降解这些易分解物质的微生物，所以主场效应强度很小；而低质量凋落物往往含有大量高抗性或有毒成分，很少有土壤群落含有可以快速降解这些抗性组分的

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植被盖度对沙丘风沙流结构及风蚀量的影响

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摘要： 以科尔沁沙地不同植被盖度沙丘为研究对象，采用野外可移动风洞进行原位测试，开展了沙丘植被盖度对风沙流输沙率影响的研究，探讨了地表风蚀量与风速及植被盖度的关系。结果表明：空气动力学粗糙度随植被盖度增加先平缓后剧烈，与植被盖度相关关系呈三次函数增长。在各植被盖度下各层输沙率均随高度增加而递减，随风速增加而递增。同一植被盖度下风蚀量随风速增加而增大，符合幂函数或二次函数关系，但二次函数相关性更高。同一风速下风蚀量随植被盖度的增加呈阶梯式降低，在盖度小于 27%时风蚀量平缓下降，盖度 27%～43%时风蚀量急剧下降，盖度 43%以上时风蚀量下降重新趋于平缓。相对截留率随风速增大而减小，随植被盖度增加而增大，沙丘草本植被盖度 43%以上时具有较好的防风固沙效果，此时平均截留率达 88.02%。

关键词： 沙丘；植被盖度；风蚀；可移动风洞
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0 引言

土壤风蚀是地表土壤颗粒在风力作用下运移的过程[1]，已成为影响全球一百多个国家和地区 9 亿多人口的严重环境问题[2]，影响面积达全球陆地表面积的 1/4[3]，中国受风蚀影响土地超过国土面积的一半[4]。风蚀是造成干旱半干旱区农田土壤沙化、草地荒漠化进程加剧的主要原因[5]。科尔沁沙地处于中国北方农牧交错带，生态环境脆弱，风蚀形成了大面积沙漠化农田[6-7]，防风固沙对该区农业生产与环境保护有重要意义。

土壤风蚀受植被状况、土壤特性、气温、降水条件及人类活动等多因素影响[8]。植被盖度作为反映植物生长状况和生态系统变化的重要指示因子，被广泛运用在各种风蚀预报模型中[9-12]。20 世纪 80 年代以来，Wasson 等[13]、Buckley[14]分别通过野外实地观测及室内风洞实验，初步建立了植被盖度与输沙率的定量关系；董治宝等[15-16]通过室内风洞模拟研究了植被盖度、密度、排列方式等对土壤风蚀的影响，发现风蚀率随植被盖度的减少呈指数增加；黄富祥等[17]通过对毛乌素沙地不同植被盖度的风蚀观测，确立了 40%～50%的有效植被盖度；赵永来等[18]、陈智等[19]研究了作物残茬及不同耕作模式对农田土壤风蚀的影响；刘艳萍等[20]、邢恩德等[21]通过风洞试验模拟了草原区不同植被盖度对土壤风蚀的影响，发现风速与总输沙率呈幂函数关系。目前，有关不同类型沙丘风沙流的研究已较为丰富，但对沙丘风沙流与植被盖度的定量关系研究甚少。本研究以草木枯萎、风沙频繁的春季为研究时段，在科尔沁沙地应用可移动式风洞对不同植被盖度沙丘地表风蚀特征进行原位观测，分析不同植被盖度下风沙流输沙率与高度及风速的变化规律，探讨植被盖度对沙丘风沙流结构及风蚀量影响机理，为干旱半干旱地区沙丘地表风蚀防治提供理论依据。

1 研究区域概况与研究方法

1.1 研究区概况

研究区位于科尔沁沙地中南部的内蒙古通辽市奈曼旗境内(42°55′N、120°41′E，海拔 358 m)，该区属于温带半干旱大陆性季风气候。年均日照时数

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内蒙古典型草原与荒漠草原 *NDVI* 对气象因子的响应

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摘要：分析了内蒙古典型草原与荒漠草原 *NDVI* 的变化，探讨了干旱对 *NDVI* 的影响，建立了 *NDVI* 与气象因子的回归模型。结果表明：2000—2016 年内蒙古典型草原与荒漠草原 *NDVI* 呈现波动变化，变异较小。干旱对典型草原区的羊草(*Leymus chinensis*)群落与大针茅(*Stipa grandis*)群落 *NDVI* 影响显著($P<0.05$)；与正常年份相比，干旱导致羊草群落与大针茅群落 *NDVI* 降低约 23%。5—8 月降水量和干燥度指数影响内蒙古典型草原羊草群落与大针茅群落 *NDVI*；荒漠草原区羊草+短花针茅(*Stipa breviflora*)群落与沙生针茅(*Stipa plareosa*)群落 *NDVI* 的主要影响因子分别为年均气温与 5—8 月平均气温；5—8 月降水量和年均气温是影响典型草原和荒漠草原 *NDVI* 的重要因子。基于气象因子的 *NDVI* 回归模型能够较好地对区域 *NDVI* 进行估测。生长季降水是影响典型草原 *NDVI* 的关键因素，而气温显著影响荒漠草原 *NDVI*。在未来气候变化的背景下，内蒙古典型草原 *NDVI* 对干旱的响应会更加敏感。

关键词：*NDVI*；逐步回归分析；气象因子；典型草原；荒漠草原
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0 引言

气候变化影响陆地生态系统生产力[1]，主要表现为改变草原生态系统植物群落的结构、组成与生物量及植被的空间格局[2]，对人类生存与区域可持续发展产生深远的影响[3]。植被变化的主要影响因素为气温和降水，而气温与降水对植被的影响因植被类型与环境等变化而表现出较大的空间异质性[4]。美国北方草地和内蒙古荒漠草原植被生产力与年降水量间存在显著的相关性[5-6]，而中国北方植被生产力与气温的相关关系高于降水[7]。内蒙古典型草原大针茅(*Stipa grandis*)群落地上生物量与年降水、月降水、关键时期降水及 1—7 月降水量没有显著的相关性[8]。中国北方草地生产力受降水限制，而地下生产力与温度间的负相关关系可能与生长季高温影响土壤水分进而制约根系生长有关[9]。虽然水分是制约干旱与半干旱地区植被生长的重要因子[10]，但是年降水量与草原植被生产力之间的关系表现出明显的区域性与时间性，不同研究区与研究时段的降水量与植被生产力间关系存在差异性[7,11]。植被对气候变化的响应存在差异，主要与区域植被类型及降水的季节分配等因素有关[8,12]。因此，识别不同类型草原植被生产力对主要气象因子的响应对深入研究气候变化及其影响具有重要的意义。

归一化植被指数(*NDVI*)与植被盖度、地上生物量等关系密切，常作为生产力的代用指标[13]。人类放牧、刈割与土地利用变化等因素会对 *NDVI* 产生影响，对区域尺度植被覆盖的影响大于气象因素[14-15]。从内蒙古草原看，长期放牧与刈割等不合理的人类活动导致草原退化与生产力降低[16]。在人类放牧等活动干扰的背景下，开展区域尺度 *NDVI* 与气候变化的关系研究存在一定的不确定性。因此，选择长期围封样地研究 *NDVI* 对气候变化的响

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极端干旱对荒漠草原群落物种多样性和地上生物量碳氮的影响

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摘要：极端干旱及其对植物群落物种多样性的影响是气候变化及其影响评估的重要内容之一，而有关干旱荒漠草原区气候变化与植物群落多样性及其功能关系的研究鲜见报道。为明晰极端干旱对荒漠草原物种多样性和地上生物量的影响，利用野外极端干旱处理试验平台，研究了荒漠草原沙生针茅群落物种多样性和地上生物量及其碳、氮密度对极端干旱的响应特征。结果表明，极端干旱改变了荒漠草原沙生针茅（*Stipa glareosa*）群落的物种组成，进而使物种多样性发生变化。在 8 月份，生长季 5－8 月截雨 66%和 6－7 月干旱 60 d 两种极端干旱处理都降低了群落的 Shannon-Wiener 指数和物种丰富度指数。两种极端干旱处理使地上现存生物量较对照降低了 50%以上（$P<0.05$）。生长季 5－8 月截雨 66%干旱处理使凋落物生物量较对照降低了 61%（$P<0.05$），同时使凋落物生物量的碳氮密度显著低于对照。两种极端干旱处理使地上现存生物量的碳氮密度显著低于对照。因此，极端干旱不仅改变了荒漠草原群落的物种组成，而且改变了地上生物量，影响了植被碳氮密度，从而减弱荒漠草原植物群落地上部分的碳氮汇功能。

关键词：荒漠草原；物种多样性；生物量；碳密度；极端干旱

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ZHANG Rui, ZHAO Xueyong, WANG Shaokun, ZUO Xiaoan, WANG Ruixiong, 2019. Effect of extreme drought on the community species diversity and aboveground biomass carbon and nitrogen in the desert-steppe region in northern China [J]. Ecology and Environmental Sciences, 28(4): 715-722.

荒漠生态系统是全球最大的陆地生态系统之一，约占陆地总面积的 41%，为全球 37%的人口提供生计资料和生活环境（Reynolds et al.，2007）。荒漠化草原是典型草原向荒漠过渡的一个脆弱生态带，易受气候变化和人类活动的共同影响（周培等，2011），特别是极端降水事件的影响。降水是干旱区荒漠生态系统的重要水分来源（张腊梅等，2014）。荒漠区降水时空分布是决定植物发芽、定植、生长、群落物种组成和生物量（Dasci et al.，2010）的极其重要的因素（Cheng et al.，2006）。中国荒漠草原总面积达 1.9×10^5 hm^2，占全国草原总面积的 4.82%（曲浩等，2014）。内蒙古荒漠草原是世界草原植被中特有的植被类型，是旱生性最强的草原生态系统（中国科学院内蒙宁夏综合考察队，1985），在生态地理条件、群落结构和功能方面都具有独特性。位于内蒙古自治区西北部的乌拉特荒漠草原属于荒漠植物成分强烈侵入草原的植被类型，属于半干旱区与干旱区的边缘地带，处于荒漠与典型草原的过渡带上（张蕊等，2019）。

物种多样性既能度量群落的结构组成和功能复杂性，也能指示环境承载力的大小（左小安等，2007）。因此，物种多样性作为生物多样性的主要研究层次备受关注。群落物种多样性与植被生产力是衡量草地生态系统生态和生产功能的重要指标，也是维持草地生态系统可持续稳定发展的基础（Tilman et al.，1996），它们可以体现群落的结构、群落组织水平、发展阶段、稳定性程度和生境差异。碳储量是生态系统碳库的重要组成成分，在全球碳循环中发挥着重要的作用（林婉奇等，2019）。植被碳储量对生态系统碳平衡具有重要调节作用，过去 100 年全球植被碳储量整体上呈增加趋势（孙晓芳等，2013）。生物量碳密度是生态系统表征碳截存能力的重要功能特征之一（张蕊等，2018）。

在全球气候变化大背景下，亟需了解干旱半干

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荒漠草原沙生针茅(*Stipa glareosa*)群落物种多样性和地上生物量对降雨量的响应

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摘要: 利用野外降雨量增减试验平台,研究了荒漠草原沙生针茅(*Stipa glareosa*)群落物种多样性和地上生物量对降雨量的响应特征。结果表明:降雨量增加或减少均能导致物种的改变,使物种多样性发生变化。处理中,4 种物种多样性指数整体表现为 8 月高于 6 月。降雨量减少 40%时,Shannon-Wiener 指数、Simpson 优势集中性指数和物种丰富度 Patrick 指数最低,减少 20%时,Pielou 均匀度指数最低。降雨量增减也能够导致盖度与生物量的响应。降雨量减少 60%、40%、20%时,6 月植被盖度高于 8 月;降雨量增加 20%、40%、60%时,6 月植被盖度低于 8 月。降雨量减少和增加对荒漠草原植被盖度都有累加效应,即随时间变化,增雨处理使植被盖度持续升高,反之亦然。随降雨量增加,地上现存生物量逐渐升高,且在降雨量增加 60%时达最大。降雨量减少 60%、40%、20%和增加 20%,都会显著降低凋落物生物量($P<0.05$)。随降雨量增加,地上现存生物量与凋落物生物量的比值增大。在荒漠草原沙生针茅群落中,降雨量增加,有利于地上现存生物量的积累和地上总生物量的提高。影响荒漠草原地区植物群落地上生物量和物种多样性的关键降雨量变化范围为减雨 40%~20%和增雨 40%~60%。超出该范围,植物群落地上生物量和物种多样性对降雨变化的响应都会减弱。增雨 20%~40%对地上生物量和物种多样性的影响不显著。

关键词: 荒漠草原; 物种多样性; 生物量; 降雨量增减
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0 引言

物种多样性是生物多样性在物种水平上的表现形式,既体现了生物之间及其与环境之间的复杂关系,又体现了生物资源的丰富性[1]。物种多样性作为生物多样性的主要研究层次备受关注。群落物种多样性与植被生产力是衡量草地生态系统生态和生产功能的重要指标,也是维持草地生态系统可持续稳定发展的基础[2],可以体现群落的结构、群落组织水平、发展阶段、稳定性程度和生境差异。群落生境的资源可利用程度可以决定其物种多样性[3],即高的环境能量可以形成高的生产力,进而承载更高的物种多样性。如随着土壤含水量的增加,物种多样性呈增加趋势,而随生境干旱程度的增加而降低[4-6]。

荒漠生态系统是全球最大的陆地生态系统,约占陆地总面积的 41%,为全球 37%的人口提供生活支撑[7]。荒漠草原是典型草原向荒漠过渡的一个脆弱的生态带,更易受到气候变化和人类活动的影响[8],特别是极端降雨事件的影响。在荒漠区,降水时空分布决定植物发芽、定植、生长、群落物种组成和生物量[9-10]。中国的荒漠草原总面积达 1.9×10^5 hm^2,占全国草原总面积的 4.82%[11]。其中内蒙古荒漠草原是世界草原中特有的类型,在生态地理条件、群落结构和功能方面都具有独特性。位于内蒙古自治区西北部的乌拉特荒漠草原属于荒

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乌拉特荒漠草原群落物种多样性和生物量关系对放牧强度的响应①

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摘 要: 以内蒙古乌拉特荒漠草原灌丛和草本植物群落为对象,研究这 2 种植物群落的物种组成、物种多样性及其与地上生物量关系对不同放牧处理(对照、中牧、重牧)的响应。结果表明:① 随着放牧强度的增加,灌丛群落中红砂(*Reaumuria songarica*)和碱韭(*Allium polyrhizum*)的优势度增大,沙生针茅(*Stipa glareosa*)的优势度减小;重牧降低草本群落中沙生针茅的优势度,增加了蒙古韭(*Allium mongolicum*)和碱韭的优势度。② 不同放牧处理显著降低了灌丛和草本群落的盖度、高度以及灌丛群落的密度,消除了灌丛和草本群落之间盖度的差异($P>0.05$)。中牧降低灌丛群落的 Pielou 均匀度指数,重牧降低灌丛群落的物种丰富度,灌丛和草本群落的其他多样性指数在放牧处理之间无显著差异($P>0.05$)。除物种丰富度外,其他多样性指数在灌丛和草本群落之间差异显著($P<0.05$)。③ 不同放牧处理降低了灌丛和草本群落的地上生物量和凋落物量,导致灌丛和草本群落之间地上生物量的显著差异($P<0.05$)。④ 地上生物量与 Simpson 优势度指数负相关,与 Shannon-Wienner 多样性指数和 Pielou 均匀度指数正相关;放牧处理下地上生物量与密度、物种丰富度正相关。放牧处理改变了荒漠草原植物群落组成、结构和功能,进而改变了群落结构和功能的重要关系。

关键词: 荒漠草原; 放牧强度; 群落结构; 物种多样性; 地上生物量; 内蒙古

草地作为世界分布最广的陆地生态系统之一,其面积占全球陆地总面积的 20%[1]。我国各种类型草地的总面积为 3.92×10^6 km^2,占国土面积的 41.7%[2],主要分布于北方地区,其中内蒙古草原面积占全国草原总面积的 19.3%[3]。在全球气候变化背景下,人类活动的剧烈影响使草地的退化十分严重,已成为干旱、半干旱地区最为突出的生态环境问题之一。这将极大地影响草地生态系统的生物多样性、生产力和稳定性,制约社会、经济和生态环境的可持续发展[4]。因而,研究草地生态系统的结构和功能对人类活动的响应及适应机制是维持草地生态系统服务功能及其可持续发展亟需解决的重大科学问题,对于指导和改善人类对草地的保护和利用具有极为重要的科学意义。

荒漠草原因其地理条件和物种组成及群落结构和功能上的独特性,故而在我国温带草原保护、利用和研究中占有重要的地位[5]。它属于草原向荒漠过渡的最干旱的草原生态系统类型[6],由于其植被稀疏,养分贫瘠的自然条件,以及气候变化和人类过度的利用,目前荒漠草原均出现不同程度的退化,且逐年加剧[7]。我国的荒漠草原总面积为 1.90×10^3 km^2,占全国草原总面积的 4.82%,并且大都分布于荒漠区以东,以狭带状呈东北—西南方向分布[8]。其中位于内蒙古西北部的乌拉特荒漠草原属于荒漠植物成分强烈侵入草原的植被类型,是草原与荒漠的过渡地带[9]。该区域的植被对气候变化的响应更为敏感,更容易受到气候变化和人类活动干扰的影响。

作为草地最主要的利用形式,放牧对生物多样性的维持和植物群落的构建具有重要影响[10]。大量关于放牧对草原群落多样性、稳定性及生产力影响的研究多有报道[11-13]。有研究发现,适当强度的放牧能使植物群落的资源丰富度和复杂程度增加,有利于草地植物群落稳定性的维持和群落生产力的

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生物炭对兰州百合(*Lilium davidii* var. *unicolor*)连作土壤的改良作用

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摘要: 连作障碍严重影响兰州百合(*Lilium davidii* var.*unicolor*)的产量和品质。生物炭在土壤改良中具有一定的作用。将竹炭和稻壳炭加入兰州百合连作土壤,测定了土壤生物化学性质,探讨生物炭对连作退化土壤的改良效应。结果表明:(1)生物炭的添加提高了百合连作土壤的有机质、碱解氮、有效磷和有效钾的含量。(2)生物炭的施用在一定程度上提高了土壤酶活性。(3)利用 Illumina Miseq 平台检测了土壤样品微生物群落,与对照相比,添加生物炭使微生物群落结构发生了明显的变化,有益细菌鞘氨醇单胞菌属(*Sphingomonas*)的丰度升高,而兰州百合主要致病真菌镰刀菌属(*Fusarium*)的丰度下降,降低了枯萎病发生的可能。(4)在盆栽试验中,各处理的根系活力和生物量皆高于对照,生物量提高 11.85%~13.21%,根系活力提高了 57.88%~58.88%。施用生物炭对克服兰州百合的连作障碍、提高土壤肥力有明显的促进作用。

关键词: 兰州百合(*Lilium davidii* var. *unicolor*); 生物炭; 土壤生物化学性质
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0 引言

兰州百合(*Lilium davidii* var. *unicolor*)是中国唯一的甜百合,鳞茎硕大,色泽洁白,口感细腻,在可食性、医学、观赏方面都具有很高的价值,中外知名。兰州百合是川百合的变种,为多年生鳞茎草本植物,在甘肃省的种植始于清代[1]。随着生活水平的提高,人们对兰州百合的需求量不断增加,兰州百合的种植面积也在不断增加。由于土地、气候等因素,适宜兰州百合的生长地域有限,连作现象非常普遍。产量和品质显著下降,影响相关产业的发展。

连作障碍的形成主要与植物分泌的化感物质累积和土壤生物环境的变化有关[2]。连作系统会改变土壤中微生物群落的结构和多样性,有益物种会减少或消失,而有害物种或病原体的丰度会增加[3]。近年来,由于真菌致病菌的普遍存在,一些经济作物产量显著下降[4]。大田兰州百合的主要病原菌属是镰刀菌属(*Fusarium*),是一种土传病原体,可引起兰州百合枯萎病,降低产量[5-6]。同时,在兰州百合种植区,连续播种百合多年后,土壤有效钾损失严重,土壤酸度强,有机质缺乏,土壤质地非常黏板,严重影响百合产量[7]。

生物炭是在少氧或无氧条件下高温(低于 900 ℃)裂解有机物而形成的固体物[8],主要由烷基和芳香族化合物组成,相对稳定,甚至可以在土壤中保存数百年[9-10]。施用生物炭可以改变土壤养分含量,改变土壤的理化性质和生物学特性,减少养分的浸出和挥发,改善土壤酶活性及供微生物发育和繁殖的矿物质营养状况[11-13]。

生物炭可以改变土壤有机质的组成,生物炭的不稳定成分可直接转化为土壤活性有机碳迅速分解和消耗,而稳定成分长期存在于土壤中[14]。目前,生物炭对土壤酶活性影响的研究集中在与土壤碳氮循环有关的土壤酶方面。生物炭会增加土壤微生物生物量,引起微生物群落组成和酶活性的显著变化,可以解释生物炭对矿质元素、植物病原体和作物生长的生物地球化学效应[15]。生物炭制备

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