荔枝-牧草复合系统节肢动物群落多样性与稳定性分析

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摘要：1997年9月到1998年9月在广东东莞对荔枝-牧草复合系统和单一系统的节肢动物群落进行了比较研究，结果表明：荔枝-牧草复合系统同单一系统相比节肢动物群落数量，物种丰富度及均匀性增加，多样性提高。复合系统中各类群的多样性几乎在一年中的任何时期都比单一系统要高，但不同系统各类群的多样性对夏季高温和荔枝树生长阶段的反应极不一致。利用3个指数来评价群落的稳定性，结果都说明复合系统中的节肢动物群落显得较为稳定。看来，荔枝-牧草复合系统是荔枝园中维持，保护和利用节肢动物群落多样性的一种很好的模式。用有序样品的最优分割方法，把荔枝-牧草复合系统的节肢动物群落最优划分为了5个阶段，各个阶段节肢动物各类群的多样性特征及主要害虫和天敌状态的明确能对复合系统中荔枝害虫综合防治措施的适时采用起指导作用。

关键词：荔枝，牧草，复合系统，节肢动物群落，多样性，稳定性

Diversity and stability analyses of arthropod community in litchi-herbage complex system

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Abstract: The experimental orchards were located at Qiaotou town of Dongguan city, Guangdong Province, China. The litchi trees were planted between 1993 and 1994 with a distance of 3m between trees and 5m between rows. In a 2 hm^2 orchard, *Desmodium intortum* (Mill. Urb.), a forage legume, was planted in litchi orchard. This orchard is subsequently referred to as a complex system consisting of a litchi subsystem and a forage subsystem. In an adjacent 2 hm^2 orchard, ground cover plants (mostly weeds) were removed by farmers, and this orchard is subsequently referred to as a simple system. In both the complex and the simple systems, integrated pest management measures were taken including culturing strong trees, releasing mass-reared wasps of *Anastatus* sp to control litchi stink bug, utilizing selective pesticides such as imidacloprid to control twig insect pests, and using petroleum spray oil to control pests such as scales and mites.

Arthopod censuses were conducted from September, 1997 to September, 1998, at 20 day intervals. 5 sample spots were selected in either system, with 2 trees at each spot. Arthropods were caught by net-sweeping and twig-checking at these spots throughout the investigation period. Arthropods in the ground cover were also gathered in 5 quadrates ($9m^2$ each) in the complex system by 30 sweeps in each quadrate. All individuals collected were counted and identified.

The arthropod community was divided into 4 assemblages including phytophagous insects, parasitic and predatory insects, spiders, and scavengers and others. The BergerParker index of dominance, Simpson

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index of dominant concentration, and Shannon-Wiener diversity index were used to analyze the arthropod community.

The phytophagous insect assemblage accounted for 60.6% of all arthopods in the simple system, in constast to 30.3% in the complex system. In the simple system, 11.2% of all arthropods were spiders, compared with 18.9% in the complex system respectively. Parasitic and predatory insects made up 11.6% and 22.4% of the simple system and the complex system respectively. Much greater percentages of polyphagous and other insects were found in the complex system (28.3%) than in the simplex system (16.6%). In comparison to the simple system, there was a decrease in the percentage of phytophagous insects in the complex system, accompanied by increase in the percentage of spider, parasitoids, predator, polyphagous and other insects.

The degree of dominance of arthropod assemblage in the complex system was much lower (0.0631) than in the simple system (0.1332), because more numerically dominant species and less rare species were collected in the simple system. Much greater average species richness of arthropod assemblage was found in the complex system (43.1) than in the simple system (25.7). There were much more species in arthropod assemblage collected in the complex system than in the simple system. The diversity of arthropod assemblage was much higher in the complex system (3.2549) than in the simple system (2.599). There was no obvious difference in the evenness between two systems.

Ecologists studied community stability from different perspectives, but there have been arguments about the relationship between diversity and stability so far, higher diversity does not always mean higher stability. So, 3 indices derived from diversity were used to assess the arthropod community stability. The same conclusion could be drawn upon using all three indices that the arthropod community in the complex system should be more stable. Planting forage in the litchi orchard improved the arthropod community diversity, as well as stability. Clear mechanisms of forage plants' role in improving arthropod diversity and stability need further studies.

The development of arthropod diversity in the litchi-herbage complex system is divided into 5 stages through using best sectioning of orderly samples. The status of phytophagous, parasitic, predatory, polyphagous insects and spiders indicated in these 5 periods could be conducive to deciding appropriate control measures in different time of a year.

The management tactics applied in this study, including cultivating forage plants, releasing mass-reared natural enemies, and utilizing selective insecticides, provided effective control of major insect pests. The numbers of major pests in the simple system were suppressed below economically damaging levels. Although there were more species of phytophagous insects in the complex system which were maintained below economic thresholds, and most of which were rare, the abundance of major pests in the complex system, such as litchi stink bug, tortricids, leafrollers, were much lower than those in the simple system. IPM practiced in this study provided a better control effect of major pests in the complex system than in the simple system.

Key words: *Desmodium intortum*; diversity; IPM; forage; arthropod community

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传统的单一作物栽培方式导致系统内生物多样性贫乏。化学农药的广泛应用又加剧了系统的生物多样性,尤其是昆虫群落多样性锐减,作物-害虫-天敌间的相对稳定性受到破坏,害虫发生周期缩短。生物多样性是生态系统稳定与发展的前提,生物多样性的恢复、保护和利用在农业生态系统中显得极其重要,是病虫害持续控制必须考虑的前提。复合农业系统能有效改善生态环境,使生物多样性增加,达到经济、生态

和社会效益的统一。1981 年黄明度等在柑桔园种植一种菊科杂草-藿香蓟(*Ageratum congzoides* L.),创造了早期的柑桔-草复合系统模式,改善了柑桔园的生态环境,助长了天敌的繁衍,害虫得到控制[1,2]。桔园内保留野生杂草后形成的复合系统同单一作物系统相比,天敌及其它节肢动物群落数量、丰富度及多样性增加[3]。柑桔园-杂草复合系统这一模式已在国内、外的一些柑桔产区应用[4~7]。国外在果园杂草的天敌种类、数量方面进行了一些研究,认为果园杂草能使一些天敌的数量增加[8~10]。本研究在荔枝园内种植牧草——旋纽山绿豆(*Desmodium intortum*(Mill. Urb.)),建立荔枝-牧草复合系统,探讨复合系统内生物多样性的恢复、保护和利用以及在害虫持续控制中发挥的作用。

1　材料与方法

1.1　试验地概况

用于试验的荔枝园位于广东省东莞市桥头镇农科园(以下简称农科园)。该地方气候温暖湿润,土壤为典型赤红壤,该园是国家赤红壤综合农业试验区的一部分。本试验在农科园选两片荔枝园。实验用的荔枝树为 5～6 年生,树高 2～3m,绝大部分为白腊品种,仅十来株为妃子笑。在其中的一片(约 30 000m^2)荔枝树的行间及株间种植牧草——旋纽山绿豆(*D. intortum*),成为本试验的荔枝-牧草复合系统(以下称复合系统),其中包括荔枝树子系统和牧草子系统,复合系统中的荔枝树子系统的节肢动物群落指仅在荔枝树冠上调查到的节肢动物群落。在另外一片(约 20 000 m^2),定期人工铲除或喷除草剂杀死荔枝园内杂草,成为本试验的单一系统(以下称单一系统)。

无论单一系统还是复合系统,都采取以下综合管理措施:合理施肥,培育健壮树势,增强对病虫抵抗力;秋、冬季清园时,修剪带有果蛀虫类、瘿螨或瘿蚊等的虫枝和虫梢等,并清除地上的残枝、落叶,以减少虫源;在修剪时,除修剪荫枝、枯枝、弱枝等以外,也修剪病虫危害枝;每年荔枝蝽蟓产卵初期,释放平腹小蜂 2 次;适时合理使用农药,选用对天敌杀伤力小的选择性农药吡虫啉防治梢期的尺蛾、毒蛾、蒂蛀虫、金龟子等;同时喷洒对环境无害的矿物油杀虫剂——机油乳剂(机油乳剂可防治介壳虫等,同时对一些害虫产卵有驱避作用)。

1.2　调查方法

本研究的田间调查始于 1997 年 9 月份,止于 1998 年 9 月份。于复合系统和单一系统各设 5 个取样点,每个样点调查 2 棵树,每 20 天调查 1 次。田间调查采用网捕法、观察法、手捕法等。复合系统由荔枝树子系统和牧草子系统构成,其中的节肢动物取样包括荔枝树冠取样和地面牧草取样。单一系统中地面杂草被定期铲除或杀死,如果在地面杂草中取样,只能采集到极少数量的节肢动物,可忽略不计,因此本试验选择单一系统中只进行树冠取样,不进行地面取样。在各取样点附近的旋纽山绿豆中,选取 $2\times2m^2$ 样方 1 个,来回扫 30 网,将收集到的昆虫等连同枝叶装瓶,带回室内分捡;然后随机抽取 10 片叶,观察并记录叶上昆虫的种类和数量。

1.3　分析方法

用 Shannon-Wiener 指数 H' 分析群落多样性;用种间相遇机率 PIE 计算的均匀度($v' =$ PIE 实测值/PIE 最大值)来分析群落的均匀性。

2　结果与分析

2.1　数量、物种丰富度与均匀度比较

表 1 对单一和复合系统中节肢动物各类群的数量,物种丰富度和均匀度进行了比较,结果表明,荔枝-牧草复合系统中各昆虫及蜘蛛类群在数量和平均物种丰富度上都极显著多于单一系统,也就是说复合系统中聚居着更多种类和更大数量的节肢动物。复合系统中整个节肢动物群落的均匀度要高于单一系统,植食性昆虫类群的均匀度显著高于单一系统,但蜘蛛等其它类群的均匀度比单一系统的略低。可以看出,荔枝园中种植牧草后,寄生性,捕食性昆虫天敌以及蜘蛛在数量和种类上都有明显的增加,另外,杂食性昆虫同样有明显增加,这对于荔枝园中害虫的生态控制无疑能起重要作用。

2.2　多样性季节变化比较

图 1 中 A,B,C,和 D 分别显示蜘蛛,寄生与捕食性昆虫,杂食性及其它昆虫和植食性昆虫类群多样性

季节变化比较,可以看出,复合系统和单一系统节肢动物群落各类群的多样性都是在11月底到翌年2

表1 [illegible]

Table 1 Comparisons on number, species richness and evenness of each arthropod group between two systems

项目 Category	系统 System	植食性昆虫类群 Phytophagous insect group	蜘蛛类群 Spider group	寄生与捕食性昆虫类群 Parasitic and predatory insect group	杂食性及其它昆虫类群 Polyphagous and other insect group	整个节肢动物群落 Whole arthropod community
数量 Number	S.S	865	160	229	173	1427
	C.S	1391	648	1303	1271	4613
		$t=4.3481$ * *	$t=6.3398$ * *	$t=3.4456$ * *	$t=7.7417$ * *	$t=6.3706$ * *
平均物种丰富度 Average richness	S.S	8	6	7	5	26
	C.S	22	15	27	18	82
		$t=6.3061$ * *	$t=7.2004$ * *	$t=8.0291$ * *	$t=9.3784$ * *	$t=10.3538$ * *
均匀度 Evenness	S.S	0.7903	0.9383	0.9296	0.8801	0.9099
	C.S	0.9247	0.9256	0.9140	0.8098	0.9581

* S.S和C.S分别表示单一系统和荔枝-牧草复合系统,* * 表示T检验差异极显著,$t_{0.01}(17)=2.8982$ S.S, C.S and * * signal simple system, litchi-herbage complex system and very significant difference through using T-test respectively

月份由于天气寒冷而比较低,在夏,秋季较高,但不同系统各类群的多样性对天气条件和荔枝树发育阶段的反应却极不一致,寄生与捕食性昆虫类群的多样性却在8月上旬为全年的最高峰。尽管各类群的多样性在一年中的变化极不规则,但复合系统各类群的多样性几乎在一年中的任何时期都比单一系统要高,如复合系统在6月初蜘蛛类群的多样性值为全年最高,其值为2.9832,而在单一系统中仅为1.7351。

表2 两系统节肢动物群落稳定性比较

Table 2 Comparison on stability of arthropod community between two systems

指数类型 Index type	单一系统 Simple system	复合系统 Complex system
S_s/S_i	0.3245	0.3604
S_n/S_p	1.6312	1.9564
d_s/d_m	0.1350	0.1174

* S_s, S_i, S_n, and S_p indicate number of species, individuals, natural enemy species, and phytophgous insect species respectively, d_s and d_m indicate the standard deviation and mean of diversity values in a year.

2.3 稳定性比较

有学者提出用S_s/S_i(S_s为物种数,S_i为个体数)以及S_n/S_p(S_n为天敌种数,S_p为植食性昆虫种数)两指数反映群落稳定性[11]。S_s/S_i指数值大说明物种数相对较多,而个体数相对较少,反映种类间数量上的制约作用。S_n/S_p指数值大说明天敌所占比例增加,反映食物网络关系的复杂性及相互制约程度大,从而使稳定性增强。丛建国提出用一年中多样性值的变异系数(d_s/d_m)来描述群落稳定性,其中d_s为标准差,d_m为平均值[12]。如果变异系数小,则在相同外界干扰下群落抗外界干扰能力强,自控能力强,便稳定一些。本文将引用这些指数来分析节肢动物群落群落稳定性。

由表2可以看出,复合系统的S_s/S_i和S_n/S_p指数值要比单一系统的大,其变异系数d_s/d_m的值要比单一系统的要小,结果都说明复合系统显得相对稳定一些。

2.4 节肢动物群落聚类分析

表3显示用有序样品的最优分割这种聚类方法,以节肢动物各类群和整个节肢动物群落的多样性为依据,把荔枝-牧草复合系统的节肢动物群落最优划分为5个阶段。第1阶段为4～5月份,即荔枝花期到幼果期,其间荔枝春梢抽发,牧草生长迅速;气温回升,杂食性昆虫类群外的其它节肢动物类群的多样性都明显增加;杂食性昆虫在数量上也明显增加,但优势种突出使其多样性反而下降;随着荔枝春梢抽发,尺蛾,毒蛾,蒂蛀虫,荔枝蝽蟓等害虫迅速增加,蜘蛛,平腹小蜂等天敌的数量也明显增加,但跟不上害虫的发展。第2阶段为6月份,即荔枝幼果至收获期,荔枝蒂蛀虫非常猖獗,需于收获前连续两次喷药,以阻止其上果为害;大量的用药杀死了蒂蛀虫等梢期害虫,使植食性昆虫多样性下降,也可能造成了寄生性天敌多样性迅速下降;但在喷选择性农药——吡虫啉的试验园里,蜘蛛多样性继续增加,成为全年最丰富的时期,吡虫

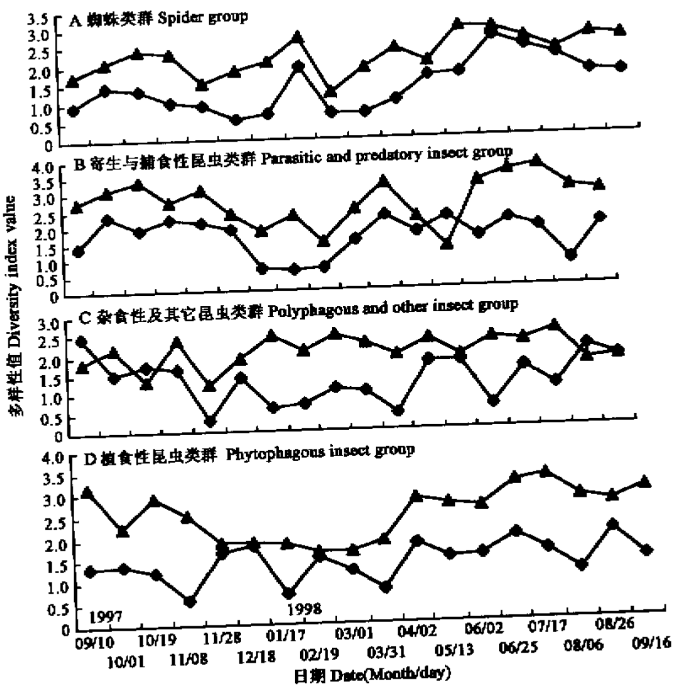

图 1　两系统中各类群多样性值季节变化比较

Fig. 1　Comparisons on diversity dynamics of each arthropod group between two systems

◆表示单一系统,▲表示复合系统 ◆ and ▲ signal simple and complex system respewctively

表 3　一年中各阶段荔枝-牧草复合系统中节肢动物各类群平均多样性

Table 3　Average diversity of each arthropod group in the litchi-herbage complex system in each phase of a year

阶段 Phase	时期 Period	PH	SP	PA	PO	T
1	4～5 **月份** Apr. ～May	2.7963	2.2385	2.7418	2.1518	3.8428
2	6 **月份** June	2.6707	2.9832	1.2886	1.8873	2.9915
3	7～9 **月中旬** Jul. ～middle Sep.	3.0328	2.6763	3.3103	2.1305	4.1154
4	9 **月中旬**～11 **月** middle Sep. ～ Nov.	2.5533	2.0294	3.0108	1.7810	3.6311
5	12～**翌年** 3 **月份** Dec. ～Mar. of Next Year	1.7955	1.9735	2.0868	2.2475	3.3029

* PH,SP,PA,PO,**和** T **分别表示植食性昆虫,蜘蛛,寄生与捕食性昆虫,杂食性及其它昆虫类群和整个节肢动物群落.** PH, SP, PA, and PO indicate phytophgous insect, spider, parasitic and predatory insect and polyphagous insect group respectively, and T indicates the whole arthropod community

啉对蜘蛛应该影响不大。第 3 **阶段为** 7 **月到** 9 **月中旬,即夏梢至秋梢期,夏,秋梢陆续抽发,牧草同样快速生长,农药压力减少,各类群昆虫的多样性明显增加,成为节肢动物群落平均多样性最高的时期,但蜘蛛的多样性却略有下降。第** 4 **阶段为** 9 **月中旬到** 11 **月份,即荔枝秋梢末期到冬梢期,其间荔枝树仅零星抽出嫩梢,牧草由于干旱生长缓慢,各类群昆虫和蜘蛛的多样性开始回落,但寄生与捕食性昆虫多样性仍维持较高的水平,此阶段可少喷药。第** 5 **阶段** 12 **月份到翌年** 3 **月份,其间有牧草花期,气温下降,除杂食性昆虫外其它昆虫和蜘蛛多样性明显下降,为全年最低的时期,但杂食性昆虫却是全年最丰富的阶段,原因可能是牧草较长的花期(约** 2 **个半月)为杂食性昆虫提供了适宜的越冬环境。**

3 结论与讨论

3.1 荔枝-牧草复合系统同单一系统相比节肢动物群落数量,物种丰富度及均匀性增加,多样性提高。复合系统和单一系统的节肢动物群落各类群的多样性都是在 11 月底到翌年 2 月份由于天气寒冷而比较低,但不同系统各类群的多样性对夏季高温及荔枝树生长阶段的反应却极不一致。尽管各类群的多样性在一年中的变化极不规则,但复合系统中各类群的多样性几乎在一年中的任何时期都比单一系统要高,如 6 月初蜘蛛类群在复合系统中的多样性值为 2.9832,而在单一系统中仅为 1.7351。生物多样性是生态系统持续发展和生产力的核心,其重要作用包括 3 个方面[13]:(1)生物多样性在复杂的时空梯度上维持生态系统过程的运行;(2)生物多样性是生态系统抗干扰能力和恢复能力的物质基础,生态系统中存在功能相似的许多生物,多样性是生态系统稳定性和功能优化的基础;(3)生物多样性是生态系统适应环境变化的物质基础。因此,荔枝-牧草复合系统是荔枝园中维持,保护和利用节肢动物群落多样性的一种很好的模式。

3.2 稳定性包括了两个方面的含义:一方面是系统保持现行状态的能力,另一方面是系统受干扰后回归该状态的倾向,即受扰后的恢复能力。但多样性与稳定性关系问题一直有争议,有学者认为认为多样性指数是反映群落稳定性的一个重要尺度,但群落多样性值的大小只能判别群落在某一时刻的稳定程度,而不能判断它在时间进程上的稳定程度。本文尝试利用由多样性指数演变来的 S_s/S_i、S_n/S_p 和变异系数来评价群落的稳定性,解释复合系统和单一系统中的节肢动物群落变化情况。复合系统的 S_s/S_i 和 S_n/S_p 值比单一系统的大,意味着复合系统中食物网络关系比较复杂,种间相互制约程度较大。复合系统的 d_s/d_m 值较单一系统小,意味着复合系统在外界干扰下多样性变动程度较小,即系统抗外界干扰能力比单一系统强,惯性大。这些都说明复合系统中的昆虫群落显得相对稳定一些。

3.3 用有序样品的最优分割这种聚类方法,以节肢动物各类群和整个节肢动物群落的多样性为依据,可各把荔枝-牧草复合系统的节肢动物群落最优划分为 5 个阶段。各个阶段节肢动物各类群的多样性特征及主要害虫和天敌状态的明确能对复合系统中荔枝害虫综合防治措施的采用起指导作用。根据各阶段的特征,可确定化学农药使用及其它措施采用的时间和用量,以利用和保护荔枝园内节肢动物群落多样性,从而达到经济效益和生态效益的统一。

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