生物多样性　2008, **16** (6): 613–617　　doi: 10.3724/SP.J.1003.2008.08128
Biodiversity Science　　http: //www.biodiversity-science.net

·研究简报·

安徽农药厂厂区及周边农田土壤线虫数量特征

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摘要: 为了解农药对不同植被下的土壤健康和土壤质量的影响, 在2006年10月对安徽省和县华星化工股份有限公司内外不同土地利用方式下土壤线虫数量和营养类群进行了调查, 包括厂内裸地(BIF)、厂内宝塔松林地(PIF)、厂外裸地(BOF)、厂外大豆地(SOF)、厂外水稻地(POF)、厂外玉米地(COF)。结果发现有植被覆盖的样地中土壤线虫总数显著多于裸地(P<0.01), 厂外裸地显著高于厂内裸地。在有植被覆盖的土壤中植物寄生类线虫为优势类群, 其中厂内松林地内植物寄生类线虫相对丰度最高, 达到84%。在裸地中以食细菌类线虫为优势类群, 厂外裸地和厂内裸地相对丰度分别为74%和72%。此次调查表明农药的过多使用会对土壤线虫的数量和相对丰度产生影响, 同时说明植被覆盖在减轻农药使用造成的环境污染中起着重要作用。

关键词: 农药, 土壤线虫, 生物指示, 土地利用方式

Soil nematode density inside and outside a pesticide factory in Anhui

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Abstract: Soil nematodes are useful as indicators of soil health. To understand the contribution of overuse of pesticides to soil pollution, we investigated the total number and relative abundance of soil nematodes in several different land use types with different degrees of pesticide use. These different land use types, found inside and outside the factory of Anhui Huaxing Chemical Industry Co., Ltd. in Hexian county, Anhui Province, China, include bare land inside the factory (BIF), stands of pagoda pine (*Pinus armandii*) trees inside the factory (PIF), bare land outside the factory (BOF), soybean field outside the factory (SOF), paddy field outside the factory (POF), and corn field outside the factory (COF). Soil nematode numbers varied greatly among landuse types, and when ranked in order of greatest to lowest number were PIF>SOF>COF>POF>BOF>BIF. Total count of soil nematodes was higher in lands with vegetation than in bare lands (P<0.01). The number of trophic levels except bacterivores and predators/omnivores were higher in areas with vegetation coverage. Land uses with vegetation coverage had the largest number of plant-parasites while bare land had the largest number of bacterivores. Relative abundance of plant-parasites of PIF was 84% while relative abundance of bacterivores of BOF and BIF were 74% and 72%, respectively. Taken together, these results indicate overuse of pesticides has an effect on the amount and relative abundance of soil nematodes, and an important role for vegetation coverage in mitigating environment pollution.

Key words: pesticide, nematode, bio-indicator, different land use types

农药是人们主动投放于环境中的数量最大、毒性最广的一类化学物质, 有的农药具有诱变性, 有的甚至是三致物(致癌、致畸和致突变)和内分泌干扰物。农药在防治农作物的病虫害、草害及家庭卫生、消灭害虫、疾病等方面发挥了重要作用, 但不可否认的是, 从农药的使用开始, 就污染了自然环境, 给人们身体健康带来了不利影响。更为严重的是, 农药的长期使用会使害虫产生抗药性, 而害虫

收稿日期: 2008-06-05; 接受日期: 2008-10-17
基金项目: 国家自然科学基金(30670377)
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的天敌却遭受农药毁灭性的打击。施用农药时, 不管采取什么方式, 大部分农药落入土壤中, 同时附着在作物上的那一部分农药以及漂浮在空气中的农药最终也因风吹雨淋落入土壤; 使用浸种拌种、毒谷等施药方式更是将农药直接混入到土壤中, 因此土壤中的农药污染是相当严重的, 不仅影响土壤健康, 而且导致土壤质量不断下降。

土壤线虫在有机质分解、养分矿化等生态过程中起着关键作用, 是土壤生态系统的重要功能组分(Freckman, 1988; 胡锋等, 1999)。土壤线虫在大多数土壤中分布是丰富的, 而且营养类群也是多样的(梁文举等, 2002)。因此, 通常土壤线虫群落可以被用来反映未受干扰的环境与人为影响的环境之间的差异(Pate *et al.*, 2000; 李琪和王朋, 2002), 是反映生态系统受到各种管理措施干扰的敏感性指示生物(Yeates & Bongers, 1999; Urzelai *et al.*, 2000; Ekschmitt *et al.*, 2001; Matlack, 2001; Schloter *et al.*, 2003; Liang *et al.*, 2005; Wu *et al.*, 2005; Wasilewska, 2006)。对其研究不仅有助于揭示土壤生态系统的结构, 还可以提供有关土壤生态过程的独特信息(Ritz & Trudgill, 1999), 近年来, 国内外土壤生态学者加强了土地利用方式尤其是农业生产活动对土壤线虫群落动态影响的研究(Freckman & Ettema, 1993; Yeates & Bird, 1994; Liang *et al.*, 1999; Fu *et al.*, 2000; Liang *et al.*, 2001; Berkelmans *et al.*, 2003; Ferris *et al.*, 2004)。我国从20世纪80年代初开始进行土壤线虫生态学方面的研究(张荣祖等, 1980), 有关土地利用方式与土壤线虫群落动态变化关系方面的研究报道近年来也有所增加(梁文举等, 2001; 李辉信等, 2002; 邓晓保等, 2003; Meng *et al.*, 2005; Ou *et al.*, 2005)。但上述研究都是人为添加化肥或农药来研究土壤线虫的响应, 而在自然条件下农药的工业化生产对其周围环境不同土地利用方式下的土壤生态系统的影响、尤其是对土壤线虫群落结构的影响研究却未见相关报道。本文主要通过对安徽省和县华星化工股份有限公司内外不同土地利用方式下土壤线虫数量和营养类群的研究, 旨在阐明农药生产对土壤线虫群落结构的影响及对环境的潜在威胁。

1 研究地点

安徽省和县华星化工股份有限公司主要生产沙蚕毒类、有机磷类、拟除虫菊酯类等杀虫剂及系列除草剂, 位于长江左岸, 地处118°27' E, 31°51' N, 北距南京市市区40 km, 南距和县县城历阳镇20 km, 占地面积420 ha。该地区为沿江冲击平原, 海拔6–8 m, 属于北亚热带湿润季风气候, 风向有明显的季节性变化, 以偏北风为主; 年日照时数在2,035–2,270 h之间; 年均气温15.7–15.9℃; 无霜期232–247 d; 年平均降水量1,000–1,158 mm, 梅雨量较集中, 约240–260 mm。

选择厂区内和厂外共6块样地作为采样地点: (1) 厂内裸地(BIF, bare land inside the factory); (2) 厂内宝塔松林地(PIF, stands of pagoda pine trees inside the factory), 为厂区内绿化带, 树龄7–8年, 株高约2 m, 株距1.5 m, 林地内无其他植被覆盖; (3) 厂外裸地(BOF, bare land outside the factory); (4) 厂外大豆地(SOF, soybean field outside the factory); (5) 厂外水稻地(POF, paddy field outside the factory); (6) 厂外玉米地(COF, corn field outside the factory); 厂外4块样地均位于厂区正南方约200 m。每块样地面积约150 m^2。

2 研究方法

2.1 土样采集

2006年10月, 在每块样地选择3个5 m×5 m的样方, 每个样方内采用s形取样法随机选10个点, 每个点用直径3 cm、长20 cm的土钻采集0–20 cm耕层土壤, 10个点的土样混匀后取约500 g土作为1个土样, 共获18个土样带回实验室4℃冰箱保存。

2.2 线虫分离与鉴定

线虫分离采用浅盘法(Goodfriend *et al.*, 2000), 每个土样称取100 g, 平铺在浅盘内, 加自来水淹没土样, 室温下进行线虫分离, 48 h后收集浅盘中的线虫悬浮液, 用500目(0.03 mm)筛网过滤, 将筛网中的线虫清洗至塑料小皿中, 室内静置3 h, 吸出上清液, 保留约5 mL线虫悬浮液, 60℃杀死, FA固定液固定, 在体视镜下计数。依据土壤湿度, 将土壤线虫数量折算成每100 g干土含有的线虫条数(条/100 g干土)。每个土样随机对100条线虫进行鉴定, 对于线虫数少于100条的土样, 对所有线虫进行鉴定。 根据线虫的头部形态学特征和取食生境分成以下4个营养类群: 植物寄生类线虫(Plant-parasites)、食细菌类线虫(Bacterivores)、食真菌类

线虫(Fungivores)、捕食类/杂食类线虫(Predators/Omnivores)(Liang *et al.*, 1999; Yeates & Bongers, 1999)。线虫标本鉴定主要依据《中国土壤动物检索图鉴》(尹文英, 1998), 只鉴定到营养类群。

2.3　数据统计及处理

本次调查主要利用线虫数量和相对丰度来衡量土壤线虫群落结构的变化。相对丰度以不同营养类群的线虫数量占线虫总数的百分比(%)来表示。

在SPSS12.0软件上进行*t*检验、方差分析及相关分析。

3　结果与分析

3.1　不同土地利用方式下线虫数量

不同样地的调查结果表明(表1), 土壤线虫的数量范围在10–898 条/100g干土。不同土地利用方式下土壤线虫总数为厂内宝塔松林地>厂外大豆地>厂外玉米地>厂外水稻地>厂外裸地>厂内裸地, 有植被覆盖地显著高于裸地, 厂外裸地显著高于厂内裸地 ($P<0.01$)。厂外3种农田地中, 仅大豆地与水稻地之间土壤线虫总数存在显著性差异。农药厂内外不同土地利用方式下土壤线虫总数均明显小于自然状态土壤(自然状态裸地土壤线虫总数为160–758条/100g干土, 有植被覆盖土壤线虫总数为519–5,233条/100g干土) (华建峰等, 2006), 说明农药工业化生产过程对其周围环境的土壤线虫数量影响较大, 土壤线虫可以作为土壤污染的敏感指示生物。有植被覆盖土壤中线虫总数显著大于裸土, 反映出植被覆盖有利于增加土壤线虫的数量, 这与华建峰等(2006)的研究结果是一致的, 也可以反映植被在消除土壤污染中起着重要作用。

3.2　不同土地利用方式下线虫营养类群统计分析

从表1可以看出, 样地内及样地间不同营养类群线虫存在显著性差异($P<0.01$), 厂内外有植被覆盖地植物寄生类线虫占主要优势, 食细菌类线虫为次优势类群; 而裸地中食细菌类线虫占主要优势, 植物寄生类线虫为次优势类群; 杂食/捕食类线虫和食真菌类线虫的数量均比较低; 其中有植被覆盖地一般为植物寄生类线虫>食细菌类线虫>食真菌类线虫、捕食类/杂食类线虫, 而裸地一般为食细菌类线虫>植物寄生类线虫>食真菌类线虫、捕食类/杂食类线虫。

植物寄生类线虫在厂内宝塔松林地与其他5种样地均有显著性差异($P<0.01$), 而在厂外3种农田地之间、厂外裸地与厂内裸地之间无显著性差异; 食细菌类线虫在厂外大豆地与厂内宝塔松林地、厂外水稻地、厂外裸地、厂内裸地间有显著性差异($P<0.01$), 而在厂外大豆地与厂外玉米地之间、厂内宝塔松林地与厂内裸地及厂外水稻地之间无显著性差异; 食真菌类线虫除在厂外玉米地与厂外裸地、厂内裸地之间有显著性差异外($P<0.01$), 在其他样地之间无显著性差异; 捕食类/杂食类线虫在厂外大豆地、厂外水稻地与厂外玉米地、厂内宝塔松林地、厂内裸地之间存在显著性差异($P<0.01$), 在其他样地之间无差异。

有植被覆盖土壤中植物根系较多, 可以为植物寄生类线虫提供食物来源, 使植物寄生类线虫易生存繁殖, 数量增多; 而裸地中植物根系很少, 不利于植物寄生类线虫生长, 数量较少, 导致食细菌类

表1　不同土地利用方式下土壤线虫总数和各营养类群线虫数量(条/100g干土) (mean ± SD, n = 3)
Table 1　Soil nematode numbers of different trophic groups in six land use types (inds./100g dry soil)

	植物寄生类线虫 Plant-parasites	食细菌类线虫 Bacterivores	食真菌类线虫 Fungivores	捕食类/杂食类线虫 Predators/Omnivores	线虫总数 Total nematodes
厂内裸地 (BIF)	2.39 ± 2.40^{cB}	7.98 ± 2.77^{cA}	0.80 ± 1.38^{bC}	0.00 ± 0.00^{bC}	11.17 ± 1.38^{e}
厂内宝塔松林地 (PIF)	647.82 ± 116.07^{aA}	108.01 ± 33.02^{bB}	14.27 ± 24.72^{abC}	0.00 ± 0.00^{bC}	770.09 ± 110.81^{a}
厂外裸地 (BOF)	39.92 ± 7.24^{cB}	132.27 ± 24.44^{bA}	0.00 ± 0.00^{bC}	7.11 ± 3.66^{abC}	179.30 ± 18.41^{d}
厂外大豆地 (SOF)	398.41 ± 75.32^{bA}	207.17 ± 56.48^{aB}	42.84 ± 40.53^{abC}	29.96 ± 12.02^{aC}	678.37 ± 111.52^{ab}
厂外水稻地 (POF)	375.69 ± 15.14^{bA}	115.32 ± 18.16^{bB}	36.44 ± 18.09^{abC}	29.82 ± 28.07^{aC}	538.59 ± 36.82^{c}
厂外玉米地 (COF)	351.59 ± 11.75^{bA}	172.21 ± 51.33^{abB}	53.99 ± 22.54^{aC}	4.17 ± 7.23^{bD}	581.96 ± 38.17^{bc}

同列内不同小写字母表示土地利用方式间有显著性差异($P<0.01$); 同行内不同大写字母表示营养类群间有显著性差异($P<0.01$)
BIF, bare land inside the factory; PIF, stands of pagoda pine trees inside the factory; BOF, bare land outside the factory; SOF, soybean field outside the factory; POF, paddy field outside the factory; COF, corn field outside the factory.
Different small letters in the same column indicate significant differences among soil samples ($P<0.01$). Different capital letters in the same row indicate significant difference among trophic groups ($P<0.01$)

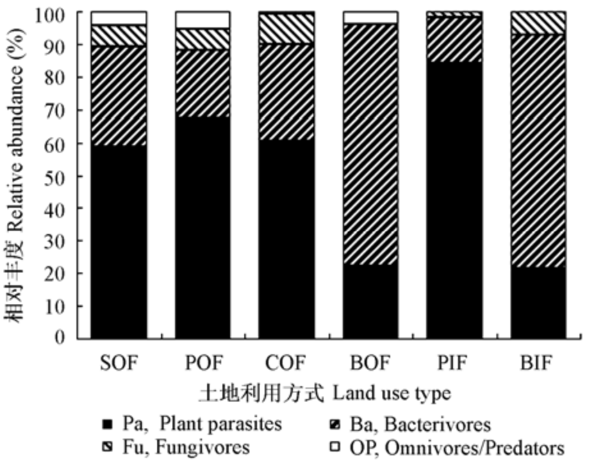

图1 不同土地利用方式下土壤线虫相对丰度比较
SOF: 厂外大豆地; POF: 厂外水稻地; COF: 厂外玉米地; BOF: 厂外裸地; PIF: 厂内宝塔松林地; BIF: 厂内裸地
Pa: 植物寄生类线虫; Ba: 食细菌类线虫; Fu: 食真菌类线虫; OP: 杂食类/捕食类线虫
Fig. 1 Relative abundance of soil nematode trophic groups in different land use types. SOF, soybean field outside the factory; POF, paddy field outside the factory; COF, corn field outside the factory; BOF, bare land outside the factory; PIF, stands of pagoda pine trees inside the factory; BIF, bare land inside the factory

线虫相对增多。

3.3 不同土地利用方式下线虫相对丰度统计分析

从图1可以看出，厂内宝塔松林地植物寄生类线虫相对丰度最高，达到84%，为其他营养类群总和的5.25倍；厂外大豆地、厂外玉米地、厂外水稻地植物寄生类线虫相对丰度分别为59%、60%和67%，为其他营养类群总和的1.44倍、1.50倍和2.03倍。厂外裸地和厂内裸地食细菌类线虫相对丰度分别为74%和72%，为其他营养类群总和的2.85倍和2.57倍。

有植被覆盖土壤中植物寄生类线虫相对丰度显著大于食细菌类线虫，而裸露土壤中食细菌类线虫相对丰度显著大于植物寄生类线虫，主要原因可能是植被种类、生物量及土壤养分的差异所致(华建峰等, 2006)，裸地易于受随机因子的影响，如降雨、光照、风吹等(Bloemers *et al*., 1997; Venette & Ferris, 1997)，使得裸地土壤线虫总数减少。食微线虫(包括食细菌类线虫和食真菌类线虫)总数显著小于自然状态土壤(自然状态土壤中食微线虫约占土壤线虫总数的 60–80%)，可能原因是农药进入土壤后，一方面直接毒害土壤线虫，使土壤线虫总数减少；另一方面可能是抑制微生物增殖，使食微线虫食物短缺，土壤线虫总数减少，也是裸地土壤肥力下降的表征(Bongers & Bongers, 1998)。

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