華中農業大學
HUAZHONG AGRICULTURAL UNIVERSITY

微量元素研究中心

Microelement Research Centre

2012-2013 年年报

Annual Report 2012-2013

Microelement Research Centre

http://mrc.hzau.edu.cn

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乘风破浪会有时，直挂云帆济沧海

—— 记华中农业大学微量元素研究中心

1985 年，原农牧渔业部批准在华中农业大学设立“微量元素研究室”，王运华教授任主任；2005 年 3 月，“微量元素研究室”更名为华中农业大学“微量元素研究中心”，王运华教授任中心主任，2006 年 9 月，中心主任由胡承孝教授担任。2009 年 12 月，在广东省建立“华中农业大学微量元素研究中心广东省分中心”。2013 年 4 月，石磊教授任中心主任。

华中农业大学植物营养学科是该中心的依托学科。该学科始于 1948 年武汉大学农学院农业化学系；1952 年，全国高校院系调整，由武汉大学、湖北农学院有关系科和湖南农学院一部分合并组成了华中农学院土壤农化系。在王运华教授等老一辈科学家的带动和努力下，本学科分别于 1984 年和 1990 年获得硕士、博士学位授予权，是中南地区最早获得植物营养学博士学位授予权的单位；1994 年，被评为湖北省首批重点学科，并获准成为农学博士后科研流动站的组成学科；1999 年，获得农业资源利用一级学科博士学位授予权和博士后科研流动站；2003 年，经湖北省学位委员会考核，被评为湖北省重点学科。2008 年，被评为湖北省高校特色学科。2013 年一级学科“农业资源与环境”再次入选“湖北省重点学科”。

在半个多世纪的发展历程中，微量元素研究中心始终坚持“立足湖北，面向全国”，紧密跟踪国外学科发展前沿；始终坚持基础研究与应用研究相结合，互促共进，为解决农业生产的现实问题和学科发展中的理论问题而不懈努力。上世纪 70 年代中期，从湖北省新洲县大面积棉花“蕾而不花”着手，在全国范围内通过大面积试验、示范和推广，首次提出我国棉田土壤有效施硼的土壤和植物诊断指标，制定了棉花、芝麻、向日葵等作物施硼技术规范以及硼与氮、磷、钾肥配合施用技术。1989 年，在湖北省新洲县，发现酸性黄棕壤缺钼导致冬小麦越冬期黄化死苗，通过湖北和河南主产麦区的多年试验、示范和推广，提出了冬小麦施用钼肥的 4 个有效条件、冬小麦缺钼的植物和土壤诊断指标及其合理施用钼肥技术。研究揭示缺钼导致冬小麦黄化死苗的生理机制以及钼在冬小麦抗寒力形成中的作用，修正了普遍认为禾本科作物对缺钼不敏感的观念，进一步巩固和强化了独具特色的微量元素研究。

目前，中心形成以养分资源高效利用和环境与农产品安全为目标，以测试技术、生物技术、信息技术和农业生产技术为支撑，基础研究与应用研究相互结合、互为促进的稳定的研究方向，主要有：作物营养机理与调控、微量元素与生态安全、现代施肥技术及新型肥料的研发与应用等。在三个方向都形成了特色和优势，成为在国内外独具特色的研究领域，为农业可持续发展提供了技术支持。

研究方向 1：作物营养机理与调控

油菜、棉花硼营养高效的生理和分子机制；冬小麦钼营养机理与合理施用钼肥技术；油菜磷营养高效的生理和分子机制；水稻耐低磷种质资源的筛选与研究；钾高、低效基因型棉花差异的生理及其机制研究；烟草营养与品质；土壤硼不同化学库动态及其植物有效性的研究；土壤硼滞后解吸机理和外源硼的土壤活性跟踪研究；负载硼的氧化物与致酸离子作用机理及其生物反应研究；高等植物体内的生物矿化过程, 以及矿化结构和功能关系研究；溶液中的无机离子(离子强度)和有机分子(有机酸,酶,多肽和蛋白) 与矿物表面的相互作用研究；矿物-水界面反应动力学之含磷矿物的结晶和溶解研究；农业土壤钾素循环转化方面的基础研究。主要研究人员：徐芳森教授、王荔军教授、赵竹青教授、贺立源教授、喻敏教授(特聘)、石磊教授、郭再华副教授、蔡红梅副教授、丁广大博士等。

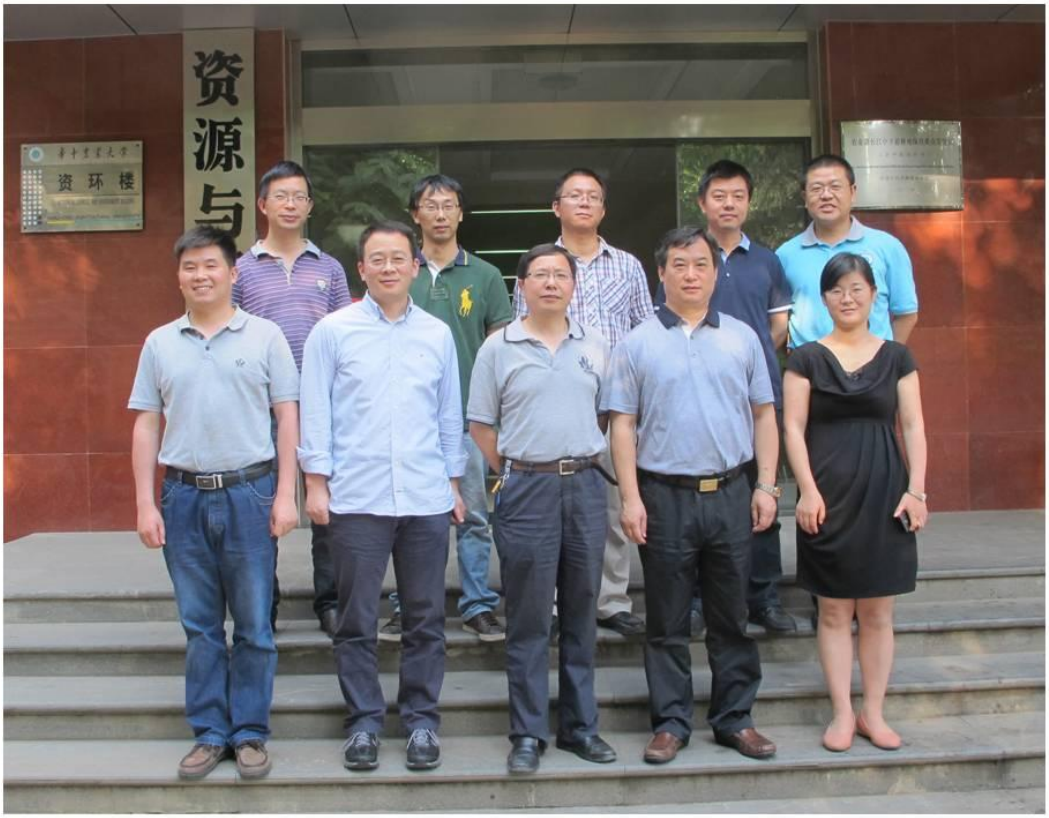
研究方向 2：微量元素与生态安全

环境污染与修复，农产品品质与安全，农业废弃物资源利用，核技术应用等。主要包括：菜地氮营养管理与蔬菜安全生产及硝酸盐污染控制；城市污泥农用与污染控制原理与技术；菹草与沉积物作用对富营养化水体磷及其它营养元素迁移影响；蜈蚣草富集土壤砷的生化机理；油菜耐砷和镉基因型的筛选及忍耐生理；生态方法修复污染水体的机理研究；环境害草凤眼莲的有效管理和后续利用；小麦、水稻、玉米耐铝毒害；耐铅细菌耐铅机制探讨及与土壤铅污染；南方红壤耐酸玉米种质引进与推广应用（耐酸玉米自交系的鉴定与推广示范）我省不同酸性土壤活性锰释放特征及其植物毒行研究；油菜和烟草硒营养研究。主要研究人员：胡承孝教授、朱端卫教授、涂书新教授、王富华研究员(特聘)、谭启玲副教授、熊双莲副教授、周文兵副教授、孙学成副教授、赵小虎博士等。

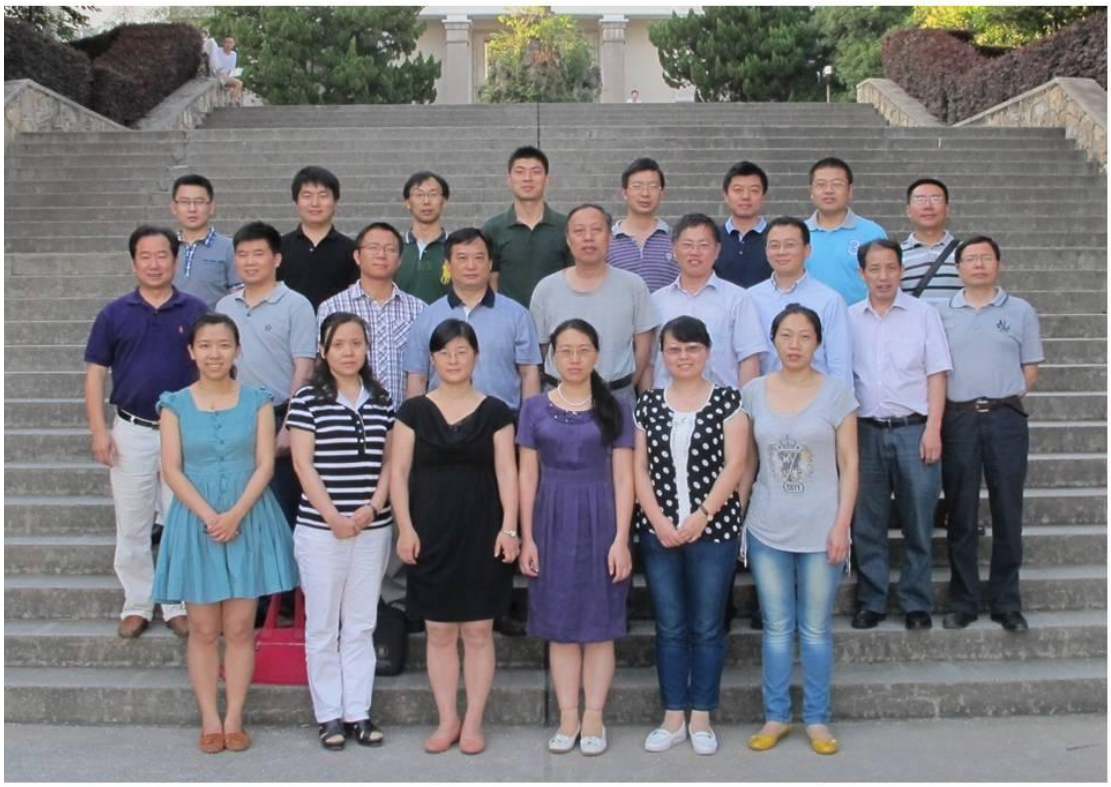
研究方向 3：现代施肥技术及新型肥料的研发与应用

主要作物（以水稻、油菜、柑橘为重点）养分综合管理技术；水旱轮作体系作物高产高效综合管理技术；绿肥作物生产与利用技术；耕地地力评价与培肥技术；秸秆还田技术与应用；测土配方施肥技术与应用。速溶高硼，螯合高铁、锌、钙、作物抗旱剂、抗寒剂及作物药害（农药及除草剂）缓解或消除剂等产品等开发与应用；缓释肥料的制备及其缓释性能的评价；中药材规范化生产中专用肥的研制与开发工作；甲壳素农业利用，水肥一体化技术、水溶肥料、长效肥料、抗旱抗逆技术以及与国际锌协和加拿大泰克资源（TECK）合作的锌肥示范推广项目等。主要研究人员：鲁剑巍教授、吴礼树教授、贺立源教授、高祥照研究员(特聘)、耿明建副教授、姜存仓副教授、李小坤副教授、任涛博士、丛日环博士等。

华中农业大学微量元素研究中心现有一支以学术带头人为核心、中青年博士为主体、结构合理的高水平学术梯队。现有科研人员 25 人，其中教授 12 人、副教授 10 人，其中现代农业产业技术体系岗位科学家 2 人，农业部测土配方施肥专家组成员 1 人、湖北省测土配方施肥专家组组长和成员各 1 人，广东省农产品质量监督检测专业技术委员会专家各 1 人，湖北省“楚天学者”特聘教授 1 人，教育部“新世纪优秀人才支持计划”4 人，湖北省杰出青年基金 1 人。常年有 120 名左右硕士、博士研究生参加科研工作。“作物微量元素营养与微肥施用”研究团队 2012 年入选湖北省自然科学基金创新群体，同年，以本中心为依托申报获批新型肥料湖北省工程实验室。中心已经拥有一支综合实力较强的、从事微量元素理论与应用研究的创新团队，正逐步成为国内外微量元素研究的重要基地之一。



微量元素研究创新团队骨干成员（湖北省自然科学基金创新群体）



微量元素研究中心团队合影

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3. 华中农业大学微量元素研究广州分中心科研工作进展

3.1 采用同步低温微波-离心高效提取技术，首次实现了不同形态 As、Hg 同时定性定量检测。

3.2 开展广东省水稻和蔬菜重金属污染研究，系统建立了一套蔬菜重金属评价与防控体系。

3.3 建立一种基于 LTP 和液相色谱-串联质谱（LC-MS/MS）的食用油中阿维菌素和伊维菌素残留的分析方法，填补了食用油中阿维菌素类药物分析方法的空白。

3.4 全面修订 36 类种植业产品的无公害检测目录，建立了农产品主要污染物标准限量库。

4.专利、成果及获奖情况

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4.4 重大成果、奖励简介：

1.中心人员简介

1.1 中心主任：

石 磊，男，1974 年 10 月生，资源与环境学院教授，博士，硕士和博士生导师，在华中农业大学作物遗传改良国家重点实验室从事油菜根系发生发育与磷、硼等养分高效利用的遗传学研究。主持完成的课题主要有国家自然科学基金和湖北省自然科学基金各 1 项，国际合作项目 1 项，973 和 863 子课题 1 项。目前，主要主持国家自然科学基金 1 项，参加 973 项目和国家自然科学基金重点项目各 1 项。近 5 年发表学术论文 30 篇，其中以第一或通讯作者发表学术论文 15 篇，SCI 收录 8 篇（IF>3.0 论文 4 篇），一级学报等核心期刊 5 篇；参编国际会议论文集 1 部；申报获批专利 2 项。2010 年获“湖北省科学技术进步二等奖”1 项（排名第 5）；2011 年获湖北省自然科学基金杰出青年基金；2013 年入选教育部新世纪优秀人才支持计划。

研究工作经历（按时间倒排序）

2012 年 12 月－今，华中农业大学资源与环境学院土壤与植物营养系，教 授

2006 年 12－2012/11，华中农业大学资源与环境学院土壤与植物营养系，副教授

2004 年 7 月－2006 年 11 月，华中农业大学资源与环境学院土壤与植物营养系，讲师

期间，2009 年 9 月至 2010 年 9 月赴英国华威大学（The University of Warwick）开展油菜根系形态构型与磷高效吸收利用的合作研究。英国合作者：华威大学国际园艺作物研究所（Warwick HRI）John P. Hammond 博士。

2012 年 7 月起，任湖北省土壤肥料学会第十届理事会理事。

1.2 中心副主任：

姜存仓，男，资源与环境学院副教授，硕士生导师。是农业部长江中下游耕地保育重点实验室、新型肥料湖北省工程实验室、湖北省自然科学基金创新群体（作物微量元素营养机理与微肥施用）固定研究人员。担任湖北省土壤肥料学会第十届理事会理事、华中农业大学微量元素研究中心副主任等职务。2012-2013 年，在英国的 Rothamsted Research Institute 做访问学者 1 年，曾先后到美国、英国、土耳其等地进行学习、交流和考察等。主持 2 项国家自然科学基金，2 项国际合作，3 项中央高校基本科研专项，1 项校青年教师科研启动项目，多项公司合作项目；参加 1 项国家科技支撑课题，1 项国家农业产业技术体系岗位科学家项目，2 项国家公益性行业农业科研专项。近年来，主要对作物的养分资源高效利用及矿质元素营养调控机理开展了较多的工作，研究结果发表在《Plant and Soil》《Journal of Plant Nutrition and Soil Science》《Soil Science and Plant Nutrition》《植物营养与肥料学报》《中国农业科学》《作物学报》等本领域主流期刊上。近 5 年，以第一或通讯作者已发表论文 30 余篇（SCI 收录 10 篇），主编专著 2 部，参编著作 4 部，授权国家发明专利 2 项（排序 1），制定省级技术标准 1 项（排序 1）。

1.3 微量元素研究中心固定研究人员（按姓氏字母排序）

序号	姓名	性别	出生年月	最高学位	研究方向	职称	进入中心时间	工作单位
1	蔡红梅	女	1980.12	博士	植物营养遗传	副教授	2009	资环学院
2	丛日环	女	1982.12	博士	土壤肥力	讲师	2012	资环学院
3	丁广大	男	1983.10	博士	植物营养遗传	讲师	2011	资环学院
4	高祥照	男	1963.12	博士	养分资源综合管理与节水农业	研究员	2005	全国农技推广中心
5	耿明建	男	1970.07	博士	绿肥种植利用	副教授	2005	资环学院
6	郭再华	女	1977.04	博士	植物营养与生态	副教授	2005	资环学院
7	贺立源	男	1951.12	学士	农业信息化、智能监控	教授	2005	资环学院
8	胡承孝	男	1964.12	博士	养分管理	教授	2005	资环学院
9	姜存仓	男	1975.04	博士	作物养分管理	副教授	2006	资环学院
10	李小坤	男	1979.08	博士	养分管理	副教授	2009	资环学院
11	鲁剑巍	男	1967.09	博士	养分管理	教授	2005	资环学院
12	任 涛	男	1984.07	博士	养肥管理	讲师	2011	资环学院
13	石 磊	男	1974.10	博士	植物营养遗传	教授	2005	资环学院
14	孙学成	男	1974.06	博士	植物营养生理	副教授	2007	资环学院
15	谭启玲	女	1966.07	博士	养分管理	副教授	2005	资环学院
16	涂书新	男	1962.02	博士	污染环境修复	教授	2005	资环学院
17	王富华	男	1962.07	学士	植物营养与农产品质量安全	研究员	2005	广东省农科院
18	王荔军	男	1968.06	博士	生物矿化	教授	2009	资环学院
19	吴礼树	男	1957	硕士	新型肥料	教授	2005	资环学院
20	熊双莲	女	1973.03	博士	污染环境修复	副教授	2005	资环学院
21	徐芳森	男	1965.10	博士	植物营养遗传	教授	2005	资环学院
22	喻 敏	女	1971.08	博士	植物营养	教授	2007	佛山科学技术学院
23	赵小虎	男	1983.08	博士	植物营养与生态	讲师	2011	资环学院
24	赵竹青	男	1965.10	博士	植物营养生理	教授	2005	资环学院
25	周文兵	男	1974.02	博士	植物营养与生态	副教授	2005	资环学院
26	朱端卫	男	1956.09	博士	植物营养与生态	教授	2005	资环学院

1.4 微量元素研究中心研究生理事会

微量元素研究中心前身为成立于 1984 的农业部“微量元素研究室”，于 2005 年 3 月更名为 “华中农业大学微量元素研究中心”。其以植物营养学科为依托，拥有一支综合实力较强的从事微量元素理论与应用研究的团队。科研需要有平台，研究需要有团队，因此我们有责任有义务把我们的这个平台管理好、经营好、发展好。团队要获得长足的发展，需要成员有宽广的心胸，科研平台优势的发挥，离不开团队成员的无私奉献。为了高效的配置中心的物质资源，也为了更好的为大家服务，各课题组推荐 1-2 名研究生负责中心的日常工作，保证中心的正常运作。理事会成员将同心协力，为创建一流的科研平台奉献自己的力量。理事会接受中心全体老师及学生的监督，由微量元素中心主任和副主任统一领导。

理事长:　刘新伟，李继福

副理事长: 王兆双，陈海飞，秦世玉

秘书组:　薛艳，刘磊超，刘雪琴，南德峰

理事会成员	主要负责项目		备注
理事长	刘新伟	掌管中心整体运行，按月汇总中心总体使用收费情况，及时公布给中心成员，定期召开会议，加强信息交流，确保微量元素中心有序运行。 Email：jiangcunzhen@163.com	各理事会成员对各自所在实验室负责，逐月对实验室研究生使用盆栽场的情况进行登记汇总，并监督本实验室对盆栽场的使用及告知注意事项，及时传达中心的通知。
	李继福	负责设备的维护，三轮车的使用及微量元素研究中心网站的更新与维护和对中心事物的监管。 Email：lijifu1004@yahoo.com.cn	
副理事长	王兆双	负责盆栽场温室大棚，光照培养室使用的监管，纯水仪的使用，登记及卫生事宜等。 Email：wangzhaoshuang@webmail.hzau.edu.cn	
	陈海飞	负责公共仪器平台的使用管理与维护，以及组织加强中心成员交流与沟通的文体活动。 Email：henhaifei@webmail.hzau.edu.cn	
	秦世玉	负责小土化楼、光照培养室水电正常运转及报账发补贴等事宜。 Email：qinshiyu1115@sina.com	
秘书组	薛艳	负责新旧盆栽场各类器材的维护及报修。 Email：21053302@qq.com	
	刘磊超	负责组织及参与中心的学术交流活动，以及与其有关的材料简报的发送，照相等事宜。 Email：991771289@qq.com	
	刘雪琴	负责对新盆栽场使用的监督管理，以及协调中心成员在资源利用中的矛盾。 Email：297093646@qq.com	
	南德峰	负责微量元素研究中心发表论文的统计汇总，优秀学术成果的公示，学术海报的制作及展览。 Email：nandefeng90@126.com	

微量元素中心研究生合影

2.科研成果与进展

2. 1 作物营养机理与调控

2.1.1 生物矿化研究小组发现植物细胞壁上存在有机硅

硅是植物生长的有益元素之一。大量的植株和器官水平上的研究已经显示硅赋予各种植物许多特殊的功能尤其是能显著地提高植物抵抗环境胁迫的能力，但相应的细胞结构和硅化学机制仍然不清晰。王荔军教授领衔的生物矿化研究小组以水稻悬浮细胞为材料，借助现代物理手段（包括 XPS，ICP-MS，AFM 和 NMT 等）发现水稻悬浮细胞中硅不是以二氧化硅的形式存在（Figure 1），而是作为细胞壁组分元素，共价结合到细胞壁基质上，形成一种新的有机硅种类。这种以前未知的有机硅种类，在细胞膨胀过程中能改善细胞壁的力学性质和稳定性，对于维持细胞形状和细胞活性具有重要作用。此外，硅修饰的细胞壁能够提高细胞壁的电负性，进而有效减少细胞对重金属镉的吸收。这些研究结果将有助于揭示植物硅营养的化学本质。相关结果系列发表在 New Phytologist 上。

(1) Congwu He *et al*., Evidence for ‘silicon’ within the cell walls of suspension-cultured rice cells. ***New Phytologist***,2013, 200: 700–709. (IF 6.736)

(2) Jian Liu *et al*., Inhibition of cadmium ion uptake in rice (*Oryza sativa*) cells by a wall-bound form of silicon. ***New Phytologist***,2013, 200: 691–699.

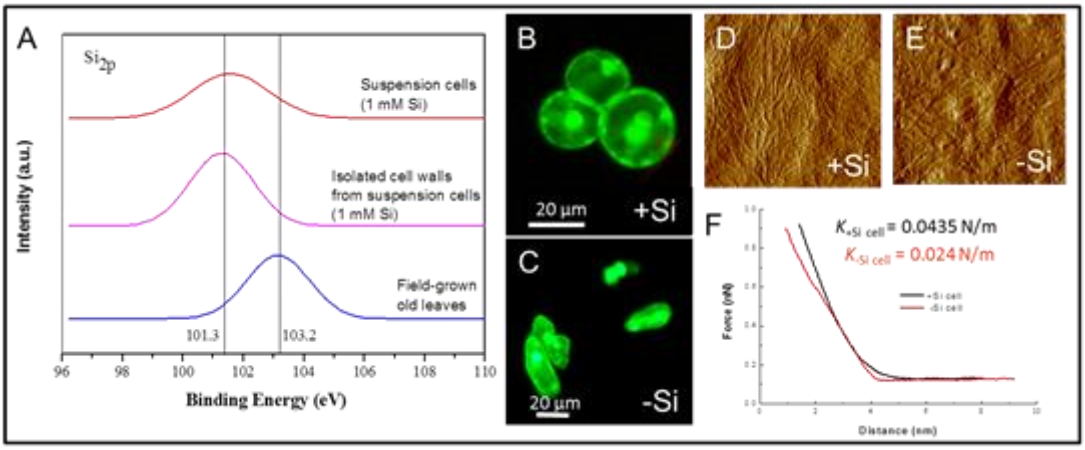


Figure1. (A)X-ray photoelectron spectroscopy (XPS) characterization of the chemical composition for Si_{2p} of (B, C) the suspension cell surfaces. (D-F) Representative force–distance curves for rice (*Oryza sativa*) cells cultivated for 3 months in the absence (-Si) and presence (+Si) of silicic acid by atomic force microscopy (AFM).

2.1.2 生物矿化研究小组揭示根分泌有机酸和难溶性磷矿表面反应机制

借助附带流动液体反应池的原位原子力显微镜（AFM），模拟根系分泌的有机酸与土壤难溶性磷矿表面的反应，系统地研究了柠檬酸在各种根际土壤溶液条件下（包括浓度，pH 和离子强度）对磷酸氢钙（DCPD）的溶解。我们直接测定了 DCPD (010)面不同方向分子级台阶（Figure 1A）溶解速度，结果表明低浓度（10?100 μM）的柠檬酸，抑制

了 $[-100]_{Cc}$ 和 $[10\text{-}1]_{Cc}$ 两个方向上的台阶移动速度（Figure 1B）；然而在高浓度下（大于 0.1 mM），柠檬酸的抑制效应转化为促进溶解（Figure 1C）。这些结果说明了柠檬酸对难溶性磷的溶解是由浓度主导的双重调控模式，这为深入理解复杂根际环境下有机酸活化难溶性磷的矿物-水界面反应过程提供了直接微观线索。

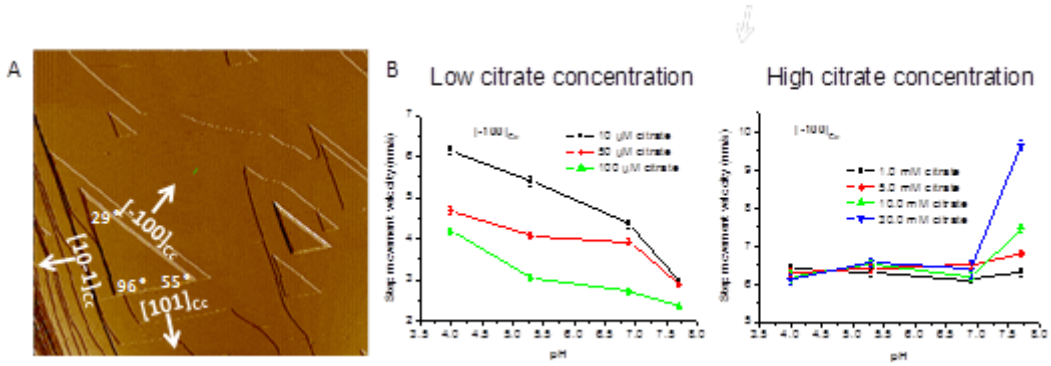


Figure 1. (A) AFM deflection image showing the immediate formation of etch pits with triangular shapes on (010) surfaces of a DCPD crystallite introduced into deionized water or citrate. Retreat velocity of the $[-100]_{Cc}$ steps for DCPD crystals dissolved in (B) low or (C) high citrate concentration solutions at varying pH (4.0?8.0).

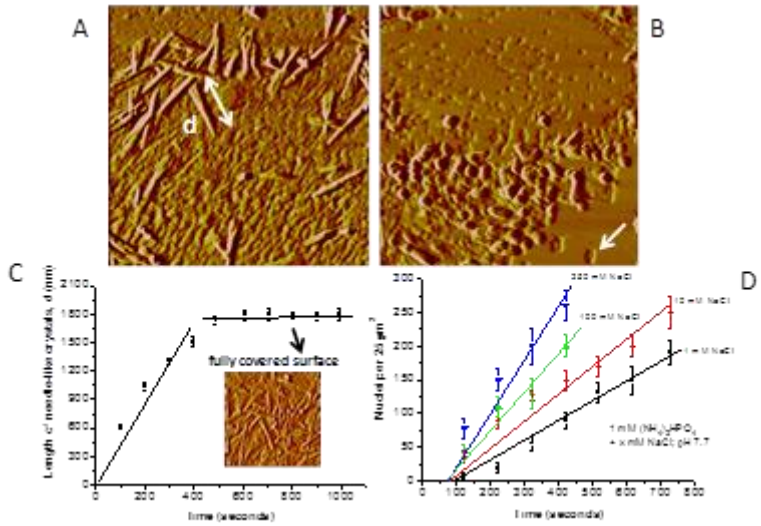


Figure 2. AFM images of the nucleation and growth of (A) needle-shaped or (B) spherical pyromorphite crystals on a dissolving cerussite surface. (C, D) Dependence of the steady-state growth and nucleation rate on time under various solution conditions.

此外，我们利用相似方法研究了可溶性磷如$(NH_4)_2HPO_4$ 是如何固定土壤重金属铅的表面化学机制，结果发现铅很容易吸附在碳酸钙表面形成碳酸铅；而可溶性磷溶解碳酸铅后将铅离子释放出来，进而在矿物-水界面层形成针形或球形的磷酸铅（Figure 2A, B）。借助原位原子力显微镜，我们定量地测定了在各种土壤溶液条件下磷酸铅的成核和生长速率（Figure 2C, D）。相关结果系列在线发表在 Environmental Science & Technology 上。

(1). Lihong Qin *et al.*, Direct Imaging of Nanoscale Dissolution of Dicalcium Phosphate Dihydrate by an Organic Ligand: Concentration Matters. *Environmental Science &*

Technology,47,13365-13374,2013.

(2). Lijun Wang *et al.*, Coupled Dissolution and Precipitation at the Cerussite-Phosphate Solution Interface: Implications for Immobilization of Lead in Soils. *Environmental Science & Technology*, 47,13502-13510,2013.

2.1.3 利用原子力显微镜研究硅对水稻悬浮细胞表面的力学和电学性质的影响及对镉毒的抵抗作用

以水稻悬浮细胞为材料，借助原子力显微镜（AFM）研究不加硅/加硅细胞不同组分力学性质的变化，及在不加硅/加硅条件下对重金属镉的吸收抑制作用，借助原子显微镜，我们观察到加硅与不加硅的细胞壁的纤维丝有明显的间距，但 Na_2CO_3 和 KOH 处理后，纤维丝显得更紧密。并且加硅细胞壁的杨氏模量显著高于不加硅，说明硅可以增强细胞壁的力学性能，并且数据表明硅极可能存在果胶或半纤维素中（图 1）。

图 2 是不同细胞壁材料在 1800-800 cm^{-1} 区间的 FT-IR 的光谱图。研究表明加硅与不加硅细胞壁有相似的特征峰，但 Na_2CO_3 处理后，半纤维素和纤维素的特征峰 (1317, 1155 和 895 cm^{-1}）增强，KOH 处理后的细胞壁主要为纤维素。而 Na_2CO_3 处理的细胞壁以及 KOH 处理的细胞壁的主要不同是酯键（1740 cm^{-1}, C=O，和 1630 cm^{-1}, COO^-），其峰强逐渐减小，最后几乎消失。

此外，硅修饰的细胞壁能够提高细胞壁的电负性，进而有效减少细胞对重金属镉的吸收。我们利用原子力显微镜凯尔文探针模式（KPFM）探究了上述不同处理表面的凯尔文电势特征，发现细胞（壁）表面的电势分布是不均匀的，这一不均匀主要由壁上的果胶、蛋白等组分引起，加硅培养会使细胞表面的电势不均匀程度变大（图 3）；进一步加入不同浓度的镉处理（0, 5, 30 和 60 μM）发现，随着镉浓度的增加，细胞表面的电势不均匀程度减小（图 4）。结果表明硅可以改变细胞壁表面的电负性，加强细胞壁对镉这样的重金属阳离子的结合能力，从而对镉进入细胞内部产生毒害起到缓解作用。

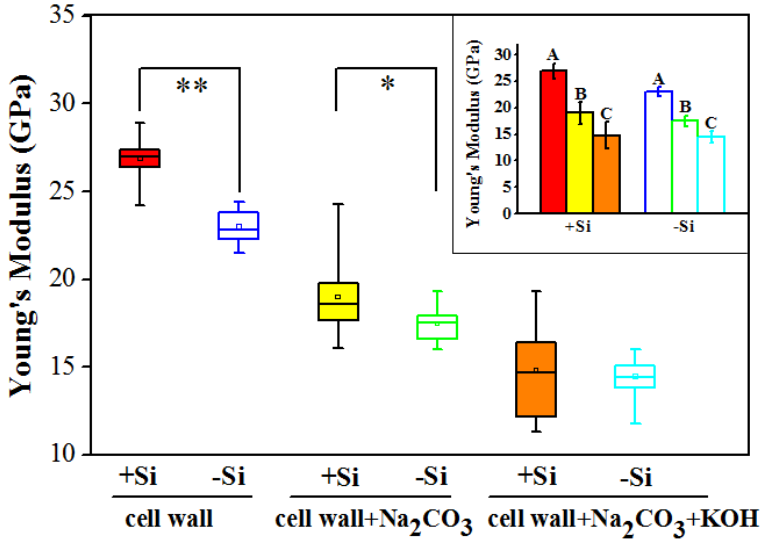


图 1 AFM 测得的不同细胞壁材料的杨氏模量。

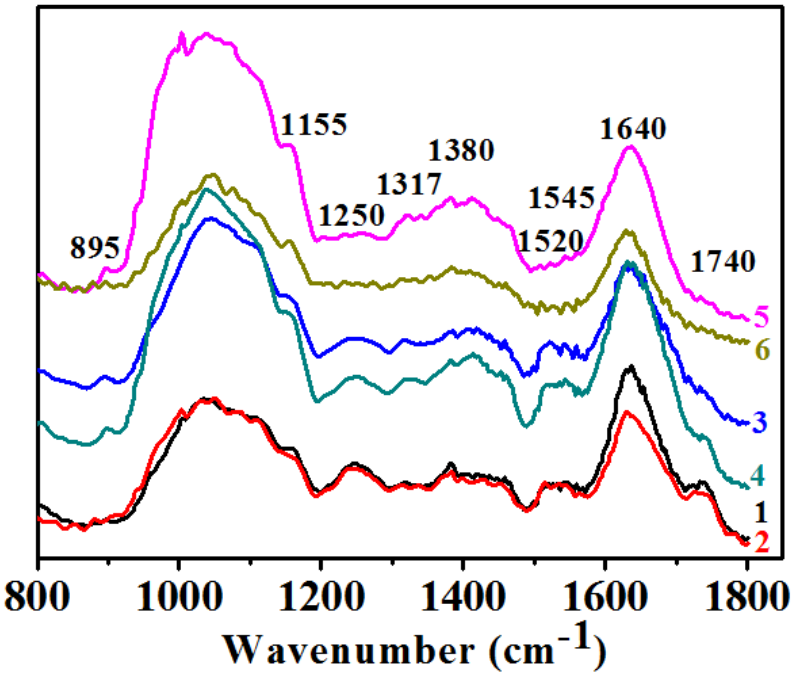


图 2 不同细胞壁材料的红外光谱图。

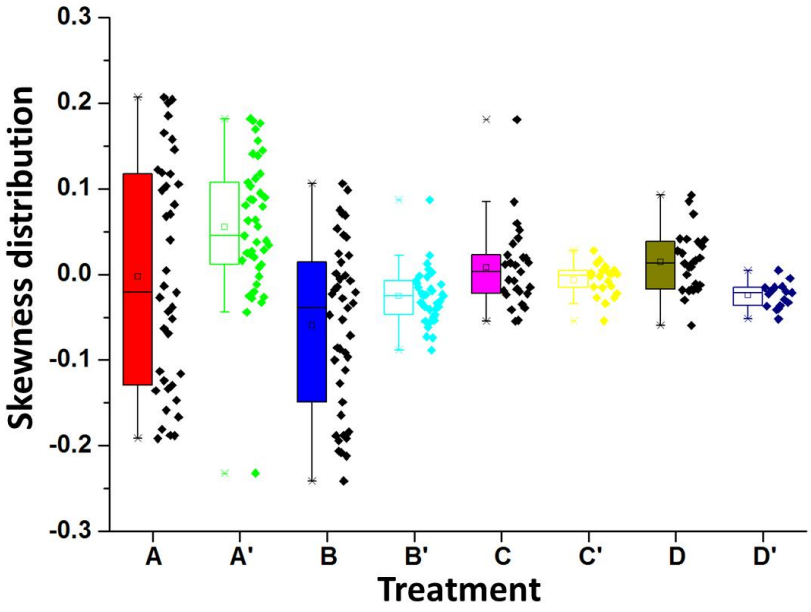


图 3 不同处理水稻悬浮细胞表面电势分布的偏斜度分布箱状图，（A）加 1mM 硅培养的细胞，（B）分离的细胞壁，（C）用碳酸钠处理去除果胶组分的细胞壁以及（D）进一步用氢氧化钾去除半纤维素组分后的细胞壁。A’到 D’为相对应的缺硅培养的悬浮细胞及其组分 (Means ±SD; n ≧ 30)。

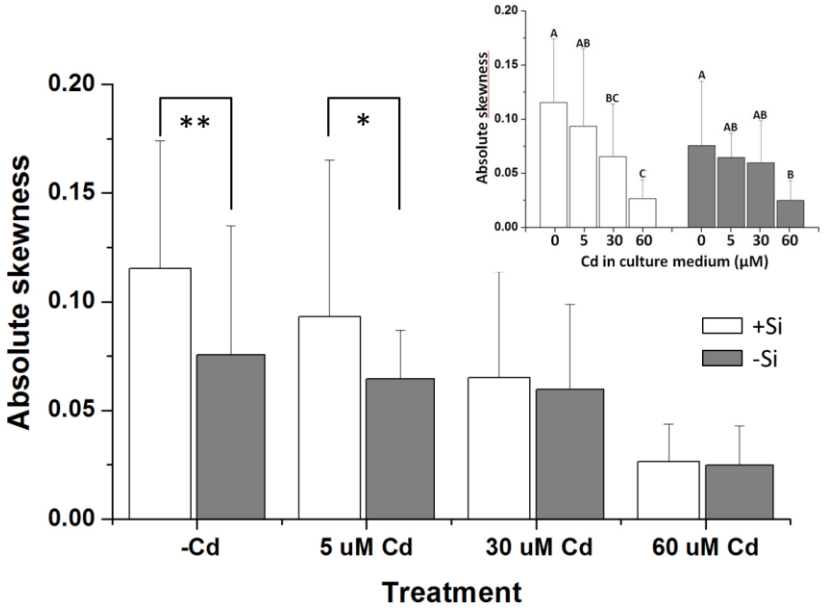


图 4 加硅（1 mM）培养或缺硅培养一个月的水稻悬浮细胞在不同浓度镉（0, 5, 30 和 60 μM）处理后的绝对偏斜度分布 (Means ±SD; n=22)。

2.1.4 背景电解质（盐）在对二水磷酸氢钙(DCPD, $CaHPO_4.2H_2O$)溶解过程中的作用

2.1.4.1 二水磷酸氢钙在不同背景电解质中和在柠檬酸溶液中的溶解动力学

我们合成了二水磷酸氢钙作为磷酸钙的模式矿物（图 1），系统地研究不同背景电解质和柠檬酸对它的溶解过程。

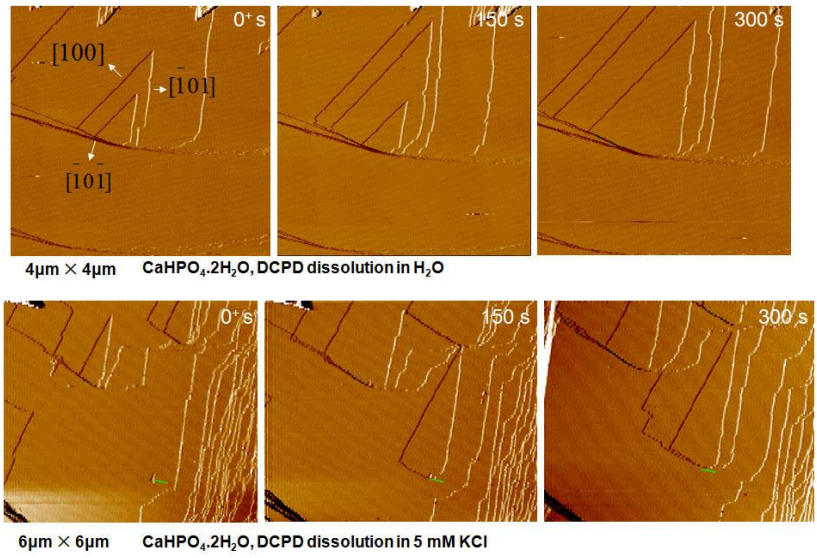


图 1. DCPD 在水(上)和在 KCl 溶液中(下)的溶解过程.

2.1.4.2. $MgCl_2$ 的作用

在 $MgCl_2$ 浓度低于 10 mM 时，DCPD 的(010)面是由较大的蚀坑所统治（图 2 上）,蚀坑斜边在位错源汇聚。当 $MgCl_2$ 浓度在 10-50 mM 范围内，DCPD 的(010)面上较小的蚀坑（具有较平的底部）密度增加（图 2 中）。当 $MgCl_2$ 浓度高于 100 mM 时，DCPD 的(010)面上同时存在较大和较小的平底蚀坑（图 2 下）。以上两种溶解特征表明成核驱动的溶解机制。盐效应的物理基础是由位错缺陷向 2D 岛的成核转变。这种转变可能与台缘自由能降低或者是动力学能垒降低有关（即从表面移去原子从而启动一个蚀坑的形成）。在这个缺陷支持的模型中，和在无缺陷的 2D 表面成核相比，杂质诱导的定域应力产生较低的自由能垒。在图 2 下所显示的表面形貌指出较大的蚀坑占主导，它们被较小的蚀坑所包围。较大的蚀坑是在缺陷处成核（图 2 C）；较小的蚀坑是均相成核的结果。

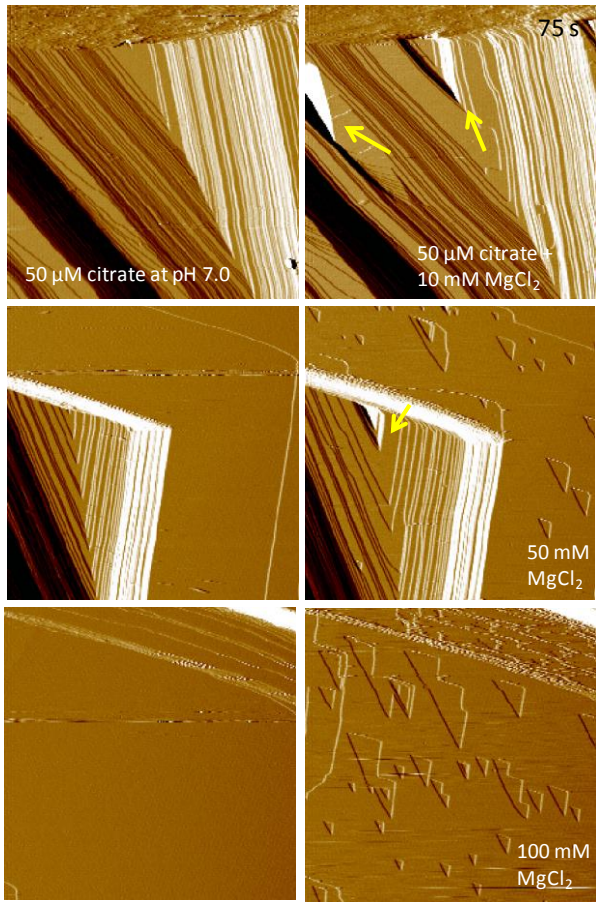


图 2. 二水磷酸氢钙（DCPD）在 50 µM 柠檬酸(pH 7.0)和不同浓度的 $MgCl_2$ 条件下的(010)表面溶解特征

在$[101]_{Cc}$和$[-100]_{Cc}$两个方向上，$MgCl_2$ 显著抑制了$[-100]_{Cc}$的溶解速度，同时也使$[101]_{Cc}$的溶解速度降为零。然而在$[10\text{-}1]_{Cc}$方向上 $MgCl_2$ 显著促进了溶解，浓度超过 10 mM 后溶解速度达到稳定（图 3）。在存在天冬氨酸时，显著抑制了 $MgCl_2$ 的作用（图 4）。

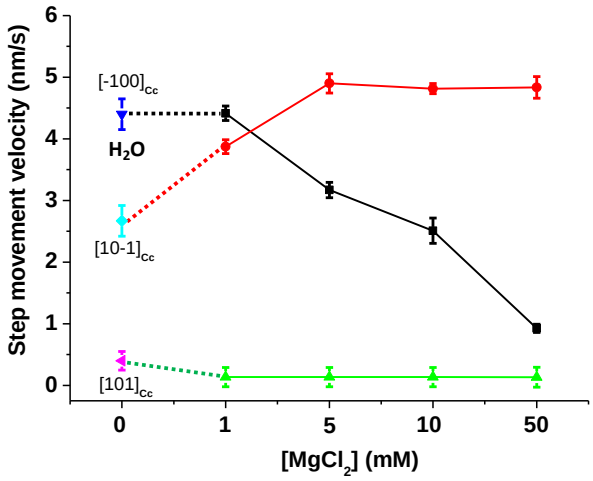


图 3. $MgCl_2$ 浓度从 1.0 到 50.0 mM （pH 7.0），DCPD（010）面在$[101]_{Cc}$, $[10\text{-}1]_{Cc}$ 和 $[\text{-}100]_{Cc}$ 三个方向台阶移动速度。

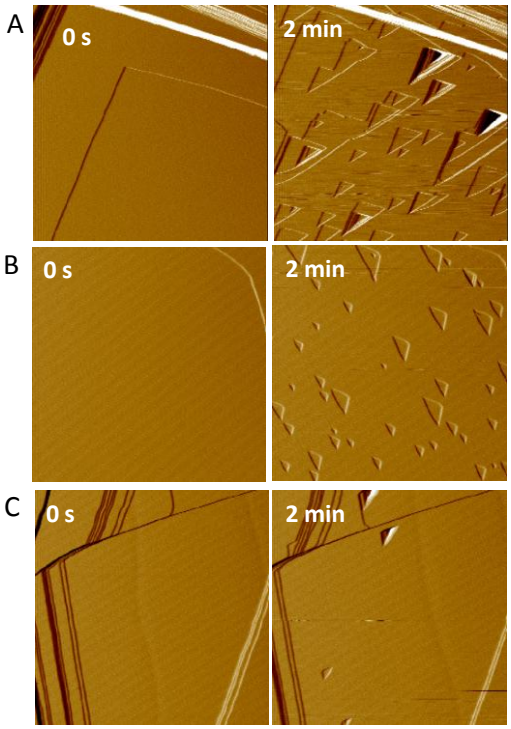


图 4. DCPD (010)表面在(A) 100 mM $MgCl_2$, (B) 100 mM $MgCl_2$ + 50 μM 柠檬酸或(C) 100 mM $MgCl_2$ + 50 μM L-天冬氨酸（pH7.0）作用下的 AFM 图。

2.1.4.3.有机酸中羟基的作用

我们选择了分别含有 0,1 和 2 个羟基的琥珀酸，苹果酸和酒石酸（图 5）。原位观察了 DCPD 的溶解。发现在 pH 4.0，在$[\text{-}100]_{Cc}$ 和$[101]_{Cc}$两个方向上溶解速度是酒石酸（2 个羟基）>琥珀酸（0 个羟基）>苹果酸（1 个羟基）；在$[10\text{-}1]_{Cc}$方向上没有明显差异（图 6）。当在 pH 6.0 时，在$[\text{-}100]_{Cc}$，$[10\text{-}1]_{Cc}$和$[101]_{Cc}$三个方向上均表现为酒石酸（2 个羟基≈苹果酸

（1 个羟基）> 琥珀酸（0 个羟基）（图 7）。然而当浓度超过 1 mM，琥珀酸对 DCPD 三个方向上的溶解速度均显著高于酒石酸和苹果酸。酒石酸和苹果酸仍保持相似的溶解速度。当在 pH 8.0 时，当三个有机酸浓度低于 1 mM 时，三个方向上的溶解速度没有明显差异（图 8）；当浓度大于 1 mM 时，在$[-100]_{Cc}$ 和$[10-1]_{Cc}$两个方向上酒石酸（2 个羟基）> 苹果酸（1 个羟基）> 琥珀酸（0 个羟基）（图 8）。在$[101]_{Cc}$上即使浓度大于 1 mM，三个有机酸对 DCPD 的溶解仍没有明显差异。

在溶解过程中蚀坑形貌也发生变化。当琥珀酸浓度为 0.1 mM 时，正常的三角形蚀坑（角度分别为 29,55 和 96 度）转变为四边形；当浓度继续增加到 1. 0 mM 时，三角形的形貌又恢复但角度发生了改变（29,75 和 76 度）（图 9）。随着酒石酸浓度增加到 5.0-10.0 mM，三角形蚀坑转变成梯形（图 10）。

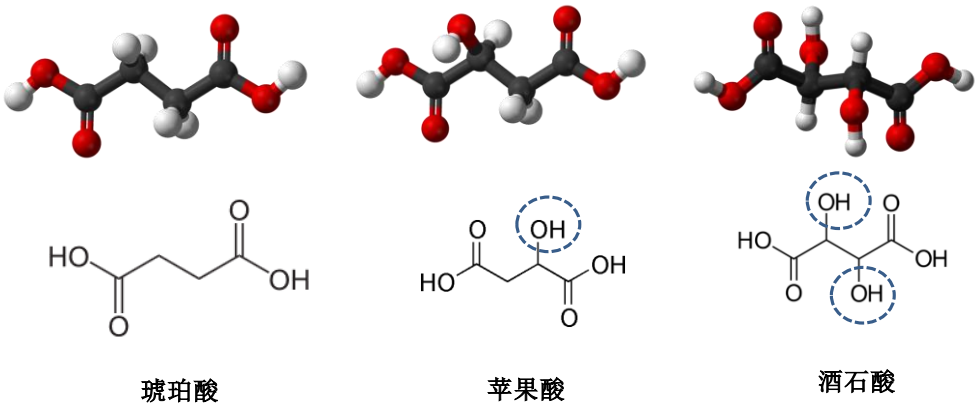


图 5. 三种有机酸包括琥珀酸，苹果酸和酒石酸分别含有 0, 1 和 2 个羟基。

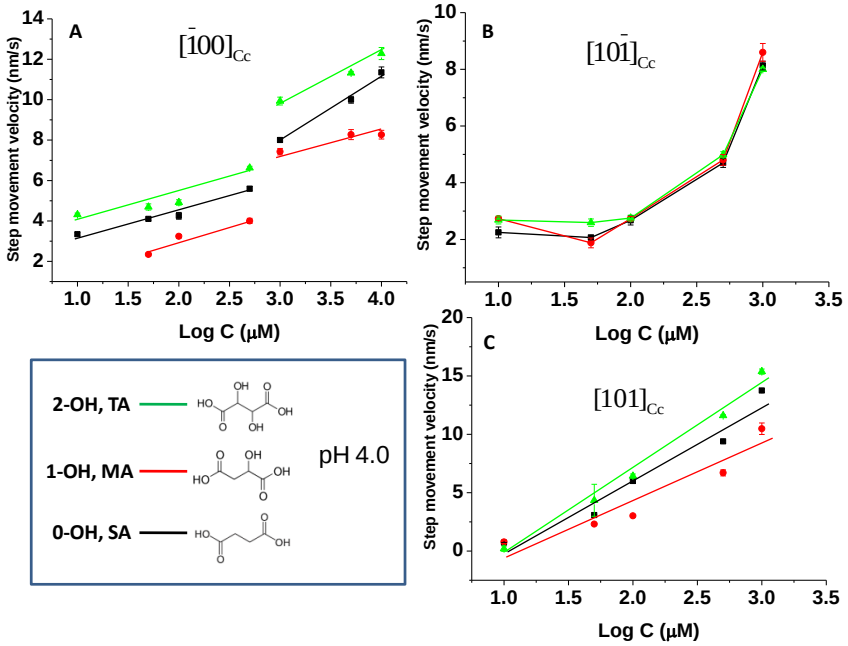


图 6. 分别含有 0,1 和 2 个羟基的琥珀酸，苹果酸和酒石酸在 DCPD 的(010)面上的三个方向的溶解速度（台阶移动速度）（在 pH 4.0）

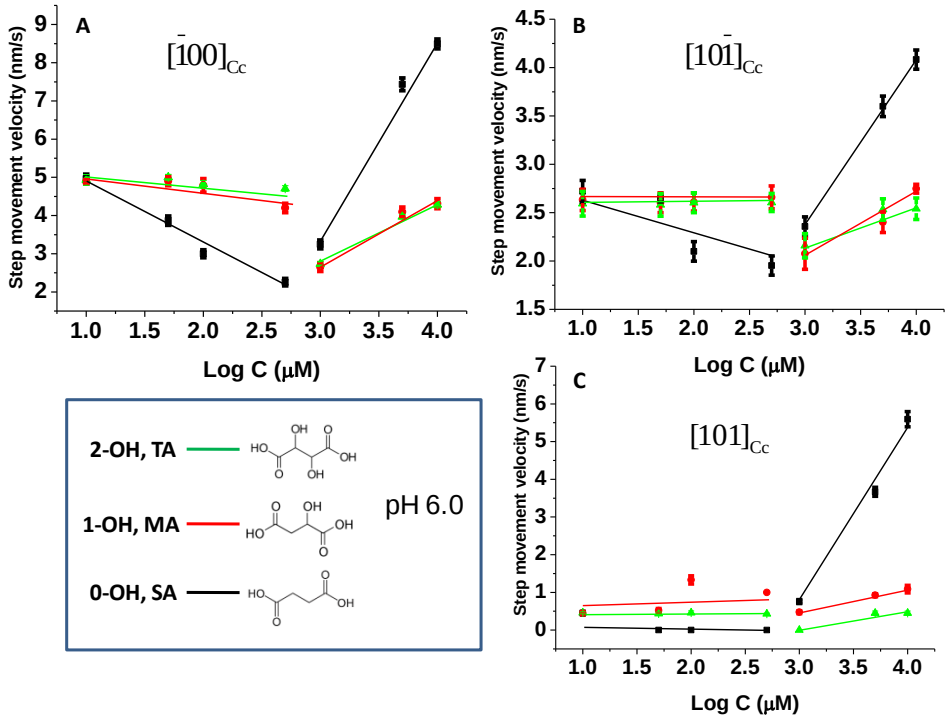


图 7. 分别含有 0,1 和 2 个羟基的琥珀酸，苹果酸和酒石酸在 DCPD 的(010)面上的三个方向的溶解速度（台阶移动速度）（在 pH 6.0）。

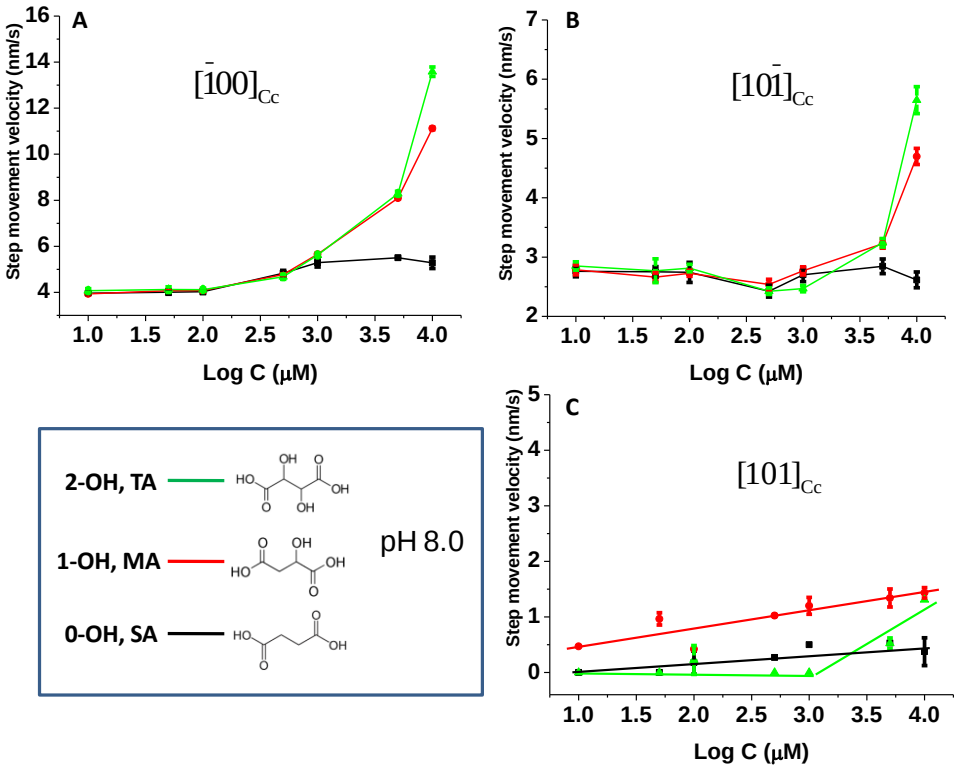


图 8. 分别含有 0,1 和 2 个羟基的琥珀酸，苹果酸和酒石酸在 DCPD 的(010)面上的三个方向的溶解速度（台阶移动速度）（在 pH 8.0）。

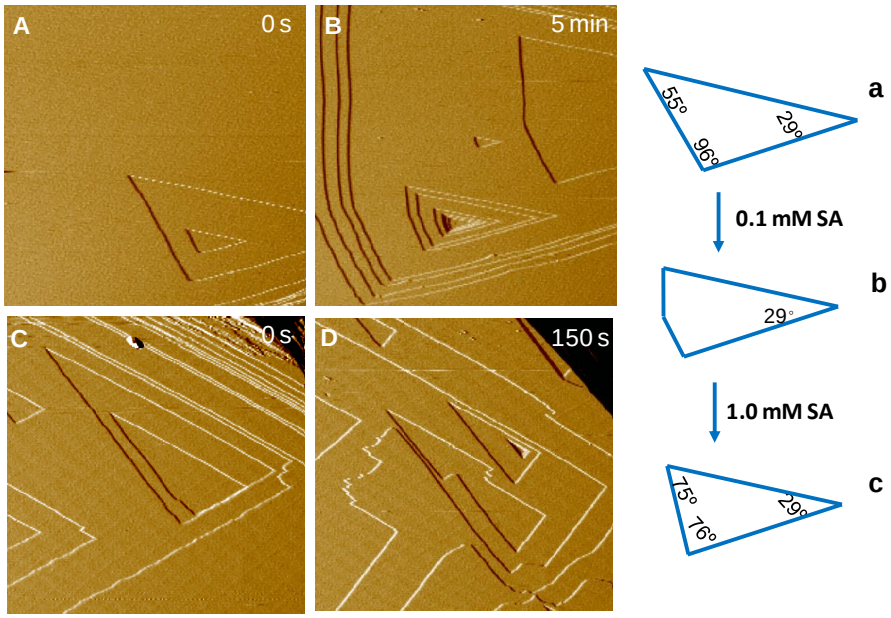


图 9.，在 pH 4.0，通入 H_2O (**A** 和 **C**)，和浓度为 0.1 mM (**B**) 和 1.0 mM (**D**)琥珀酸时 DCPD（010）面在 0s 和 150s 时蚀坑形貌的变化，a–c 显示的是蚀坑形貌变化的示意图。

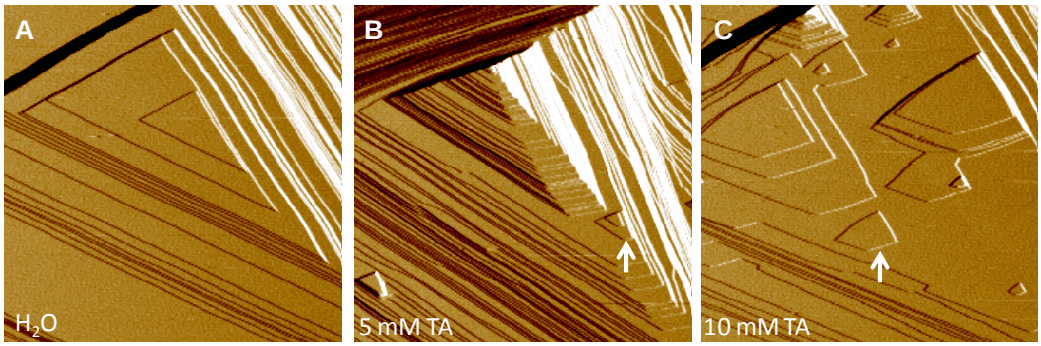


图 10. 在 pH 8.0，通入 H_2O(**A**)，和浓度为 0.5 mM (**B**)和 10 mM(**D**)酒石酸时 DCPD（010）面蚀坑形貌的变化。

2.1.5 甘蓝型油菜响应低磷胁迫的产量及相关性状 QTL

土壤有效磷的缺乏严重影响了作物的生长发育及产量形成。甘蓝型油菜是我国主要的油料作物，需磷多，对缺磷极为敏感。揭示甘蓝型油菜磷营养高效的机制，将有利于推进磷高效品种的选育。

华中农业大学植物营养遗传与分子生物学课题组以甘蓝型油菜磷高效品种宁油 7 号和磷低效品种 Tapdidor 所构建的的 DH 群体为材料，通过三年田间试验，调查了低磷胁迫对种子产量、第一分枝高度、株高、相对分枝高度、分枝数、每角果粒数、单株角果数及千粒重的影响。结果表明，低磷胁迫显著降低了 TN DH 群体的分枝数、株高、每角果粒数、单株角果数及产量，显著增加了第一分枝高度和相对分枝高度，但是对千粒重几乎没有影响。7

个产量相关性状中，单株角果数、相对分枝高度及分枝数对低磷胁迫最敏感。在 TN DH 遗传连锁图 G-map 的基础上整合了 53 个磷功能标记（GBM），构建了含 798 个标记的高密度的 TN 遗传连锁图，图谱总长为 2050.9 cM，标记间距为 2.6 cM。利用新建的遗传连锁图，对所调查的性状进行了 QTL 定位。共检测到 155 个显著性的 QTL，集中分布于 A2、A3、A5、A9、C6 和 C9 连锁群上。根据 QTL 置信区间相互重叠情况将 155 个 QTL 整合成了 81 个染色体区段，其中 29 个为低磷特异 QTL 区段、29 个为磷正常特异 QTL 区段、23 个为组成型表达的 QTL 区段。3 个低磷特异的 QTL 区段内，同一性状的 QTL 可在两年试验中重复出现。6 个组成型的 QTL 区段内，同一性状的 QTL 至少可在两年试验中的低磷水平下重复出现。这些低磷水平下重复检查到的 QTL 区段为甘蓝型油菜耐低磷产量性状的分子标记辅助育种提供了依据。通过 TN 遗传连锁图谱与白菜及甘蓝的基因组序列的比较作图，发现 *LPR1*、*GPT1*、*SIZ1*、*MGD2* 和 *PYK10* 等 5 个基因位于低磷水平下重复检测到的 QTL 区段内，这些白菜或甘蓝同源基因的序列信息将为下一步 QTL 的精细定位和候选基因的预测提供丰富的信息。

该研究结果 2013 年 1 月在 PLoS ONE（IF2013: 4.092）发表，第一作者为我中心博士研究生石桃雄（毕业后在贵州师范大学工作），通讯作者为中心老师石磊教授（Shi Taoxiong, Li Ruiyuan, Zhao Zunkang, Ding Guangda, Long Yan, MengJinling, XuFangsen, Shi Lei.（2013） QTL for yield traits and their association with functional genes in response to phosphorus deficiency in *Brassica napus*. PLoS ONE, 8(1): e54559. DOI:10.1371/journal.pone.0054559）。

2. 1.6 油菜磷高效相关根系形态构型 QTL 的定位

土壤缺磷是作物生长的主要限制因子之一。油菜是我国重要的油料作物，需磷较多，对缺磷敏感。油菜磷高效是复杂的数量性状，以根长和根重为主的根系特性对油菜磷的吸收，促进地上部生长发育起着很重要的作用。

最近，我中心与澳大利亚西澳大学（the University of Australia）、英国诺丁汉大学（the University of Nottingham）、英国詹姆士哈顿研究所（the James Hutton Institute）合作，采用琼脂培养，对磷高效品种宁油 7 号和磷低效品种 Tapidor 衍生的 TN DH 群体 188 个株系的根系形态构型进行了筛选，定位了不同磷水平主根长（PRL）、侧根长(LRL)、侧根数量(LRN)、侧根密度(LRD)和生物量等性状的 QTL。结果表明，两个磷水平地上部生物量均与根系性状密切相关。低磷水平，在 A3 染色体上检测到一个与侧根数量（LRN）、侧根密度（LRN）和生物量等性状显著相关的 QTL (quantitative trait loci)簇；在 A07 和 C06 染色体分别检测到主根长 QTL (表 1)。研究结果将为解析油菜磷高效的遗传机制，通过分子育种和转基因等现代生物技术改良油菜磷的吸收效率奠定基础。该研究结果 **2012 年 11 月 21 日在 Annals of Botany（IF2012: 4.03）**在线发表，第一作者为我中心石磊教授，通讯作者为西澳大学 John P. Hammond 博士（High-throughput root phenotyping screens identify genetic loci associated with root architectural traits in *Brassica napus* under contrasting phosphate availabilities.Annals of

Botany. DOI: 10.1093/aob/mcs245）。

表1　TN DH遗传连锁图谱上定位的生物量和根系形态构型显著性QTL

性状 Trait	QTL名称 QTL Name	染色体 Chromosome	分子标记 Marker	位置 Position (cM)	LOD值 LOD Score	区间 LOD support interval (cM)	加性效应 Additive Effect	解释表型方差 R2 (%)
SDW at LP	SDW_LP_A02a	A02	znS16M07-1-230	80.3	3.46	77.8 - 83	-0.30	6.2
	SDW_LP_A03a	A03	BRMS-043	44.2	7.68	42 - 44.6	-0.47	14.9
	SDW_LP_A04a	A04	JICB0283	7.2	5.15	5.3 - 17.2	-0.36	9.9
SDW at HP	SDW_HP_A03a	A03	BRMS-043	44.2	4.28	43.2 - 46	-0.43	8.5
	SDW_HP_C02a	C02	sN3761b	11.9	3.33	8.5 - 15	0.36	7.2
RDW at LP	RDW_LP_A03a	A03	BRMS-043	44.2	3.89	43.2 - 46	-0.07	7.8
RDW at HP	RDW_HP_A03a	A03	CNU098	61.3	3.13	60.3-62.4	-0.07	6.4
LRN at LP	LRN_LP_A03a	A03	HBr082	37.5	4.11	36.8 - 38	-1.19	8.9
	LRN_LP_A03b	A03	BRMS-043	44.2	4.81	43.2 - 46	-1.30	10.4
	LRN_LP_A03c	A03	B068E07-2	51.9	3.71	50.8 - 52.5	-1.13	8.4
LRN at HP	LRN_HP_C09a	C09	CB10064	36.0	3.51	34.6 - 43.6	1.06	8.2
LRD at LP	LRD_LP_A02a	A02	em12me31-320	73.3	3.92	66.6 - 75.5	-0.14	7.5
	LRD_LP_A03a	A03	CNU098	61.5	4.55	60.3 - 62.4	-0.16	8.7
	LRD_LP_A03b	A03	H034E17-1	69.3	3.83	67.3 - 70.7	-0.14	7.4
	LRD_LP_A03c	A03	BnPYK10-A3b	76.7	3.89	70.7 - 76.8	-0.14	7.8
	LRD_LP_A09a	A09	B019F12-3	37.9	5.37	34.9 - 40.6	-0.23	11.5
	LRD_LP_C06a	C06	JBnB061J08	29.0	3.74	25.7 - 35.2	-0.13	7.1
LRD at HP	LRD_HP_A04a	A04	JICB0283	16.2	5.98	7.6 - 21	-0.15	13.2
	LRD_HP_C04a	C04	sN12353c	50.6	3.36	49.9 - 52.3	-0.10	6.8

	LRD_HP_C04b	C04	Na10C01a	62.2	3.64	59.6 - 62.7	-0.10	7.5
TRL at HP	TRL_HP_A03a	A03	BnWRKY-A3	14.4	3.64	10.8 - 17	-1.33	7.5
PRL at LP	PRL_LP_A03a	A03	BnPHT3-A3	15.5	3.36	13.5 - 18.8	-0.40	5.8
	PRL_LP_A07a	A07	BRAS023	29.8	4.76	28.8 - 36.3	0.48	9.5
	PRL_LP_A07b	A07	HR-Tp4-305	42.6	5.70	39.5 - 46.4	0.50	10.2
	PRL_LP_A07c	A07	sR7223	50.6	4.46	48 - 54.3	0.44	8.2
	PRL_LP_C06a	C06	em18me23-350	27.5	6.07	17.6 - 34.7	0.53	12.0
PRL at HP	PRL_HP_A03a	A03	BnPHT3-A3	15.5	4.59	14.4 - 17	-0.67	8.3
	PRL_HP_A03b	A03	H003M07-4	21.9	3.88	20.9 - 27.8	-0.64	8.0
	PRL_HP_C06a	C06	CNU053a	21.4	6.82	20.6 - 25.7	0.82	14.8
	PRL_HP_C06b	C06	em18me23-350	27.5	8.00	25.7 - 33.6	0.85	16.3

2.1. 7 油菜细胞分裂素不敏感（6-BA）根系突变体表现为磷高效

根系是植物吸收养分和水分的重要器官。在模式植物拟南芥中，利用筛选获得的突变体研究植物养分吸收利用及其生理机制是一种有效的手段，但农作物中利用突变体进行类似研究较少，在油菜中利用筛选获得的根系突变体研究植物养分吸收利用及其生理机制，尚无一例报道。

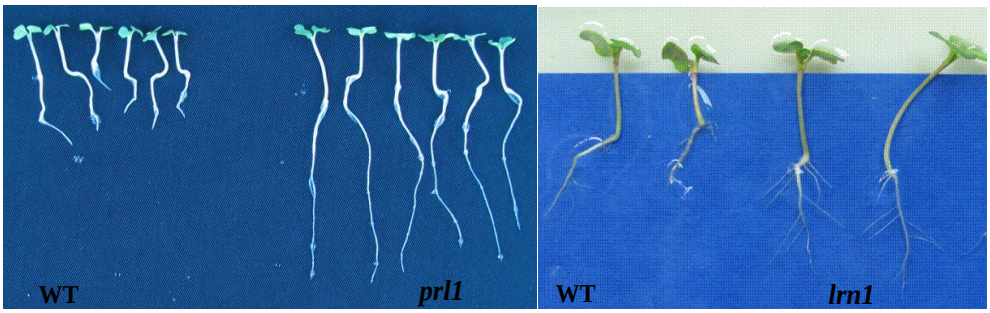


图 1 0.2 μM 6-BA 溶液中根系突变体与野生型的根系形态差异

最近，我中心植物营养遗传与分子生物学课题组采用一种适合油菜根系突变体筛选的方法，分离鉴定了数个油菜外源细胞分裂素不敏感根系突变体。在此基础上，对主根突变体 *prl1* 和侧根突变体 *lrn1* 的磷效率进行了鉴定，发现 *prl1* 和 *lrn1* 与野生型相比，在低磷和高磷处理下生物量显著增加，表现为磷高效。通过分析低磷和高磷水平下突变体和野生型内源细胞分裂素水平和磷吸收利用相关基因表达的差异，揭示了根系突变体磷高效的机制，这为

油菜磷高效机制的研究和培育油菜磷高效品种提供了新思路。相关研究结果已在 Plant Soil 上发表，通讯作者为石磊教授（*Brassica napus* root mutantsinsensitive to exogenous cytokinin showphosphorusefficiency. *Plant and Soil.* 2012, 358: 61-74.DOI: 10.1007/s11104-012-1219-2）。

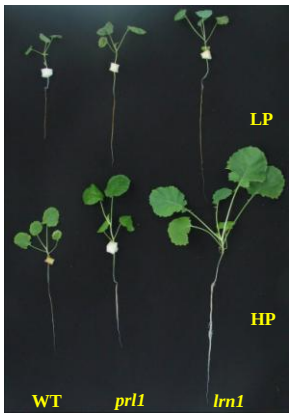


图 2 不同磷水平下突变体和野生型苗期长势。LP 低磷（5 μM P）；HP 高磷（1000 μM P）。

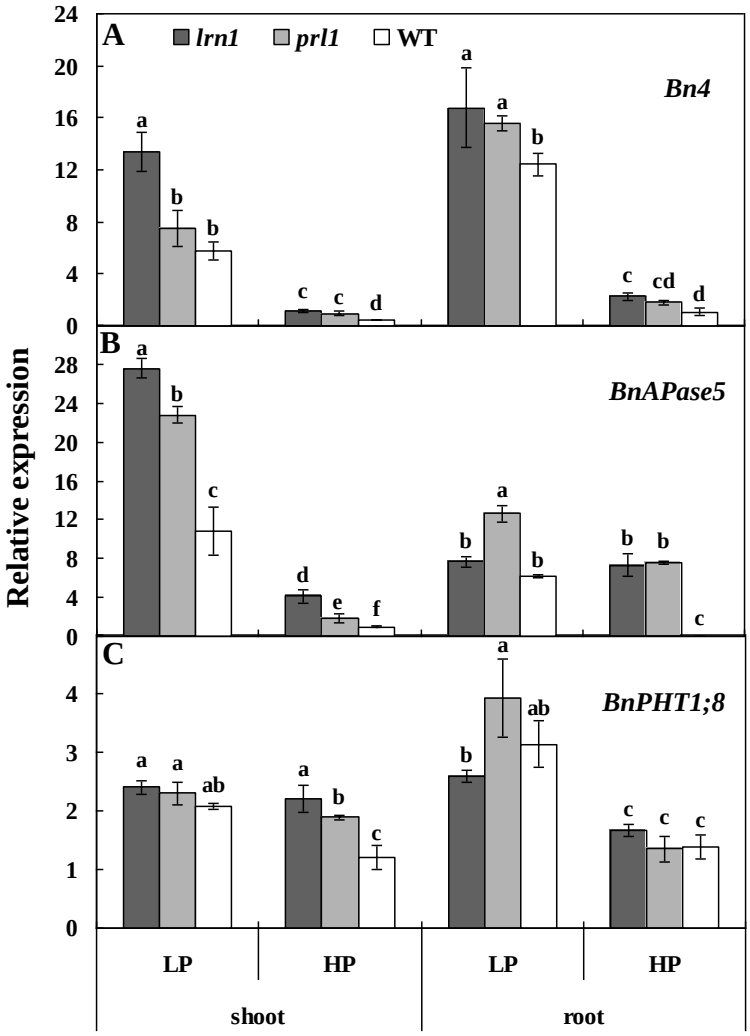


图 3 低磷和高磷处理下突变体和野生型地上部及根部 *Bn4*、*BnAPase5* 和 *BnPHT1;8* 的相对表达量。LP 表示低磷处理（5 μM P）；HP 表示高磷处理（1000 μM P）。误差线表示 3 次重复的标准差。小写字母（a, b, c, d, e, f）表示在 $P = 0.05$ 的置信水平的显著性分析。

2.1.8 烟草对硒的吸收、形态转化及硒胁迫响应

硒是人体和动物必需的微量元素。缺硒会导致克山病、心血管疾病、肌综合征等病甚至死亡。中国约 72%的土地缺硒，通过施用硒肥来生产富硒食品是解决人体缺硒的一种有效方法。硒对人和动物的有益和毒性作用不仅依赖于其剂量，还与硒的化学形态及其生物有效性有关。有机硒较无机硒相比，具有更安全和高效的特性。因此，明确硒施入土壤后植物对硒的吸收及富硒植物体内硒的形态变化对于了解硒在植物体内的代谢机制以及对人体健康的影响具有十分重要的意义。目前关于作物和蔬菜体内硒的存在形态已有不少研究，然而关于不同剂量硒处理条件下作物体内硒的形态变化却少有报道。

烟叶中含有丰富和优质的可溶性蛋白，是生产富硒蛋白的良好材料。微量元素中心污染环境与修复课题组以烤烟（*Nicotiana tabacum*）为供试材料，研究了不同水平硒处理条件下烤烟植株中硒的累积、形态及对烟草生长和抗氧化系统的影响。结果表明：（1）土壤低硒处理(Se≤4.4 mg kg^{-1})促进了烤烟的生长，提高了烤烟抗氧化胁迫的能力；而高硒处理(22.2 mg kg^{-1})降低了烤烟抗氧化胁迫的能力，使烤烟生长受到抑制。（2）烤烟植株中硒含量随土壤中硒处理浓度的增加显著提高。（3）随硒处理浓度的增加，烤烟根和叶中有机态硒（Se-Cys 和 Se-Met）所占比例减少，无机态硒[Se(Ⅳ)和 Se(Ⅵ)]所占比例增加。（4）硒对烤烟的生长和抗氧化能力的影响与烤烟中无机硒（Se(Ⅵ)和 Se(Ⅳ)）的含量比例密切相关，土壤硒含量过高导致植物体内无机硒比例提高，从而降低烤烟抗氧化能力，抑制植物生长。相关研究结果在 Enivronmental and Experimental Botany 上发表，第一作者为中心博士研究生韩丹，通讯作者为熊双莲副教授（Selenium uptake, speciation and stressed response of Nicotianatabacum L., *Enivronmental and Experimental Botany* ,2013, 95: 6-14. ）

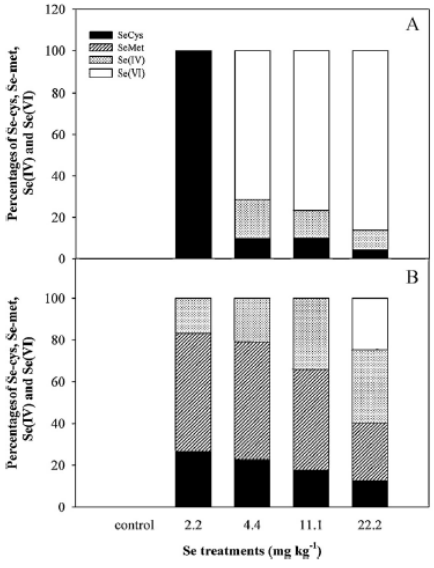


图 3 烤烟根和叶中不同硒形态所占的百分比

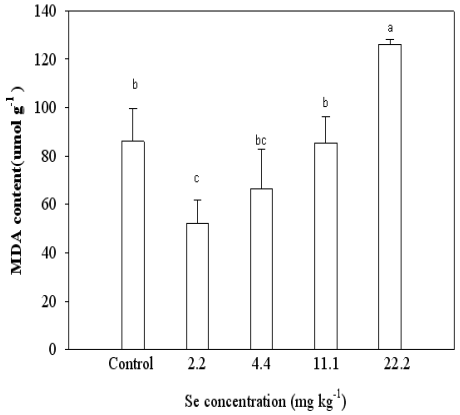


图 6 不同硒处理对烤烟叶中 MDA 含量的影响

2.1. 9 新吸收的硼在柑橘体内的分配以及叶片施硼后硼的移动性

柑橘是世界第一大水果，而我国的柑橘无论是种植面积还是总产量都已位居世界第一

位，其在我国农业中占有重要的作用。然而，近年来我国柑橘产区由于严重缺硼而造成的叶片黄化以及落果等症状严重影响了柑橘的产量和品质。而对缺硼的诊断以及最有效的施硼方式的选择，则因硼在不同植物中不同的移动性而有所不同。因此，明确硼在柑橘体内的分配以及移动性，对于采取合理的施硼方式以减轻其缺硼状况具有重要的作用。

我中心的植物营养课题组通过同位素 10B 示踪，研究了新吸收的硼在柑橘体内的分配以及下部老叶施硼后硼的移动性。结果表明：（1）新吸收的硼优先往新叶中转运，且在不同砧木脐橙老叶中的分配模式存在差异，新吸收的硼往枳橙砧木纽荷尔脐橙老叶中的分配远高于往枳壳砧木脐橙老叶中的分配，这些结果从一个角度解释了大田中观察到的枳壳砧木纽荷尔脐橙老叶缺硼症状更明显的现象；（2）脐橙叶片施硼可以发生转运，下部老叶施硼后往新叶中的转运大于往其他老叶中的转运，枳橙与枳壳砧木纽荷尔脐橙中分别至少有吸收总硼的 15.8% 和 17.6 % 转运到其他部位；（3）叶片施硼不能转运到根中，反而还会降低根中硼的积累量，在缺硼的土壤中如果只采取叶片施硼的方式，反而可能会加重根的缺硼症状，从而还会导致根对其他元素的影响。因此，农业生产中在缺硼的柑橘园施硼方式应以土施为主，叶施为辅。相关结果在 PLANT SOIL 上发表，通讯作者为姜存仓副教授（Liu Guidong, Wang Ruidong, Wu Lishu, Peng Shuang, Wang Yunhua, Jiang Cuncang*,2012. Boron distribution and mobility in navel orange grafted on citrange and trifoliate orange [J], *Plant and Soil*,360: 123-133. DOI: 10.1007/s11104-012-1225-4）。

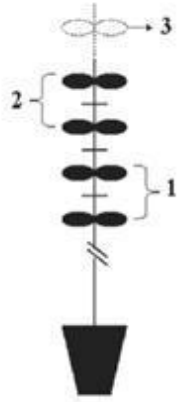


图1 同位素 10B 涂抹不同部位叶片示意图

Fig. 4 Influence of foliar fertilization with enriched ^{10}B on the percent abundance of ^{10}B in the lower old leaves (a), the root (b), the upper old leaves (c), and the new leaves (d) of 'Newhall' navel orange grafted on citrange or trifoliate orange supplied with low concentration of natural-abundance B as root fertilization. The lower old leaves were treated with 47 m*M* boric acid containing 95 % enriched ^{10}B (foliar B) or distilled water (control). These plants were cultured for 35 days. *Bars* represent means of three replicates ± SD. Different letters in each plant part indicate significant differences between control and foliar B (*t*-test, $n=3$, $P<0.05$)

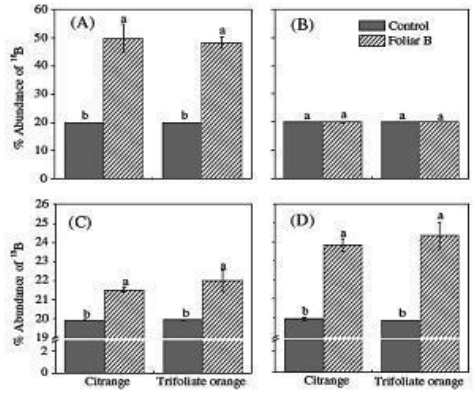


图 2 枳壳和枳橙砧木的纽荷尔脐橙根系及不同部位叶片 10B 的丰度

2.1.10 硒增强油菜对菌核病抗性研究

通过喷施与土施硒素，比较不同浓度硒对油菜菌核病的防治效果，确定最佳施硒量；分析了硒对油菜各部位矿质元素含量的影响，测定各结合态硒的含量，分析其与增强油菜抗病性的关系；分析油菜超微结构变化、防卫反应相关基因的表达情况与增强油菜抗病性的关系。油菜菌核病发病情况分别从叶片、茎杆的发病率和病斑大小进行分析。与对照相比，土壤施用 0.1 mg/Kg 硒有效降低了茎杆发病率，而土壤施硒 1 mg/Kg 和叶片喷施均未表现出显著的抑制效果。与接种对照相比，土壤施用 0.1 mg/Kg 硒和叶片喷硒 0.1 mg/L 有助于维持叶片叶

绿体片层结构的稳定，增加质体颗粒数，而高浓度的硒则加剧了叶绿体的解体。硒增加了 Se、N、P、K、Ca、Mg 等元素在油菜叶片的积累，但不同浓度硒处理之间并未呈现出显著一致的规律。土壤施用 0.1 和 0.5 mg/Kg 硒有助于上调与 JA/ET 抗病途径相关基因的表达量，同时增加了 *PAL*、*FeSOD* 两个主要抗氧化酶基因表达量。

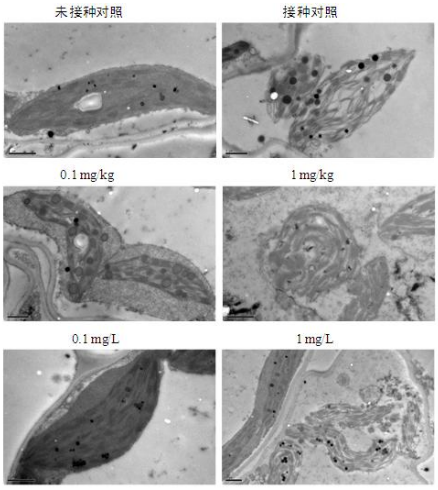


图 2 硒作用下油菜叶片叶绿体超微结构

2.1.11 黏胶层对豌豆根尖铝毒的保护作用

根边缘细胞是从根尖脱落下来并聚集在根尖周围的一群特殊的细胞，与一系列从根冠细胞分离而被降解的细胞壁碎片，以及有机酸、糖和其它高分子有机物组成了根尖周围的根冠粘胶层，其在感受和响应逆境胁迫，保护根尖免受不利环境因素的胁迫起重要作用。喻敏课题组通过研究豌豆根尖铝毒机理发现，去除黏胶层后根尖铝含量、胼胝质含量显著增加，铝毒程度加深，表明铝毒时黏胶有保护根尖的作用; 对黏胶多糖的柱层析分析,发现铝毒条件下高分子量和低分子量多糖分子量增加，且铝峰与多糖峰重叠，高分子多糖铝含量较高，表明铝起着阳离子桥的作用，将较小分子量多糖复合在一起，不但牢牢固定了铝，而且形成更致密的粘胶层，因而铝毒时粘胶层对根尖起着有效保护作用。相关结果系列发表在 ***Acta physiologiae plantarum*** 上。

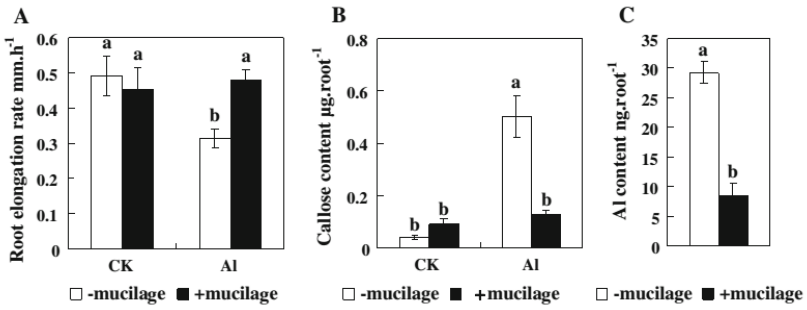


Fig. 1 The effects of mucilageon root elongation (**a**), callose induction (**b**) and Alaccumulation (**c**) under Al mistexposure for 24 h.

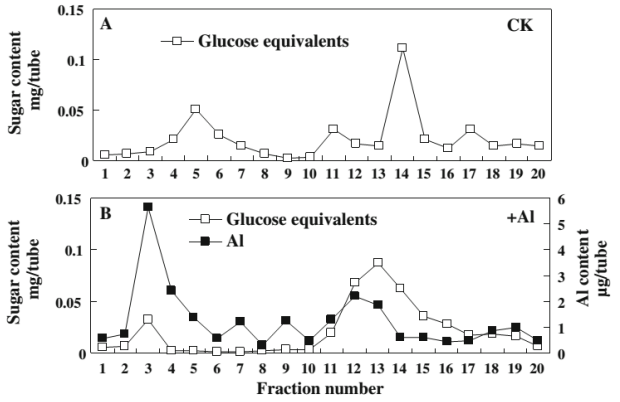


Fig. Elution curves ofpolysaccharides from mucilage of pea root with/without Alexposure by Sephacryl^{TM}S-200size exclusion chromatography.**a** Elution curves of sugarcontent (open block) at control,**b** elution curves of sugarcontent (open block) and Alcontent (closed block) at Al exposure. Geng M, Xu M, Xiao H, et al. Protective role of mucilage against Al toxicity to root apex of pea (*Pisum sativum*)[J]. ***Acta physiologiae plantarum***, 2012, 34(4): 1261-1266.

2.1.12 硼对铝在细胞壁上吸附解吸的影响

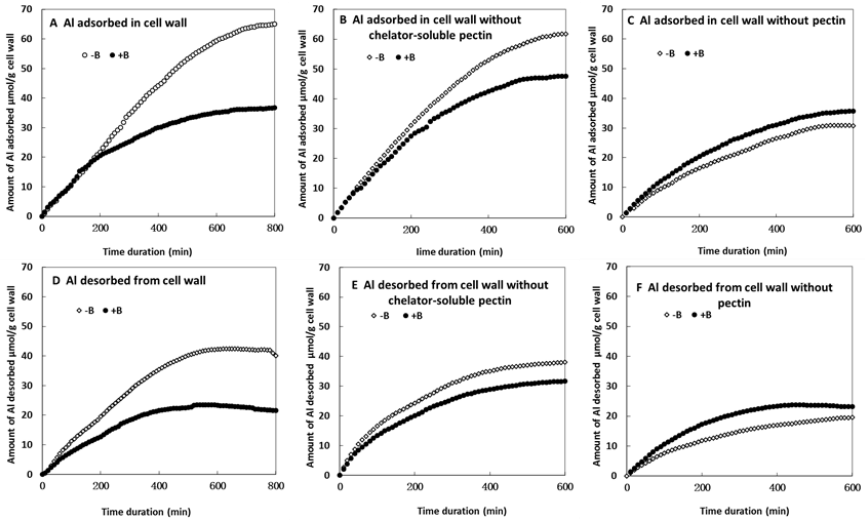


Fig.1Influence of B on Al Adsorption (A-C) and Desorption (D-F) in Different Root Cell Wall Materials. Later roots were collected and cell wall was extracted as described in Materials and methods. Cell wall (A,D); Cell wall without chelator-soluble pectin (B,E) and Cell wall without pectin (C,F).

植物根尖细胞壁作为植物响应铝毒环境的第一道屏障，既是铝毒害的最初位点，也是铝积累的主要部位，果胶作为细胞壁的主要组成成分，其携带的-COOH 被认为是铝在细胞壁上的主要吸附位点。喻敏课题组通过铝在细胞壁上的吸附解吸动力学研究发现，离体条件下外源硼能够有效减少铝在细胞壁尤其是螯合态果胶中的吸附；原位培养时发现，硼还显著降低根尖铝敏感区域 PME 活性，而 PME 与细胞壁果胶甲酯化程度相关，硼可能通过降低 PME

活性，改变果胶甲酯化程度，减少铝在细胞壁及根尖敏感区域的累积，因而减轻了根尖铝毒。相关结果系列拟发表在 ***Soil Science and Plant Nutrition*** 上。

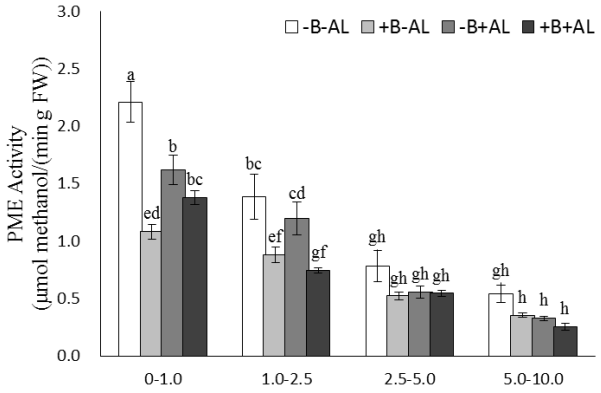


Fig. 2 Influence of B and Al on activity of PME (B) in root segment. Pea seedlings were grown with B (+B) or without B (-B), and treated with Al (+Al) or without Al (-Al).

2.1.13 植物硼高效的生理与遗传机理

硼是高等植物生长发育所必需的微量营养元素。世界很多地区硼的缺乏已经成为影响作物产量的主要限制因子。为了更好理解植物响应缺硼胁迫的适应性机制，我们使用 Affymetrix 基因芯片对拟南芥硼高效基因型 Cs1938 在短期和长期低硼胁迫下的差异表达基因进了鉴定。结果表明在短期缺硼胁迫后的 3 h、24 h 和 72 h 三个时间点上，共有 843 个基因的表达发生了显著变化，其中 446 个基因上调表达，397 个基因下调表达。而在长期低硼胁迫 20 d 后，共有 2,473 个基因的表达量发生显著改变，848 个基因表达量上升，1,626 个基因表达量下降。此外，我们也对拟南芥硼低效基因型 Cs933 在长期低硼胁迫下的差异表达基因进了鉴定，835 个基因受低硼胁迫诱导表达，653 个基因被抑制表达（图 1）。

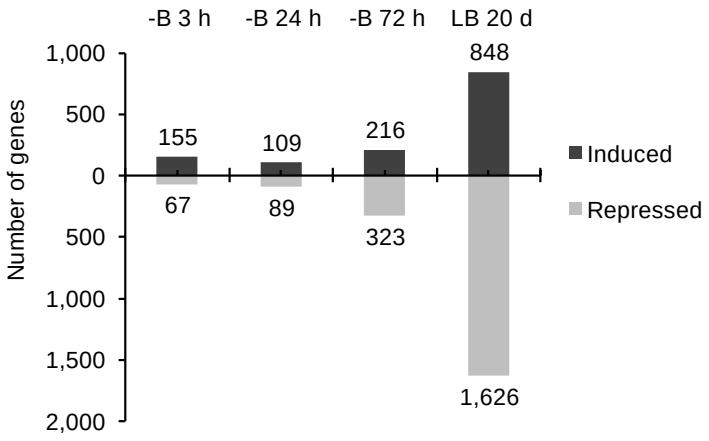


图 1 短期和长期低硼胁迫下诱导或抑制表达基因数

通过对获得的差异表达基因进行功能分析，我们发现在短期缺硼条件下，主要是一些参

与信号转导、转录调控、激素代谢、逆境响应和次生代谢等相关的基因的表达模式发生了改变。而在长期胁迫条件下，更多的与细胞壁代谢、离子运输、中心代谢和细胞生长的相关的代谢途径的基因的表达产生变化。基于这些差异表达的基因，我们构建了一个植物响应低硼胁迫的分子模型。其中，茉莉酸被推测在整合植物对缺硼胁迫的适应性反应中扮演了重要的角色（图 2）。

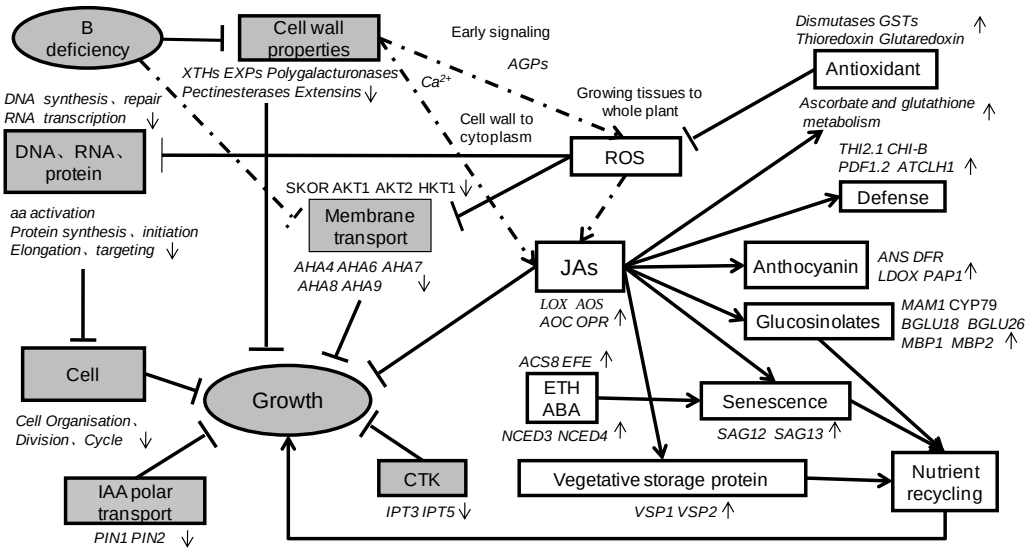


图 2 植物响应低硼胁迫的分子模型。图中连线主要基于在本实验中鉴定的低硼响应基因和已发表的信息。向上和向下的箭头分别表示受缺硼诱导和抑制表达的基因。

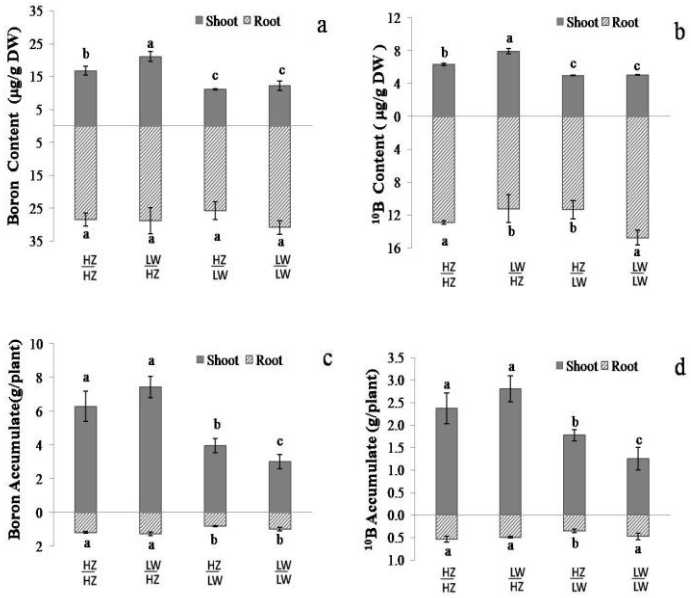


图 3 供应同位素后不同嫁接油菜总 B, ^{10}B 的含量和累积量

甘蓝型油菜是我国主要的油料作物之一，对缺硼敏感。我们以硼高效品种 HZ、HQ 和硼低效品种 LW、LB 为试验材料，采用同位素示踪、嫁接、土培等方法，较系统地研究了

不同硼效率品种甘蓝型油菜对硼的吸收、转运差异的机理，并建立了不同硼效率品种甘蓝型油菜的悬浮细胞系，为从细胞水平上研究不同基因型油菜硼效率差异的机制奠定基础。同位素实验结果表明高效品种 HZ 和 HQ 在硼的吸收、转运方面均显著高于低效品种，其中 HZ 的抗低硼胁迫能力高于 HQ。低效品种 LW 是一个转运低效品种，低效品种 LB 是一个吸收低效品种。进一步以高效品种 HZ 和低效品种 LW 为材料进行嫁接试验，结果证明了高效品种 HZ 的吸收转运能力强于低效品种 LW，硼的吸收转运能力决定于根系（图 3）。

对硼高效品种 HZ、HQ 和硼低效品种 LW、LB 进行低硼胁迫，分析硼相关基因 *BnBOR1*，*BnGUT1*，*BnGUT2*，*KDOPS* 在油菜不同部位的表达。结果表明，高效品种 HZ 在低硼胁迫下，根系中的 *BnBOR1;1a*、*BnBOR1;1c*、*BnBOR1;2c* 、*BnBOR1;3a* 基因的表达均较强，说明低硼胁迫下，高效品种 HZ 能够将更多的硼转运到根系木质部导管中（图 4）。

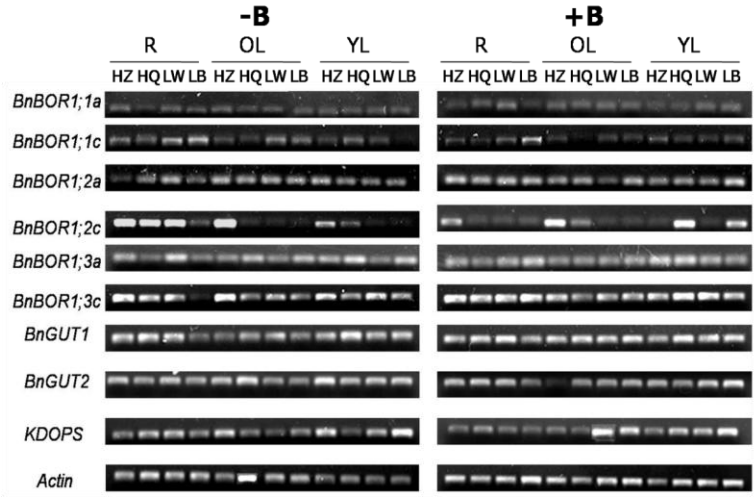


图 4 不同硼处理下硼相关基因在不同组织器官的表达

NIP5 ;1 是植物忍耐低硼胁迫的一个关键基因。我们从甘蓝型油菜硼高效品种青油 10 号和硼低效品种 Westar10 中分别克隆得到 6 个拟南芥 *NIP5;1* 的同源基因，并分别命名为 *BnNIP5;1-1a*、*BnNIP5;1-1c*、 *BnNIP5;1-2a* 、*BnNIP5;1-2c*、*BnNIP5;1-3a* 和 *BnNIP5;1-3c*，统称为 *BnNIP5;1s*（图 5）。

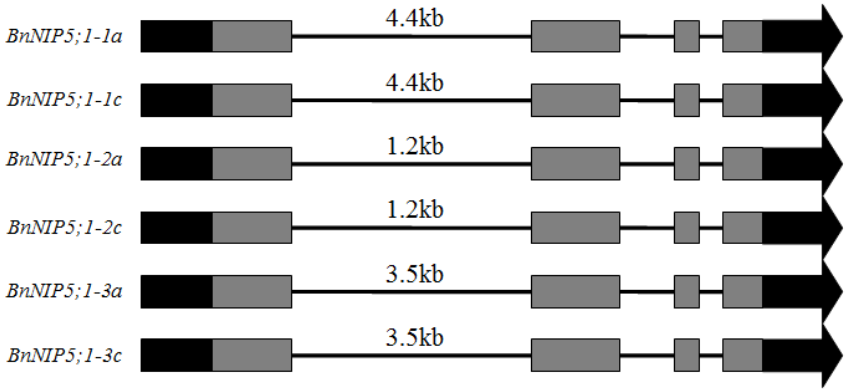


图 5 甘蓝型油菜 *NIP5;1* 结构示意图

此外，我们以甘蓝型油菜硼高效 BQ DH 群体为材料构建高密度的遗传连锁图。通过三年的田间试验调查硼缺乏和硼正常条件下群体成熟期的籽粒产量及产量相关性状的表型变异。结合 BQ DH 遗传连锁图谱和群体表型进行了全基因组硼高效相关 QTL 定位与分析（Zhao et al. 2013）。

2.1.14 油菜磷高效的遗传机理研究

土壤有效磷的缺乏严重影响了作物的生长发育及产量形成。甘蓝型油菜是我国主要的油料作物，需磷多，对缺磷极为敏感。以甘蓝型油菜磷高效品种 Ningyou7 和磷低效品种 Tapdidor 所构建的 DH 群体为材料，通过三年田间试验，调查了缺磷和磷正常条件下成熟期产量及产量相关性状的表型变异，结合 TN DH 遗传连锁图谱和群体表型共定位了 155 个显著性的 QTL（图 6）。

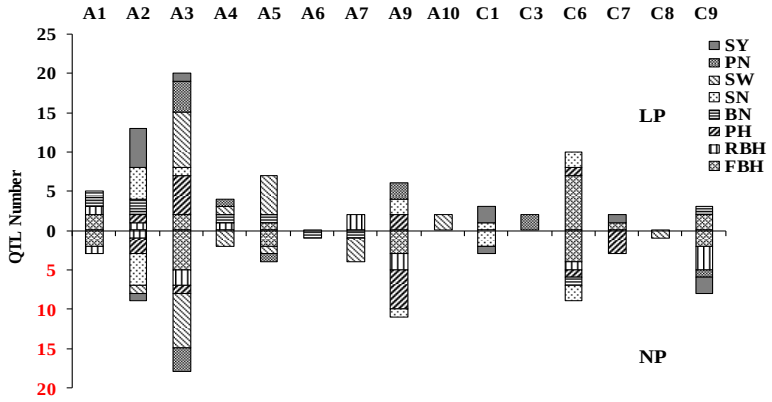


图 6 低磷（横坐标上）和磷正常（横坐标下）条件下检测到的种子产量及相关性状 QTL 在连锁群上的分布

以细胞分裂素 6-苄基腺嘌呤（6-benzyl adenine, 6-BA）作为突变体筛选试剂筛选了甘蓝型油菜 EMS 突变体库的 3500 个 M_2 代自交株系，获得了对 6-BA 不敏感主根突变体 *prl1* 和侧根突变体 *lrn1*。通过对突变体的研究发现，*lrn1* 根系内源细胞分裂素水平的下降，削弱了其对根系生长和磷饥饿诱导基因表达的抑制作用，从而提高了 *lrn1* 磷吸收和利用效率。*lrn1* 和 *prl1* 之间根系生长及磷饥饿基因上调表达的差异可能导致了它们磷营养效率不同（图 7）。

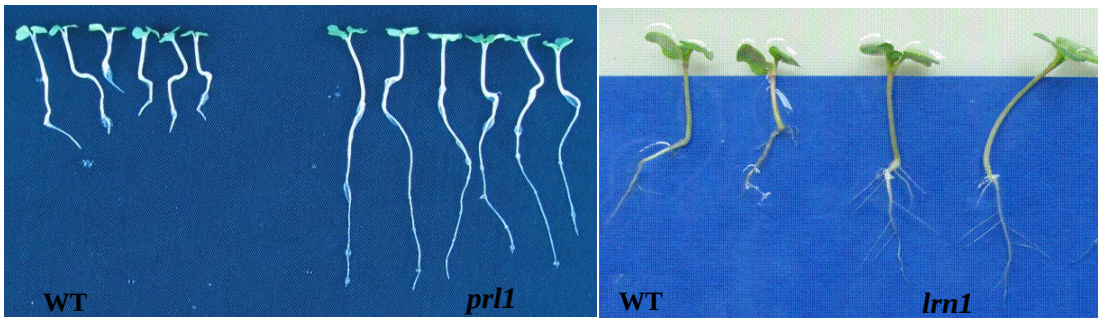


图 7 0.2 μM 6-BA 溶液中根系突变体与野生型的根系形态差异

此外，通过农杆菌介导的基因遗传转化技术，在获得甘蓝型油菜超量表达 *Pseudomonas aeruginosa* 柠檬酸合成酶（CS）基因、及整合有胡萝卜外展蛋白的植酸酶基因 *phyA* 和 *appA* 的转基因株系的基础上，利用水培、砂培、土培等方法研究了转基因植株对铝毒害和低磷胁迫的抗性、及其生理和分子机理。结果表明，在甘蓝型油菜中超量表达 *CS* 基因不仅提高了转基因株系柠檬酸的分泌量，而且影响了苹果酸的合成代谢，这两种有机酸分泌量的增加提高了转基因株系 CS3 和 CS6 的铝毒抗性和低磷忍耐力。甘蓝型油菜超量表达融合有胡萝卜外展蛋白信号肽序列的植酸酶基因可以显著增强转基因植株根系分泌的植酸酶活性，提高转基因株系对植酸磷的吸收利用能力。并且，转基因植株种子具有很高的植酸酶活性（wang et al. 2012,2013）。

2.1.15 水稻氮代谢关键基因研究

以超量表达 *GS1;1*、*GS1;2*、*AMT1;3*、*GS2* (*OX-GS1;1*、*OX-GS1;2*、*OX-AMT1;3*、*OX-GS2*) 四种转基因水稻为研究材料，将碳氮代谢平衡作为切入点，从生长表型和产量；叶片 SPAD 值和光合作用参数；水溶性蛋白质和碳水化合物含量；总碳、总氮以及碳/氮比；NR、GS 和 RUBISCO 活性；碳氮关键基因的表达水平以及氮的吸收转运方面开展了系列研究，探讨了超量表达单个基因 *GS1;1*、*GS1;2*、*AMT1;3*、*GS2* 对植株碳氮代谢的影响，解析上述转基因植株生物量及产量低下的主要原因，为今后揭示氮高吸收、利用的生理生化基础和分子机理提供理论参考。研究表明，*GS1;1*、*GS1;2* 的超量表达导致转基因植株氮吸收能力降低，碳氮代谢产物的含量和关键基因表达水平发生改变，最终影响转基因植株的正常生长和产量形成。*AMT1;3* 的超量表达导致转基因植株碳氮代谢水平降低，最终影响转基因植株的正常生长和产量形成。

2.2 微量元素与生态安全

2.2.1 两个冬小麦品种对土壤钼活化差异及其机理研究

2.2.1.1 两个冬小麦基因型钼吸收动力学差异及机理研究

随着环境介质中钼浓度的增加，两基因型冬小麦钼吸收速率逐渐增加，在 10μmol/L 时达到最大值。当介质浓度超过 10μmol/L 时，又出现降低的趋势，说明适宜的钼浓度能提高冬小麦吸收钼的能力，但当浓度过高会对冬小麦造成毒害效应，这种毒害效应短时间不会在外观上体现出来，而最直接的体现则表现在钼吸收速率及吸收量的降低。当环境介质钼浓度低于 1μmol/L 时，97003 的吸收速率显著高于 97014 且在钼浓度为 0.6-1μmol/L 范围内达显著差异，而当环境介质钼浓度高于 1μmol/L 时， 97003 又显著低于 97014 且在 5-20μmol/L 之间达到显著差异(图 1)。两个冬小麦基因型在低钼和高钼条件下吸收能力强弱不同的原因有待深入研究。

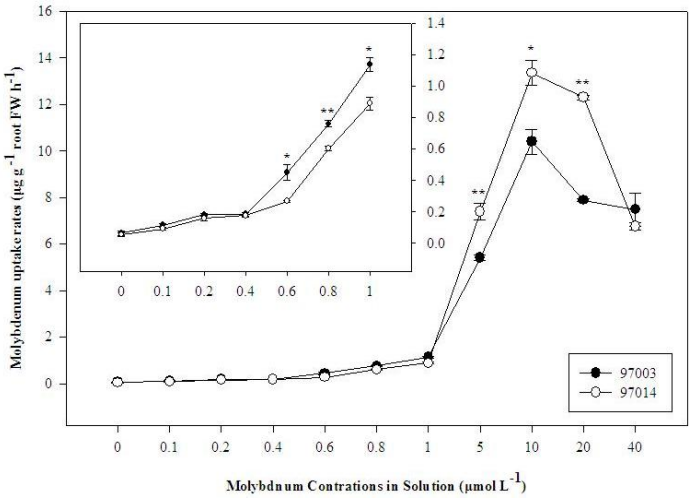


图 1 两个冬小麦基因型钼吸收随环境钼浓度变化的差异

2.2.1.2 两个冬小麦基因型钼吸收转运相关基因表达分析

为了深入理解两个冬小麦基因型钼吸收转运的差异，研究了钼吸收相关基因 TaSultr1.1、TaSultr5.2、TaSultr5.1、TaCnx1、TaPht1.1 、TaPht1.2 和 TaPht1.4 表达量随时间和介质钼浓度变化情况。经过逐步回归分析，发现冬小麦钼吸收速率与 TaSultr5.2 显著正相关，吸收量与 TaSultr5.1、TaSultr5.2 和 TaCnx1 显著相关，说明 TaSultr5.1、TaSultr5.2 和 TaCnx1 这三个蛋白在冬小麦钼酸盐的吸收上起着关键的作用，也是两个冬小麦基因型钼吸收差异的原因之一。

表 2 钼吸收速率与钼吸收、转移及同化相关蛋白基因表达的逐步回归分析

Correlation	Rates	TaSultr1.1	TaSultr5.2	TaSultr5.1	TaCnx1	TaPht1.1 or 1.9	TaPht1.2	TaPht1.4
Rates	1.000	-.033	.889**	.500*	.083	-.100	.273	.545*
TaSultr1.1	-.033	1.000	.009	.406*	.333	.254	-.040	-.392
TaSultr5.2	.889**	.009	1.000	.703**	-.099	-.073	.195	.687**
TaSultr5.1	.500*	.406*	.703**	1.000	-.325	.241	-.099	.241
TaCnx1	.083	.333	-.099	-.325	1.000	.035	.334	.062
TaPht1.1 or 1.9	-.100	.254	-.073	.241	.035	1.000	-.478*	-.230
TaPht1.2	.273	-.040	.195	-.099	.334	-.478*	1.000	.366
TaPht1.4	.545*	-.392	.687**	.241	.062	-.230	.366	1.000
Regression equation	Rate=0.212×TaSultr5.2+0.074 (R=0.889**)							

Note: * and ** indicate correlation by ANOVA followed by t-test (*: P＜0.05, **: P＜0.01)

2.2.2镉污染影响城郊菜地土壤氮素循环和迁移机制研究

2.2.2.1镉胁迫对小白菜氮素吸收代谢和光合作用的影响

以硝酸盐低积累（L45）和高积累（H64）两个品种小白菜为试验材料，采用盆栽的方式研究了不同浓度镉（Cd）处理对小白菜叶片中硝酸盐、铵态氮、游离氨基酸、可溶性蛋

白、氮代谢相关酶活性及光合作用的影响。综合本研究结果，可看出：镉胁迫扰乱小白菜对氮素的吸收代谢，降低光合速率，对硝酸盐低积累品种（L45）的影响更为明显。

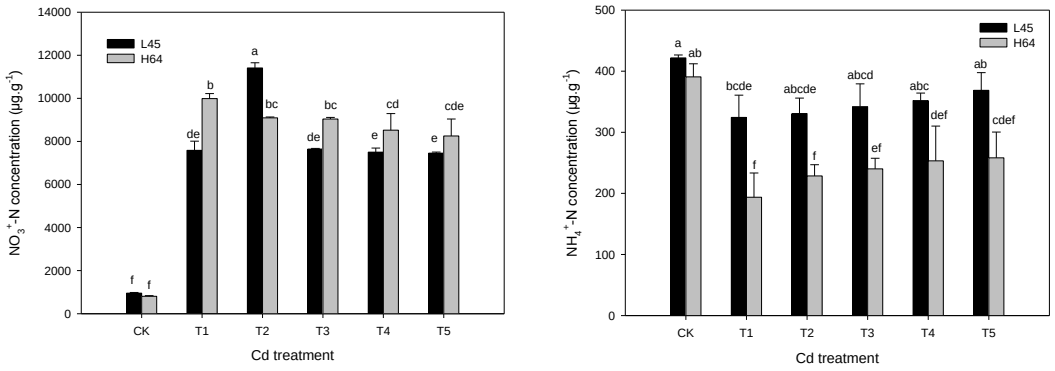


图3 镉胁迫对两个小白菜品种叶片中硝态氮和铵态氮含量的影响

2.2.2.2镉污染对菜地土壤氮素转化的影响

以硝酸盐高低积累小白菜品种（分别为L45和H64）为试验材料，研究了镉污染下小白菜中镉、硝态氮、全氮含量，土壤中镉、硝态氮、全氮含量，以及淋失液中硝态氮含量和土壤中氧化亚氮排放量。结果表明，小白菜具有一定的耐镉性，L45比H64地上部镉含量高27.7%，说明L45比H64更敏感。随着镉浓度的升高，小白菜体内硝态氮含量呈先增后降的趋势，说明低镉促进了小白菜体内硝酸盐的积累；低浓度的镉还增加了土壤硝态氮的淋失，最大值分别为31.99mg L^{-1}（H64）、37.26mg L^{-1}（L45）。对土壤和植物体内全氮含量则无显著影响,说明镉对土壤中氮肥的主要利用形式硝态氮影响更显著。随着镉浓度的增加，土壤氧化亚氮的日排放量显著增加。

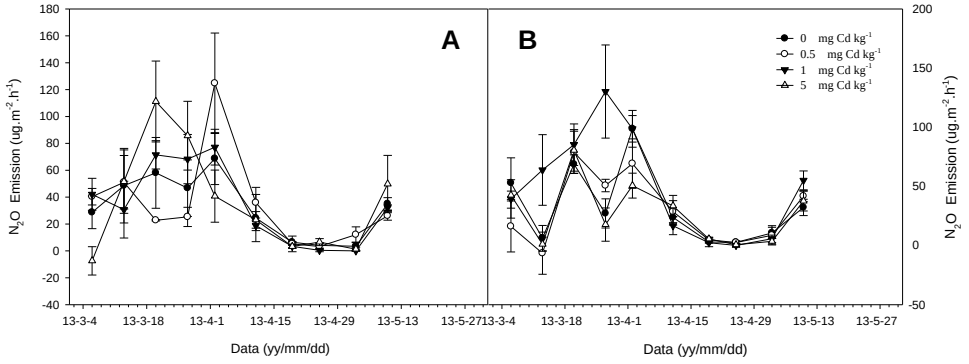


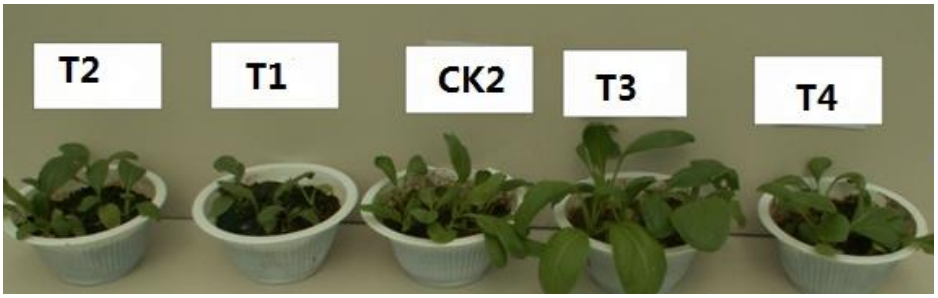
图4 镉胁迫对土壤中氧化亚氮排放的影响

2.2.2.3 镉低积累蔬菜品种的筛选及铅镉污染土壤微生物修复方面取得了进展

1、通过对全国广泛种植的 400 多份叶菜、根菜、茄果和茎菜类蔬菜品种及大豆、油菜品种(品系)资源进行筛选，已获得镉低积累材料近 30 份，并已初步确立了镉低积累蔬菜作物种植模式 2 个

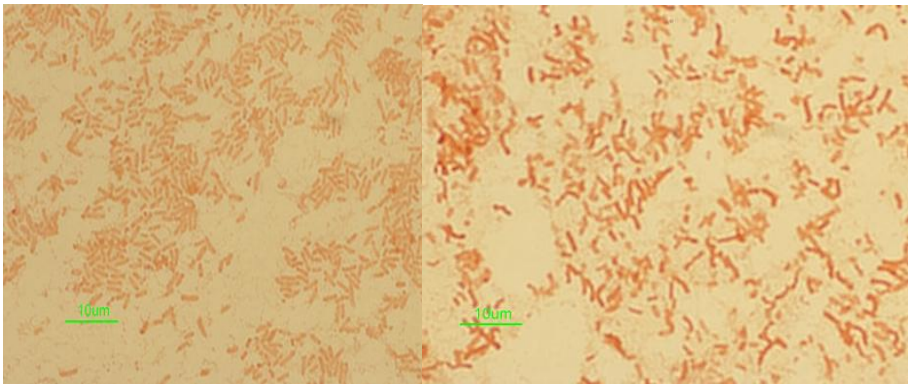
2、筛选获得耐铅镉真菌及细菌各 2 株，盆栽试验结果表明这几株菌株均能通过分泌大量金属硫蛋白、在菌体表面与 S、P 等形成大量结晶颗粒而沉淀铅镉，逐渐成为土壤中的优

势菌种而降低土壤有效态铅镉含量，减少小白菜对铅镉的吸收及累积量（最高可下降 50%），显著增加小白菜株高和产量。

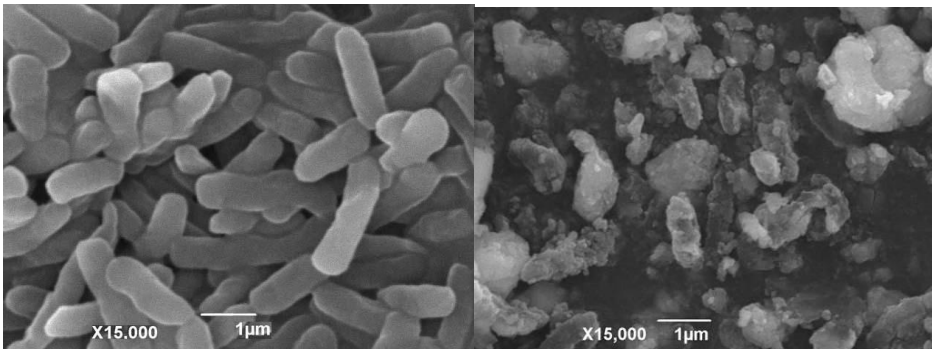


产黄头孢霉菌不同接种量对小白菜生长的影响

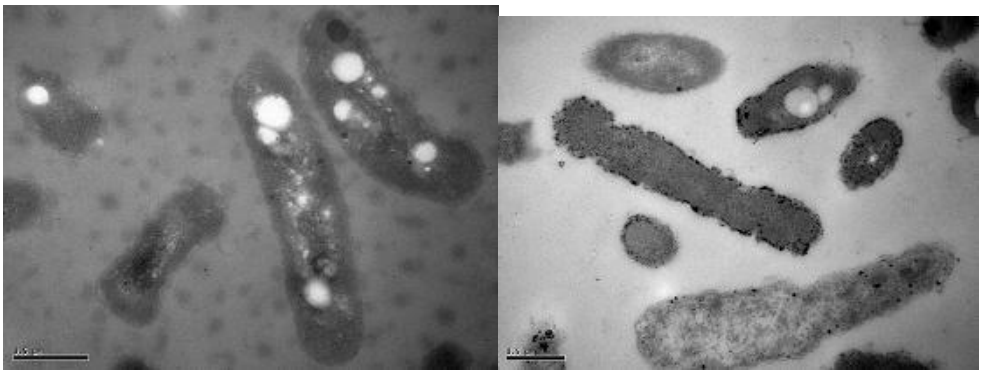
（ck1,T1,T2 为不灭菌土不加菌,加 10ml,20ml 菌；ck2,T2,T3 为灭菌土壤不加菌,加 10ml,20ml 菌液）



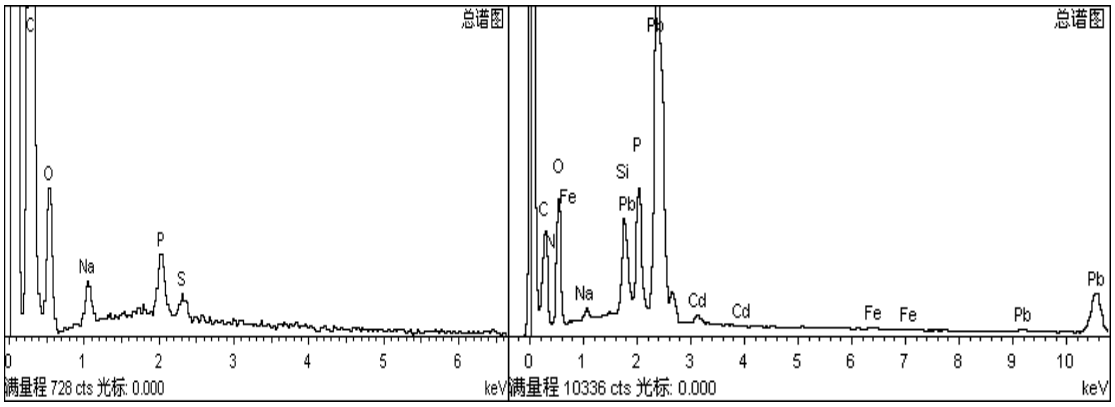
细菌在无铅镉（左）和 Pb200Cd100 mg L^{-1}（右）时的生长状况(1000×)



细菌在无铅镉（左）和 Pb200Cd100 mg L-1（右）时的扫描电镜图



细菌在无铅镉（左）和 Pb200Cd100 mg L-1（右）时的透射电镜图



细菌在无铅镉（左）和含 Pb200Cd100 mg L-1（右）时的 EDX 能谱图

2.2.3 华中农业大学微量元素研究中心生态与环境工程研究室 2012-2013 年度主要研究工作进展

实验室简介：该研究室致力于环境污染机制及其生态修复机理和技术的研究，重点关注水生植物在水环境污染治理中的作用，同时研究点源污染及非点源污染的防治技术，团队的研究兴趣覆盖了土壤化学、植物营养学和生理学、环境化学和矿物学、生态学的众多领域，现已形成植物营养与生态环境相辅相承的研究格局。近年来也开展了大流域尺寸的流域水环境管理和水环境安全的评价技术体系研究，以及物理、化学等手段和植物联合修复污染水体的研究。目前，该研究室由教授 1 人（朱端卫），副教授 5 人（周文兵、华玉妹、赵建伟、廖水姣、万小琼），讲师 2 人（刘广龙、蔡建波），博士研究生 3 人和硕士研究生 25 人组成。

2012-2013 年度研究室的主要课题的研究进展如下（按方向和课题）：

一、水环境污染机理及治理技术研究方向

沉水植物修复是目前水体生态修复技术之一，因其经济、对环境破坏性小等优点被人们广泛应用（Louisa, 2010）。在沉水植物生长过程中，伴随着 $CaCO_3$-P 共沉淀发生。钙是一种营养元素，生长在水体中的沉水植物，不仅从沉积物中吸取钙离子，还在生长中从叶面不断将体内的钙离子分泌到水柱中，叶面局部浓度过高的钙离子与水柱中的无机碳、磷一起形成 $CaCO_3$-P 共沉淀，改变水环境中无机磷的循环周期，从而抑制水体富营养化过程。国家基金“菹草驱动的生物钙泵在水/沉积物磷循环中的作用机制研究”（40973056，2010-2012）及博士点基金“沉水植物叶面泌钙与叶际碳酸钙-磷共沉淀的形成机制研究”（20100146110020，2010~2012）（朱端卫主持）研究印证了从沉积物中钙活化为起点，钙经菹草根系吸收转运至地上部，从地上部分泌迁移至叶际，导致叶际中碳酸钙的形成，同时，磷酸盐与其发生 $CaCO_3$-P 共沉淀使水中磷酸盐归趋于沉积物的过程（Fig. 1, Fig. 2）。相关结果发表在 ***International Journal of Environmental Science and Technology*** 上： He Jun, Liu Guanglong, Zhu Duanwei*, Cai Jianbo, Zhou Wenbing, Guo Wenwen. Sequential extraction of calcium in lake sediments for investigating the cycle of phosphorus in water environment. International Journal of Environmental Science and Technology, 2013, DOI: 10.1007/s13762-013-0490-y (*通讯作者，下同，SCI，IF=1.846)

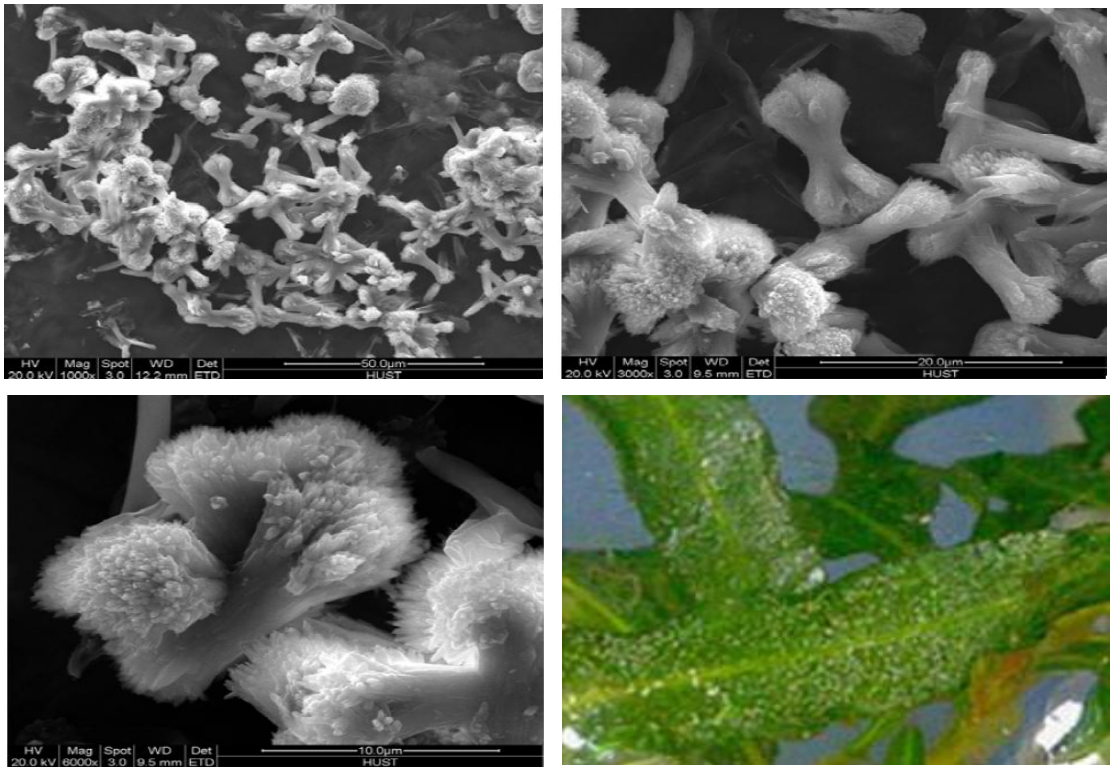


Fig. 1 The precipitates formed on the surface of *P. crispus* leaf in the pot experiment (distilled water as the overlying water, sediment of Lake Nanhu, *P. crispus* grew for 70 days).

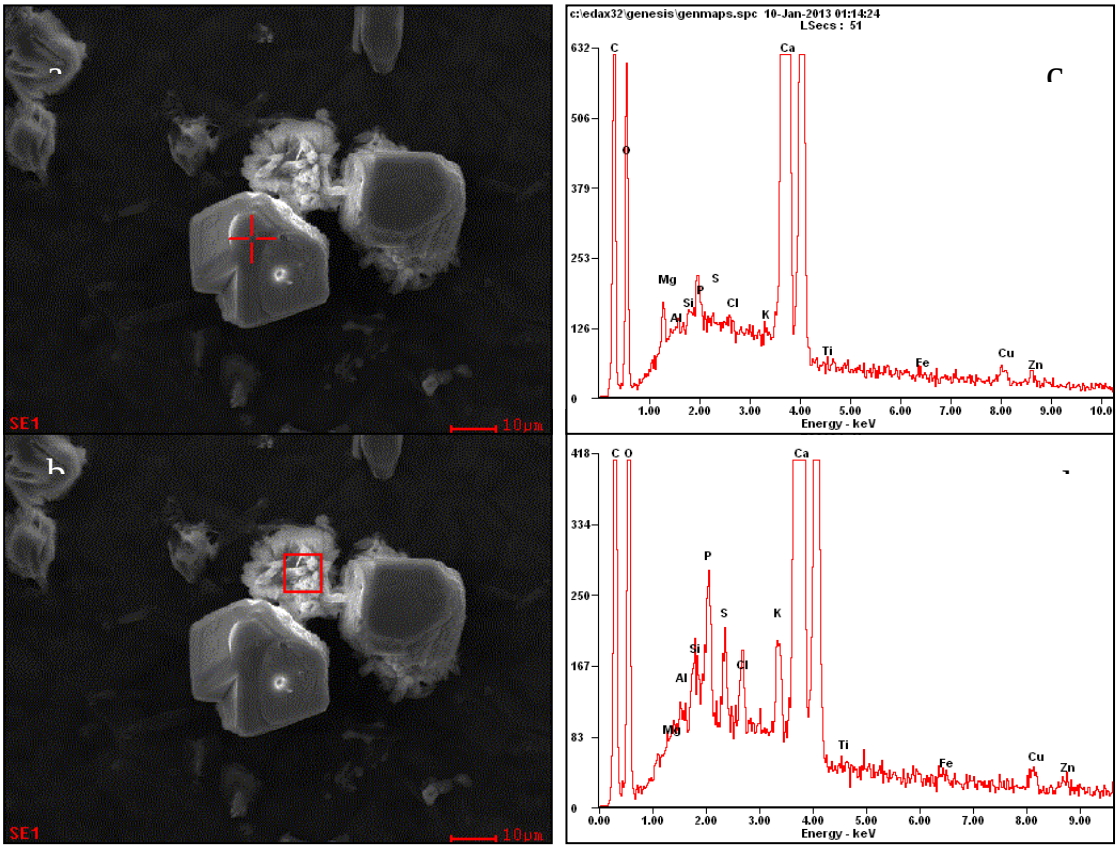


Fig. 2 SEM images of $CaCO_3$-P coprecipitates and corresponding EDX spectra on the leaf surface of *P. crispus* under the constant temperature condition

国家基金“淡水湖泊沉积物的厌氧氨氧化作用特征及其环境效应研究”（40901264，2010-2012，赵建伟主持）研究表明厌氧氨氧化菌在淡水湖泊，尤其是富营养化湖泊中可能广泛存在。反硝化与厌氧氨氧化之间存在显著的正相关关系，两个反应间存在耦合效应。研究结果丰富了湖泊氮素循环理论，为水体氮素污染治理提供了一些新思路。

国家自然科学基金青年基金项目“金属硫蛋白和外源硫酸盐在凤眼莲富集重金属中的协同作用”（41201510，2013-2015，万小琼主持），将凤眼莲分别暴露于含不同浓度 Zn、Cd 的 Hoagland 营养液中，凤眼莲生长时，重金属富集于其根部，该植物能超累积 Cd、Zn，且对两种重金属的富集途径存在差异。本研究建立了凤眼莲中水溶性蛋白的 Tris 饱和酚提取方法及金属硫蛋白的初步鉴定方法。通过对 Cd、Zn 处理下凤眼莲根、茎、叶中水溶性蛋白的分析，发现对不同重金属响应的蛋白类型不一样，其分子量均低于 43kDa。中央高校基本科研业务费专项资金项目“金属硫蛋白在凤眼莲富集铜和镍中的化学行为”（万小琼主持），利用分子克隆技术，成功构建了含凤眼莲金属硫蛋白基因 *mt1* 的质粒。

中央高校基本科研业务费专项资金项目“外源硫酸盐对沉积物中重金属活性的作用效应”（2012ZYTS033，2012-2013，华玉妹主持）研究发现硫酸盐的输入前期促进了硫酸盐还原菌的生长，加强有机质的分解，促进了重金属向水相中的释放，后期因生成硫化物与重金属的结合，水相中的重金属出现下降。研究表明，较大量硫酸盐输入水体后短期内引起的沉积物重金属释放问题不容忽视。

中央高校基本科研业务费专项资金项目“养猪废水中重金属对 UASB 运行影响研究”（2011PY114，2011-2012，蔡建波主持）针对 UASB 处理养猪废水过程中对温室效应的影响进行定量评估，为畜禽养殖派生的温室气体减排提供依据；弄清养猪废水中重金属对 UASB 运行的影响过程，厌氧微生物种群的变化情况，找出优势菌种；用养猪废水培养厌氧颗粒污泥，进行 UASB 反应器的启动和调试，确定适用于养猪废水的最佳工艺参数。

中央高校基本科研业务费专项资金项目“TiO_2 光催化与菹草植物修复耦合体系协同消减甲基对硫磷的机制研究”（2013QC044，刘广龙主持）、博士后项目“湖泊硝态氮调控有机磷转化的光化学机制研究”（2013M540619，刘广龙主持）：分别在光催化与植物修复协同修复和湖泊富营养机制研究两个方向展开。相关研究结果如下：（1）采用溶胶凝胶法可以制备高效稳定具有可见光响应的 TiO_2 薄膜；（2）光催化与植物修复协同降解有机染料的工作正在展开；（3）湖泊硝态氮的光化学活性可显著影响水体磷形态转化。上述工作的相关结果正在进一步展开和整理。

二、城市面源污染控制研究方向

经过十一五期间的努力，依据以屋面和路面为代表的城市典型硬化地表径流污染特点，开发了有针对性的面源控制单元技术，主要有：屋面径流集水器、模块化绿色屋顶、亚表层促渗技术、道侧渗流带等。技术实验的结果表明，这些技术对面源污染物具有较高的去除效率。其中，亚表层促渗技术和道侧渗流带技术的出水达到了回用要求，在污染治理的同时，还创造了经济效益。研究组还建立了面源控制示范工程，取得了较好的工程示范效果。在此

基础上开展了“十二五”水专项“山地城市老城区面源污染负荷削减技术集成研究与示范”（2012ZX07307-002，2013-2015，赵建伟主持），该课题针对屋面、路面等典型硬化下垫面和汇水区排水口进行了实地采样监测。研究结果表明，餐饮路面污染最为严重，为重点预防区域，磷主要以颗粒态形式存在，应优先选择沉降和过滤措施加以控制。依据伏牛溪老城区地表特征和发展现状，设定初期重污染径流为主要治理对象，初步确立了溢流雨水初期径流分流和梯级湿地联合控制的技术策略，完成了老城区面源控制示范工程的设计，形成施工图。

三、流域水生态安全的评价技术体系研究方向

本课题组在“十二五”期间正在开展水专项“三峡库区水生态风险阈值及其安全保障方案研究” 课题（2012ZX07104-001，2012-2015，朱端卫主持），课题主要任务为针对三峡库区水环境问题特征，服务于流域水环境管理，建立大型水库水环境安全的评价技术体系，评估三峡库区水环境安全状态，诊断库区水环境问题及成因，识别关键影响因子，丰富对大型水库蓄水运用期水环境问题及成因的认识；形成定量分析平台，深入了解三峡库区经济社会发展、土地利用、水库蓄水运用方式等与库区水环境和水生态之间的胁迫－响应关系；对三峡库区蓄水运用期的水环境问题的发展趋势进行分析和评价，研究水污染防治的主要手段。

根据课题的年度研究目标、考核指标以及课题的总体进展规划，课题组在 2013 年度主要从以下五个方面开展了相关的研究工作：

① 收集了 2008 年至 2012 年三峡水库流域长序列水文观测资料，对其进行了分类建档，对库区水位、流速、流量、流场、泥沙等环境水力学要素的变化趋势进行分析，拟建立水文水质模型，阐明水文物理参量变化对水环境过程的可能影响。

② 鉴于课题启动会专家对于水质短期、中长期预测的相关意见，我们开展了基于时间序列分析的三峡各断面污染物指标预测工作。通过对 2008 年到 2012 年的三峡库区各断面数据进行分析，采用 ARIMA 模型对断面短期内水质变化情况进行了预测。

③ 采用主成分分析法进行三峡库区水环境安全问题诊断研究，依据三峡库区 2008-2010 年水质监测数据，通过主成分分析法，对三峡库区干流 8 个断面水环境质量的时间和空间变化进行评价。

④ 采用 DPSIR 模型对三峡库区水环境安全评价进行研究，以三峡流域的特点及水环境安全形势为依据，建立三峡库区水环境评价体系，依据运用层次分析法(AHP 法)对模型涉及的指标进行赋权值。进而对三峡库区重庆段水环境安全进行了评价。

⑤ 开展全排列图示指标法对三峡库区水环境进行评价，基于三峡流域的特点和水环境安全形势，从资源开发利用、水污染物排放、生态环境状况和环境质量状况等方面构建水环境安全评价指标体系，引入全排列多边形图示指标法构建评价模型，对水环境质量进行评价。相关结果发表在 ***Ecological Engineering*** 上：(1) Peng Lian, Hua Yumei*, Cai Jianbo, Zhao Jianwei, Zhou Wenbing, Zhu Duanwei. Effects of plants and temperature on nitrogen removal and microbiology in a pilot-scale integrated vertical-flow wetland treating primary domestic wastewater. ***Ecological Engineering***, 2014, 64: 285– 290 (SCI, IF: 2.985)

四、水生植物资源特性及其开发利用研究方向

国家自然科学基金“铁锰硅介导下凤眼莲秸秆及其化学改性产物的结构与吸附特性研究”（20806032，2009-2011，周文兵主持）研究发现，水生植物凤眼莲相比几种陆生植物含有更活泼的官能团，其经过化学或生物化学预处理改性后产物具有更高的重金属吸附能力和改性效率，水生植物凤眼莲经过生物方法脱胶和化学方法脱胶的产物重金属吸附性能相近，但其制备过程环境友好。相关结果发表在 ***Bioresource Technology***，以及 EI 收录的国际会议 ***2014 International Conference on Environment and Sustainability*** 上。

(1) Deng Li, Geng Mingjian, Zhu Duanwei, Zhou Wenbing*, Langdon Alan, Wu Hongwei, Yu Yun, Zhu Zhenxiang, Wang Yanyan. Effect of chemical and biological degumming on the adsorption of heavy metal by cellulose xanthogenates prepared from Eichhornia crassipes. ***Bioresource Technology***, 2012, 107, 41-45 (SCI, IF: 4.98)

(2) Liu Xueqin, Deng Li, Zhou Wenbing*, Zhu Duanwei, Wu Hongwei. Stability of cellulose xanthogenates of various metals. ***2014 International Conference on Environment and Sustainability***, accepted. 2014, 5, 25-26, Hong Kong (EI)

中央高校基本科研业务费专项资金课题“植物生物质酶解产糖效率与其结构组成及生育期关系研究”（2011PY113，2011-2012，周文兵主持）比较了水生和陆生植物在纤维素含量和纤维素结晶度指数 CrI 上的差异，发现纤维素的 CrI 与其酶解产糖效率的负相关性，水生植物凤眼莲因其原料的低 CrI 而显示出产糖优势；基于不同植物来源纤维素的人工生物质中，较低纤维素 CrI 的人工生物质的酶解产糖更快，纤维素相比木聚糖对还原糖的贡献相对更大（以下论文（1））；发现生育期对水生植物的可酶解性有较大影响（以下论文（2））。相关结果发表在 ***Bioresources*** 和 EI 收录的国际会议 ***2014 International Conference on Environment and Sustainability*** 上。

(1) Li Li, Zhou Wenbing*, Wu Hongwei, Yu Yun, Liu Fen, Zhu Duanwei. Relationship between crystallinity index and enzymatic hydrolysis performance of celluloses separated from aquatic and terrestrial plant materials. ***Bioresources***, 2014, 5, accepted. (SCI, IF: 1.309)

(2) Wang Yanyan, Zhou Wenbing*, Wu Hongwei, Yu Yun, Li Li, Yuan Yu, Hua Yumei, Zhu Duanwei. Effect of harvest time on the composition, structural characteristics and enzymatic hydrolysis performance of *Eichhornia crassipes* biomass. ***2014 International Conference on Environment and Sustainability***, accepted. 2014, 5, 25-26, Hong Kong (EI)

2.3 现代施肥技术及新型肥料的研发与应用

2.3.1 长江中下游水旱轮作区主要作物高产高效施肥技术体系构建与应用

由我中心牵头主持并联合湖北省土壤肥料工作站、全国农业技术推广中心、湖北省农业科学院、安徽省农业科学院、湖南省农业科学院、江西省农业科学院和浙江省农业科学院 8 家单位共同完成了“长江中下游水旱轮作区主要作物高产高效施肥技术体系构建与应用”成

果。在多个项目的支持下，该成果在长江中下游 6 省持续 9 年的研究基础上，明确了水旱轮作区主要作物施肥状况和耕作土壤养分肥力现状，揭示了土壤养分变化规律和主要作物高产条件下的养分需求规律，提出了水旱轮作制度土壤养分供应能力变化的“水分、温度、生物及其互作”协同驱动理论；创建了水稻、油菜和小麦三类作物种植的土壤养分丰缺新指标体系，建立了与之相配套的主要作物因土因产分区施肥推荐指标体系；制定了水旱轮作体系作物周年丰产、持续稳产、养分用培兼顾、施肥经济高效的施肥技术策略；构建了以养分综合管理、有机无机结合、中微量元素因缺补缺、水肥一体、秸秆还田、轮作运筹优化、根区施用等为核心的高效施肥技术体系；集成了适合于长江中下游高强度种植的稻-油、稻-麦、稻-稻-油轮作高效施肥模式 7 套；开发了施肥专家系统，研发生产了区域尺度的作物专用肥，获授权发明专利 3 项和软件著作权 1 项，颁布实施地方行业标准 2 项，发表相关科技论文 135 篇，编写专著 6 部。成果在长江中下游水旱轮作区得到大面积推广，经济、社会、生态效益显著。该成果 2014 年 1 月 14 日通过了湖北省科技厅组织的成果鉴定，成果整体处于同类研究的国际领先水平。

2.3.2 油菜区域尺度的施肥调查及科学施肥效果分析

肥料投入在油菜生产中起到非常关键的作用，科学施肥可以明显提高油菜籽产量，改善油菜品质，同时能显著增加农民的经济收益。然而目前仍缺乏在大区域尺度上油菜施肥状况的调查与研究，油菜施肥中的关键问题还未掌握，因而无法给出针对性指导意见。同时，近年来各地进行了大量的油菜科学施肥试验和示范，调查评估这些科学施肥技术措施的优点，分析其中的问题，对进一步优化施肥原则和制定科学施肥方案有着重要的参考意义。养分资源综合管理课题组采用农户抽样问卷调查的方法，并结合全国测土配方施肥项目中油菜示范试验结果，研究了长江流域冬油菜产区 11 个省（市）油菜种植及施肥状况和配方施肥效果。通过分析油菜栽培方式、施用化肥和有机肥种类及用量、施肥次数、氮磷钾肥基追比例及经济效益等内容，明确了长江流域冬油菜产区油菜种植及农民习惯施肥状况，并分析指出了存在的问题；利用油菜示范试验数据，分析比较了不同区域油菜施肥效果和区域特点，为区域推荐施肥提供理论基础。相关结果发表在《Journal of Plant Nutrition and Soil Science》（第一作者任涛，通讯作者鲁剑巍）和《中国农业科学》（通讯作者丛日环）上，并出版《油菜施肥调查与推荐施肥技术》（任涛主编，中国农业出版社 2013 年出版）专著 1 部。

2.3.3 秸秆还田对水稻产量的影响及钾肥替代量研究

通过在湖北省 10 个县市开展的秸秆还田田间试验，分析不同土壤速效钾含量下秸秆还田对水稻产量的影响，评估了秸秆还田替代化学钾肥的潜力。结果表明，与 CK 处理相比，施用钾肥后，高钾、中钾和低钾土壤的平均增产量分别为 263、751 和 621 kg/hm^2，增产率分别为 3.1%、7.7%和 8.4%。研究发现，在秸秆还田的基础上，施用当前推荐钾肥用量，中钾和低钾土壤的增产效果要优于高钾土壤。秸秆还田条件下，高钾土壤试验区水稻钾肥用量为 75 kg/hm^2 时，增产率呈现下降的趋势，钾肥用量相对过多；而对于低钾土壤试验区，该

用量条件下仍有较高的增产率，钾肥用量相对不足。根据钾肥用量和实际产量，通过线性加平台肥效模型拟合，得出高钾和中钾土壤的最佳钾肥用量。高钾土壤钟祥和宜城试验点，水稻最低理论产量分别为 8281 和 9423 kg/hm^2，即短期秸秆还田不施用钾肥情况下水稻产量仍高于施钾肥的实产。最高理论产量分别为 8447 和 9423kg/hm^2，比施钾处理实产分别增加 488 和 348 kg/hm^2，对应最佳的钾肥用量分别为 36.1 和 40.4 kg/hm^2，平均为 38.2 kg/hm^2，比推荐用量平均减少 49.1%。中钾土壤各试验点通过线性平台拟合得出的最低理论产量均低于施用钾肥处理的实产。肥效模型得出中钾土壤试验点的最佳钾肥用量平均为 60.0 kg/hm^2，比推荐钾肥用量平均减少 20%，且能取得较高的产量。相关结果发表在《中国农业科学》、《应用生态学报》和《PLoS ONE》上（通讯作者为鲁剑巍）。

2.3.4 油菜高效专用肥研发与应用进展

为了满足油菜高产高效轻简生产的需要，本中心国家油菜产业技术体系科学家岗位团队在多个项目（以国家油菜产业技术体系建设专项和国家科技支撑计划为主）的支持下，在全国多家油菜种植研究和土壤肥料研究单位及众多专家的协助下，通过多年的研究，研制出“全营养长效缓释型油菜专用配方肥”，并由湖北宜施壮农业科技有限公司（系农业部测土配方施肥示范企业和国家油菜产业技术体系对接企业）中试生产，用于油菜生产一次性施用。

2012/2013 年度，在国家油菜技术体系有关岗位专家（傅廷栋院士、官春云院士、张冬青研究员、张书芬研究员）和相关综合试验站（六安、巢湖、常德、长沙、衡阳、思南、宜昌、荆州、黄冈、宜春、信阳、成都、重庆、桂林）的支持下，在全国冬油菜生长区共布置“全营养长效缓释型油菜专用配方肥”试验示范 24 个。24 个试验结果小结如下：（1）试验覆盖区域广，涉及耕作制度全。试验地点包括四川、重庆、湖北、湖南、江西、广西、安徽、浙江、河南，覆盖了全国冬油菜主产区；耕作制度涉及到油稻稻三熟、油稻两熟、油玉两熟，既有水田油菜也有旱地油菜，既有移栽油菜也有直播油菜，既有高产区也有中低产区。（2）增收节支总体效果好（表 1）。从 24 个试验统计来看，“全营养长效缓释型油菜配方肥”平均 N、P_2O_5 和 K_2O 投入量分别为 8.4、2.9 和 3.4 kg/亩，比习惯施肥处理（实际上是当地推荐施肥）减少 N、P_2O_5 和 K_2O 投入量分别为 2.8、2.4 和 1.8 kg/亩（共计减少纯养分投入 7.0 kg/亩），比当地油菜专用肥处理（仍需追肥）减少 N、P_2O_5 和 K_2O 投入量分别为 2.5、0.9 和 2.3 kg/亩（共计减少纯养分投入 5.7 kg/亩），与习惯施肥和当地油菜专用肥处理直接减少肥料成本分别为 38.0 和 31.3 元/亩；与习惯施肥和当地油菜专用肥处理相比，专用肥处理的油菜籽产量略有提高，分别增产 5.9 和 5.3 kg/亩，增产率分别为 3.9%和 3.6%，增收分别为 29.5 和 26.5 元；总增收节支分别为 67.5 和 57.8 元/亩。（3）省工省力。由于“全营养长效缓释型油菜配方肥”施肥简化（一次性施肥），与习惯施肥（一般采用一基两追施肥方式）及当地专用肥（一般采用一基一追或一基两追施肥方式）相比，平均每亩可减少追肥用工量 0.5 个左右，考虑到目前用工成本，加上肥料节支部分，油菜专用配方肥技术与目前施肥技术相比可增收节支达 80-100 元/亩。（4）肥料养分利用率显著提高。根据油菜养分吸收量结果，利用差减法计算的结果表明，习惯施肥和当地专用肥的氮肥利用率为 30%左右、磷肥

利用率为 18-22%、钾肥利用率为 40-45%，而油菜长效专用肥的氮、磷、钾养分利用率分别平均达 48%、30%和 60%，已接近国际水平。（5）增产增收试验比例大。对 24 个试验进行分类分析，与习惯施肥（当地推荐施肥）相比，油菜专用肥增产的比例为 62.5%、平产的比例为 12.5%、减产的为 20.8%；不考虑用工成本条件下，油菜专用肥增收的比例为 75.0%、平收的比例为 8.3%、减收的比例为 16.7%，如果考虑用工成本，则增收比例达 87.5%。该研发成果已申报国家发明专利，并被国家油菜产业技术体系作为重点成果推广应用。

2.3.5 柑橘营养诊断与矫正施肥研究与示范

2.3.5.1 柑橘矫正施肥技术及柑橘专用肥示范

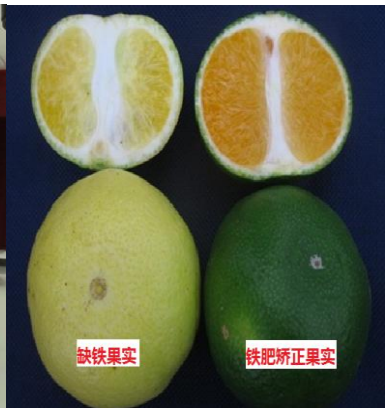
连续5年开展柑橘主产区果园土壤肥力和柑橘营养调查，获得大量土壤、叶片、果实矿质营养与果实品质相关数据，正在建立柑橘营养数据库；按照“以果定肥、因土补肥、因树调肥”的技术思路，以调配中微量元素为重点，以改善果实品质、提高果实产量和施肥效益为目标，研制并生产柑橘系列专用配方肥，分别在湖北宜昌夷陵、当阳市、丹江口，江西南丰，湖南宜章，云南瑞丽等地提供柑橘专用肥配方并进行产品示范。施用柑橘专用配方肥均较常规肥树势强、叶色绿、果大、品质好，产量增加，可缓解大小年现象。目前，越来越多的果农已经开始接受并使用柑橘专用配方肥。

2.3.5.2 柑橘园中微量元素营养诊断和营养生理与调控

在湖北秭归、宜昌夷陵，江西南丰、浙江衢州等地开展了中微量元素施用对柑橘产量及果实品质的影响。B、Zn 是限制宜昌夷陵酸性土壤温州蜜柑生长的主要微量元素，B、Zn 配施可以显著提高果实可溶性固形物和 Vc 含量；宜昌夷陵碱性土壤温州蜜柑 EDDHA-Fe 配施 Zn、Mn，显著提高果实可溶性固形物和 Vc 含量；江西南丰在平衡施肥的基础上增施石灰，能有效降低南丰蜜桔中水不溶及总膳食纤维的含量，有效改善南丰蜜桔不化渣的问题；钙镁硼三者配施，不仅能提高胡柚产量，还可有效降低胡柚果实可滴定酸含量，增加可溶性固形物含量，从而改善胡柚的果实品质。

2.3.5.3 广泛开展柑橘矫正施肥技术培训

坚持开展柑橘矫正施肥技术培训，走到田间地头为果农讲解柑橘营养矫正与施肥，培训人员包括相关农业领导人，技术骨干等，遍布湖北、湖南、江西、福建、四川等地，培训人数达 1500 人次以上。



2.3.6 华中单、双季稻一次性施肥关键技术研究与集成

水稻是我国主要粮食作物之一，其高产稳产在保障国家粮食安全和农民经济收入上具有重要的意义。水稻生产中，由于农村劳动力结构的变化，省工省力的种植方式快速发展；在作物施肥方面，减少施肥次数是普遍存在的现象，但为了满足高产的需求，一次性施肥必然代价是增加施肥量。而我国南方地区降雨丰富且季节性分配集中，农田中未被作物吸收的养分极易流失，同时早期一次性重施肥料易造成水稻分蘖过旺，需要采用稻田排水晒田手段来控制过多分蘖，晒田排水也将大量的养分排到江河湖泊等水体，既浪费了养分，又是水体富营养化的重要来源。控释肥作为一种新型肥料，具有养分释放与作物吸收同步的特点，能够实现一次性施肥满足作物整个生长期的需要。根据不同作物和不同区域的土壤及气候特点研发的作物区域控释肥为解决农业生产的施肥问题提供了可能性和有效途径。为此，研究开发水稻一次性施肥产品和应用技术，既减少施肥次数、省工节本、提高肥料利用效率，又能满足水稻高产稳产优质需要，是当前水稻轻简化栽培的重要内容，也是农民迫切需要的技术，是进一步发展水稻生产、保障我国粮食安全的重要途径。养分资源综合管理课题组通过研究单、双季稻养分吸收规律，制定了适合不同区域、不同季型水稻的配方，并中试生产了相应的控释尿素（CRU）。田间试验结果表明不同 CRU 处理与不施氮处理相比，显著增产 54.3%-75.0%；与普通尿素分期施用处理相比增产-4%-8.9%，均达到了普通尿素分期施用的效果。CRU 处理氮肥当季表观利用率与普通尿素一次性施用处理相比提高 17.4 个百分点。与普通尿素一次性施用处理相比，尿素分期施用、CRU 均可减少氮素径流损失。建立华中单季稻一次性施肥关键技术研究与集成湖北省荆州市试验示范区和华中双季稻一次性施肥关键技术研究与集成湖北省武穴市试验示范区；举行了控释肥料在中、晚稻上施用效果现场观摩会 1 次；申请专利 1 项；制定早稻一次性施肥技术 1 项；举行技术培训会 1 次。

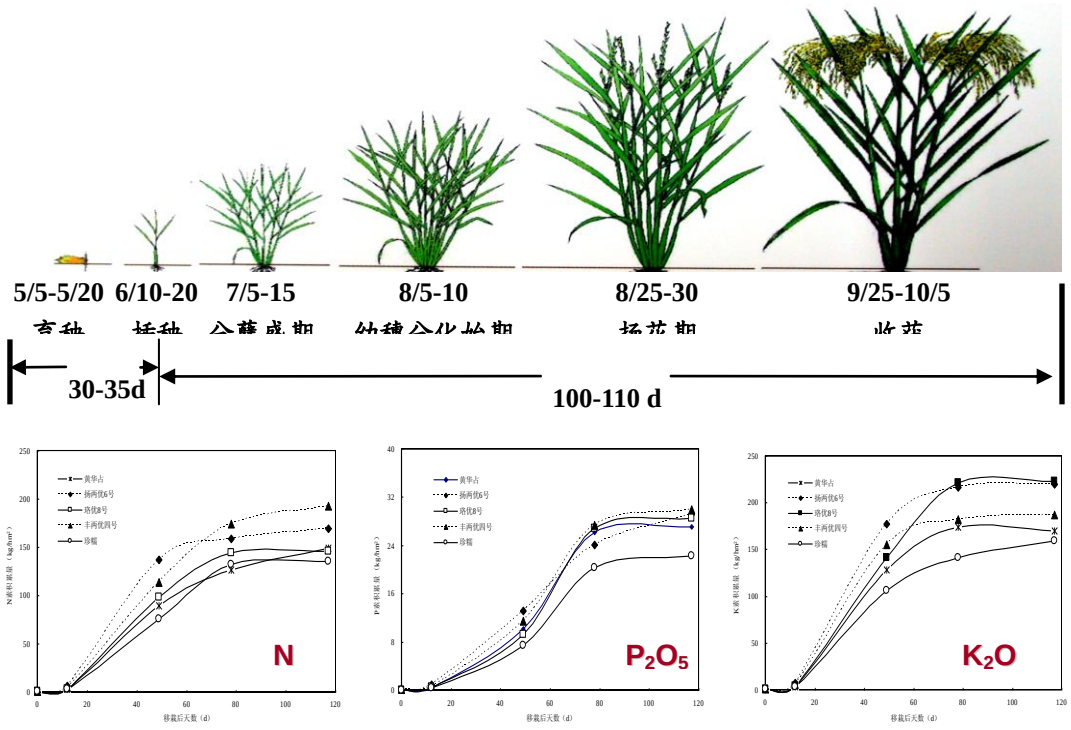


图　中稻生长发育及养分吸收规律

图　武穴市核心试验示范区及现场观摩会

3 华中农业大学微量元素研究广州分中心科研工作进展

3.1 采用同步低温微波-离心高效提取技术，首次实现了不同形态 As、Hg 同时定性定量检测。

2013 年中心再次派 1 名博士工作人员和 1 名在读博士赴与我们多年合作的实验室澳大利亚 SYMBIO ALLIANCE 实验室开展重金属形态分析研究。采用低温微波-离心高效提取技术，将农产品中 As^{3+}、As^{5+}、Hg^{+}、Hg^{2+}等无机形态重金属和有机 Hg、有机形态 As（DMA、MMA 等）同步提取，建立了农产品中不同形态 As、Hg 的 HPLC-ICP-MS 同时测定的方法。该技术实现了重金属形态的同时测定，减少了检测时间和成本，在国内处于领先。

3.2 开展广东省水稻和蔬菜重金属污染调查与研究，系统建立了一套蔬菜重金属评价与防控体系。

在广东省广州、韶关、梅州、惠州、江门、阳江、湛江、肇庆、清远、潮州等 10 个市的 27 个稻米主产县（市、区），采集样本 1069 份，在广州、深圳、东莞、惠州、江门、中山、珠海、湛江、潮州、韶关 10 个地市监控 12 种蔬菜 1117 个样点，对土壤和农产品中的 Pb、Cd、As、Hg、Cr 5 种重金属进行摸查，获得 1.6 万多条数据，基本摸清了广东省水稻和蔬菜重金属的污染特征。由于污染途径主要来自于土壤，更近一步采用菜稻菜轮作方式控制重金属向农产品中的转移，达到了良好的效果。同时还研究不同的土壤改良剂（石灰、活性炭等）对主要蔬菜作物的生长，重金属转移以及土壤重金属含量的影响，找出了降低蔬菜产地土壤重金属 Pb 和 Cd 污染的修复方法。开展有机肥中重金属的环境风险评价，提出了有机肥合理施用技术。为土壤和蔬菜稻米的重金属风险评价提供数据支撑，增加了土壤资源利用效率，保障农产品质量安全的同时提升了、品质，形成了一整套的重金属防控技术体系。

3.3 建立一种基于 LTP 和液相色谱-串联质谱（LC-MS/MS）的食用油中阿维菌素和伊维菌素残留的分析方法，填补了食用油中阿维菌素类药物分析方法空白。

将一种简便、操作简单、经济、环境友好的前处理方法低温净化（low temperature purification，LTP）技术引入到复杂样品中痕量农药残留的分析。建立了一种基于 LTP 和液相色谱-串联质谱（LC-MS/MS）的食用油中阿维菌素和伊维菌素残留的分析方法。以正己烷饱和过的乙腈提取样品中的阿维菌素和伊维菌素，离心后将乙腈层放在-30℃冷冻处理除

去干扰物，采用 LC-MS/MS 检测目标物。食用油中阿维菌素和伊维菌素的检出限为 0.1~0.4 μg/kg；定量限为 0.3~1.3 μg/kg，低于食品法典委员会制定的最严格的最大残留限量。花生油、玉米油、橄榄油、大豆油和猪油中 3 个添加浓度 10，20 和 100 μg/kg 的回收率为 71.1%~119.3%，相对标准偏差为 3.2%~10.3%。整个前处理过程仅需消耗很少的有机溶剂（3.4 mL/g 样品），能有效降低样品中油脂的干扰。填补了食用油中阿维菌素类药物分析方法的空白，为食用油中农、兽药标准分析方法的建立提供了实验依据。

3.4 全面修订 36 类种植业产品的无公害农产品检测目录，建立了种植业产品主要污染物标准限量库。

针对 2013 年实施的《茄果类蔬菜等 55 类无公害农产品检测目录》中 36 类种植业产品（包括茄果类蔬菜、瓜类蔬菜、豆类蔬菜、叶菜类蔬菜、根菜类蔬菜、葱蒜类蔬菜、多年生蔬菜、水生蔬菜、食用菌、茶叶、稻米、薯类、芝麻、西甜瓜、浆果类果品、荔枝龙眼红毛丹、柑果类果品、坚（壳）果类果品、核果类果品、麦类作物、玉米类作物、大豆、花生、小杂粮、仁果类果品、聚复果类果品、香辛料等），通过对现行法律法规、标准等最新动态查询、检测数据的全面收集整理、舆情关注情况分析研判等，对种植业产品开展检测项目、限量值、执行依据、检测方法等指标的全面修订。完善了无公害农产品标准体系建设，保障了种植业农产品的动态管理和风险控制，确保了无公害农产品检测目录的先进性、权威性和普遍性，为科学评价农产品质量安全提供了有效凭证。

4.专利、成果及获奖情况

4.1 申请专利表

序号	专利类别	学院	专利名称	发明人	申请日期/申请号
1	发明专利	资环	一个甘蓝型油菜缺磷诱导表达启动子	徐芳森、杨广哲	2012-1-9
2	发明专利	资环	一种精确获取非根际距根际不同距离土壤的切土装置	占丽平、李小坤、鲁剑巍、任涛、王筝、何达力	2012-3-5
3	发明专利	资环	一种适用于种植植物的根箱试验装置	李小坤、鲁剑巍、占丽平、任涛、王瑾、何达力	2012-3-5
4	发明专利	资环	一种直播油菜专用配方肥	鲁剑巍、李小坤、任涛、王寅、刘波、周鹂、丛日环、刘祖锋	2012-10-1
5	发明专利	资环	种植植物的根箱试验装置	李小坤、鲁剑巍、占丽平、任涛、王瑾、何达力	2012-3-5
6	发明专利	资环	一种适用于研究土壤和土壤溶液的盆栽土柱实验	卜容燕、鲁剑巍、任涛、李小坤、汪洋、何达力	2012-3-5
7	发明专利	资环	一种合流制管网溢流雨水拦截分流控制装置	赵建伟，段丙政，单保庆，张洪，李立青，华玉妹	201310697747.2

4.2 授权专利表

序号	专利类别	学院	专利名称	发明人	专利号
1	实用新型	资环	精确获取非根际距根际不同距离土壤的切土装置	占丽平、李小坤、鲁剑巍、任涛、王筝、何达力	2012200790285
2	实用新型	资环	一种适用于研究土壤和土壤溶液的盆栽土柱装置	卜容燕、任涛、鲁剑巍、李小坤、汪洋、何达力	2012200791108

序号	专利类别	学院	专利名称	发明人	专利号
3	实用新型	资环	种植植物的根箱试验装置	李小坤、鲁剑巍、占丽平、任涛、王瑾、何达力	2012200790209
4	发明	资环	甘蓝型油菜缺磷特异诱导表达的启动子	徐芳森、杨广哲、石磊	2010105957552
5	发明	资环	屋面径流分流集水器	赵建伟、高勇、朱端卫、周文兵、华玉妹、范俊楠、张钰	2010105323788
6	实用新型	资环	一种深水栽培自动控制装置	贺立源、段益星、陈国徽、张龙	2013200474969
7	实用新型	资环	屋面径流分流集水器	赵建伟，高勇，朱端卫，周文兵，华玉妹，张钰，范俊楠	ZL 2010 1 0532378.8
8	实用新型	资环	人行道侧渗流带	赵建伟，高勇，单保庆，李立青，张洪	ZL 2010 1 0532307.8
9	发明	资环	适用于紫色页岩土壤的柑橘专用配方肥及应用	胡承孝，黄鸿，谭启玲，孙学成	ZL.2010 1 0210907.2

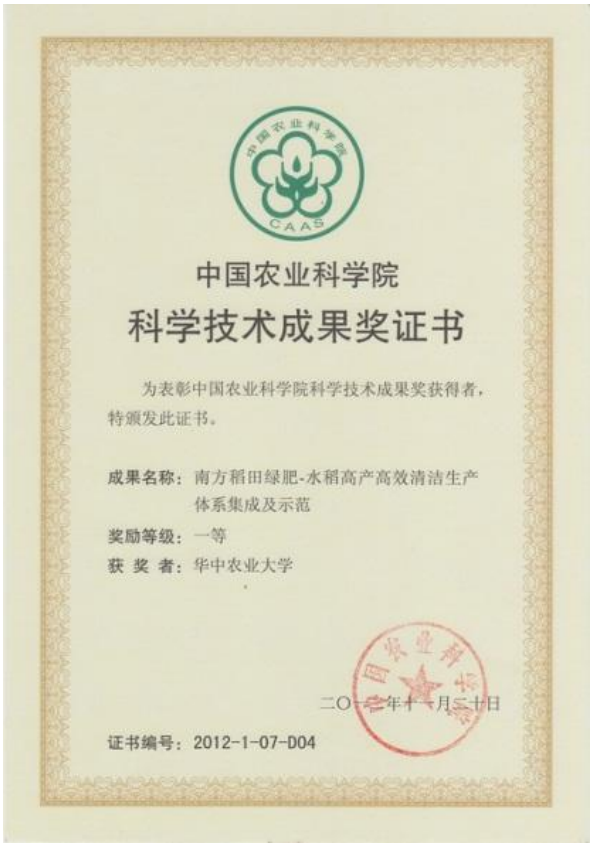
4.3 获得成果奖励

序号	成果名称	获奖人	奖励等级	获奖类别	奖励时间
1	南方稻田绿肥-水稻高产高效清洁生产体系集成及示范	曹卫东、徐昌旭、聂军、耿明建、林新坚、刘春增、郭熙盛、鲁剑巍、王允青、潘兹亮、王建红、高菊生、张辉、陈云峰、白金顺	中国农业科学院科学技术成果一等奖	科技成果奖	2012
2	测土配方施肥技术集成与推广应用	张德才、童军、黄和平、乔艳、鲁剑巍、余勇、巩细民、黄小菁	湖北省科技成果推广三等奖	科技成果奖	2012
3	油菜硼高效利用机制与硼肥优化施用技术研究应用	徐芳森	湖北省梁亮胜侨界科技三等奖	科技成果奖	2012

4	瓜类蔬菜高效安全生产关键技术研发与集成示范	罗少波，何自福，胡开林，李明珠，李莲芳，万凯，李丽，王富华等	广东省科技进步二等奖/广东省农业科学院科技技术一等奖	科技成果奖	2012
5	高产高效优质油菜中油杂 12 的选育与应用	胡琼、梅德圣、张春雷、马霓、陈玉峰、刘佳、付丽、鄂文弟、赵启、鲁剑巍、付桂萍、陈遵东、荣维国、李晓琴、余有桥	武汉市科技进步一等奖	科技成果奖	2013
6	武汉市蔬菜清洁生产技术研究及集成示范	别之龙 朱林耀 徐爱仙 谭启玲 王孝琴 黄远 祝花 孔秋生 宋朝阳 黄兴学	武汉市科技进步奖二等奖	科技成果奖	2013
7	长江中下游水旱轮作区作物高效施肥关键技术	鲁剑巍	第八届大北农科技三等奖	科技成果奖	2013
8	秸秆腐熟还田技术研究及其应用	周先竹、徐辉、杨文兵、鲁剑巍、戴志刚、郭凯、关绍华、邹家龙	湖北省科技成果推广奖	科技成果奖	2013
9	稻田绿肥-水稻高产高效清洁生产体系集成及示范	曹卫东、徐昌旭、聂军、耿明建、林新坚、刘春增、郭熙盛、鲁剑巍、王允青、潘兹亮、王建红、高菊生、张辉、陈云峰、白金顺	中华农业科技一等奖	科技成果奖	2013
10	《现代农业技术实用教程》系列科普丛书	陈栋、黄洁容、刘建峰、胡建广、王富华等	中华农业科技奖科学研究成果科普奖	中华农业科技奖	2012
11	Quantitative trait loci affecting seed mineral concentrations in Brassica napus grown with contrasting phosphorus supplies	丁广大、杨美、胡一帆、 廖原、石磊等	湖北省自然科学优秀论文二等奖	科技论文奖	2012
12	Arsenic removing from water by two types of nano TiO2 crystals.	马琳、涂书新	湖北省自然科学优秀论文三等奖	科技论文奖	2012
13	赣南脐橙叶片黄化及施硼效应研究	姜存仓、王运华、刘桂东，夏颖、彭抒昂、钟八莲、曾庆銮	“领跑者 5000 中国精品科技期刊顶尖学术论文”（F5000）	科技论文奖	2013
14	非金属元素掺杂半导体矿物制备、结构表征及其光催化高/大分子有机污染物的研究	刘广龙、朱端卫	湖北省优秀博士学位论文	科技论文奖	2013

4.4 重大成果、奖励简介：

4.4.1 中心老师参加的“南方稻田绿肥-水稻高产高效清洁生产体系集成及示范”成果获中华农业科技一等奖和中国农业科学院科学技术成果一等奖


中国农业科学院

科学技术成果奖证书

为表彰中国农业科学院科学技术成果奖获得者，特颁发此证书。

成果名称：南方稻田绿肥-水稻高产高效清洁生产体系集成及示范

奖励等级：一等

获 奖 者：华中农业大学

二〇一二年十一月二十日

证书编号：2012-1-07-D04

2012 年度中国农业科学院科学技术成果奖揭晓，共有 23 项成果获此奖项，其中一等奖 9 项，二等奖 14 项。由中国农业科学院农业资源与农业区划研究所主持，我校及江西省农业科学院土壤肥料与资源环境研究所、湖南省土壤肥料研究所等单位共同完成“南方稻田绿肥–水稻高产高效清洁生产体系集成及示范”荣获一等奖。中心老师耿明建副教授、鲁剑巍教授为主要完成人。

该成果在公益性行业（农业）科研专项、国家科技基础条件平台、作物种质资源保护等项目资助下，创新性地开展了以下研究：稻区绿肥作物种质资源，稻田绿肥作物发展的关键技术，基于绿肥的水稻高产高效清洁生产技术体系，绿肥在南方现代水稻生产中的贡献及作用机制，科研平台和队伍建设，等。2008-2011 年共发表论文 80 多篇，出版著作 4 部，获得新品种认定 7 个、新产品登记 3 个、专利授权 3 项，制订绿肥相关技术规程 13 项、地方标准 2 项。4 年累计示范及推广面积 370 万多亩，增产稻谷 13.4 万多吨，节约氮磷钾肥 2.0 万多吨（折纯），增效 4.3 亿多元。通过生物固氮、土壤固碳、减少化肥用量，产生了显著的生态环境效益。

4.4.2 中心老师 3 部作品荣获湖北省优秀科普作品

近日，接到“省科技厅关于表彰 2011 年全省优秀科普作品的通知”（鄂科技发政【2011】15 号），2011 年省科技厅评审出 20 部（套）科普作品为湖北省科普优秀作品予以表彰。我中心鲁剑巍等老师主编或参编的 3 部科普作品入选，分别是《油菜常见缺素症图谱及矫正技术》《柑橘常见缺素症图谱及矫正技术》《棉花常见缺素症图谱及矫正技术》玉米常见缺素症图谱及矫正技术》—作物常见缺素症状系列图谱、《测土配方与作物配方施肥技术》和《油菜优质高效栽培技术》。

4.4.3 中心石磊老师入选 2013 年新世纪优秀人才支持计划

日前，教育部科技司公布了新世纪优秀人才支持计划 2013 年度入选人员名单，我中心石磊老师榜上有名，均获资助 50 万元，资助年限为 2014 年至 2016 年。

4.4.4 中心研究生荣获国际植物营养研究所优秀研究生奖

2013 年 10 月 15 日上午，国际植物营养研究所（IPNI，International Plant Nutrition Institute）在厦门举办的“现代农业中的养分管理学术研讨会”上为来自南京农业大学、中国农业科学院、华中农业大学、中科院南京土壤研究所和西北农林科技大学的 5 名研究生颁发了 2013 年度国际植物营养研究所优秀研究生奖，我中心博士生王寅名列其中。国际植物营养研究所副所长 Adrian Johnston 博士专程前往中国为获奖学生颁奖，来自加拿大、日本、印度和我国的 160 位植物营养与养分管理领域的参会专家学者见证了这一时刻。在随后的学术研讨会上，王寅还代表鲁剑巍教授团队作了“移栽和直播冬油菜产量及养分吸收对养分缺乏的响应差异”的大会学术报告。

国际植物营养研究所优秀研究生奖（the International Plant Nutrition Institute Scholar Awards）由国际植物营养研究所于 2007 年设立，旨在发现和鼓励植物营养学学科未来的“学术明星”。该奖在全球范围内公开接受各国有学位授予权的大学或研究机构的在读研究生申请，研究领域包括土壤和植物营养以及相关学科（包括土壤学、植物营养学、农学、园艺、农业生态、作物生理等），优先奖励从事与 IPNI 宗旨相关的研究领域的申请者。该奖主要从申请人的学习成绩、参加的研究课题、社会活动、发表论文、所获奖项及今后的职业取向等方面进行评选，每年评审一次，获奖者除授予获奖证书外，同时每人颁发奖金 2000 美元。据悉，经过申请人申请、专家推荐和奖励委员会评审，2013 年度国际植物营养研究所优秀研究生奖从来自美国、加拿大、法国、澳大利亚、中国等 15 个国家的 129 位候选人中产生出 26 名获奖者，其中中国获奖学生 5 名。

5.国内外学术交流

5.1 微量元素中心组织召开的学术会议

5.1.1 我校微量元素研究中心 2012 年学术年会顺利召开

2013 年 1 月 11 日，华中农业大学微量元素研究中心（以下简称“中心”）2012 年学术年会在我校资环楼一楼会议室召开。学校科学技术发展研究院姚江林常务副院长、自然科学处梅方竹处长、基地与重大专项处唐仁华处长，校发展规划处处长、资源与环境学院党委书记冯永平研究员、院长黄巧云教授等应邀参加了本次年会。中心老一辈科学家王运华教授、我校兼职教授广东省农科院农产品质量安全与标准研究中心王富华研究员应邀参加了本次年会。副院长谭文峰教授、刘震老师等也应邀参加了本次年会。

本次会议主要由“专题汇报”、“青年教师和优秀博士生报告”、“讨论”三部分组成。在专题汇报中，胡承孝教授介绍了 2012 年新获批的“新型肥料湖北省工程实验室”的定位、建设和管理的一些设想；徐芳森教授汇报了 2012 年新获批的湖北省自然科学基金“微量元素营养与微肥施用”创新群体的研究进展、面临的机遇和挑战。姚江林副院长等职能部门领导对工程试验室和创新群体的定位、方向、资源、人才、建设方案和管理等方面提出了很多宝贵的意见和建议。随后，青年教师耿明建、熊双莲、石磊、孙学成、李小坤、郭再华、周文兵、蔡红梅、张文君、任涛、赵小虎、丁广大、丛日环等，博士生赵尊康、张木、刘威、刘波等报告了 2012 年的研究的主要进展及个人规划。王富华研究员也介绍了广州分中心 2012 年度的主要工作及其成绩。报告结束后，院领导和中心成员就“青年队伍成长与培养”、“新型肥料湖北省工程实验室建设与发展”、“作物微量元素营养与微肥施用”湖北省创新群体建设与创新、“集成力量谋划项目”等进行了深入的讨论。校自然科学处梅方竹处长参加了讨论，并对重大项目的谋划提出了中肯的建议。最后，中心主任胡承孝教授对本次研讨会进行了总结，并对 2013 年“中心”的工作进行了部署。

中心主任胡承孝教授在汇报“新型肥料湖北省工程实验室”建设的设想

徐芳森教授在汇报湖北省自然科学基金“微量元素营养与微肥施用”创新群体的研究进展、面临的机遇和挑战


华中农业大学微量元素研究中心
2012年学术年会

学校科学技术发展研究院姚江林副院长、自然科学处梅方竹处长、基地与重大专项处唐仁华处长，校发展规划处处长、资源与环境学院党委书记冯永平研究员、院长黄巧云教授等与中心成员在一起讨论微量元素研究中心的发展

华中农业大学微量元素研究中心 2012 年学术年会合影（2013 年 1 月 11 日）

5.1.2 我校微量元素研究中心 2013 年学术年会顺利召开

2013 年 11 月 23 日，华中农业大学微量元素研究中心（以下简称“中心”）2013 年学术年会在我校资环楼二楼会议室召开。会议邀请了中国科学院南京土壤研究所所长沈仁芳研究员（2009 年国家自然科学基金杰出青年基金获得者）、王火焰研究员、杜昌文研究员，南京农业大学资源与环境学院赵方杰教授（“千人计划”特聘教授），中国科学院武汉植物园陈防研究员。学校发展规划处处长冯永平研究员，科学技术发展研究院成果与综合管理处刘兴斌处长、基地与重大专项处兰芝祥老师，资源与环境学院党委书记唐仁华研究员、院长黄巧云教授、副院长谭文峰教授等应邀参加了本次年会。中心老一辈科学家王运华教授、我校兼职教授农业部全国农业技术推广服务中心节水处高祥照处长、佛山科学技术学院喻敏教授、微量元素研究中心分中心广东省农科院农产品质量安全与标准研究中心王旭博士应邀参加了本次年会。

本次会议主要由“研究进展报告”、“特邀报告”和“讨论”三部分组成。会议开始，中心前主任胡承孝教授致辞欢迎各位专家、各位领导，感谢他们对中心工作的支持！随后，中心主任石磊教授向与会的专家介绍了我校微量元素研究中心的发展历程、总体定位及主要研究方向、研究平台及管理机构、中心近年申请获批的研究项目及取得的成果等。随后，中心姜存仓副教授、孙学成副教授、张文君博士、任涛博士、李小坤副教授、涂书新教授、赵小虎博士、谭启玲副教授、周文兵副教授、蔡红梅副教授、丁广大博士、喻敏教授、王旭博士、郭再华副教授、丛日环博士等报告了他们近一年来研究工作取得的重要进展和下一步的工作计划。这些报告数据翔实、内容具有创新性，体现了中心的研究水平，得到了与会专家的肯定。在特邀报告中，沈仁芳研究员首先介绍了南京土壤研究所研究平台及其研究方向，并作了报告“植物如何协调适应土壤多种共存胁迫因子?”；赵方杰研究员报告了“植物砷的吸收、运输与解毒机理”；陈防研究员介绍了“一种养分管理专家系统及其应用”；王火焰研究员报告了“根区施肥-提高肥料利用率和减少面源污染的关键和必需措施”；杜昌文研究员介绍了“硼肥中硼的速测”和“土壤红外信息系统及其应用”。这些报告内容丰富、具有较强的科学性和创新性，给了中心成员很多启示，也为将来开展合作提供了契机。会议最后，特邀专家、学校和学院领导、中心成员等就“青年队伍成长与培养”、“中心的建设与发展”、“重大项目的谋划”等进行了深入的讨论。沈仁芳研究员、赵方杰教授、陈防研究员、高祥照处长、冯永平研究员等特邀专家对微量元素研究中心进一步发展、青年人才的培养提出了很多好的意见和建议。他们强调科学研究要与农业生产实际相结合，从生产中发现问题、研究问题、解决问题；年轻人要多看文献、

多想科学问题；要沉得住气、不浮躁、踏踏实实做事情；青年人才的培养除了自己要努力，还需学院领导和团队的支持；要引进优秀人才，更要培养本土人才；要做好中心的宣传和重大项目的谋划。最后，院长黄巧云教授对本次年会进行了总结，肯定了中心的工作，并对下一年的工作提出了新的希望。

中心成员在做报告

中国科学院南京土壤研究所所长沈仁芳研究员在做报告

南京农业大学资源与环境学院赵方杰教授

特邀专家与中心成员讨论微量元素研究中心的发展和青年人才培养

华中农业大学微量元素研究中心 2013 年学术年会合影

5.2 国内外专家来中心访问、交流

5.2.1 国外专家来中心访问、讲学

5.2.1.1 日本东京大学 Toru Fujiwara 教授访问我院

2012 年 11 月 11 日至 14 日，应我中心老师徐芳森教授课题组的邀请，日本东京大学（The University of Tokyo）Toru Fujiwara 教授来我校进行学术交流。本次学术交流是我院 2012 研究生学术年会的重要组成部分。

Toru Fujiwara 教授是日本东京大学农业与生命科学研究生院应用生物化学系植物营养与肥料学研究室教授，主要从事养分转运蛋白的克隆，植物响应不同养分条件的分子机制以及抗养分胁迫植物的培育等方面的研究，相关学术论文发表在 *Science, Nature, Proc. Natl. Acad. Sci. USA, Plant Cell, Plant Physiology, the Plant Journal, Current Opinion in Plant Biology, Trends in Plant Science, Journal of Experimental Botany, Plant Cell Physiology* 等国际顶尖期刊上。

本次访问中，Toru Fujiwara 教授在资源与环境学院二楼会议室做了“New developments in boron transport mechanisms and boron response in *Arabidopsis*”的报告。报告中，Toru Fujiwara 教授首先介绍了拟南芥硼转运子基因 *BOR1*、*NIP5;1*、*NIP6;1* 等的克隆、对低硼胁迫的反应。然后介绍了这些基因在植物耐低（或高）硼胁迫中的生理和分子机制的研究进展，主要包括 Molecular mechanisms of boron transport and its regulation by boron status in plants、Nutrient transport regulated through protein trafficking (and others): case of boron transporters、

Analysis of boron-dependent regulatory mechanism of *NIP5;1* in *Arabidopsis thaliana* roots、DNA damage is amajor cause of B toxicity and condensing II is required for reducing the damage 等。我中心徐芳森教授，赵竹青教授，石磊教授，耿明建教授，孙学成副教授、丁广大博士等及相关课题组研究生共 50 多人参加了本次学术交流。

Toru Fujiwara 教授在讲解 PPT

访问期间，植物营养遗传学课题组石磊教授、蔡红梅博士、丁广大博士、博士后赵华、博士生赵尊康、张迪迪等代表课题组向 Toru Fujiwara 教授介绍了我们在油菜硼和磷营养高效、水稻氮营养高效等的研究进展，Toru Fujiwara 教授提出了很多宝贵的意见和建议。我院党委书记冯永平研究员和院长黄巧云教授也与 Toru Fujiwara 教授进行了会谈，在院系合作交流方面双方交换了意见。

通过访问和交流，双方增进了相互了解、在相互感兴趣研究领域形成了进一步合作的方案，为争取共同申请国际合作项目，合作发表研究成果奠定了基础；另外，本次交流将进一步促成院系和院系之间的合作，推动研究人员、硕士和博士研究生的交流和交换培养。

5.2.1.2 英国诺丁汉大学 Martin R. Broadley 教授来校交流访问

2013 年 11 月 16 日-21 日，应我校资源与环境学院石磊教授的邀请，英国诺丁汉大学（The University of Nottingham）Martin R. Broadley 教授来我校开展学术交流。

11 月 18 日下午，应资源与环境学院研究生辅导员庞湃的邀请，Martin R. Broadley 教授出席了华中农业大学 2013 年研究生学术年会资源与环境学院分论坛英语专场的评委。他认真聆听了 8 位博士和硕士研究生的研究进展报告，并给出了中肯的建议和评论。他认为“这次学术活动非常成功”，希望“资环学院越来越好”。

11 月 19 日晚上，石磊教授在资环楼 204 会议室为 Martin 教授举办了一个以学术文化交流为主要目的的 party，包括留学生在内有近 40 人参加了此次 party。在 party 上，大家和 Martin 教授做了科研、生活以及文化等方面的交流，Martin 教授不仅给大家传授了和植物营养相关方面的知识，也很好地向大家展示了英国文化，其间，还为大家唱了一首英文歌，相继有中国学生以及巴基斯坦学生上台表演了节目。

Martin R. Broadley 教授参加研究生为他准备的 Party

11 月 20 日上午，Martin R. Broadley 教授在资环楼 204 会议室为资环学院师生作了题为“Dietary mineral micronutrient supplies in Africa & role of plant nutrition in alleviating deficiency risks”的学术报告，石磊教授主持报告。

Martin R. Broadley 教授的报告主要介绍了如何量化膳食中矿物微量营养素缺乏的风险及其解决办法。首先，他指出医学分析和膳食供应与摄入调查可以为风险定量化提供直接或间接证据。随后，他用详实的数据、图表等分析了 Fe、Cu、Mg、Se、Ca、Zn 等膳食微量营养素在非洲国家的缺乏现状、风险以及由其引发的一系列人类健康问题，并以马拉维为例做了详细说明。最后，Martin R. Broadley 教授结合自己在植物矿质营养方面的研究特长，提出了运用农艺学、作物繁育、饮食多样性等方法来调节植物中微量营养元素的含量，间接改善人体微量营养元素含量，并对以马拉维为例开展试验与研究所取得的进展与成果做了展示。报告结束，与会师生就自己感兴趣的问题与 Martin R. Broadley 进行了深入的讨论交流。通过访问和交流，双方增进了了解、在相互感兴趣研究领域形成了进一步合作的方案，为争

取共同申请国际合作项目，合作发表研究成果奠定了基础；另外，本次交流就推动研究人员和博士生的互访达成了一致意见。

Martin R. Broadley 教授、Graham King 教授与石磊教授所在课题组进行学术讨论

此外，Martin R. Broadley 教授在华农期间还给我校选修《微量元素与微肥施用》课程的研究生上课并与相关课题组进行学术交流。

在《微量元素与微肥施用》课程教学中，Martin R. Broadley 教授以植物矿质营养的进化为主线，首先介绍了植物进化多样性概况（An overview of plant evolutionary diversity）、然后从根系生物学（Root biology）、重金属超积累（Metal hyperaccumulation）和地上部矿质养分组成（Shoot mineral composition）等三个方面阐述了植物获取矿质营养的进化（Evolutionary aspects of nutrient capture），最后，介绍了植物获取矿质养分的生态学（Ecological aspects of nutrient capture）。《微量元素与微肥施用》课程总学时 32 学时，Martin R. Broadley 教授授课 10 学时。选修该门课程的学生 60 人，其中资源与环境学院植物营养专业研究生 20 人，国际学院留学生 40 人。

Martin R. Broadley 教授在求是楼（一教）给研究生上课

Martin R. Broadley 教授与研究生在求是楼（一教）合影

资料链接：Martin R. Broadley 是英国诺丁汉大学生物科学学院（School of Bioscience）植物营养专业教授，主要从事植物矿质营养的基础研究和应用研究。在应用研究方面，主要通过杂交育种和/或转基因手段提高作物的养分利用效率和矿质养分相关的品质性状，如甘蓝和白菜 Ca, Mg 和 Se 等养分高效和生物富集的研究。在基础研究方面，主要是揭示植物养分吸收和积累的机制，重点研究芸薹属植物对养分胁迫的反应。近年，在 Plant Physiology，PloS ONE, New Phytologist, Journal of Experimental Botany 等知名杂志发表几十篇文章，在英国国内和国际植物营养学领域已具有较大的影响力。

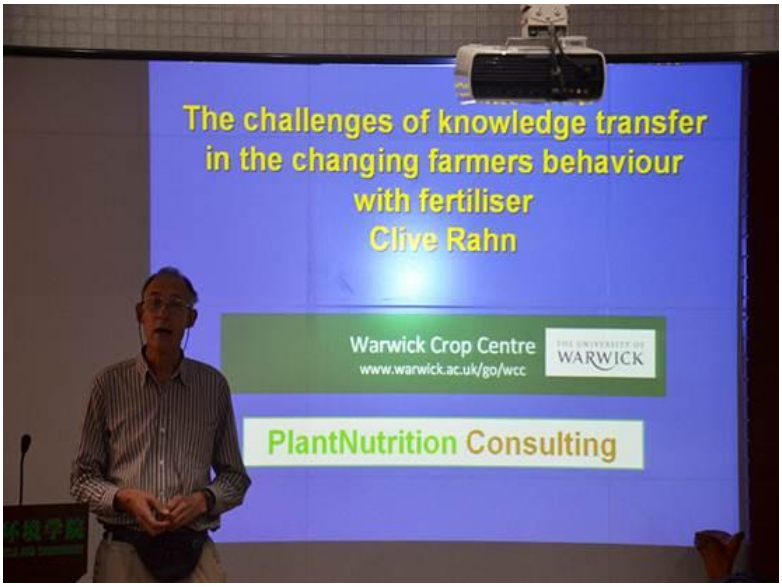
5.2.1.3 英国华威大学 Clive Rahn 教授来我校进行学术交流

2013 年 11 月 21 日-12 月 6 日，应资环学院养分资源综合管理课题组的邀请，英国华威大学（University of Warwick）的 Clive Rahn 教授来我校开展学术交流。

首先，在鲁剑巍教授、任涛博士及相关研究生的陪同下，Clive Rahn 教授先后参观了养分管理课题组在华农校内、武穴、宜昌和荆州的水稻-油菜、柑橘科学施肥试验示范基地，对课题组与当地农业技术推广部门共建科研推广平台的做法赞赏有加。随后，Clive Rahn 教授为资源与环境学院师生作了题为“The Challenges of Knowledge Transfer in Changing Farmers Behavior with Fertilizer”的学术报告，阐述了农业大学的科研成果如何应用于实际生产，以及农民如何及时有效接受科研成果信息的问题。另外，Clive Rahn 教授邀请了他在国内的合作伙伴浙江大学的张科锋教授参与了养分资源综合管理课题组的讨论。李小坤副教授、任涛博士、丛日环博士和其他五位博士生分别介绍了各自在水稻、油菜养分管理方面的研究进展，得到了 Clive Rahn 教授的肯定和指导。最后，Clive Rahn 教授还为 2013 级植物营养专业的硕士研究生作了题为“Soil nutrient status and fertilizer recommendation systems”的专题讲座，详细介绍了英国的推荐施肥工作以及如何利用模型进行推荐施肥，开阔了研究生的视野。

通过本次交流访问，增进了双方的相互了解，有利于科学信息、思想、观点的学习和沟

通，对国际科研项目的合作起到推动作用。



Clive Rahn 教授在讲解 PPT

5.2.1.4 中外专家考察武穴市油菜施肥试验示范基地

11 月 24 日，中国科学院南京土壤研究所王火焰研究员，英国华威大学 Clive 教授在我中心老师鲁剑巍教授的陪同下考察了养分资源综合管理课题组的武穴市油菜科学施肥试验示范基地。试验负责人任涛博士在基地向中外专家汇报了公益性行业专项课题“华中地区钾肥高效利用与替代技术研究”的研究进展，武穴市农业局梅金先局长介绍了武穴市农业生产情况。公益性行业专项负责人王火焰研究员高度赞扬了华中课题试验规范、技术实用、推广措施得力、综合成效显著，是整个项目的领头羊。Clive 教授对课题组与地方农业技术推广部门共同构建科研与推广平台，既培养研究生又推广应用技术的做法赞赏有加。在实地考察过程中，两位专家对试验和示范工作提出了很多有建设意义的建议，并对现场进行试验的研究生进行了指导。根据目前试验示范规模、试验效果等情况，王火焰研究员、梅金先局长及鲁剑巍教授商定在明年 3 月底在武穴基地召开一次全国性的油菜科学施肥现场会。

5.2.1.5 美国弗罗里达大学李允聪教授来我校访问

5 月 23-24 日，美国弗罗里达大学李允聪教授应资源与环境学院耿明建副教授邀请来我校交流访问。

5 月 23 日上午，李允聪教授在资源与环境学院 204 会议室做客“绿博论坛”，首先介绍了弗罗里达大学以及个人科研、教学和社会服务工作，随后做了“美国南弗罗里达作物生产与生态恢复的平衡”的学术报告，详细阐述了利用覆盖作物、养分综合管理技术、土壤水分管理技术等，在实现农业生产力提高与生态环境恢复平衡方面开展的理论和技术研究。随后资源与环境学院部分青年教师和研究生介绍了湖北省绿肥生产利用、水环境改良、生物质利用等方面开展的科学研究。双方就感兴趣的问题展开了深入讨论，协商了今后合作研究的设想。

附：李允聪教授简介

李允聪，博士，美国佛罗里达大学食品和农业科学学院热带研究教育中心土壤和水科学系教授，山东农业大学和中国热带农业科学研究院的客座教授。1982 年毕业于山东农学院土化系，1990 年在美国乔治亚大学获农学硕士学位，1993 年获马里兰大学环境科学博士学位。获美国农学会 Fellow，美国土壤科学学会 Fellow；威尔逊波普诺奖（泛美热带园艺学会)，青年教师研究奖（国际荣誉科学与工程协会），高级教师奖（Gamma Sigma Delta 荣誉农业协会) 美联银行推广奖，Art Hornsby 杰出推广奖 (佛罗里达州推广协会)，国际年度教育家（佛罗里达大学 IFAS）和研究基金会教授奖（佛罗里达大学）。李允聪教授主要致力于研究土壤与水质量监测、评估与治理、通过优化管理提高养分利用效率以及土壤中的养分循环等。共发表研究论文 180 余篇，推广论文 70 篇，参与编写书籍 15 本，担任 Reviews in Environmental Science 和 Technology and Communications in Soil Science and Plant Analysis 杂志副编，是《 Water Quality Concepts, Sampling, and Analyses》和《Handbook of Soil Sciences》主编之一。共培养研究生 20 余名，指导博士后 15 名及多名国际交流访问学者。

5.2.2 中心老师参加国内外学术会议

序号	参加人	会议名称	时间	地点	报告题目	报告形式	类别
1	胡承孝	中国寻乌蜜桔展暨中国柑橘学会 2013 年学术年会	2013.11.06-2013.11.08	寻乌	柑橘营养特性与矫正施肥技术	大会报告	全国会议

2	徐芳森	中国作物学会油料作物专业委员会第七次会员代表大会暨学术年会	2013.11.01-2013.11.03	文昌	新型甘蓝型油菜氮效率的研究	分组报告	全国会议
3	鲁剑巍				直播冬油菜增密覆草省肥与前促后稳养分管理技术		
4	石磊				油菜根系发生与磷高效利用		
5	胡承孝	新型肥料湖北省工程实验室 2013 年年会暨首届工程技术委员会成立大会	2013.11.24	武汉	园艺作物施肥	大会报告	全国会议
6	李小坤				作物专用肥的研制及优势		
7	徐芳森	BORON 2013	2013.08.15-2013.08.25	土耳其伊斯坦布尔	Boron efficiency in oilseed rape (*Brassica napus*)	大会报告	国际会议
8	石磊				Effect of Etibor-48 and Colemanite on seed yield and seed quality of oilseed rape (*Brassica napus*) and their residual effectiveness for rotated rice		
9					Cloning and expression analysis of*BnNIP5;1*s of oilseed Rape (*Brassica napus* L.) with different boron efficiency		

5.2.3 朱端卫教授率团应邀参加 2012 中欧环境与健康研讨会(SESEH 2012)

2012 年 8 月 18-28 日，我院朱端卫教授率团赴爱尔兰的戈尔韦参加了 2012 中欧环境与健康研讨会（SESEH2012）。组成人员有朱端卫教授、王革娇教授、华玉妹副教授、廖水姣副教授、蔡建波讲师、万小琼博士和研究生何君。朱端卫教授和万小琼博士应邀主持了会议中的“Water Quality b”分组报告，王革娇教授、万小琼博士以及研究生何君作了口头报告，其他老师以墙报的形式与与会代表进行了交流。

5.2.4 谭启玲副教授参加国际园艺学会（ISHS）组织的第七界国际果树矿质营养会议（泰国）

2012 年 5 月 19-25 日，我院谭启玲副教授和博士生黄鸿赴泰国参加由国阮园艺学会（ISHS）组织的第七界国际果树矿质营养学术会议。其中黄鸿博士做了大会报告 Effects of Nitrogen, Phosphorus and Potassium on Yield and Fruit Quality of Three Navel Orange Cultivars（氮磷钾配施对三种脐橙产量和品质的影响）。

5.2.4 中心青年老师和研究生 18 人参加在沈阳举行的“青土会”

2013 年 7 月 23-26 日，华中农业大学微量元素研究中心师生 18 人应邀参加在沈阳举行的“第十三届中国青年土壤科学工作者暨第八届中国青年植物营养与肥料科学工作者学术讨论会”，本次大会的主题是“土壤—植物营养科学：粮食安全与生态健康的双重挑战”。组委会邀请了张福锁教授、沈其荣教授、沈仁芳研究员、潘根兴教授、汪景宽教授、张旭东研究员、刘学军教授、庄杰教授（美国）等土壤与植物营养学界知名专家 8 人做了特邀报告。会上，中心石磊教授做了大会报告；李小坤副教授、任涛、从日环、张文君博士（讲师）；研究生贺从武、马捷、王典、张祥、张瑛等分别做了分组报告，其他研究生也分别提交了墙报。此外，参加本次会议的老师还有姜存仓副教授和赵小虎博士。通过学术交流，促进和加深了国内同行对我们研究工作的了解，也聆听到了很多建设性的意见和建议，这将增进中心与相关高校青年学者间的合作。据悉，下次会议将由西南大学承办，2014 年 10 月在重庆举行。

6.发表的论文及专著

6.1 2012 年发表外文论文题录

通讯作者	第一作者	论文题目	期刊名称	卷、页	IF
蔡红梅	卢永恩	Molecular characterization, expression and functional analysis of the amino acid transporter gene family (OsAATs) in rice	ACTA PHYSIOLOGIAE PLANTARUM	34(5):1943-1962	1.639
胡承孝	刘金山	Differences in Soil Fertility Parameters between 1981 and 2006 in Jingzhou County, China Associated with Changes of Agricultural Practices	COMMUNICATIONS IN SOIL SCIENCE AND PLANT ANALYSIS	42(20):2504-2514	0.506
胡承孝	刘全吉	Effects of high concentrations of soil arsenic on the growth of winter wheat and rape	PLANT SOIL AND ENVIRONMENT	58(1):22-27	1.078
胡承孝	张木	Molybdenum improves antioxidant and osmotic-adjustment ability against salt stress in Chinese cabbage	PLANT AND SOIL	355(1-2):375-383	2.733
姜存仓	刘桂东	Boron distribution and mobility in navel orange grafted on citrange and trifoliate orange	PLANT AND SOIL	360(1-2):123-133	2.733
练兴明	蔡红梅	Transcriptome response to nitrogen starvation in rice	JOURNAL OF BIOSCIENCES	37(4):731-747	1.648
练兴明	蔡红梅	Transcriptome response to phosphorus starvation in rice	ACTA PHYSIOLOGIAE PLANTARUM	34(1):327-341	1.639
鲁剑巍	李雅颖	Effect of phosphorus fertilization on yield and phosphorus use efficiency of winter oilseed rape with two different cropping intensities in the middle and lower reaches of Yangtze River	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(2):576-579	0.517
鲁剑巍	王伟妮	Inorganic fertilizer application ensures high crop yields in modern agriculture: A large-scale field case study in Central China	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(2):703-709	0.517
鲁剑巍	张文君	Accumulation and distribution characteristics for nitrogen,	SCIENTIA HORTICULTURA	141:83-90	1.527

		phosphorus and potassium in different cultivars of Petunia hybrida Vlim	E		
石磊	石桃雄	Brassica napus root mutants insensitive to exogenous cytokinin show phosphorus efficiency	PLANT AND SOIL	358(1-2):57-70	2.733
涂书新	马琳	Arsenic removal from water using a modified rutile ore and the preliminary mechanisms	DESALINATION AND WATER TREATMENT	32(40911):445-452	0.614
涂书新	王学龙	Effect of phosphorus and potassium nutrition on nicotine and nutrient accumulation during topping stage of Nicotiana tabacum L	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(2):732-740	0.517
涂书新	杨琼	Effectiveness of applying arsenate reducing bacteria to enhance arsenic removal from polluted soils by pteris vittatal	INTERNATIONAL JOURNAL OF PHYTOREMEDIATION	14(1):89-99	1.298
王富华	王旭	Comparing the health risk of toxic metals through vegetable consumption between industrial polluted and non-polluted fields in Shaoguan, south China	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(2):943-948	0.517
王荔军	李诗燕	Phosphorylated osteopontin peptides inhibit crystallization by resisting the aggregation of calcium phosphate nanoparticles	CRYSTENGCOMM	14(23):8034-8043	3.842
王荔军	王荔军	Kinetics of Calcium Phosphate Nucleation and Growth on Calcite: Implications for Predicting the Fate of Dissolved Phosphate Species in Alkaline Soils	ENVIRONMENTAL SCIENCE & TECHNOLOGY	46(2):834-842	5.228
王荔军	王荔军	Posner's cluster revisited: direct imaging of nucleation and growth of nanoscale calcium phosphate clusters at the calcite-water interface	CRYSTENGCOMM	14(19):6252-6256	3.842
徐芳森	丁广达	Quantitative trait loci for seed yield and yield-related traits, and their responses to reduced phosphorus supply in Brassica napus	ANNALS OF BOTANY	109(4):747-759	4.03
徐芳森	潘媛	Differences in cell wall components and allocation of boron to cell walls confer variations in sensitivities of	PLANT AND SOIL	354(1-2):383-394	2.733

		Brassica napus cultivars to boron deficiency			
徐芳森	石磊	Identification of quantitative trait loci associated with low boron stress that regulate root and shoot growth in Brassica napus seedlings	MOLECULAR BREEDING	30(1):393-406	2.852
徐芳森	孙进华	Cloning and characterization of boron transporters in Brassica napus	MOLECULAR BIOLOGY REPORTS	39(2):1936-1973	2.929
徐芳森	杨广哲	Characterization of phosphorus starvation-induced gene BnSPX3 in Brassica napus	PLANT AND SOIL	350(40910):339-351	2.733
徐芳森	张海伟	Genotypic variation in phosphorus acquisition from sparingly soluble P sources is related to root morphology and root exudates in Brassica napus	SCIENCE CHINA-LIFE SCIENCES	54(12):1134-1142	2.024
徐芳森	赵尊康	Dissecting Quantitative Trait Loci for Boron Efficiency across Multiple Environments in Brassica napus	PLOS ONE	7(9)	4.092
喻敏	耿明建	Protective role of mucilage against Al toxicity to root apex of pea (Pisum sativum)	ACTA PHYSIOLOGIAE PLANTARUM	34(4):1261-1266	1.639
周文兵	邓丽	Effect of chemical and biological degumming on the adsorption of heavy metal by cellulose xanthogenates prepared from Eichhornia crassipes	BIORESOURCE TECHNOLOGY	107:41-45	4.98
朱端卫	崔京珍	Effect of boron-doped goethite on soil acidity,different forms of manganese in red soil and the growth of rape(brassica napus L.)seedlings	JOURNAL OF PLANT NUTRITION	35(13):1923-1936	0.641
朱端卫	胡珊	Synthesis, Characterization, and Evaluation of Boron-Doped Iron Oxides for the Photocatalytic Degradation of Atrazine under Visible Light	INTERNATIONAL JOURNAL OF PHOTOENERGY	1-4	1.769
胡承孝	黄鸿	Effects of Fe-EDDHA application on iron chlorosis of citrus trees and comparison of evaluations on nutrient balance with three approaches	SCIENTIA HORTICULTURAE	146:317-142	1.527
胡承孝	张木	Impact of molybdenum on Chinese cabbage response to selenium in solution culture	SOIL SCIENCE AND PLANT NUTRITION	58(5)：595:603	0.763

胡承孝	黄鸿	Diagnosing of the nutritional status of 'Newhall' navel orange trees with the method of modified diagnosis and recommendation integrated system (M-DRIS)	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(3-4):379:383	0.517
胡承孝	刘洪恩	Interactive effects of molybdenum and phosphorus fertilizers on dry matter accumulation, seed yield and yield components in Brassica napus	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	10(3-4):389-392	0.517
王富华	刘聪云	Behavior of mixed formulation of metalaxyl and dimethomorph in grape and soil under field conditions	Ecotoxicology and Environmental Safety	84(10)：112-116	2.203

6.2 2012 年发表中文期刊论文题录(第一单位为华中农业大学）

序号	作者	论文名称	期刊名称	期、卷、页号
1	卜容燕，任涛，鲁剑巍，李小坤，李云春，汪洋，鲁君明	水稻-油菜轮作条件下氮肥效应及其后效	中国农业科学	2012，45（24）：5049-5056
2	程杨,刘新伟,宁大伟,韩玲君,赵竹青	氮磷钾配施对油菜产量及其构成因子的影响	江西农业学报	2012,24(5):111-113,116
3	崔敏,胡承孝,Di Hong Jie,孙学成,谭启玲,张木	武汉市城郊区集约化露天菜地生产系统硝态氮淋溶迁移规律研究	植物营养与肥料学报	2012,18(3) : 637-644
4	戴志刚,鲁剑巍,周先竹,杨文兵,胡劲红,刘光文	不同耕作模式下秸秆还田对土壤理化性质的影响	中国农技推广	2012,28(3):46-48
5	丁广大,杨美,李兴美,石磊,徐芳森	甘蓝型油菜分子标记在重组自交系群体中的偏分离分析	中国农业科技导报	2012,14 (2):56-61
6	范俊楠，赵建伟，朱端卫	湖泊氮素氧化及脱氮过程研究进展	生态学报	2012,32（15）：4924-4931
7	冯繁文,赵书军,耿明建,袁家富,徐大兵,汤凤兰,柯昌煌	不同绿肥利用模式对棉花干物质和氮素积累的影响	湖北农业科学	2012,51(22):4998-5001
8	韩宝吉,石磊,徐芳森,黄见良,曾祥明,马欣,郭龙飞	湖北省水稻施肥现状分析及评价	湖北农业科学	2012,51(12) : 2430-2435
9	赖世刚,李春子,贺立源	利用本体技术实现的智能搜索与录入系统	计算机工程与应用.	2012,48(6):131-133:142

10	李小坤,李云春,鲁剑巍,鲁君明,邹俊	强降雨致洪涝灾害下不同因素对水稻倒伏的影响	自然灾害学报	2012,21(6):99-103
11	李秀丽,张文君,鲁剑巍,王荔军	植物体内草酸钙的生物矿化	科学通报	2012,57(26):2443 -2455
12	刘红恩,胡承孝,聂兆君,孙学成,谭启玲	钼磷配合施用对甘蓝型油菜产量和子粒品质的影响	植物营养与肥料学报	2012,18(3) : 678-688
13	刘金山、胡承孝、孙学成、邱伟红、谭启玲	基于最小数据集和模糊数学法的水旱轮作区土壤肥力质量评价	土壤通报	2012，43（5）：1145-1150
14	刘晓伟,鲁剑巍,李小坤,卜容燕,刘波	直播冬油菜钙、镁、硫养分吸收规律	中国油料作物学报	2012,34(6):638-644
15	刘晓伟,鲁剑巍,李小坤,徐维民,潘琴	不同钾效率类型油菜的农艺性状及钾素积累特征比较	中国油料作物学报	2012,34(4):402-406
16	刘新伟,龚德平,高超,张晓丽,娄希凤,韩玲君,杨德桦,赵竹青	江北农场土壤养分状况分析与评价	湖北农业科学	2012,51(1):21-23
17	刘新伟,龚德平,巩细民,王巍,娄希凤,韩玲君,杨德桦,赵竹青	湖北江北农场小麦肥效试验与施肥推荐	麦类作物学报	2012,32(2):338-343
18	刘新伟,龚德平,娄希凤,韩玲君,杨德桦,程杨,赵竹青	江汉平原中稻氮磷钾配施效果及推荐施肥量研究	江西农业学报	2012,24(1):77-80
19	刘新伟,龚德平,娄希凤,韩玲君,杨德桦,赵竹青	江汉平原腹地中稻氮磷钾肥效及其适宜用量	福建农业学报	2012,27(1):18-23
20	龙小燕,涂书新	活性炭负载纳米二氧化钛对水体中砷的去除	工业水处理	2012,32(4):29-32
21	陆志峰,李继福,徐正伟	喷施宝叶面肥的防灾减灾作用及机理研究	中国农技推广	2012,28(5):47-49
22	潘福霞,李小坤,鲁剑巍,鲁君明,刘威,魏云霞,耿明建,曹卫东	不同播期对紫云英生长及物质养分积累的影响	土壤	2012,44(1):67-72
23	潘福霞,鲁剑巍,李小坤,刘威,魏云霞,朱德雄,耿明建,曹卫东	不同施肥量对绿肥产量和养分积累的影响	中国生态农业学报	2012,20(2):158-162
24	潘福霞,鲁剑巍,李小坤,鲁君明,刘威,魏云霞,耿明建,曹卫东	水稻季施肥对后季绿肥物质养分积累的影响	土壤	2012,44 (5):762-768
25	孙懿慧,贺立源	基于 GIS 的湖北省水稻生产潜力研究	长江流域资源与环境	2012,21(10):1209-1215
26	唐徐红,矣跃平,何云燕,刘磊,尹晓东,曹林海,何结望,李琳,涂书新	指纹图谱技术在云南省烤烟质量分类中的应用研究	湖北农业科学	2012,51(6):1156-1160
27	唐徐红,矣跃平,涂书新,	云南烤烟 HPLC 指纹图谱数据库	中国烟草科	2012,33(2):

	袁仕信,何云燕,刘磊,尹晓东,何结望,李琳	的建立和规程研究	学	1-6
28	田飞,徐芳森,石桃雄,赵尊康,石磊,蔡红梅,马朝芝,孟金陵	白菜型、芥菜型和甘蓝型油菜对低氮低磷胁迫反应差异的评价	华中农业大学学报	2012,31(6):725-730
29	王典,张祥,姜存仓,彭抒昂	生物质炭改良土壤及对作物效应的研究进展	中国生态农业学报	2012,20(8):963-967
30	王瑾,李小坤， 鲁剑巍,王筝,占丽平	不同酸提取条件下几种含钾矿物中钾释放动力学研究	中国农业科学	2012,45(22):4643-4650
31	王俊,朱端卫,杨特武,刘保财,杨瑞玮,耿明建	林荫银莲花不定芽增殖培养基的优化	药物生物技术	2012,19(1):45-48
32	王素萍,李小坤,鲁剑巍,李慧,吴庆丰,汪航,王寅,肖国滨,薛欣欣,徐正伟	控释尿素施用对油菜籽产量、氮肥利用率及土壤氮素收支平衡的影响	植物营养与肥料学报	2012,18(6):1449-1456
33	王伟妮,鲁剑巍,鲁明星,戴志刚,李小坤	水田土壤肥力现状及变化规律分析—以湖北省为例	土壤学报	2012,49(2):105-116
34	王伟妮,鲁剑巍,鲁明星,戴志刚,李小坤	水田土壤肥力现状及变化规律分析——以湖北省为例	土壤学报	2012,49(2):319-330
35	王晓丽,姜存仓,郝艳淑,王典,夏颖,陈防	钠和其他离子对钾离子替代作用的研究进展	中国土壤与肥料	2012,(1):1-6:13
36	王寅	移栽和直播油菜适宜的施氮量	农家顾问	2012,(2):31-31
37	王寅,李小坤,李雅颖,李继福,肖国滨,郑伟,袁福生,鲁艳红,廖育林,鲁剑巍	红壤不同地力条件下直播油菜对施肥的响应	土壤学报	2012,49(1):121-129
38	王寅,鲁剑巍,李小坤,刘波,袁福生,肖志强	施肥对红壤地区直播油菜生长、产量及养分吸收的影响	中国土壤与肥料	2012,(1):38-43
39	王筝,鲁剑巍,张文君,李小坤	田间土壤钾素有效性影响因素及其评估	土壤	2012,44 (6):898-904
40	魏云霞,鲁剑巍,李小坤,耿明建,宋莉,杨文兵,李登荣,汪航,肖春梅	湖北省不同双季稻区适宜紫云英品种比较研究	中国土壤与肥料	2012,(6):93-97
41	夏颖,姜存仓,王晓丽,郝艳淑,陈防,鲁剑巍	嫁接对不同棉花基因型钾效率的影响	中国生态农业学报	2012,20(1):34-39
42	熊双莲,宋俊英,涂书新,金瓯,喻法金,杜巍,陈永芳,谭启玲,杨俊城	不同芥菜型油菜基因型砷毒耐性研究	中国油料作物学报	2012,34(3) : 273- 279
43	杨 玲,连 娟,郭再华,张秀,杜爽爽,何兴龙,赵竹青	砷胁迫下磷用量对不同磷效率水稻产量、生物量以及 P、As 含量的影响	中国农业科学	2012,45(8):1627-1635
44	叶祥盛,宗虹,张丽梅,王	加强仪器设备管理,提高仪器利	实验科学与	2012,10(2):

	贻俊,徐芳森,赵竹青	用率	技术	178-181
45	袁探，华玉妹，朱端卫，丁敏，蔡建波	外源硫酸盐对武汉南湖表层沉积物磷形态的作用	中国环境科学	2012,32(4):666-673
46	曾祥明,韩宝吉,徐芳森,黄见良,蔡红梅,石磊	不同基础地力土壤优化施肥对水稻产量和氮肥利用率的影响	中国农业科学	2012,45(14):2886-2894
47	占丽平，丛日环，李小坤，鲁剑巍，廖志文，王瑾	低分子量有机酸影响下土壤 K+ 吸附动力学的研究	土壤学报	2012，49（6）：78-88
48	张赪,胡富女,金育红,刘光文,邢烈火,游江峰,莫菁华,周洁,李小坤	鄂东南双季稻区硅肥在早稻上的施用效果研究	湖北农业科学	2012,51(22):5005-5007
49	张丽,张洋洋,薛欣欣,任涛,鲁剑巍,吕忠群	不同形态钾肥在油菜上的施用效果	湖北农业科学	2012,51(16):3442-3444
50	章英,贺立源,叶颖泽,吴昭辉	基于 LS-SVM 的烤烟烟叶产地判别	湖北农业科学	2012,51(3):583-585
51	赵长盛,胡承孝,黄魏,孙学成,谭启玲	利用原状土柱研究华中地区菜地土壤氮素的矿化规律	土壤通报	2012,43(4):883-889
52	赵长盛,胡承孝,孙学成,黄魏	温度和水分对华中地区菜地土壤氮素矿化的影响	中国生态农业学报	2012,20(7):861-866
53	赵长盛、胡承孝、陈庆峰	不同氮处理对蔬菜产量和硝酸盐含量的影响	长江蔬菜	2012，14：71-77
54	朱端卫,朱红,倪玲珊,肖鹏程	沉水植物驱动的水环境钙泵与水体磷循环的关系	湖泊科学	2012,24(3):355-361

6.3 2013 年发表外文期刊论文题录

通讯作者	第一作者	论文题目	期刊名称	期、卷、页号	IF
王荔军、林拥军	贺从武	Evidence for 'silicon' within the cell walls of suspension-cultured rice cells	NEW PHYTOLOGIST	200（3）：700-709	6.736
王荔军、Christine V. Putnis	王荔军	Coupled Dissolution and Precipitation at the Cerussite-Phosphate Solution Interface: Implications for Immobilization of Lead in Soils	ENVIRONMENTAL SCIENCE & TECHNOLOGY	47（23）：13502-13510	5.257
徐芳森、杨春雷	梁思威	Application of exogenous substances reduces tobacco-specific nitrosamines content by regulating biosynthesis of nicotine and nitrite in burley tobacco	ACTA PHYSIOLOGIAE PLANTARUM	35（10）：3027-3036	1.305
张文君、	刘建、	Inhibition of cadmium ion uptake in	NEW	200	6.73

王荔军	马捷、贺从武	rice cells by a wall-bound form of silicon	PHYTOLOGIST	（3）：691-6990	6
蔡红梅	蔡红梅	Comparative Analysis of Differentially Expressed Genes in Rice Under Nitrogen and Phosphorus Starvation Stress Conditions	PLANT MOLECULAR BIOLOGY REPORTER	31(1):160-173	5.319
熊双莲	Li X, Xiong S*	Selenium uptake, speciation and stressed response of *Nicotiana tabacum* L.	Environmental and Experimental Botany	V(95):6-14	2.578
Hammond, John P.	石磊	High-throughput root phenotyping screens identify genetic loci associated with root architectural traits in Brassica napus under contrasting phosphate availabilities	ANNALS OF BOTANY	112(2):381-389	3.449
贺立源	王夏	Synchronous Segmentation of Reflection and Transmission Images of Flue-Cured Tobacco Leaves	SENSOR LETTERS	11(6-7):1298-1304	0.517
胡承孝	汤亚芳	Genotypic differences in nitrate uptake, translocation and assimilation of two Chinese cabbage cultivars	PLANT PHYSIOLOGY AND BIOCHEMISTRY	70:14-20	2.775
姜存仓	姜存仓	Effect of K on dry matter accumulation and distribution and changes of root-zone K in different cotton genotypes	JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT	11(1):604-608	0.517
姜存仓	郝艳淑	Assessment of economic and environmental impacts of two typical cotton genotypes with contrasting potassium efficiency	JOURNAL OF PLANT NUTRITION AND SOIL SCIENCE	176(3):460-465	1.380
姜存仓	刘桂东	Cellular boron allocation and pectin composition in two citrus rootstock seedlings differing in boron-deficiency response	PLANT AND SOIL	370(1-2):555-565	2.638
鲁剑巍	王伟妮	Evaluating regional mean optimal nitrogen rates in combination with indigenous nitrogen supply for rice production	FIELD CROPS RESEARCH	137:37-48	2.474
鲁剑巍	任涛	Potassium-fertilizer management in	JOURNAL OF	176(3):	1.38

		winter oilseed-rape production in China	PLANT NUTRITION AND SOIL SCIENCE	429-440	0
石磊	石桃雄	QTL for Yield Traits and Their Association with Functional	PLOS ONE	8(1)	3.730
石磊	曾祥明	Effects of modified fertilization technology on the grain yield and nitrogen use efficiency of midseason rice	FIELD CROPS RESEARCH	137:203-212	2.474
涂书新	管冠	Phosphorus Fertilization Modes Affect Crop Yield, Nutrient Uptake, and Soil Biological Properties in the Rice-Wheat Cropping System	SOIL SCIENCE SOCIETY OF AMERICA JOURNAL	77(1):166-172	1.821
王荔军	秦利鸿	Direct Imaging of Nanoscale Dissolution of Dicalcium Phosphate Dihydrate by an Organic Ligand: Concentration Matters	ENVIRONMENTAL SCIENCE & TECHNOLOG	47(23):13365-13374	5.257
徐芳森	彭李顺	Transcriptional Profiling Reveals Adaptive Responses to Boron Deficiency Stress in Arabidopsis	ZEITSCHRIFT FUR NATURFORSCHUNG SECTION C-A JOURNAL OF BIOSCIENCES	67(9-10):510-524	0.604
徐芳森	王祎	Dual effects of transgenic Brassica napus overexpressing CS gene on tolerances to aluminum toxicity and phosphorus deficiency	PLANT AND SOIL	362(1-2):231-246	2.638
徐芳森	丁广大	Genetic analysis of seed mineral accumulation affected by phosphorus deprivation in Brassica napus	EUPHYTICA	193(2):251-264	1.643
徐芳森	王祎	Overexpression of phyA and appA Genes Improves Soil Organic Phosphorus Utilisation and Seed Phytase Activity in Brassica napus	PLOS ON	8(4)	3.730
徐芳森	杨广哲	Identification of phosphate-starvation-inducible gene BnIPS1 in Brassica napus	ACTA PHYSIOLOGIAE PLANTARUM	35(7):2085-2094	1.305
徐芳森	杨露	Characteristics of root boron nutrition confer high boron efficiency in Brassica napus cultivars	PLANT AND SOIL	371(1-2):95-104	2.638
朱端卫	刘广龙	Innovative photocatalytic degradation	CHEMICAL	213:28	3.47

		of polyethylene film with boron-doped cryptomelane under UV and visible light irradiation	ENGINEERING JOURNAL	6-294	3
朱端卫	米玮洁	Distinguishable root plaque on root surface of Potamogeton crispus grown in two sediments with different nutrient status	LIMNOLOGY	14(1):1-11	0.875
王富华	刘聪云	Pyrimethanil residue and dissipation in tomatoes and soil under field conditions	Environ Monit Assess	(2013), 185:9397–9402	1.592
王富华	孙芳芳	Soil threshold values of total and available Cd for vegetable growing based on field data in Guangdong province, south China	Journal of the Science of Food and Agriculture，J Sci Food Agric	2013;93:1967-1973	1.759

6.4 2013 年发表中文期刊论文题录(第一单位为华中农业大学）

序号	作者	论文名称	期刊名称	期、卷、页号
1	丁广大、陈水森、石磊、蔡红梅、叶祥盛	植物耐低磷胁迫的遗传调控机理研究进展	植物营养与肥料学报	2013，19:733-744
2	李慧，马常宝，鲁剑巍，李小坤，任涛，丛日环	中国不同区域油菜氮磷钾肥增产效果	中国农业科学	2013，46（9）:1837-1847
3	王寅，李雅颖，鲁剑巍，李小坤，徐正伟，邹家龙，姚忠清	栽培模式对直播油菜生长、产量和养分吸收利用的影响	植物营养与肥料学报	2013,19（3）:597-607
4	王寅，鲁剑巍，李小坤，任涛，丛日环，占丽平	长江流域直播冬油菜氮磷钾硼肥施用效果	作物学报	2013，39（8）:1491-1500
5	余芬芳，华玉妹，范乐，蔡建波，朱端卫	外源硫酸盐对武汉墨水湖沉积物磷迁移的影响	水土保持学报	2013,27(5):89-94
6	占丽平，李小坤，鲁剑巍，王瑾，王筝，廖志文.	水旱轮作条件下不同类型土壤供钾能力及钾素动态变化研究	土壤学报	2013，50（3）:169-177
7	赵长盛、胡承孝、黄 魏	华中地区两种典型菜地土壤中氮素的矿化特征研究	土壤	2013，45（1）:41-45。
8	张秀，郭再华，杜爽爽，王阳，	砷胁迫下水磷耦合对不同磷效率水稻生物学性状及精米砷含	作物学报	2013，39(9):1-7

	石乐毅，张丽梅，赵竹青，贺立源	量的影响		
9	张祥，王典，姜存仓，朱盼，雷晶，彭抒昂	生物炭对我国南方红壤和黄棕壤理化性质的影响	中国生态农业学报	2013，21（8）：979-984
10	张祥，王典，姜存仓，彭抒昂	生物炭及其对酸性土壤改良的研究进展	湖北农业科学	2013，52（5）：997-1001
11	张祥，王典，朱盼，姜存仓，彭抒昂	生物炭对酸性红壤改良及纽荷尔脐橙苗生长的影响	中国南方果树	2013，42（6）：38-41
12	安堃达，熊双莲，涂书新等	豇豆和蕃茄对砷胁迫的响应	华中农业大学学报	2013，V32(1):73-77
13	孔伟，储刘专，鲁剑巍，吴文昊，袁家富，赵书军，解晓菲，曹卫东，耿明建.	光叶紫花苕子不同翻压期对烤烟生长发育的影响	中国农学通报	2013，29(1):150-154

6.5 2013 年出版的科技著作

著作名称	参与作者姓名	著作字数（千）	出版社	书号（以 ISBN 为开头）	出版时间
油菜施肥调查与推荐施肥技术	（主编）任涛；（编委）李小坤、徐华丽、邹娟、周鹂、丛日环、李慧、鲁剑巍	101	中国农业出版社	978-7-109-18274-5	2013.12

7 中心仪器设备

7.1 已有的仪器展示

我中心在依托单位的大力支持下，近 3 年购买了价值 500 余万元的仪器设备，加上实验室原有的设备条件，具备从事土壤、植物、环境样品的分析与监测等所需要的全部大型仪器。

中心拥有的 10 万元以上的大型仪器设备主要有：扫描电子显微镜、透射电子显微镜、原子力显微镜、全谱直读电感耦合等离子体发射光谱仪、X 射线衍仪、微量热仪、大容量高速离心机、红外分光光度计、原子吸收分光光度仪、气（液）相色谱仪、流动注射分析仪、TOC 分析仪、全自动表面分析仪、自动电位滴定仪、土壤时域反射仪（TDR）、微地形激光扫描仪、压力膜仪、偏光显微镜、差热分析仪、紫外分光光度计、液相色谱仪、可见光/近红外地物光谱仪、数据服务共享系统、A0 扫描仪(CoaTex)、A0 绘图仪(Hp)及激光彩色打印机、AroInfor、Map Object 及 GeoStar、遥感影像、冷冻干燥机。所有仪器设备均能正常运行，并对外开放。

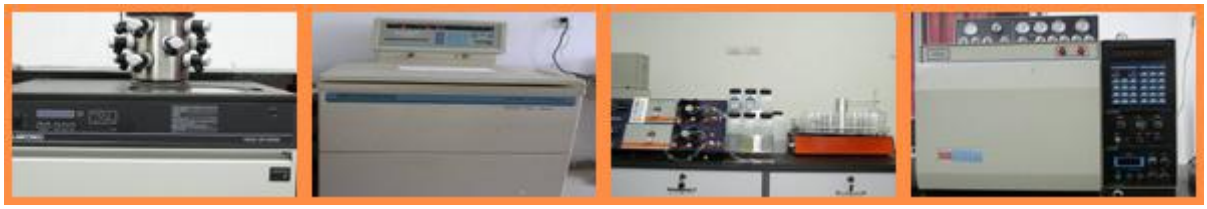
实验室设备展示

TCP 测定仪
Apollo 9000

超纯水器
(美国 LABCONCO
Water pro PS)

超低温冰箱
(Polar 530)

等离子体发射光谱仪
ICP



冻干机
(美国 LABCONCO)

高速冷冻离心机
Beckman Centrifuge

流动注射仪
Flow Injector

气相色谱
Gas Chromography

盆栽实验室

光照培养室（一）

光照培养室（二）

光照培养室（三）


光照培养室（四）


光照培养室（五）


盆栽试验场（一）


盆栽试验场（二）


1-3 级水制水机（一）


1-3 级水制水机（二）


人工气候室


土培试验


水培试验（一）


水培试验（二）


原子吸收分光光度计 AAS


人工气候室

7.2 中心仪器管理

仪器名称	放置地点	技术负责人	联系方式	负责人
酶标仪	125	刘磊超	18202719721	姜存仓
制冰机	420	王兆双	15102768941	涂书新
旋转蒸发仪	429	林亚蒙	13871371542	赵竹青
超低温冷冻离心机	429	矫威	15527792838	赵竹青
核酸蛋白分析仪	406	陈海飞	15527792838	蔡红梅
凝胶成像系统	406	陈海飞	15872399945	蔡红梅
根系扫描仪	404	陈海飞	15872399945	蔡红梅
示波极谱仪	401	秦世玉	18071042316	胡承孝
行星式磨样机（玛瑙）	新盆栽场	秦世玉	18071042316	胡承孝

8 微量元素广州分中心基本情况

华中农业大学微量元素中心广州分中心设在广东省农业科学院农产品公共监测中心，建有农业部农产品质量安全检测与评价重点实验室、农业部农产品质量安全风险评估实验室（广州）、农业部蔬菜水果质量监督检验测试中心（广州）、农业部农药登记残留试验室、中国农业科技华南创新中心农产品安全与质量标准中心等平台。承担广东省饲料工业职业技能鉴定站饲料检验化验员培训及广东省种植业标准化技术委员会秘书处的工作。现有科技人员 50 余人，其中高级职称 12 名，有博士 10 人。有博士生导师 1 名，硕士生导师 3 名，有 1 人享受国务院政府特殊津贴，多名专家受聘为全国和省农产品质量安全、农业标准化等相关专业委员会专家。现有实验室 3600㎡，野外栽培试验基地 2800 ㎡，配套设施完备齐全，仪器设备先进完善，现有包括液相—质谱—质谱联用仪、液相色谱-等离子发射光谱-质谱仪、气相色谱—质谱仪、等离子发射光谱仪、形态分析仪、氨基酸分析仪、液相色谱仪、气相色谱仪、离子色谱仪、原子吸收、原子荧光等仪器设备 100 余台（套），仪器设备价值 1500 余万元。

附：中心优秀 SCI 论文

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Effect of chemical and biological degumming on the adsorption of heavy metal by cellulose xanthogenates prepared from *Eichhornia crassipes*

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Adsorption
Lead

ABSTRACT

Cellulose xanthogenates, derived from the straw of *Eichhornia crassipes*, were prepared as adsorbents for heavy metals by CS_2 sulfonation and magnesium substitution after degumming with alkali, self-isolated A_1 strain and pectase, respectively. The effects of three degumming treatments were compared by functional groups analysis, surface morphology and surface element composition and heavy metal (Pb^{2+}) adsorption studies. The results demonstrate that bio-degumming treatments by A_1 strain and pectase have weaker degumming effects than alkali treatment. However, the surface characteristics of the bio-degumming products, especially the pectase degumming product, are more beneficial to heavy metal adsorption. In comparison to that of the raw plant materials, the Pb^{2+} adsorption performances of the three xanthogenates improved significantly, although no obvious differences being observed among themselves. From an environmental point of view, the two bio-degumming treatments, especially the pectase degumming treatment, are more beneficial to prepare heavy metal adsorbents than the alkali degumming treatment.

1. Introduction

Efficient systems for water remediation such as heavy metal removal have become increasingly important and urgent. Derivatives of cellulose, starch and chitosan, are attractive options for water treatment, offering significant advantages such as abundant sources, low cost, easy handling and biodegradability that minimizes secondary pollution (Nawirska, 2005; Belhalfaoui et al., 2009; Salam et al., 2011). Cellulose based adsorbents for adsorption of pollutants such as heavy metals and ionic dyes can be prepared via esterifying, etherifying and ingrafting with propylene, CS_2 or acrylamide, etc. (Anirudhan and Jalajamony, 2010; O'Connell et al., 2008; Lukasiewicz et al., 1999). It is known that grafting CS_2 into the cellulose or starch structure leads to xanthogenates of increased capacity for heavy metals adsorption (Tan et al., 2008; Chang et al., 2008). For this reason much attention has been directed towards the preparation of effective xanthogenates from a variety of parent plant materials.

Eichhornia crassipes (*E. crassipes*, i.e. water hyacinth) is a noxious floating weed growing in shallow waters, especially in tropical and subtropical waters, and can proliferate extremely quickly in eutrophic waters (Zhou et al., 2007). Excessive growth of *E. crassipes* can cause serious environmental problems, e.g. infest large areas of water with reduced light penetration and dissolved oxygen levels, pose health hazards through harboring of a variety of disease vectors, cause water pollution after decay, reduce biodiversity and generally degrade the water ecosystem (Zhou et al., 2007; Malik, 2007; Ismail and Beddri, 2009).

However, *E. crassipes* is well known as an efficient absorber of nutrients and heavy metals from eutrophic water bodies. To take advantage of its beneficial role in pollutant removal, efficient utilization of *E. crassipes* after its harvest is highly desired. *E. crassipes* is rich in cellulose (>30%), hemicellulose and lignin (Tan et al., 2008). The straw of *E. crassipes* can be treated with high concentration of NaOH to obtain an alkali-treated straw intermediate. When sulfonated with CS_2 and substituted by magnesium salt, such an intermediate forms magnesium cellulose xanthogenate that is known to have high adsorption capability for heavy metals (Tan et al., 2008; Kumar et al., 2000; Zhou et al., 2011). Unfortunately, the large amount of alkali–wastewater produced by this process poses a severe secondary pollution problem.

Biological degumming (i.e. bio-degumming) may offer an alternative to alkaline treatment. It can be achieved by microbe-degumming and/or enzyme-degumming. In a microbe-degumming

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Effects of Fe–EDDHA application on iron chlorosis of citrus trees and comparison of evaluations on nutrient balance with three approaches

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CND
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Iron chlorosis
Iron deficiency

ABSTRACT

Iron deficiency chlorosis occurred frequently in many fruit trees grown on calcareous soils with a high pH. A field experiment of Fe–EDDHA application and a nutritional status survey on citrus orchards were conducted to observe the effects of Fe–EDDHA application on iron chlorosis of citrus trees. Three approaches, i.e., Sufficiency Range Approach (SRA), Diagnosis and Recommendation Integrated System (DRIS) and Compositional Nutrient Diagnosis (CND), were performed to evaluate the nutrient balance status of citrus trees. DRIS and CND were suitable to diagnose and evaluate nutrient balance status of citrus trees grown on calcareous soils with a high pH. The diagnosis results revealed that Fe–EDDHA application significantly improved Fe nutrition and decreased Zn in chlorotic citrus trees. The nutritional status of Zn, Mn, Fe, P and Mg were at the deficient levels and Cu, N, Ca and K at the excessive levels in iron treatment citrus trees. The results demonstrated that the leaf chlorosis of citrus trees grown on calcareous soils with a high pH was mainly caused by iron deficiency, but it was not the single cause leading to the nutrient imbalance in iron chlorotic citrus trees. DRIS and CND were suitable to diagnose and evaluate nutrient balance status of citrus trees grown on calcareous soils with a high pH. The results revealed that Zn and Mn deficiencies became the new limiting factors in iron deficiency citrus trees after iron chlorosis correction.

1. Introduction

Iron deficiency chlorosis occurred on approximately 30% of cultivated land area worldwide (Chen and Barak, 1982) and led to nutritional disorder frequently in many fruit trees grown on calcareous soils with a high pH. The high HCO_3^- concentration and pH in calcareous soil are two main factors responsible for low Fe availability in soil and low Fe efficiency in plant (Mengel, 1994). Iron chlorosis is a more complex phenomenon in fruit trees than in annual crops (Tagliavini et al., 2000), because: (i) fruit trees bearing a large amount of fruits each year are more likely to suffer severe chlorosis in the following year; (ii) chlorosis occurs more frequently in spring when rainfalls increase soil bicarbonate concentration in this period of intense Fe demand (Boxma, 1972); and (iii) Fe transport needs a longer distance in fruit trees to reach the canopy than in annual crops (Tagliavini and Rombola, 2001).

According to the hypothesis of Mengel (1994), iron deficiency chlorosis in calcareous soils was caused by restriction of Fe translocation from the root apoplast into the root symplast and from leaf apoplast into the leaf symplast. Therefore, the leaf total Fe concentration can not accurately reflects the Fe nutritional status in fruit trees and crops on calcareous soils (Pestana et al., 2003). Active Fe (Fe(II)), which extracted in leaves with 1 mol L^{-1} HCl, was a suitable index to evaluate iron chlorosis (Köseoğlu and Açikgöz, 1995; Sönmez and Kaplan, 2004). The concentration of chlorophyll or active Fe is often used to diagnose the iron deficiency status (Pestana et al., 2005; Fernández et al., 2008). However, these two indices cannot use to evaluate the whole nutrient balance in fruit trees. Belkhodja et al. (1998) reported that the leaf K/Ca ratio of peach tree increased significantly when iron chlorosis occurred. The leaf concentration ratios of both K/Ca and 50(10P + K)/Fe could be used to diagnose iron deficiency, which were adopted by Álvarez-Fernández et al. (2005) in analyzing various nutrient concentrations in sunflower, pear trees and peach trees grown in calcareous soil. Similar conclusions were drawn by Wang et al. (2008) in citrus sand culture experiment. Their studies suggest that the ratios of

Abbreviations: SRA, Sufficiency Range Approach; DRIS, Diagnosis And Recommendation Integrated System; CND, Compositional Nutrient Diagnosis norms; Nil_M, The Mean Of Nutritional Imbalance Index; I_X, The Nutrient Index of DRIS and CND Models; EDDHA, ethylenediamine-N,N′-di-(ortho-hydroxyphenyl) acetic acid.

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Evaluating regional mean optimal nitrogen rates in combination with indigenous nitrogen supply for rice production

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Rice

ABSTRACT

Nitrogen (N) is an essential nutrient that requires careful management in intensive rice systems, since insufficient amounts might result in yield losses, and excessive application might harm the environment. However, farmers often tend to apply a large excess of N fertilizer to ensure high rice yields, primarily because of the absence of reliable methods to estimate optimal N application rates. Therefore, a large-scale study comprising 514 field experiments for rice was conducted in seven rice regions (totaling 1.253 million ha) in Hubei province, Central China. We (i) evaluated yield responses to different N application levels, (ii) established indigenous soil N supply (INS) classification systems for different rice regions by identifying and using the preferable predictor of INS, and (iii) determined the optimal N application rates for each region based on regional mean optimal N rates (RMONR) in combination with INS. In all of the rice regions, rice yields were significantly higher in plots receiving N than in plots without N (termed no-N plots). The highest yields were obtained in plots receiving medium nitrogen (MN) treatment, where the average partial factor productivity (PFP_N) and agronomic efficiency (AE_N) were 50.4 kg grain kg^{-1} N and 12.5 kg grain kg^{-1} N, respectively. Yield responses of rice to N fertilizer were different among different rice regions because of regional variations in climatic conditions and soil fertility. A significant positive relationship between grain yield with and without N fertilizer also proved an important effect of INS on yield response to N fertilizer. On the basis of regression models, relative yields of 90%, 80%, 70%, 60%, and 50% were used as the critical values to obtain INS classifications, which were estimated by the yield of the no-N treatment but not by alkaline hydrolyzable-N. An obvious increasing trend of economic optimum N rate (EONR) with decreasing INS (from Class 1 to Class 6) was found for each rice region. Averaged across all rice regions of Hubei province, EONR was 150 kg ha^{-1}, which was lower than the N application rate for the MN treatment of 171 kg ha^{-1}. The results indicated that the N application rate recommended by local rice technicians could be cut by 12% (1–18% in different rice regions) without any loss of yield. In conclusion, the recommended N fertilizer application, based on RMONR in combination with INS, is feasible for regional rice production in China and other countries that have large numbers of small farmland areas and where agricultural testing equipment is absent or less modern.

1. Introduction

The world population is expected to increase to 9 billion by about the mid-21st century (Godfray et al., 2010); hence, rice yields must be increased to match rising food demand. Given the difficulty to expand areas used for rice crops, because of competition for land from urbanization and other sectors, increase in rice production must be achieved using the same or an even smaller area of land. This requirement means that appropriate rice production practices must be adopted to improve rice yield per unit area (Fageria, 2007). Among existing production practices, the application of nitrogen (N) fertilizer has earned increasing popularity. Substantial growth in the use of N fertilizer has contributed significantly to the improvement of crop yields in the world (Cassman et al., 2003).

The global use of N fertilizer has increased sevenfold between 1960 and 1995, and it is expected to increase another threefold by 2050, unless there is a substantial increase in fertilizer efficiency (Tilman et al., 2002). As the largest consumer of N fertilizer in the world, China accounts for about 32% of global N consumption, and approximately 18% of N fertilizer is applied to paddy rice (Heffer, 2009). Rice yield per-hectare in China is currently 50%

Abbreviations: AE_N, agronomic efficiency; EONR, economic optimum N rate; EOY, economic optimum yield; INS, indigenous soil N supply; PFP_N, partial factor productivity; RMONR, regional mean optimal N rate.

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Effects of modified fertilization technology on the grain yield and nitrogen use efficiency of midseason rice

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ABSTRACT

Local popular midseason varieties of rice were used to study the effects of modified fertilization technology on the grain yield and nitrogen (N) use efficiency of midseason rice in central China. Field trials with five N treatments and four replications were conducted in Jingmen County (2008–2009), Honghu County (2009–2011), and Chibi County (2008–2011) in Hubei Province. The results showed that, relative to most farmers' fertilizer practices (FFP), the grain yield of modified farmers' fertilizer practices (MFP) in eight out of nine experiments showed an increase in ratio ranging from 0.3% to 16.6% and grain yield of super-high-yield fertilizer practice (SHY) in six of nine experiments showed an increase in ratio ranging from 2.4% to 20.9%. Relative to SHY, the grain yield of modified super-high-yield fertilizer practice (MSP) treatments in seven out of nine experiments showed an increase in ratio ranging from 0.2% to 20.4%. Relative to FFP, the nitrogen agronomic efficiency (NAE) and nitrogen physiological efficiency (NPE) values of MFP treatment in eight out of nine experiments showed an increase in ratio ranging from 26.0% to 110.3% and from 1.3% to 46.1%, respectively. Relative to SHY, the NAE and NPE values of MSP treatment in eight out of nine experiments showed an increase in ratio ranging from 5.2% to 151.7% and from 7.4% to 82.6%, respectively. Further analysis showed that the number of panicles in MFP, SHY, and MSP were greater than in FFP. This was attributable to the ability of the modified fertilizer technology to delay functional leaf senescence, maintain optimum leaf area index (LAI), an optimize shoot biomass, to a reasonable tiller number and to a healthy population structure with a high relative amount of productive tiller. This study may provide technical and theoretical support for simultaneously increasing rice grain yield and nutrient use efficiency, for optimization of the use of fertilizer by local farmers, and for facilitating sustainable increases in grain yield.

1. Introduction

China has 31% of the paddy fields in Asia and 19% of paddy fields on Earth, more than any individual country in the world. It also ranks among the world's highest in terms of both total rice yield and unit area rice yield (Shen and Zhang, 2006). This gives China substantial influence on the stability of world grain production. In the past 60 years, food production has increased through the use of high-yield crop varieties and modern fertilizers, irrigation, and pesticides. It is estimated that the world population will reach 9 billion by 2050 (Godfray, 2010). The demand for food will continue to increase while agriculture fields decrease in size and the environment deteriorates. China and other rapidly developing countries face the dual challenge of substantially increasing grain yields while at the same time reducing the environmental impact of intensive agriculture (Chen et al., 2011; Vitousek et al., 2009).

A 2004 investigation of rice-planting practices in seven provinces (Jiangsu, Hunan, Zhejiang, Guangdong, Hubei, Hebei, and Heilongjiang) showed the use of nitrogen (N) in China's rice fields to be significantly greater than the world average, with an average amount of 220 kg hm^{-2} used for midseason rice (Shen and Zhang, 2006). Among these provinces, the average amount of N-fertilizer used was the lowest in Heilongjiang Province at 150 kg hm^{-2} and the highest in Jiangsu Province at 314 kg hm^{-2}. It was 200 kg hm^{-2} in Hubei Province. According to Peng et al. (2002a), the average amount of nitrogen-based fertilizer applied to paddy fields in Jiangsu Province from 1995 to 2000 was 270.9 kg hm^{-2}. According to Tang and Rong (2009), in Hunan province from 1994 to 2003, more than 65% of the paddy fields were fertilized with more than 200 kg hm^{-2} of N-fertilizer. This indicated a significant increase in the amount of N fertilizer used in the recent years. It may continue to increase in the future.

Over-fertilization is the main reason for the low N efficiency of fertilizers in China. Zhang et al. (2011) analyzed the results of

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Research article

Genotypic differences in nitrate uptake, translocation and assimilation of two Chinese cabbage cultivars [*Brassica campestris* L. ssp. *Chinensis* (L.)]

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ABSTRACT

A hydroponic trial was conducted to investigate genotypic differences in nitrate uptake, translocation and assimilation between low nitrate accumulator L18 and high accumulator H96 of Chinese cabbage [*Brassica campestris* L. ssp. *Chinensis* (L.)]. The results suggested that H96 could uptake more nitrate than L18 in the root but lower transport inside leaf cells and assimilation in the leaf. It was showed that root morphology parameters – length, surface area and volume of H96 were 18.0%, 31.6% and 46.5% higher than L18. Nitrate transporters *NRT1.1* and *NRT2.1* transcription levels were 41.6% and 269.6% higher than those of L18 respectively. *NRT1.1* and *NRT2.1* expression amount in leaf blade of two cultivars were opposite to in the root, L18 *NRT1.1* and *NRT2.1* expressions were 279.2% and 80.0% higher than H96. In addition, nitrate assimilation capacity of L18 was significantly higher than H96 in leaf. It was showed that Nitrate Reductase (NR; EC 1.7.1.1) activity and *NIA* expression level of L18 leaf were 234 0.4% and 105.4% higher than those of H96, Glutamine Synthetase (GS; EC 6.3.1.2) activity, *Gln1* and *Gln2* expression levels in the leaf blade of L18 were 43.9%, 331.5% and 124.8% higher than those of H96 respectively. Nitrate assimilation products-Glu, total amino acid, soluble protein content in the leaf of L18 were all significantly higher than those of H96. The results above suggested that nitrate accumulation differences were due to differential capacities to uptake, mechanisms for nitrate transport in leaves and assimilate nitrate. Comparing contribution of three aspects in nitrate accumulation, translocation and assimilation were contributed more in low nitrate concentration in the leaf blade.

1. Introduction

High nitrate accumulation in vegetable is harmful to human health because of the possibility of resulting in gastric cancer, thyroid cancer and other diseases [1,2]. Vegetables, the major source of daily nitrate intake by human beings, is responsible for 75–80% of the total intake [3]. Thus reducing nitrate content in Chinese cabbage can decrease a risk of human illness. Chinese cabbage [*Brassica campestris* L. ssp. *Chinensis* (L.)] was classified as high nitrate concentration vegetable with nitrate ranging from 1500 to 4000 mg N kg^{-1} [4]. Differences in nitrate accumulation among cultivars were due to their differential capacities in absorbing, reducing and assimilating nitrate [5–7].

Uptake of nitrate in plants are mediated by nitrate transporters such as *NRT1* (Low-affinity transport system, LATS) and *NRT2* (High-affinity transport system, HATS) families [8]. In *Arabidopsis*, low- and high-affinity transport systems are mediated primarily by *AtNRT1.1* and *AtNRT2.1* [9]. Expression of *AtNRT1.1* was induced by NO_3^- in the roots rapidly, and reached a maximum level that was 2.5 times higher than that of the 0 h. This high level of transcription was sustained from 12 h to 48 h [9]. Further studies indicated that *AtNRT1.1* was a dual-affinity nitrate transporter, its mode of action being switched by phosphorylation and dephosphorylation of threonine T101 [10,11]. In seven *NRT2* members, *AtNRT2.1* transcript abundance in the root was in significant correlation ($r^2 = 0.74$) with HATS activity [9]. Several mutants disrupted for both *AtNRT2.1* and *AtNRT2.2* genes have lost up to 75% of the high-affinity nitrate uptake activity [12], with *AtNRT2.2* expression pattern marching the HATS profile only during the first 3 h [9]. Thus, *AtNRT2.1* appears to be a more likely candidate for HATS influx. In Chinese cabbage,

Abbreviations: N, nitrogen; LATS, low-affinity transport system; HATS, high-affinity transport system; NR, nitrate reductase; NRA, nitrate reductase activity; NiR, nitrite reductase; GS, glutamine synthetase; GSA, glutamine synthetase activity; RT-PCR, real-time polymerase chain reaction; Glu, glutamic acid; GOGAT, glutamate synthase.

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Innovative photocatalytic degradation of polyethylene film with boron-doped cryptomelane under UV and visible light irradiation

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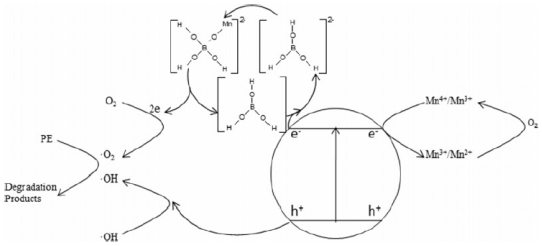
HIGHLIGHTS

- The boron doped cryptomelane was successfully prepared by a sol–gel method.
- B-OMS-2 exhibited greater light absorption property than that of OMS-2.
- Higher weight loss and greater texture change were obtained in PE-B-OMS-2 sample.
- A plausible mechanism was proposed on the basis of experimental results.

GRAPHICAL ABSTRACT



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ABSTRACT

The boron doped cryptomelane prepared by a sol–gel method was employed as photocatalyst for the degradation of polyethylene (PE) film under the UV and visible light irradiation. The cryptomelane (OMS-2) and boron doped cryptomelane (B-OMS-2) were characterized by X-ray diffraction (XRD), laser particle size analysis, Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), UV–vis spectroscopy and porosimeter analysis. The results indicated that the particle size, crystallinity of the boron doped OMS-2 increase, whilst surface area increase compared to regular OMS-2. FTIR and Raman results suggested that the dopants were dispersed into the framework of manganese oxide. The existence of interstitial boron in doped cryptomelane was confirmed by XPS. The UV–vis spectra showed that B-OMS-2 sample exhibited greater absorption property than that of OMS-2 sample after boron doping. In order to explore the application of these manganese oxides in environmental remediation, an attempt has been made for the degradation of polyethylene films using synthesized particles as catalyst in the form of PE-OMS-2 and PE-B-OMS-2 composite films under the UV–vis light irradiation. Higher PE weight loss rate and greater texture change could be obtained in the system of PE-B-OMS-2 composite in comparison with PE and PE-OMS-2 composite film, which indicated that the B-OMS-2 catalyst made the photodegradation of PE film more effective, and B-OMS-2 showed a higher catalytic activity than the regular OMS-2 under UV light irradiation. Compared to the UV light irradiation, no obvious change was detected under the visible light irradiation. Finally, the mechanism of degradation of composite film was also discussed.

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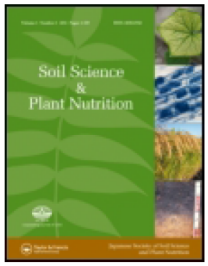

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Impact of molybdenum on Chinese cabbage response to selenium in solution culture

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Research Article

Synthesis, Characterization, and Evaluation of Boron-Doped Iron Oxides for the Photocatalytic Degradation of Atrazine under Visible Light

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Photocatalytic degradation of atrazine by boron-doped iron oxides under visible light irradiation was investigated. In this work, boron-doped goethite and hematite were successfully prepared by sol-gel method with trimethylborate as boron precursor. The powders were characterized by XRD, UV-vis diffuse reflectance spectra, and porosimetry analysis. The results showed that boron doping could influence the crystal structure, enlarge the BET surface area, improve light absorption ability, and narrow their band-gap energy. The photocatalytic activity of B-doped iron oxides was evaluated in the degradation of atrazine under the visible light irradiation, and B-doped iron oxides showed higher atrazine degradation rate than that of pristine iron oxides. Particularly, B-doped goethite exhibited better photocatalytic activity than B-doped hematite.

1. Introduction

Atrazine, 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine, has been widely used in the fields of corn, sorghum, orchard, and forest, controlling broad-leaf and grassy weeds [1]. However, due to the toxicity to aquatic organisms and mammals, high mobility, low-sorption affinity, and slow biodegradability [2, 3], atrazine has been banned by many European countries. It is frequently detected in ground water and surface water [4] and seriously influenced water quality. Therefore, many ways have been found to resolve atrazine contamination, such as advanced oxidation processes [5], microorganism removal [6], and microwave irradiation [7].

It has been reported that photocatalysis is effective way in the degradation of organic pollutants. TiO_2 is considered to be the most promising photocatalyst due to its nontoxicity, chemical inertness, and high reactivity. Parra found that both suspended and supported TiO_2 could destroy atrazine although atrazine could not be completely mineralized [8]. However, the widespread technological use of TiO_2 is impaired by its wide-band gap (3.2 eV), which can only be activated under UV light. Iron oxides especially goethite and hematite have been studied as photocatalysts in recent years because their lower band gap (2.2 eV), and nonmental doping could improve reactivity of photocatalysts [9, 10]. It is reported that PE films with boron-doped goethite has higher photo-induced degradation than pure PE films under the UV irradiation [11]. In this paper, B-doped goethite and hematite were prepared as photocatalysts, and enhancement of photocatalytic activity of atrazine degradation was observed under visible light irradiation.

2. Experimental

2.1. Materials. $Fe(NO_3)_3$, $(CH_3O)_3B$, KOH, methanol were supplied from Guoyao Chemical Co. (Shanghai, China) and atrazine was supplied from the Laboratories of Dr. Ehrenstorfer (Germany). All chemicals were used without further purification, and deionized water was used in all the experiments.

2.2. Preparation of Photocatalysts and Characterization. The original goethite (G-S-B0%) was prepared according to the

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Quantitative trait loci for seed yield and yield-related traits, and their responses to reduced phosphorus supply in *Brassica napus*

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• *Background and Aims* One of the key targets of breeding programmes in rapeseed (*Brassica napus*) is to develop high-yield varieties. However, the lack of available phosphorus (P) in soils seriously limits rapeseed production. The aim of this study was to dissect the genetic control of seed yield and yield-related traits in *B. napus* grown with contrasting P supplies.

• *Methods* Two-year field trials were conducted at one site with normal and low P treatments using a population of 124 recombinant inbred lines derived from a cross between 'B104-2' and 'Eyou Changjia'. Seed yield, seed weight, seed number, pod number, plant height, branch number and P efficiency coefficient (PEC) were investigated. Quantitative trait locus (QTL) analysis was performed by composite interval mapping.

• *Key Results* The phenotypic values of most of the tested traits were reduced under the low P conditions. In total, 74 putative QTLs were identified, contributing 7·3–25·4 % of the phenotypic variation. Of these QTLs, 16 (21·6 %) were detected in two seasons and in the mean value of two seasons, and eight QTLs for two traits were conserved across P levels. Low-P-specific QTLs were clustered on chromosomes A1, A6 and A8. By comparative mapping between *Arabidopsis* and *B. napus*, 161 orthologues of 146 genes involved in *Arabidopsis* P homeostasis and/or yield-related trait control were associated with 45 QTLs corresponding to 23 chromosomal regions. Four gene-based markers developed from genes involved in *Arabidopsis* P homeostasis were mapped to QTL intervals.

• *Conclusions* Different genetic determinants were involved in controlling seed yield and yield-related traits in *B. napus* under normal and low P conditions. The QTLs detected under reduced P supply may provide useful information for improving the seed yield of *B. napus* in soils with low P availability in marker-assisted selection.

Key words: *Brassica napus*, phosphorus deficiency, phosphorus use efficiency, recombinant inbred line, seed yield, quantitative trait locus, comparative mapping.

INTRODUCTION

Brassica napus (genome AACC, $2n = 38$), which is commonly used as food oil for human and animal feed, is the second most important oilseed crop in the world after soybean. One of the key targets of breeding programmes in *B. napus* is to develop high-yield varieties. However, yield is the most complex trait in crops. It is directly determined by three yield-component traits (seed weight, pod number and seed number per pod) and is also indirectly influenced by other yield-related traits, such as plant height, branch number, and resistance to biotic and abiotic stresses. Each of these traits is complex and is quantitatively controlled by several genes. Hence, it is difficult to accurately evaluate and select for high-yield traits in conventional breeding programmes, owing to the influence of the interactions between the environment and the genotype in all growth and development processes (Quarrie *et al.*, 2006).

The application of molecular marker techniques for quantitative trait locus (QTL) analysis has proved to be a powerful genetic approach to dissect complex traits (Paran and Zamir, 2003). Several research groups have associated QTLs with yield and yield-related traits in *B. napus*, including plant height (Mei *et al.*, 2009), yield and yield components (Radoev *et al.*, 2008; Fan *et al.*, 2010), and yield and other complex traits (Quijada *et al.*, 2006; Udall *et al.*, 2006; Chen *et al.*, 2007; Li *et al.*, 2007; Basunanda *et al.*, 2010). Eighty-five QTLs for seed yield along with 785 QTLs for eight yield-associated traits were identified in ten natural environments and two related populations of rapeseed by Shi *et al.* (2009). More recently, Zhang *et al.* (2011) performed QTL mapping for silique traits in a double haploid population across three seasons and two locations and detected a number of QTLs with stable effects across environments. However, the genetic basis and possible candidate genes for these traits in rapeseed are not well elucidated, and QTL analysis of seed yield and yield-related traits under abiotic stress has not been well investigated so far in *B. napus*.

Phosphorus (P) is an essential macronutrient in plants (Marschner, 1995). Although the total amount of P in soils may be high, P is diluted and less available for plants in the rhizosphere because of its high absorption and low mobility in soils. A lack of available P in soils seriously limits crop production (Vance *et al.*, 2003; Raghothama and Karthikeyan, 2005). P deficiency can be alleviated by the application of inorganic P fertilizers, but the high P-absorption capacity of the soils results in a very low P recovery rate in plants. High inputs

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Genetic analysis of seed mineral accumulation affected by phosphorus deprivation in *Brassica napus*

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Abstract The mineral content of plant seeds depends on both environmental and genetic factors. The aim of this study was to detect quantitative trait loci (QTLs), and their candidate genes, for the accumulation of phosphorus (P), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn) in seeds of *Brassica napus* under normal and low P conditions using an F_{10} recombinant inbred line (RIL) population. Two-year field trials were conducted to investigate seed mineral accumulation. The results showed a significant decrease in most of the minerals in the BE RIL population, as well as in two parental lines, when grown in a low P environment compared to a normal P environment. In total, 60 putative QTLs were identified, 33 of which overlapped with each other in nine genomic regions in seven linkage groups. Twenty-one of the 60 significant QTLs co-located with eight seed weight QTLs, and only five overlapped with three seed yield QTLs. Moreover, only six QTLs for the same minerals were identified both in normal and low P levels. By comparative mapping of *Arabidopsis* and *B. napus*, 148 orthologs of 97 genes involved in the homeostasis of the seven minerals in *Arabidopsis* were associated with 47 QTLs corresponding to 24 chromosomal regions. These results offer insight into the genetic basis of mineral accumulation across different P conditions in seeds of *B. napus* and allow the potential utilization of QTLs in biofortification.

Keywords *Brassica napus* · Seed mineral accumulation · Phosphorus deprivation · Quantitative trait loci · Candidate gene

Introduction

Phosphorus (P) is one of the essential macronutrients for plants and is also likely the most limiting mineral nutrient for plants (Raghothama 1999). Multiple factors contribute to P limitation in soils. One is that a large fraction of soil P is held very tightly to the surface of soil particles or is fixed as organic P compounds and is therefore relatively unavailable for assimilation by plant roots (Kochian 2012). Hence, many soils are low in available P, including approximately half of the world's agricultural lands (Lynch 2011). Low phytoavailability of P leads to a severe obstruction of plant growth and development by affecting many physiological and biochemical

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Identification of quantitative trait loci associated with low boron stress that regulate root and shoot growth in *Brassica napus* seedlings

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Abstract *Brassica napus* (Brassicaceae) is among the most important oil crops and a promising biofuel. In the tropics and subtropics, boron (B) deficiency is a major factor limiting *Brassica* yields. The effect of B on the regulation of root and shoot growth in a doubled haploid (DH) population was evaluated in experiments that utilized hydroponic culture. Strong genetic variability for traits of interest at normal and low B concentrations was demonstrated. Quantitative trait loci (QTL) were analyzed for seven plant growth parameters: increment of primary root length (IPRL), shoot dry weight (SDW), root dry weight (RDW), ratio of RDW to SDW (R/S), shoot B accumulation (SBA), root B accumulation (RBA), and ratio of RBA to SBA [(R/S)BA] in the population. Twenty-seven QTL were detected at normal B levels: four for IPRL, seven for SDW, three for RDW, two for R/S, six for SBA, two for RBA, and three for (R/S)BA. At low B, 18 QTL were detected: four for IPRL, three for SDW, two for RDW, two for R/S, five for SBA, one for RBA, and one for (R/S)BA. Three QTL for adaptability were detected: one A_IPRL and two A_SDW. No putative QTL was detected at both low and normal B. B-related genes were mapped in silico and their locations compared with the QTL identified. The present analyses show the profound and varied effects of B on *B. napus* and studies on QTL related to B efficiency will help to locate candidate genes and elucidate possible functions of B-efficiency-related QTL.

Keywords *Brassica napus* · Boron efficiency · QTL · Shoot and root growth · Candidate genes

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Introduction

Boron (B) is an essential micronutrient for plants and its importance in plant growth and development has been well known for over eight decades (Warington 1923). Boron is essential for the crosslinking of pectic polysaccharides through the formation of boratediol bonds between two rhamnogalacturonan II (RG-II) molecules (Ishii and Matsunaga 1996; Kobayashi et al. 1996; O'Neill et al. 1996). This crosslinking is critical to maintaining the structure and function of plant cell walls (O'Neill et al. 2004). Additional studies have indicated that borate-crosslinked RG-II is essential for the development and function of male and female plant tissues (Iwai et al. 2006; O'Neill et al. 2001). However, most plant species cannot retranslocate B efficiently, and thus require a continuous supply of B throughout their life.

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Cloning and characterization of boron transporters in *Brassica napus*

Jinhua Sun · Lei Shi · Chunyu Zhang · Fangsen Xu

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Abstract Six full-length cDNA encoding boron transporters (*BOR*) were isolated from *Brassica napus* (AACC) by rapid amplification of cDNA ends (RACE). The phylogenic analysis revealed that the six *BOR*s were the orthologues of *AtBOR1,* which formed companying with the triplication and allotetra-ploidization process of *B. napus,* and were divided into three groups in *B. napus*. Each group was comprised of two members, one of which was originated from *Brassica rapa* (AA) and the other from *Brassica oleracea* (CC). Based on the phylogenetic relationships, the six genes were named as *BnBOR1;1a*, *BnBOR1;1c*, *BnBOR1;2a*, *BnBOR1;2c*, *BnBOR1;3a* and *BnBOR1;3c*, respectively. The deduced *BnBOR1* s had extensive similarity with other plant *BOR*s, with the identity of 74–96.8% in amino acid sequence. The *BnBOR1;3a* and *BnBOR1;3c* resembled *AtBOR1* in number and positions of the 11 introns, but the others only have 9 introns. After the gene duplication, there was evidence of purifying selection under a divergent selective pressure. The expression patterns of the six *BnBOR1 s* were detected by semi-quantitative RT–PCR. The *BnBOR1;3a* and *BnBOR1;3c* showed a ubiquitous expression in all of the investigated tissues, whereas the other four genes showed similar tissue-specific expression profile. Unlike the non-transcriptional regulation of *AtBOR1*, the expression of *BnBOR1;1c* and *BnBOR1;2a* were obviously induced by boron deficiency. This study suggested that the *BOR1* s had undergone a divergent expression pattern in the genome of *B. napus* after that the *B. napus* diverged from *Arabidopsis thaliana.*

Keywords Boron transporter · *Brassica napus* · Phylogenetic analysis · Gene expression profile · Purifying selection

Abbreviations

B	Boron
MIPs	Major intrinsic proteins
RACE	Rapid amplification of cDNA ends
MYA	Million years ago
CDS	Coding sequence
PCR	Polymerase chain reactions
RT–PCR	Reverse transcription polymerase chain reactions
LRT	Likelihood ratio test
TR	Two ration model
HWSB	Hot water-soluble boron

Introduction

Boron (B) is an essential microelement for higher plants [1], and the new evidences suggested that B is also essential or beneficial for several animals, including humans [2]. Most of B is localized in cell wall of plants, which plays an important function for the maintenance of cell wall integrity by its cross-linking with rhamnogalacturonan II (RG-II) in pectins [3–6]. The B requirement of plants is low but

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REGULAR ARTICLE

Molybdenum improves antioxidant and osmotic-adjustment ability against salt stress in Chinese cabbage (*Brassica campestris L. ssp. Pekinensis*)

Mu Zhang · Chengxiao Hu · Xiaohu Zhao · Qiling Tan · Xuecheng Sun · Anyong Cao · Min Cui · Ying Zhang

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Abstract
Aims A pot experiment was conducted to determine the effects of molybdenum on antioxidative defense and osmotic-adjustment systems of Chinese cabbage under salt stress.
Methods Molybdenum fertilizer was applied at three levels (0, 0.15, 0.3 mg kg^{-1}). Ten days after sowing, 500 ml 136.8 mM of NaCl solution was added to half of the plants for each treatment every 10th day for three consecutive times.
Results The results revealed that with the application of molybdenum in Chinese cabbage under salt stress the fresh weight significantly increased; activities of antioxidant enzymes such as superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) were dramatically improved; the contents of non-enzymatic antioxidants such as glutathione (GSH), carotenoid (CAR) and ascorbic acid (ASA) were significantly increased. There was also an significant increase in low molecular osmotic-adjustment products such as soluble sugar, soluble protein and proline. Moreover, molybdenum significantly increased potassium ion (K^+) content and reduced sodium ion (Na^+) contents, which eventually improved the K^+/Na^+ ratios.
Conclusions The present study suggests that the application of molybdenum enhances the salt stress tolerance in Chinese cabbage by increasing the capacity to eliminate active oxygen and the ability of osmotic-adjustment.

Keywords Molybdenum · Antioxidant · Osmotic-adjustment · Salt stress · Chinese cabbage (Brassica campestris L. ssp. Pekinensis)

Abbreviations

Mo	Molybdenum
SOD	Superoxide dismutase
POD	Peroxidase
CAT	Catalase
ASA	Ascorbate
GSH	Reduced glutathione
CAR	Carotene

Introduction

Molybdenum (Mo) is a component of nitrate reductase and nitrogenase which are involved in nitrogen metabolism of plants (Mulder 1948), and Mo is also involved in phosphorus and sulphur metabolism (Mendel and Hansch 2002; Liu et al. 2010). In addition, Mo also plays an important role in resisting

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REGULAR ARTICLE

Brassica napus root mutants insensitive to exogenous cytokinin show phosphorus efficiency

Taoxiong Shi · Dongyue Zhao · Dongxia Li · Nian Wang · Jinling Meng · Fangsen Xu · Lei Shi

Received: 3 November 2011 / Accepted: 11 March 2012 / Published online: 27 March 2012

Abstract
Background and aims Cytokinins are known to negatively regulate plant root development and phosphorus (P) starvation responses. In this study, two *Brassica napus* root mutants insensitive to exogenous cytokinin, *prl1* (a mutant with an elongated primary root) and *lrn1* (a mutant with more lateral roots), were identified and used to evaluate P efficiency, alongside wild type (WT) plants.
Methods Solution and pot culture, RNA isolation, RT-PCR were used.
Results *lrn1* produced the highest shoot dry weight (SDW) and root dry weight (RDW) among the three genotypes at both low P (LP) and high P (HP) conditions. *prl1* had higher SDW at both P conditions, and higher RDW at LP, in contrast to WT plants. *lrn1* not only accumulated more P from the culture medium but utilized it effectively in shoot growth, whilst *prl1* just showed higher P use efficiency compared to WT at LP. Trans-zeatin riboside (tZR) and isopentenyl adenosine (iPA) concentration in *lrn1* roots were both significantly lower than that in WT roots at both P conditions. Root iPA concentration in *prl1* was lower than that in WT under both P conditions, however, root tZR concentration was greater in *prl1* than WT under LP condition. Transcription of the P starvation induced genes *BnSPX3;1* and *BnSPX3;2* were up-regulated in the roots of mutants under both P conditions.
Conclusions These results suggested that an improved root system might be associated with the reduced cytokinin concentration and lead to a significant increase in acquisition and utilization of P nutrient for *lrn1*.

Keywords *Brassica napus* · Cytokinin · *prl1* · *lrn1* · Phosphorus efficiency

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Introduction

Phosphorus (P) is one of the least available macronutrients in the soil, due to very low availability and/or accessibility (Holford 1997). To overcome P deficiency, plants have evolved a number of developmental and metabolic responses to increase phosphate (Pi) availability in soils, such as regulation of root development (Lopez-Bucio et al. 2002; Williamson et al.

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REGULAR ARTICLE

Boron distribution and mobility in navel orange grafted on citrange and trifoliate orange

Gui-Dong Liu · Rui-Dong Wang · Li-Shu Wu · Shu-Ang Peng · Yun-Hua Wang · Cun-Cang Jiang

Received: 20 October 2011 / Accepted: 19 March 2012

Abstract
Background and Aims In China, boron (B) deficiency is frequently observed in citrus orchards, and is responsible for considerable loss of productivity and quality. A better understanding of B distribution and remobilization within orange plants is important for developing programs in rational fertilization and effective mitigation of B-deficiency. In the present study (i) the distribution of newly absorbed B and (ii) the translocation of foliar-applied B in 'Newhall' navel orange grafted on citrange and trifoliate orange was investigated.
Methods ^{10}B was applied in the nutrient solution or sprayed on the lower-old leaves of both grafted plants for 35 days.
Results In the ^{10}B uptake experiment, citrange-grafted plants showed higher newly acquired total B content and B concentration in both lower-old and upper-old leaves than those in trifoliate-orange-grafted plants. The newly absorbed B in the new leaves was much higher than that in the lower-old leaves and the upper-old leaves in both grafted plants. Foliar application of ^{10}B to the lower-old leaves resulted in B translocation to the upper-old leaves and the new leaves with preference mainly to the new leaves in both citrange and trifoliate orange when root B supply was relatively low. However, ^{10}B sprayed to the lower-old leaves not only did not increase the abundance percentage of ^{10}B in the root, but also reduced B concentration and the total B content in the root.
Conclusions The results suggest that foliar-applied B can be translocated within both grafted plants, which might also depress B uptake from root medium with low B supply. Rootstock can affect the B distribution in old leaves in navel orange, and newly absorbed B was preferentially transported to the new leaves.

Keywords Boron distribution · Translocation · ^{10}B isotope · Citrange · Trifoliate orange

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Introduction

Boron (B) is an essential micronutrient element for growth and development of higher plants (Loomis and Durst 1992). It plays important roles in stability of cell walls (Matoh 1997) and cellular activities (Cakmak and Römheld 1997). B deficiency in plants may restrain root elongation by limiting cell enlargement and cell division in the growing zone of root tips, and possibly impede

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REGULAR ARTICLE

Dual effects of transgenic *Brassica napus* overexpressing CS gene on tolerances to aluminum toxicity and phosphorus deficiency

Yi Wang · Heng Xu · Jiaojiao Kou · Lei Shi · Chunyu Zhang · Fangsen Xu

Received: 3 November 2011 / Accepted: 3 May 2012 / Published online: 16 May 2012

Abstract
Background and aims Low phosphorus (P) bioavailability and aluminum (Al) toxicity are two major constraints to plant growth in acid soil. To improve the tolerance of *Brassica napus* to Al toxicity and P deficiency, we generated transgenic canola (*Brassica napus* cv Westar) lines overexpressing a *Pseudomonas aeruginosa* citrate synthase (CS) gene and then investigated the effects of CS gene overexpressing in canola on enhancing tolerance to the two constraints.
Methods The vector construction and plant transformation, molecular identification, estimation of extracellular and cellular citrate and malate concentrations, enzyme activity and gene expression analyse and Al tolerance and P acquisition assays were conducted using both hydroponics and soil culturing in the study.
Results Both the root citrate and malate concentrations and their exudations in the two transgenic lines significantly increased compared with wild type (WT) following exposure to Al. These increases may be attributed to higher activities of the CS, malate dehydrogenase (MDH) and phosphoenolpyruvate carboxylase (PEPC) enzymes in the TCA cycle and the expression of *BnALMT* and *BnMATE* in the transgenic plants following Al exposure. The primary root elongation and prolonged Al treatment (10 days) experiments revealed that the transgenic lines displayed enhanced levels of Al tolerance. In addition, they showed enhanced citrate and malate exudation when grown in P-deficient conditions. Moreover, the enzyme activities of the transgenic lines were significantly higher compared with WT in response to P-deficient stress. The soil culture experiment showed that the transgenic lines possessed improved P uptake from the soil and accumulated more P in their shoots and seeds when $FePO_4$ was used as the sole P source.
Conclusions These results indicate that the overexpression of the CS gene in *B. napus* not only leads to increased citrate synthesis and exudation but also changes malate metabolism, which confers improved tolerances to Al toxicity and P deficiency in the transgenic plants. These findings provide further insight into the dual effects of CS gene overexpression on Al toxicity and P deficiency in plants.

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Keywords Citrate synthase · *Brassica napus* · Citrate overproduction · Malate · Al tolerance · P deficiency

Abbreviations

35S	Cauliflower mosaic virus 35S promoter
CS	Citrate synthase

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REGULAR ARTICLE

Cellular boron allocation and pectin composition in two citrus rootstock seedlings differing in boron-deficiency response

Gui-Dong Liu · Rui-Dong Wang · Lei-Chao Liu · Li-Shu Wu · Cun-Cang Jiang

Received: 3 January 2013 / Accepted: 21 February 2013 / Published online: 2 March 2013

Abstract
Aims Variation in boron (B) efficiency in citrus in different rootstock genotypes is expressed as large differences in the occurrence of leaf symptoms and dry mass production under low B conditions, but the mechanisms responsible for such differences are unknown. This paper aims to determine whether differences in B uptake, cellular B allocation, and pectin content can explain genotype differences in B efficiency between B-efficient citrange (*Citrus sinensis* (L.) Osb. × *Poncirus trifoliata* (L.) Raf.) and B-inefficient trifoliate orange (*Poncirus trifoliata* (L.) Raf.) citrus rootstock.
Methods Plants were grown hydroponically in a nutrient solution supplemented with 5 μ*M* B for 14 days and then transferred to a B-free medium (0 μ*M* B) or control medium (5 μ*M* B) for 35 days. Boron uptake and allocation and cell wall pectin contents were examined.
Results After 35 days under B deprivation, shoot dry mass in trifoliate orange decreased by 28 %, but shoot dry mass of citrange was not significantly affected. Root growth of both types of rootstock seedlings was inhibited, but the trifoliate orange was affected more than the citrange. In comparison with B concentrations in plants prior to the commencement of B treatments, B deprivation for 35 days decreased B concentration in various parts of citrange plants, and the reduction was much greater in trifoliate orange plants. Trifoliate orange seedlings contained higher B concentration and total B in cell wall on a dry leaf basis than citrange subject to 5 μ*M* B treatment. However, the proportion of leaf B allocated in cell wall was higher in citrange than trifoliate orange when B supply was deficient in the nutrient. The changes in pectin composition in cell wall due to B deprivation differed between citrange and trifoliate orange. The decreased uronic acid (UA) content in the Na_2CO_3-soluble pectin was observed in both rootstock, but the increased UA content in CDTA-soluble pectin was observed only in citrange.
Conclusions These results demonstrated that a combination of greater B uptake ability, greater B accumulation in cell walls, as well as the increased CDTA-soluble pectin, under limited external B supply, contribute to the integrity of cell walls in citrange and therefore increased tolerance to B deficiency.

Keywords B deficiency · Efficiency · Cell wall · Citrus rootstock

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Introduction

Boron (B) is an essential micronutrient element for growth and development of higher plants (Loomis and

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REGULAR ARTICLE

Characteristics of root boron nutrition confer high boron efficiency in *Brassica napus* cultivars

Lu Yang · Quan Zhang · Jina Dou · Ling Li · Longfei Guo · Lei Shi · Fangsen Xu

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Abstract
Background and aims *Brassica napus* has high boron (B) demand, but significant genotype differences exist with respect to B deficiency. The aim of this research was to elucidate the relationship between the different sensitivities of *Brassica napus* cultivars to low B stress and the characteristics of B uptake and transport to characterise the regulation of B efficiency in *Brassica napus*.
Methods B-efficient and B-inefficient *Brassica napus* cultivars were used to compare the uptake and transport of B using the stable isotope ^{10}B tracer and grafting experiments, as well as expression of B transporters by RT-PCR.
Results B-efficient cultivars have significant advantages with regard to B limitation. The B-efficient cultivar HZ showed less severe B deficiency symptoms and higher dry biomass than the B-inefficient cultivars LW and LB. Both the amount of total B and the ^{10}B concentration and accumulation in the shoots and roots of B-efficient HZ were higher than those of B-inefficient cultivars. In B-inefficient LW, the amount of total B and the ^{10}B that was transported into shoots was less than in the other three cultivars and the content and accumulation of total B and ^{10}B in the roots of B-inefficient LB were the lowest among all of the cultivars. When the roots of B-efficient HZ were used as stocks, the grafted plants showed B-efficient characteristics, such as mild B deficiency symptoms, and higher dry biomass and B accumulation, regardless of whether they originated from B-efficient or B-inefficient cultivars. In contrast, the grafted plants with B-inefficient LW used as stocks were B-inefficient. The expressions of *BnBOR1;1c*, *BnBOR1;2a* and *BnNIP5;1* were up-regulated in roots under low B stress compared with the normal B condition. However, there was no obvious difference in the expressions of the three genes or of four other *BnBOR1s* between B-efficient and B-inefficient cultivars in low or normal B environments.
Conclusions These results indicate that the B efficiency of *Brassica napus* is controlled primarily by roots, which allow more uptake and accumulation of B in B-efficient cultivars than B-inefficient cultivars in a low B environment. However the molecular mechanism regulating B efficiency in *Brassica napus* remains to be determined.

Keywords *Brassica napus* · Uptake · Transport · Boron efficiency · Graft · Gene expression

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Introduction

Boron (B), an essential element for plant growth and development (Warington 1923), plays a crucial role in various biochemical and physiological processes, such

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ORIGINAL PAPER

Protective role of mucilage against Al toxicity to root apex of pea (*Pisum sativum*)

Mingjian Geng · Miaomiao Xu · Hongdong Xiao · Huizhen Wang · Lilan He · Zhuqing Zhao · Min Yu

Received: 11 May 2011 / Revised: 28 November 2011 / Accepted: 7 December 2011 / Published online: 31 December 2011

Abstract Mucilage can strongly bind Al in the rhizosphere. Although there are still debates about the role of mucilage in protection of the root apex from Al toxicity, we considered that it might be associated with the characteristics of Al adsorption in mucilage. When the mucilage was kept intact, the accumulation of Al and induction of callose in root tips of pea (*Pisum sativum*) remained lower; thus root elongation was less inhibited than when mucilage was removed under Al exposure in mist culture. Size exclusion chromatography showed both a high and a low molecular weight polysaccharide fraction from root mucilage. Aluminum was predominately detected in high molecular weight polysaccharides, which strongly bound cations. The results indicate that the persistence of mucilage does protect the root apex from Al toxicity by immobilizing Al in high molecular weight polysaccharides.

Keywords Pea (*Pisum sativum*) · Al immobilization · High molecular weight polysaccharides

M. Geng and M. Xu contribute equally to the article.

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Introduction

Aluminum toxicity is a worldwide problem in acid soils (Kochian 1995; Moffat 1999). An early symptom of Al toxicity is the limitation of cell expansion as well as the inhibition of root elongation (Matsumoto 2000; Ma et al. 2001; Kochian et al. 2004; Horst et al. 2010). Generally, the root apex is surrounded by a number of root border cells and series of exudates mainly classified as low and high molecular weight compounds that function as the protective biological, physical and chemical interface between root tips and rhizosphere (Hawes et al. 1998; Walker et al. 2003; Wen et al. 2007). In legumes, the production of thousands of root border cells effectively protects the root apex from Al toxicity (Hawes et al. 2000; Brigham et al. 2001; Miyasaka and Hawes 2001; Li et al. 2000; Yu et al. 2009; Cai et al. 2011). Organic acids, the important low molecular-weight exudates, detoxify root Al^{3+} into non-toxic stable Al complexes (Pellet et al. 1995; Ma et al. 2001). Mucilage is the high molecular weight exudate from root tips that lubricates soil particles and affects soil aggregate stability, thus reducing soil mechanical impedance for root elongation (Baluska et al. 1996; Traoré et al. 2000; Knee et al. 2001; Nagahashi and Douds 2004; Iijima et al. 2004; Somasundaram et al. 2008), confining rhizosphere microbial population and resisting pathogens (Hawes et al. 2000; Mounier et al. 2004; Wen et al. 2007). It also immobilizes toxic metal ions in the rhizosphere (Horst et al. 1982; Ryan et al. 1993; Archambault et al. 1996; Li et al. 2000; Kinraide et al. 2005; Watanabe et al. 2008). Thus, it has been hypothesized that mucilage could protect root apices from Al toxicity by immobilizing rhizosphere Al^{3+}. However, there are still debates about the role of mucilage in Al toxicity (Horst et al. 1982; Ryan et al. 1993; Archambault et al. 1996;

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PAPER

Posner's cluster revisited: direct imaging of nucleation and growth of nanoscale calcium phosphate clusters at the calcite-water interface

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Although many *in vitro* studies have looked at calcium phosphate (Ca–P) mineralization, they have not emphasized the earliest events and the pathway of crystallization from solvated ions to the final apatitic mineral phase. Only recently has it become possible to unravel experimentally the processes of Ca–P formation through a cluster-growth model. Here we use mineral replacement reactions by the interaction of phosphate-bearing solutions with calcite surfaces in a fluid cell of an atomic force microscope (AFM) and reveal that the mineral surface-induced formation of an apatitic phase proceeds through the nucleation and aggregation of nanosized clusters with dimensions similar to those of Posner's clusters, which subsequently form stable amorphous calcium phosphate (ACP) plates prior to the transformation to the final crystalline phase. Our direct AFM observations provide evidence for the existence of stable Posner's clusters even though no organic template is applied.

Introduction

During the synthesis of hydroxyapatite (HAP) crystals through the interaction of calcium and phosphate ions in neutral to basic solutions, a precursor amorphous calcium phosphate phase (ACP) is formed that is structurally and chemically distinct from HAP.[1,2] For the formation pathway of Ca–P phases in solutions or on surfaces, a cluster-growth model has been proposed and debated for decades.[3] The constancy in their chemical composition over a relatively wide range of chemical preparation conditions and chemical analysis of the precursor phase indicated that this noncrystalline phase is a hydrated calcium phosphate ($Ca_3(PO_4)_2{\cdot}xH_2O$) with a Ca/P ratio of 1.50, consisting of roughly spherical $Ca_9(PO_4)_6$ so-called "Posner's clusters" (PC) close-packed to form larger spherical particles with water in the interstices.[3] Simulations of the peak distribution have been made regarding the particle size of Ca–P clusters and their prevalence confirmed that particles ranging in size from 0.8 to 1.0 nm are likely to exist as clusters in simulated body fluid.[4] Ca–P clusters, from which HAP crystals can be constituted, must form in solutions as HAP grows.[4] However, such nanometer-sized clusters as building blocks for ACP and subsequent transformation to HAP are difficult to visualize directly. Very recently, Dey *et al.* used a Langmuir monolayer of arachidic acid to mimic biological Ca–P mineralization, and they observed clusters with an average diameter of 0.87 ± 0.2 nm during the earliest stages of nucleation using high-resolution cryogenic transmission electron microscopy (HR-cryoTEM).[5] Despite the significance of this study, the formation pathway of Ca–P phases in the absence of organic templates has never been directly observed, and thus the role of nanosized clusters formed on mineral surfaces and their connection to larger aggregates remain largely unknown.

Recently, it has been shown that solvent-mediated mineral replacement reactions involve an interface-coupled mechanism of the dissolution of a solid in an aqueous fluid and the subsequent precipitation of a new, thermodynamically more stable solid phase that replaces the parent solid.[6,7] Using this novel strategy of re-equilibration of solids in the presence of a fluid phase, various Ca–P materials have been formed by the replacement of different calcium carbonate polymorphs.[8,9] In this work, we follow the earliest stages of the formation of Ca–P phases resulting from the interaction of phosphate-bearing solutions with a calcite surface in a fluid cell of an atomic force microscope (AFM), without the support of an organic template, by adjusting the concentration of $(NH_4)_2HPO_4$ solutions to control the nucleation rates. We observe that the formation of Ca–P phases assisted by calcite surfaces is initiated by the aggregation of clusters that leads to the formation of ACP, which finally transforms into crystalline HAP.

Experimental

In situ dissolution experiments were performed using a Digital Instruments Nanoscope IIIa AFM working in contact mode. The scanning frequency was *ca.* 3 Hz with an average scan time 1.5 min per scan. Iceland Spar fragments (*ca.* 3 × 3 × 1 mm in size) were freshly cleaved before each dissolution experiment, and {$10\bar{1}4$} calcite surfaces were exposed to the solutions in an O-ring-sealed

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PAPER

Phosphorylated osteopontin peptides inhibit crystallization by resisting the aggregation of calcium phosphate nanoparticles

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Under near-physiological pH and ionic strength, the role of a 14 amino acid segment of osteopontin (OPN) in inhibiting hydroxyapatite (HAP) nucleation and growth was kinetically examined by measuring the induction time *via* pH monitoring. The phosphorylated 14-mer OPN peptide segments (PP) significantly inhibit nucleation of HAP by markedly increasing induction times with an increase in the number of phosphorylation sites at their lower concentrations (<156 nM). The presence of phosphate groups in OPN peptides not only enhances the stability of the calcium phosphate (Ca–P) nanoparticles and limits their aggregation, but also inhibits the phase transformation from amorphous calcium phosphate (ACP) to the final crystalline phases. The extent of phosphorylation of OPN peptides is important to its protective roles in inhibiting crystallization by resisting the aggregation of Ca–P nanoparticles at a given concentration range. The nonphosphorylated peptide segment (NPP) had relatively little effect on induction times at concentrations lower than 156 nM, whereas at a higher concentration (234 nM), the effect of NPP in inhibiting HAP nucleation was enhanced. These results clearly showed that OPN inhibits HAP crystallization by prolonging induction times and delaying subsequent growth in a phosphorylation and/or concentration-dependent manner.

Introduction

In addition to calcium oxalate (CaO_x), which is the dominant constituent of calcium stones, small quantities of calcium phosphate (Ca–P) are surprisingly common, at least in renal and ureteral stones.[1] More than 50% of CaO_x stones contain variable amounts of phosphate, usually brushite ($CaHPO_4{\cdot}2H_2O$, DCPD) and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, HAP), in a "nuclear" location.[2] Studies on renal stone development in a mixed oxalate–phosphate system have shown that brushite dissolution provides calcium ions that raise the calcium oxalate mononydrate ($CaC_2O_4{\cdot}H_2O$, COM) supersaturation, which is heterogeneously nucleated either on or near the surface of the dissolving Ca–P crystals.[3] Recent findings showed that elevated Ca and P have direct and synergistic effects on vascular smooth muscle cells (VSMCs), which promote vascular Ca–P mineralization in chronic kidney disease.[4] Osteopontin (OPN) proteins present in urine and in a prototype of the aspartic acid (D)-rich proteins (AARP)[5] have been shown to be phosphorylated *in vivo* by a combination of sequence analysis of *S*-ethylcysteine-derivitized peptides and mass spectroscopy.[6] OPN molecules have also been identified as an inhibitory molecule against kidney stones *in vivo*.[7]

In vitro experimental results have previously shown that OPN inhibits the formation of COM in a phosphorylation-dependent manner, and that OPN activity requires phosphate and carboxylate groups, possibly including the conserved sequence of aspartic acid residues.[8] Our recent studies have shown that a 14 amino acid segment, with highly conserved aspartic acid residues (DDVDDTDDSHQSDE) from 93 to 106 of the full-length OPN sequence with two phosphorylation serine sites, significantly inhibits both the nucleation and growth of COM.[9] However, the phosphorylation-deficient form of this segment fails to inhibit COM crystal nucleation and growth.[9] In addition to two highly conserved serine sites, this region of OPN peptide segment also contains a threonine (T) that can be post-translationally modified.

Phosphorylation of full-length OPN molecules might also have a functional role in Ca–P nucleation and growth. Decreased inhibition of HAP crystal growth was observed following dephosphorylation of OPN.[10,11] Although OPN inhibits several aspects of Ca–P crystallization, quantitative studies of bulk Ca–P crystallization, especially at the earliest nucleation stages, remain limited. Thus, we synthesized 14-mer OPN peptide segments with different degrees of phosphorylation (up to three phosphorylation sites) and examined the roles of phosphorylation in modulating *in vitro* Ca–P crystallization at the earliest nucleation stages under near-physiological pH (7.40) and ionic strength (0.15 M). In addition, a newly developed method for monitoring Ca–P crystallization kinetics provides reproducible induction times, and the results show that the highly phosphorylated14-mer OPN peptide segments could kinetically stabilize

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Kinetics of Calcium Phosphate Nucleation and Growth on Calcite: Implications for Predicting the Fate of Dissolved Phosphate Species in Alkaline Soils

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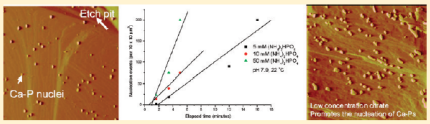
Supporting Information

ABSTRACT: Unraveling the kinetics of calcium orthophosphate (Ca−P) precipitation and dissolution is important for our understanding of the transformation and mobility of dissolved phosphate species in soils. Here we use an in situ atomic force microscopy (AFM) coupled with a fluid reaction cell to study the interaction of phosphate-bearing solutions with calcite surfaces. We observe that the mineral surface-induced formation of Ca−P phases is initiated with the aggregation of clusters leading to the nucleation and subsequent growth of Ca−P phases on calcite, at various pH values and ionic strengths relevant to soil solution conditions. A significant decrease in the dissolved phosphate concentration occurs due to the promoted nucleation of Ca−P phases on calcite surfaces at elevated phosphate concentrations and more significantly at high salt concentrations. Also, kinetic data analyses show that low concentrations of citrate caused an increase in the nucleation rate of Ca−P phases. However, at higher concentrations of citrate, nucleation acceleration was reversed with much longer induction times to form Ca−P nuclei. These results demonstrate that the nucleation-modifying properties of small organic molecules may be scaled up to analyze Ca−P dissolution−precipitation processes that are mediated by a more complex soil environment. This in situ observation, albeit preliminary, may contribute to an improved understanding of the fate of dissolved phosphate species in diverse soil systems.



INTRODUCTION

Phosphorus (P) is an essential nutrient required for plant growth and it is also defined as 'the disappearing nutrient' due, in part, to the potential shortage of phosphate rock resources and a faster growth in demand for phosphate-based fertilizers.[1] Calcium orthophosphate (Ca−P) is the most ubiquitous form of P among the geological phosphate-bearing minerals.[2] Various components, structures, crystal phases, and hydration states of phosphates are present in soils as a result of P fertilizer application. Precipitation of soluble P in soil solutions and/or on mineral surfaces involves the formation of metastable intermediate precursor phases such as amorphous Ca−P (ACP) and brushite (DCPD) followed by the transformation to the least soluble, hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, HAP), as the thermodynamically stable phase of the final product in neutral to alkaline environments.[3] P present as HAP, as well as other solid phases including octacalcium phosphate (OCP) and tricalcium phosphate (TCP), is much less bioavailable to plant uptake than dissolved P species.[4] The recognition that total soil P concentration is a poor predictor of the P bioavailability has led to extensive research on chemical speciation of P in soils with the emphasis on predicting its bioavailability.[5]

It is well established that citrate is the dominant carboxylate-bearing organic molecule released by plant roots to enhance the soluble P concentration under P deficient conditions.[6,7] Moreover, alkaline soils, subjected to long-term organic additives, have been shown to accumulate substantial quantities of P in plant-available forms,[8,9] and the sorption capacities of soils for P are reduced by organic additives.[10] Despite much evidence, understanding the chemical nature of organic molecules, especially low molecular weight organic acids and their influences on P mobility in soil solutions, remains limited.

Calcite is a common mineral and constituent of sediments and phosphate can both adsorb on and desorb from calcite surfaces.[11] Thus, calcite can serve as both a source and sink of phosphate in alkaline soils, thereby influencing the fate of phosphate. The interactions between soluble orthophosphates and calcite have been extensively studied, both as a novel method of apatite synthesis[12] and also because of the frequent occurrence of soil systems rich in calcite and the dominant effect of calcite on phosphate solubility.[13] It is evident that surface adsorption/reaction and subsequent precipitation are major mechanisms of P immobilization (precipitation) in

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Effects of high concentrations of soil arsenic on the growth of winter wheat (*Triticum aestivum* L) and rape (*Brassica napus*)

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ABSTRACT

Soil arsenic (As) levels are particularly high in parts of China, where wheat and rape are widely grown. Understanding the effects of As concentration on the growth of these two major crops is of significance for food production and security in China. A pot experiment was carried out to study the uptake of As and phosphorus (P), and the soil As bioavailability at different growth stages of wheat and rape. The results indicated that winter wheat was much more sensitive to As stress than rape. Wheat yields were elevated at low rates of As addition (< 60 mg/kg) but reduced at high rates of As concentrations (80–100 mg/kg); while the growth of rape hadn't showed significant responses to As addition. Phosphorus concentrations in wheat at jointing and ear sprouting stages increased with increasing soil As concentrations, and these increases were assumed to contribute a lot to enhanced growth of wheat at low As treatments. Arsenic did not significantly affect P concentrations in rape either. The highest As concentrations in wheat shoot and rape leaf were 8.31 and 3.63 mg/kg, respectively. Arsenic concentrations in wheat and rape grains did not exceed the maximum permissible limit for food stuffs of 1.0 mg/kg. When soil As concentration was less than 60 mg/kg, both wheat and rape could grow satisfactorily without adverse effects; when soil As concentration was 80–100 mg/kg, rape was more suitable to be planted than wheat.

Keywords: arsenic; stimulation; phytotoxicity; phosphorus

Arsenic is a toxic element widely encountered in the environment and in organisms. Arsenic can enter terrestrial and aquatic environments through both natural formation and anthropogenic activities (Tu and Ma 2003).

Persistence of arsenic within soil and its toxicity to plants and animals is of concern. Long-term exposure to low concentrations of As can lead to skin, bladder, lung, and prostate cancer. Non-cancer effects of ingesting As at low levels include cardiovascular disease, diabetes, and anemia (Zhang et al. 2002). There are a number of ways by which people can become exposed to As. The most important one is probably through ingestion of As in drinking water or food (Le et al. 2000). In some areas of Hubei, Shanxi, Yunnan, and Hunan provinces of China, soil As concentrations were much higher compared with other provinces because of coal fuels and metal smelters. For example, fourty hectares of agricultural soil was polluted in Hunan province due to irrigation of As-contaminated water by local farmers (Liao et al. 2004). In 1995, Chinese government constituted the environmental quality standard for soils (GB15618-1995). When soil arsenic concentrations exceed the limitation of 40 mg/kg, the soil is prohibited to plant crops. In 2005, Chinese government constituted the maximum of contaminants in foods (GB2762-2005), and the limitations of inorganic arsenic in some crop products were less than 0.2 mg/kg.

However, in some regions, although soil heavy metals concentrations exceed the limitations, people plant the certain crops, because the produces As concentrations do not exceed the limitations.

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QTL for Yield Traits and Their Association with Functional Genes in Response to Phosphorus Deficiency in *Brassica napus*

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Abstract

Background: Oilseed rape (*Brassica napus* L.) is one of the most important oil crops. A primary limitation to the cultivation of this crop is the lack of available phosphorus (P) in soils. To elucidate the genetic control of P deficiency tolerance in *Brassica napus*, quantitative trait locus (QTL) for seed yield and yield related-traits in response to P deficiency were identified using a double haploid mapping population (TN DH) derived from a cross between a P-efficient cultivar, Ningyou 7 and a P-inefficient cultivar, Tapidor.

Results: Three field trials were conducted to determine seed yield (SY), plant height (PH), number of primary branches (BN), height to the first primary branch (FBH), relative first primary branch height (RBH), pod number per plant (PN), seed number per pod (SN) and seed weight of 1,000 seeds (SW) in 188 lines of TN DH population exposed to low P (LP) and optimal P (OP) conditions. P deficiency decreased PH, BN, SN, PN and SY, and increased FBH and RBH with no effect on SW. Three reproducible LP-specific QTL regions were identified on chromosomes A2, A3 and A5 that controlled SN, PN and SW respectively. In addition, six reproducible constitutive regions were also mapped with two each for SY-LP on A2, and FBH-LP on C6 and one each for PH-LP and SW-LP on A3. About 30 markers derived from 19 orthologous genes involved in *Arabidopsis* P homeostasis were mapped on 24 QTL regions by comparative mapping between *Arabidopsis* and *Brassica napus*. Among these genes, *GPT1*, *MGD2* and *SIZ1* were associated with two major loci regulating SY-LP and other yield-related traits on A2 between 77.1 and 95.0 cM.

Conclusion: The stable QTLs detected under LP conditions and their candidate genes may provide useful information for marker-assisted selection in breeding high-yield *B. napus* varieties with improved P efficiency.

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Introduction

Phosphorus (P) is one of the essential macronutrients for plants and is a major limitation for plant development worldwide due to its low availability and inaccessibility in soil [1–3]. To mitigate this, P fertilizers are applied to improve P availability in soils. However, cost and low recovery rates of P fertilizers not only increase the cost of crop production but also lead to serious environmental pollution and exhaust non-renewable phosphate resources. Therefore, a sustainable strategy for crop production would be to breed crops with high efficiency in acquiring P from native soil reserves or fertilizer sources.

Nutrient-efficient plants produce higher yields per unit of nutrient applied or absorbed compared with other plants grown under similar agroecological conditions [4]. One way to determine the genetic basis of tolerance to nutrient deficiency is to map quantitative trait loci (QTL) based on molecular markers. A number of QTLs associated with P efficiency traits have been detected in rice [5–7], maize [8], wheat [9,10], common bean [11,12] and soybean [13,14]. Using a soybean F_9 recombinant inbred lines (RILs), 13 QTLs associated with root traits and 18 associated with P-efficiency were identified under low P and high P conditions, and three QTL clusters were found to be associated with traits for root and P-efficiency at low P levels [14]. In wheat, each QTL detected for P use efficiency (PUE) was found to be linked to QTLs regulating agronomic traits [10]. *Pup1* is a major locus that confers P deficiency tolerance in rice [5,7,15,16]. Overexpression of a *Pup1*-specific protein kinase gene (*PSTOL1*) in phosphorus-starvation-intolerant varieties significantly enhanced grain yield in phosphorus-deficient soil [17]. These results provide strong evidence for the hypothesis that enhancing P efficiency would improve agronomic performance of crops.

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Overexpression of *phyA* and *appA* Genes Improves Soil Organic Phosphorus Utilisation and Seed Phytase Activity in *Brassica napus*

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Abstract

Phytate is the major storage form of organic phosphorus in soils and plant seeds, and phosphorus (P) in this form is unavailable to plants or monogastric animals. In the present study, the phytase genes *phyA* and *appA* were introduced into *Brassica napus* cv Westar with a signal peptide sequence and CaMV 35S promoter, respectively. Three independent transgenic lines, P3 and P11 from *phyA* and a18 from *appA*, were selected. The three transgenic lines exhibited significantly higher exuded phytase activity when compared to wild-type (WT) controls. A quartz sand culture experiment demonstrated that transgenic *Brassica napus* had significantly improved P uptake and plant biomass. A soil culture experiment revealed that seed yields of transgenic lines P11 and a18 increased by 20.9% and 59.9%, respectively, when compared to WT. When phytate was used as the sole P source, P accumulation in seeds increased by 20.6% and 46.9% with respect to WT in P11 and a18, respectively. The P3 line accumulated markedly more P in seeds than WT, while no significant difference was observed in seed yields when phytate was used as the sole P source. Phytase activities in transgenic canola seeds ranged from 1,138 to 1,605 U kg^{-1} seeds, while no phytase activity was detected in WT seeds. Moreover, phytic acid content in P11 and a18 seeds was significantly lower than in WT. These results introduce an opportunity for improvement of soil and seed phytate-P bioavailability through genetic manipulation of oilseed rape, thereby increasing plant production and P nutrition for monogastric animals.

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Introduction

Phosphorus (P) is an essential macroelement required for plant growth. Poor availability of P in soils and consequent P-deficiency are major constraints to crop production globally [1]. Phosphorus is taken up by plants as orthophosphate (P_i). However, in most cultivated soils for agriculture, organic P comprises 30–80% of the total P, and approximately 60–80% of organic P exists in the form of phytate and is not directly available to plants [2,3]. Thus, improving phytate-P bioavailability is important for plant P nutrition, and for sustainable agricultural development due to the exhausting P ore resources worldwide [4].

Phytase is a type of phosphatase enzyme that catalyses the hydrolysis of phytic acid into inorganic phosphate (P_i) and myo-inositol [5]. Phytases have been most commonly detected and characterised in fungi but have also been found to occur in animals, plants and bacteria [6]. Because phytate in plant seeds is largely indigestible by monogastric animals, much attention has been given to the improvement of phytate-P bioavailability in animal feed by overexpressing phytase genes in plant seeds [4]. The transgenic production of high phytase activity in plant seeds would reduce the costs of producing the enzyme which is currently achieved by fermentation technology [7]. Plant overexpressing either phytase gene *phyA* or *appA* significantly increased phytase activity in wheat grains [8], soybean seeds [9,10], canola seeds [11,12] and maize grains [13].

Plants have developed a variety of mechanisms to increase the availability of soil P, including changes in root morphology and architecture, symbiosis with mycorrhizal fungi, improvement of internal phosphatase activity, secretion of organic acids and phosphatases, and up-regulation of high affinity phosphate transporters [3,1]. Phosphatases are required for the mineralisation of organic P to release phosphate into the soil [14]. Phytases have been identified in roots and root exudates in plants [15,16,17]. However, it has been suggested that the enzymatics activity in root exudates is not enough for effective utilisation of organic P [4,17]. When exogenous phytase was added into the media, phytate became available for plant growth [16,18,19]. Therefore, in recent years, more attention has been focused on the potential for overexpressing phytase in plant roots by genetic manipulation for the improvement of organic P use from soil. Overexpression of *phyA* in transgenic *Arabidopsis* with the *Pht1;2* promoter increased extracellular phytase activity and phytate-P use efficiency, and the transgenic plants were able to grow in a medium containing phytate as the sole P source [20,21]. Transgenic *Trifolium subterraneum* expressing *phyA* showed a 77-fold

Research

New Phytologist

Evidence for 'silicon' within the cell walls of suspension-cultured rice cells

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Key words: cell wall, organosilicon, rice (*Oryza sativa*), Si-polysaccharide complex, silicon (Si), suspension cell.

Summary

- Despite the ubiquity and beneficial role of silicon (Si) in plant biology, structural and chemical mechanisms operating at the single-cell level have not been extensively studied.
- To obtain insights regarding the effect of Si on individual cells, we cultivated suspended rice (*Oryza sativa*) cells in the absence and presence of Si and analyzed single cells using a combination of physical techniques including atomic force microscopy (AFM).
- Si is naturally present as a constituent of the cell walls, where it is firmly bound to the cell wall matrix rather than occurring within intra- or extracellular silica deposition, as determined by using inductively coupled plasma mass spectrometry (ICP-MS) and X-ray photoelectron spectroscopy (XPS). This species of Si, linked with the cell wall matrix, improves the structural stability of cell walls during their expansion and subsequent cell division. Maintaining cell shape is thereby enhanced, which may be crucial for the function and survival of cells.
- This study provides further evidence that organosilicon is present in plant cell walls, which broadens our understanding of the chemical nature of 'anomalous Si' in plant biology.

Introduction

Silicon (Si) is beneficial to plant growth (Richmond & Sussman, 2003), and intra- or extracellular silica in plants is useful for improving mechanical strength and alleviating biotic and abiotic stress (Wang *et al.*, 2000, 2005; Yeo *et al.*, 2002; Gao *et al.*, 2004; Fauteux *et al.*, 2006; Currie & Perry, 2007; Epstein, 2009). Rice (*Oryza sativa*) plants have a feature whereby they accumulate Si at proportions of up to 10% in dry weight of shoots for maintaining high and sustainable production (Savant *et al.*, 1997), and it has been regarded as the prototype for controlled formation of silica in higher plants (Ma & Yamaji, 2006; Neethirajan *et al.*, 2009). Si uptake by rice roots involves a type of transporter (Ma *et al.*, 2006), and more than one transporter has been identified and is likely involved in the Si uptake system in plants. Following its uptake, Si is translocated to shoots as monomeric silicic acid and disilicic acid (Casey *et al.*, 2003) and deposited in specialized cells (Kaufman *et al.*, 1969, 1985) or on cell walls, forming amorphous silica-cuticle/cellulose double layers in the epidermis of leaves and on the surfaces of stems and hulls (Kaufman *et al.*, 1985; Sangster *et al.*, 2001).

Rice takes up silicic acid at a relatively high rate (Ma *et al.*, 2006), raising the possibility that organosilicate complexes may subsequently be formed in the roots and shoots. Despite several attempts to look for evidence of organosilicate complexes (Kinrade *et al.*, 2001a,b; Benner *et al.*, 2003), most investigations to determine the protective roles played by silica in leaves have been carried out at the level of the whole plant, tissue or organ, and advances in the detection of roles of Si at the single-cell level remain limited (Prabagar *et al.*, 2011). We used suspended rice single cells to perform a comprehensive investigation of the existence of Si at cell surfaces, demonstrating that a form of Si covalently bound to organic moieties in cell walls is present. This finding reveals a structural role of Si in individual rice cells, contributing to the stability of cell walls during their expansion and subsequent cell division. Cell shape is thereby maintained, which may be crucial for the function and survival of cells.

Materials and Methods

Cell culture

Suspension-cultured cell lines of rice (*Oryza sativa* L. cv Zhonghua 11) were established following the processes of Chu *et al.* (1975) and Thomas *et al.* (1989a,b): mature seeds were dehusked, sterilized with 75% ethanol for 1 min, 0.1% mercury chloride for 10 min and washed with sterilized water five times. Sterilized seeds were incubated at 28°C in the dark for 1 month in a modified N6 medium and subcultured three times in subculture medium for callus formation. The calli (50–100) were

New Phytologist

Research

Inhibition of cadmium ion uptake in rice (*Oryza sativa*) cells by a wall-bound form of silicon

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Key words: cadmium (Cd), cell wall, organosilicon, rice (*Oryza sativa*), silicon (Si), Si-wall-Cd complexation.

Summary

- The stresses acting on plants that are alleviated by silicon (Si) range from biotic to abiotic stresses, such as heavy metal toxicity. However, the mechanism of stress alleviation by Si at the single-cell level is poorly understood.
- We cultivated suspended rice (*Oryza sativa*) cells and protoplasts and investigated them using a combination of plant nutritional and physical techniques including inductively coupled plasma mass spectrometry (ICP-MS), the scanning ion-selective electrode technique (SIET) and X-ray photoelectron spectroscopy (XPS).
- We found that most Si accumulated in the cell walls in a wall-bound organosilicon compound. Total cadmium (Cd) concentrations in protoplasts from Si-accumulating (+Si) cells were significantly reduced at moderate concentrations of Cd in the culture medium compared with those from Si-limiting (−Si) cells. *In situ* measurement of cellular fluxes of the cadmium ion (Cd^{2+}) in suspension cells and root cells of rice exposed to Cd^{2+} and/or Si treatments showed that +Si cells significantly inhibited the net Cd^{2+} influx, compared with that in −Si cells. Furthermore, a net negative charge (charge density) within the +Si cell walls could be neutralized by an increase in the Cd^{2+} concentration in the measuring solution.
- A mechanism of co-deposition of Si and Cd in the cell walls via a [Si-wall matrix]Cd co-complexation may explain the inhibition of Cd ion uptake, and may offer a plausible explanation for the *in vivo* detoxification of Cd in rice.

Introduction

Among the well-known phytotoxic heavy metals in the environment, cadmium (Cd) is of considerable importance because of its high water solubility, mobility, persistence, and toxicity even in minute amounts (Wagner, 1993; Sanita di Toppi & Gabrielli, 1999). Cd in rice (*Oryza sativa*) and other grains poses a potential health problem for human safety, and increased dietary intake of Cd has been correlated with an increased consumption of rice (Egan *et al.*, 2007). The source of Cd in rice grains is soil; paddy rice is able to accumulate high concentrations of Cd, and Cd is absorbed by rice roots and transported to the grains, resulting in considerable Cd accumulation even when plants are grown on slightly to moderately Cd-polluted soils (Uraguchi *et al.*, 2009). A major transporter of Cd, *Nramp5*, is responsible for the transport of Cd from the external solution to root cells (Sasaki *et al.*, 2012). Subsequently, Cd is transported into grains by another transporter, *OsLCT1* (Uraguchi *et al.*, 2011).

Silicon (Si) is the second most abundant element in soils, but its availability to plants as silicic acid may be limiting, and hence silicate fertilizers in rice production are applied (Ma & Takahashi, 2002a). Rice is the most effective known Si-accumulating plant (Epstein, 2009), taking up > 10% of its dry weight (DW) (Ma & Takahashi, 2002b). Moreover, Cd toxicity in rice plants (Wang *et al.*, 2000; Zhang *et al.*, 2008) has been shown to be alleviated by the presence of Si in the cell walls. Liang *et al.* (2005) and Vaculik *et al.* (2009) described this phenomenon in maize (*Zea mays*) plants. Differences in Cd uptake of roots and shoots are probably related to the development of the apoplastic fraction (Vaculik *et al.*, 2012). Recently, Nwugo & Huerta (2011) used a proteomic approach to investigate the effect of Si on Cd tolerance in rice plants, suggesting a more active involvement of Si in plant physiological processes than previously proposed.

Despite evidence of the role of Si in the amelioration of heavy metal Cd toxicity in plants at the whole-plant level, our understanding of the mechanisms involved in Si-induced Cd tolerance at the single-cell level remains very limited. Recently, a study was designed to investigate aluminium (Al)–Si interactions at the cellular level using suspension cultures of Norway spruce (*Picea abies*) (Prabagar *et al.*, 2011). Notably, the presence of Si reduced the concentration of free Al in the cell wall, and formation of aluminosilicate complexes in the wall was proposed (Prabagar *et al.*,

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