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中国土壤种子库研究进展与挑战*

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摘　要　查阅了维普《中文期刊数据库》(1989—2006年)和 Web of Science (1985—2006年)中发表的土壤种子库研究文献,按《中国植被》划分的 29个植被类型对土壤种子库密度、丰富度和研究方法等数据进行归类总结,共采集到 14个植被类型的 238个样地信息. 结果显示:研究者使用的研究方法及获得的种子库密度和丰富度数据差异巨大. 所有研究中采样时间以 4和 10月最多;样方面积介于 78～10000 cm^2 之间,样方数量介于 2～480之间; 10 cm ×10 cm和 20 cm ×20 cm是最常用的采样方式;总采样面积介于 600～500000 cm^2 之间,并以 1000～10000 cm^2 为最多. 土壤种子库密度值变化范围在 8粒 · m^{-2} (沙漠) ～ 65355粒 · m^{-2} (热带雨林的次生林)之间,物种数变化范围在 1 (温带草原次生光碱斑) ～74 (热带季雨林)之间,同一植被类型下的变异也相当大. 热带的季雨林和雨林的密度值和物种数显著高于温带的针叶林;而人工林的密度和物种数量大于农地,农地又大于裸地. 草原、荒漠和草甸的物种数量相对较少. 未来的土壤种子库研究需要从广度和深度上进行扩展,并重点加强重要生态系统的土壤种子库长期定位研究以及种子库对策研究,特别是应将这些研究与植被群落的演替、更新和恢复有机地联系起来. 同时应加强对不同植被类型的种子库采样、检测方法的探索性研究.

关键词　植被类型　土壤种子库　研究方法　密度　丰富度
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Soil seed bank research in China: Present status, progress and challenges. SHEN You-xin, ZHAO Chun-yan (*Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Kunming* 650223, *China*). -*Chin. J. Appl. Ecol.*, 2009, **20** (2): 467- 473.

Abstract: By searching soil seed bank (SSB) papers from http://www.cqvip.com (1989- 2006) and Web of Science (1985- 2006), the information on SSB density, species richness, and research methods were summarized according to the 29 classified vegetation types in Vegetation of China. In total, the data of 238 sites with 14 vegetation types were collected. The results showed that the research methods adopted by different researchers and the obtained data of SSB density and species richness varied greatly. In related researches, sampling work was mostly conducted in April and October, sampling plot number ranged from 2 to 480, plot area ranged from 78 cm^2 to 10000 cm^2, with 10 cm ×10 cm and 20 cm ×20 cm as most common, and total sampling area ranged from 600 cm^2 to 500000 cm^2, with the most being 1000- 10000 cm^2. SSB density varied from 8 ind · m^{-2} (desert) to 65355 ind · m^{-2} (tropical rain forest), and species richness varied from 1 (secondary bare alkali-saline patch in temperate) to 74 (tropical seasonal rain forest) per site. SSB density and species richness were higher in tropical rain forest and seasonal rain forest than in temperate coniferous forest, and in manmade forest than in agricultural land or barren land. Grassland, desert, and meadow had smaller species richness. In future, the SSB research should be extended both in scope and in deepness, with the focus on the long term research and strategy research of some important ecosystems, and the research should be incorporated into vegetation regeneration and restoration studies. The related methodological research should be also emphasized in the future.

Key words: vegetation types; soil seed bank; research method; density; species richness

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土壤种子库由一定时期土壤表层和土壤中的活性种子总和构成,是植物种群、群落更新与恢复的物质基础.某一时刻土壤种子库的种类组成、数量和分布状况是种子传播的直接后果,也反映了生境对种子储藏的影响.欧洲、北美等区域的土壤种子库研究已经十分深入. Thompson等[1]收集了欧洲西北部1882—1994年的土壤种子库文献,建立了以物种为基础的数据库,并以此为基础对该区域的土壤种子库研究方法、种子寿命、密度变异、埋藏深度和种子库对策等进行了总结.中国已经进行了多年的土壤种子库研究,但迄今为止,仍然无人对这些研究结果进行总结.本研究通过检索维普资讯网站和Web of Science上有关的土壤种子库研究文章,对中国已经开展的不同植被类型的土壤种子库研究进行了相对全面的总结,旨在推进未来土壤种子库的研究工作.

1 数据来源及分析处理

于维普《中文期刊数据库》(http://www.cqvip.com)中查找到1989—2006年公开发表的117篇相关研究论文,其中有60篇文献[2-61]含有植被类型的土壤种子库数据;在Web of Science上检索到1985—2006年发表的有关中国土壤种子库的文章15篇,其中4篇为关于植物群落土壤种子库的文章[62-65].本研究中未收录发表于图书和其他非期刊资源的论文和一些早于1985年(Web of Science)和1989年(维普)公开发表于期刊的文章,以及未正式出版的文献数据,因此在对各种植物群落的土壤种子库分析上可能存在一定的误差.

采用Microsoft Excel对数据进行处理分析:将所有文章编码,逐篇摘录其中的样地地理信息(地点、经纬度、坡度)、植被信息、研究方法(采样时间、面积、深度、样方数量)、研究结果(丰富度、密度、与地表植被的相似程度),并进行归类处理.植被类型划分严格参照《中国植被》中的分类形式(10个植被类型组29个植被类型)[66].同一作者在不同刊物上发表的同一样地数据只记录一次,在中文和外文文章中同时出现的样地,统一采用中文数据.最后共采集到238个样地信息.

2 研究结果

2.1 采样与种子鉴定方法

研究表明,一年中每个月份都有研究者采集土壤种子库研究样品,其中4月最为集中(图1),占总样地数的30%,其次为10月,占11%.在238个样

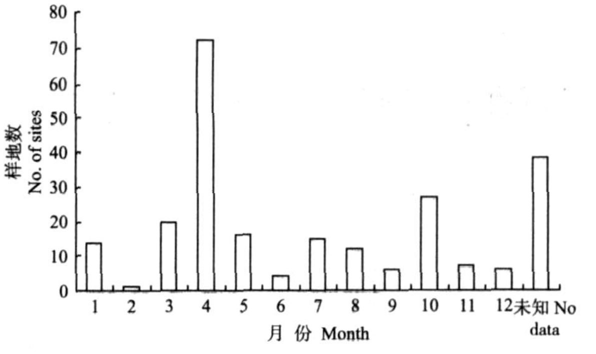

图1 238个样地土壤种子库的采样时间分布

Fig. 1 Distribution of sampling time in soil seed bank of the 238 sites

地中,单个样方面积介于78～10000 cm^{2}之间,其中以100 cm^2(10 cm ×10 cm)和400 cm^2(20 cm ×20 cm)两种取样面积使用最多,分别占总样地数的28.5%和16.0%.从样方数量来看,最少的为2个,最多的达到480个.多数研究者使用的样方数量在10～30个(表1).从总取样面积来看,最小的面积只有600 cm^2,而最大的面积为500000 cm^2,多数研究者采用的面积介于1000～10000 cm^{2}之间(表1).样方面积与样方数量之间有均衡(trade-off)关系,样方数量多时,面积相对小,而面积大时,则样方数量少(图2).采样深度介于2～30 cm之间,其中以10和5 cm最为普遍,分别占总样地数的55.7%和23.4%.

在研究方法上,所统计的论文中,80%的作者通过直接萌发方式检测幼苗数量和种类,进而推断土壤种子库的密度和丰富度;另外20%的作者通过筛选、手检等方式直接由土壤中挑选种子,然后鉴定其种类和活性种子数量.

2.2 不同植被类型的土壤种子库密度

由表2可以看出,在238个样地中,土壤种子库密度变化范围在8粒·m^{-2}(沙漠)[44]～65355粒·m^{-2}(热带雨林的次生林)[32]之间. 29个中国植被类

表1 238个研究样地的采样样方数量和总采样面积

Tab. 1 Number of samples and total collection area of the 238 sites

采样样方数量 Number of samples	总样地中所占比例 Ratio of the total sites (%)	样方总面积 Total sampling area (cm^2)	总样地中所占比例 Ratio of the total sites (%)
<10	22.5	<1000	1.7
11～20	37.1	1001～10000	55.3
21～30	15.8	10001～20000	15.0
31～50	12.9	20001～30000	9.2
>50	11.7	>30000	18.8

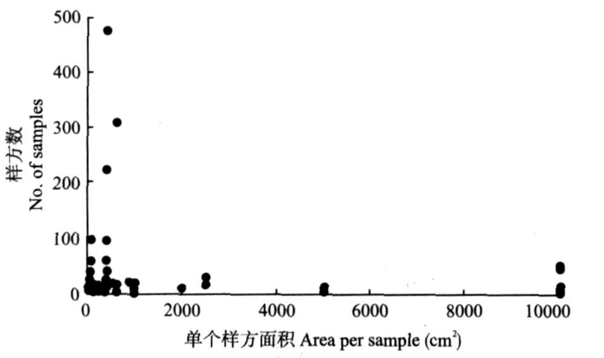

图 2 238个样地的采样面积与样方数的关系

Fig. 2 Relationship between the number of samples and area per sample of the 238 sites

表 2 不同植被类型的土壤种子库密度值

Tab. 2 Soil seed bank density of different vegetation types

植被类型 Vegetation type	样点数 No. of sites	最高值 Density max	最低值 Density min	平均密度 Density mean (ind·m^{-2})	标准差 Standard deviation
寒温性针叶林 Cold-temperate coniferous forest	3	4526	404.8	2224.3	2102.5
温性针叶林 Temperate coniferous forest	1	455	455.0	455.0	
暖性针叶林 Warm-temperate coniferous forest	7	18960	45.3	2943.3	7065.9
落叶阔叶林 Deciduous broadleaved forest	3	17677	45.0	7215.3	9265.3
常绿、落叶阔叶混交林 Evergreen- deciduous broad-leaved forest	2	9933	75.0	5004.0	6970.7
常绿阔叶林 Evergreen broadleaved forest	42	14930	40.0	1922.6	2999.3
季雨林 Seasonal rainforest	3	31945	4555.0	13695.0	15805.0
雨林 Rain forest	12	65355	240.0	12547.6	19161.6
落叶阔叶灌丛 Deciduous broadleaved scrub	2	19250	600.0	9925.0	13187.5
常绿阔叶灌丛 Evergreen broadleaved scrub	4	10960	406.6	4839.2	4418.0
灌丛草地 Shrubland	13	7270	53.2	3340.2	2695.4
草原 Grassland	78	63730	10.0	5373.9	9558.5
荒漠 Desert	21	19022	8.0	3910.6	4328.6
草甸 Meadow	5	33033	2945.6	9977.9	12911.5
裸地 Bare land	5	1390	33.0	399.2	562.5
农地 Agricultural land	8	11853	112.0	2417.4	3951.2
人工林 Tree plantation	29	31360	91.0	5232.0	8717.6
总计 Total	238	65355	8.0	4766.2	8667.4

型中已经有 14个植被类型取得了数量不等的研究结果.其中草原、常绿阔叶林为研究最多的植被类型.同一植被类型的密度最高值和最低值之间差异较大,产生的平均值标准偏差巨大.但从中也能看出一些规律性,如热带的季雨林、雨林的密度值远高于温带的针叶林;同处温带的落叶阔叶林密度值较针叶林高,而亚热带常绿阔叶林的土壤种子库密度值则很低.草原的平均密度值较荒漠高.在人类干扰较大的生态系统中,人工林的平均密度大于农地,而农地又大于裸地.

2.3 土壤种子库的物种丰富度及与地表植被的关系

从表 3可以看出,不同植被类型物种数量在 1(温带草原次生光碱斑)[7-8]～74(热带季雨林)[33]之间变化.热带季雨林、雨林的物种数量远高于亚热带阔叶林和温带针叶林;人工植被类型中,人工林的平均物种数大于农地,农地大于裸地;草原、荒漠和草甸的物种数量相对较少.由于研究者在各自的研究中使用的样方总面积差异很大,直接比较各植被类型的土壤种子库物种丰富度(样地物种数)时其精度难以保证.在所统计的论文中,只有 9位作者给出了 24份相似性系数,其值介于 0.1～0.8之间,其中相似系数 <0.5的占 20.1%, 0.5～0.7的占 62.5%, >0.7的占 16.8%.

3 中国土壤种子库研究面临的挑战

土壤及其表面存储的植物种子是植物群落再生、退化后恢复的重要物质基础,也是植物占领新栖息地的物质基础.经过几十年的努力,我国已经完成

表 3 不同植被类型的土壤种子库物种数量

Tab. 3 Number of species in soil seed bank of different vegetation types

植被类型 Vegetation type	样点数 No. of sites	最大值 Species max	最小值 Species min	平均值 Species mean	标准差 Standard deviation
寒温性针叶林 Cold-temperate coniferous forest	3	42	26	33.0	8.2
温性针叶林 Temperate coniferous forest	1	19	19	19.0	
暖性针叶林 Warm-temperate coniferous forest	4	28	5	19.5	10.1
落叶阔叶林 Deciduous broadleaved forest	3	50	14	31.3	18.0
常绿、落叶阔叶混交林 Evergreen-deciduous broad-leaved forest	2	40	28	34.0	8.5
常绿阔叶林 Evergreen broadleaved forest	26	46	6	25.3	12.4
季雨林 Seasonal rainforest	3	74	49	61.3	12.5
雨林 Rain forest	12	70	21	51.7	15.3
落叶阔叶灌丛 Deciduous broadleaved shrub	2	57	16	36.5	29.0
灌丛草地 Shrubland	9	41	12	22.0	9.5
草原 Grassland	55	46	1	14.9	10.4
荒漠 Desert	21	32	2	18.7	6.4
草甸 Meadow	1	19	19	19.0	
裸地 Bare land	5	15	1	8.5	6.2
农地 Agricultural land	5	26	11	17.4	6.3
人工林 Tree plantation	28	60	8	24.3	14.4
总计 Total	180	74	1	23.0	15.5

了全国植被类型的识别和分类,以及植被类型的地上物种组成调查. 截至 2006年,我国已经开展了 29个植被类型中的 14个类型的土壤种子库研究 (表 2、表 3). 除 3个相对极端生境的植被类型组 (冻原、高山稀疏植被、沼泽和水生植被)下的 5个植被类型外,尚有温性针阔叶混交林、硬叶常绿阔叶林、珊瑚岛常绿林、红树林、竹林、常绿针叶灌丛、常绿革叶灌丛、常绿阔叶灌丛、稀树草原、肉质刺灌丛 10个植被类型[66]尚未有研究结果. 在已有的研究结果中,很多植被类型下的样方数量十分有限 (表 2、表 3),难以满足统计学需要,对于了解该植被类型的土壤种子库特征还远远不够. Thompson等[1]收集到欧洲西部、北部 1882—1994年的 275份土壤种子库研究文献,涵盖了该区域总物种数的 46% (2568种中的 1189种),从时间段、文献数量还是物种比例上都反映了其研究的深入程度. 而我国有关土壤种子库的研究刚刚开始积累数据,对应于植被的中级分类单元 群系而言,现有的研究成果十分稀少,对中国主要植被的再生物质基础的了解还不够深入,与国外先进地区相比,还存在巨大的差距.

从研究深度上看,目前的研究还停留在对群落瞬时土壤种子库的物种组成和密度的研究. 这些结果对于解释植物群落的更新、恢复、退化起到了积极作用,但研究还相当肤浅,主要表现在: 1)缺乏季节性、长期的定点、定位研究. 群落演替 (顺向或逆向)的基础是新种源的到达 /消失. 瞬时的研究很难反映种子的这种动态消长规律. 而且一些物种的种子在土壤中的任何时刻都可能存在,而另一些物种的种子可能只存留一定的时间[67-68]. 长期的、季节性土壤种子库研究将为探明种子库的年度 /季节动态消长规律,以及物种在土壤中的存留行为提供坚实基础. 2)缺乏对物种种子库对策的研究. 植物物种具有多种土壤种子库对策[68]. 持久性土壤种子库 (persistent soil seed bank) 和短暂土壤种子库 (transient soil seed bank) 是两种最基本的土壤种子库对策. Thompson等[1]收集的土壤种子库类型 (短暂土壤种子库,持久性土壤种子库 <5年,持久性土壤种子库 >5年,其他)、物种在土壤中的寿命等信息在植被恢复、物种管理方面更具有实际意义. 目前国内涉及这种对策研究的研究论文较少[19,69],主要是由于对策研究需要做很多长期的埋藏试验[1,67],而我国这方面的研究还处于空白. 3)缺乏系统性的研究. 种子在土壤中的存留只是植物生活史的一个部分,其时空特征与地表植被[70]、群落演替史和更新动态[71]紧密联系,必须把对土壤种子库的研究与其他群落学研究 (如群落更新、对干扰和入侵的响应)有机结合起来[59].

另外,现有文献中仅有少量关于种子库研究方法的论文[72]. 群落土壤种子库内的种子具有多种生活型,不同物种的种子个体大小、密度,在土壤中的水平和垂直分布特征,以及萌发特性等差异显著. 不同研究者选用的采样时间、采样面积,种子检测方式千差万别. 但很少有研究者认真考虑这些采样面积、采样时间、种子检测方法等是否适合于所研究的植被类型. 采样面积与物种数量之间有着很高的相关关系[72],采样时间不同也会影响到检测出的物种数量和种类[68]. 细小的种子很难由土壤中直接分离,而个体太大的种子则难以同细小种子一起萌发. 这些问题可能限制了土壤种子库研究数据在群落更新研究中发挥其应有的作用[73]. 正是由于不同作者在不同时间采集不同数量和不同面积的样本,使其研究结果缺乏直接的可比性,甚至连最基本的对我国主要植被类型的密度和丰富度的比较都难以展开 (表 2、表 3).

有鉴于此,未来的中国土壤种子库研究面临着巨大的挑战,必须从研究广度和深度上同时扩展. 1)必须将研究向那些尚未涉及的植被类型扩展,例如红树林和稀树草原. 这些植被类型的分布面积相对小、或是生境条件恶劣,其种子库研究更有助于揭示种子的生物学和生态学规律,同时也为这些植被类型的科学管理提供技术支撑; 2)对一些重要生态系统,例如常绿阔叶林和草原,需要加强土壤种子库的季节性研究和长期定位研究,并加强实验研究,将土壤种子库动态与群落动态相联系; 3)将研究深入到物种水平,揭示植被类型内的各物种,尤其是一些重要物种种子在土壤内的存在类型 (持久性)和存在寿命; 4)加强方法性研究工作. 我国的植被类型丰富,应该加强适宜于不同植被类型的采样时间、面积和种子检测方法的研究,为研究植物群落的演替、更新、恢复服务; 5)重视土壤种子库基础数据库的建立,包括区域基础或是植被类型基础上的数据库,这将为植被管理和植被恢复的研究者和实践者提供基础数据.

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