第 22 卷第 8 期
2002 年 8 月

生 态 学 报
ACTA ECOLOGICA SINICA

Vol. 22, No. 8
Aug., 2002

稻田蜘蛛生态位变化及杀虫剂对捕食功能的影响

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摘要: 通过对稻田各蜘蛛和害虫空间生态位的研究发现, 空间生态位宽度随季节而变化, 狼蛛的生态位宽度值逐渐变大; 肖蛸两头高中间低; 微蛛在 7 月下旬最大; 球腹蛛在 8 月下旬 9 月上旬最大。各类群的数量是影响该类群空间生态位的重要因素。空间生态位具有明显的日节律, 狼蛛在 7～8 月份以中午最宽, 微蛛变化不大; 肖蛸在 7～8 月份下午的生态位宽度值大于上午, 9 月份则上午大于下午; 球腹蛛 7～8 月份以上午为最大; 跳蛛下午大于上午。不同种类农药在一天中不同时间施用对各类蜘蛛存活率及捕食功能的影响不同, 杀虫双上午用药对蜘蛛集团的捕食功能减退率影响较小, 甲胺磷则相反。

关键词: 稻田蜘蛛; 空间生态位; 杀虫剂

Influence of Seasonal and Daily Changes of Spatial Niche of Spiders in Paddy Field and Two Insecticides to Spatial Niche and Predatory Function

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Abstract: The experiment was conducted in the experimental farm of Yangzhou Agricultural School. Rice was transplanted on 21, June 1999. A plot ($0.1333hm^2$) was selected for spatial niche observation, and another four plots, $0.01667hm^2$ for each plot, were used for comparing the effect of spraying of two insecticides, bisultap and methamidophos, at common dosage at different time on niche breadths of spiders and planthopper and predation function of spiders. Rice plants were distinguished into three resource grades, upper leaf layer, stem and base. Number of spiders and planthoppers was recorded on schedule. Number of various species in leaf, stem and base was observed in morning (6 : 00), at noon (12 : 00) and in afternoon (18 : 00) at three selected stages of rice, 21 July, 22 August and 10 September (representatives of early-, middle- and late-stage of rice, respectively). The niche breadth (Bn) was measured using the equation index, $Bn=\frac{1}{\sum_{i=1}^{s} P_i^2(s)}$, where Bn is the niche breadth of observed species, P_i is the proportion occupied by the species in total resource series, and s is total resource series number. Measurements of similarity were calculated using Schoener index of proportional similarity of niche, $C_{ij}=$

基金项目: 国家自然科学基金重点资助项目(39830040)

收稿日期: 2000-12-18; 修订日期: 2001-07-05

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$1-\frac{1}{2}\sum_{h=1}^{s}|P_{ih}-P_{jh}|$, where C_{ij} is the measurements of similarity of niche, P_{ih} is the proportion occupied by species i in resource series h, P_{jh} is the proportion occupied by species j in some resource series h. Function decrease rate was also used to evaluate the effect of spraying two insecticides on predation function of spiders, $FD_t=D_t+(1-D_t)(F_{ck}-F_t)/F_{ck}$, where FD_t is the function decrease rate of natural enemies at time t, D_t is the mortality rate of natural enemies at time t, F_t is the predation function of surviving natural enemies at time t after insecticide application, F_{ck} is the one of control (CK), meanwhile, the spiders were considered as a predator guild, thus the function decrease rate of the guild after insecticide application (FD) can be obtained by the following equation, $FD=\sum_{i=1}^{s}a_i\times FD_t$, where a_i is the predation share of species i in the whole predation number of the guild, calculating by the following equation, $a_i=\frac{N_{a_i}\times B_i}{\sum_{i=1}^{n}N_{a_i}}$, where N_{a_i} is the mean predation number of the spider i in the field, which was the predation number in disc equation of function response when N is 10, B_i is the relative abundance of the species i in the guild. The results were as follows:

The spatial niche breadth of spiders and planthopper varied with season, but different species had different regularity. The trend of the spatial niche breadth of Micryphantidae and planthopper was consistent before 22 august, but opposite after that. That of Lycosidae increases gradually as rice development, but that of Tetragnathidae was just opposite; that of Tetragnathidae decreased continually before 22 august, but there was a peak on September 1, and declined quickly. That of Theridiidae reached the maximum during late august to early September.

Change of spatial niche in a day varied with species. The spatial niches of planthopper and Theridiidae were broadest in morning, narrowest in afternoon; that of Saltidae was narrowest in morning, but broadest in afternoon; Tetragnathidae was similar with Saltidae during July to August, but inversely during September. However, that of wolf spiders was narrowest in morning and broadest at noon during July to August, but narrowest at noon during September; that of Micryphantidae and Araneidae was changeable, without obvious regularity.

Proportional similarity index (C_{ij}) was an important index reflecting the species similarity for resource utilization. The bigger the value is, the bigger the similarity extent of the distribution in resource series between species was. The index of wolf spiders was smaller than other species, but other species had bigger ones with one another. Among spiders, Micryphantidae had biggest similarity index with planthopper, other species also had higher ones with planthopper. This indicated that spiders have very high encountering chance with planthopper, which was related to the habitats of themselves. Wolf spiders mainly distributed on the base of rice plant, and Tetragnathidae mainly on leaf and stem, so C_{ij} between the former and the later was the smallest, being only 0.2576; Apart from planthopper and Micryphantidae, other species mainly distributed on stem, so they have smaller ones with wolf spiders.

Application of bisultap and methamidophos in morning and in afternoon showed different effects on spatial niche of spiders and planthopper. For bisultap appication in morning, the niche of Micryphantidae and planthopper was broader than CK, while that of Tetragnathidae and Lycosidae was just opposite; for methamidophos application in afternoon, the niche of Micryphantidae, Tetragnathidae and Theridiidae was broader than CK and in morning, but inversely for wolf spiders and planthopper. Generally, the impacts of methamidophos on spatial niche of spiders were bigger than that of Bisultap, but inversely for

planthopper.

Spraying of two insecticides in morning and in the afternoon also had different impacts on predation function. The effects of spraying of bisultap in morning on predation functions of Micryphantidae, Lycosidae and Theridiidae were bigger than that in afternoon, and there are the same results for predator guild, but reverse for Tetragnathidae; methamidophos application had the opposite results with bisultap. To minimize the effects of insecticides on spiders, it was better to spray in afternoon than in morning, but reverse for methamidophos.

Key words: spiders; spatial niche; insecticide; rice field

文章编号:1000-0933(2002)08-1286-07　**中图分类号**:S43　**文献标识码**:A

在水稻害虫综合治理实践中,增强天敌的自然控制作用、利用品种抗性和合理地使用杀虫剂是 IPM 三大重要因素。化学农药尽管有一系列的副作用,但仍是害虫猖獗时的主要控制手段。因而协调杀虫剂的使用与自然控制作用是害虫可持续控制的重要研究课题。稻田捕食性天敌种类多,其中蜘蛛无论在数量上还是在功能方面均是重要的天敌类群。不同种类的蜘蛛占据不同的空间生态位,这是物种长期演化的结果。有关捕食性天敌的空间生态位和时间生态位已有一些研究[1~4]。但天敌空间生态位的季节变化及日变化,稻田常用杀虫剂在一天中不同时段使用对空间生态位的影响及其评价还未见报道。作者于 1999～2000 年进行了 2a 的田间试验,目的是要依据主要天敌的生态位日变化规律合理使用农药,使保护天敌和农药使用的矛盾有所协调。

1　材料和方法

1.1　调查田情况

调查田块为扬州市农业学校实验农场的大田,品种为香粳 49,单季晚稻,6 月 21 日移栽。选取一丘($0.133hm^2$)进行生态位调查,整个生长季节不施用任何化学农药,另选一丘($0.133hm^2$)用于不同时间用药对飞虱和蜘蛛生态位影响以及对蜘蛛捕食功能影响的试验。

1.2　调查方法

采用对角线 10 点取样,每点 10 穴,10d 调查 1 次。调查时采用目测法,轻轻拔开稻丛,分别计数稻株上部叶片层、中部茎秆层和基部水面 3 部位的物种和数量。

1.3　一天中不同时段蜘蛛和飞虱(以下简称蛛虫)生态位调查

在水稻生长前期(7 月 21 日)、中期(8 月 22 日)、后期(9 月 10 日),分别调查一天中早晨(6：00)、中午(12：00)、下午(18：00)3 个时间段的蛛虫空间生态位,调查方法同上。

1.4　不同时间用药对蛛虫空间生态位以及对蜘蛛捕食功能的影响

1999 年选 4 个相邻小区,面积各为 $0.01667hm^2$,在 7 月 24 日上午和下午分别对每个小区喷施杀虫双(18%水剂 江苏省盐城农药厂)或甲胺磷(50%乳油 江苏省苏州化工农药集团公司),杀虫双亩用量 100ml,稀释 320 倍;甲胺磷亩用量 100ml,稀释 640 倍,药前和药后一天分别采用生态位调查的方法,每个小区 5 点取样,调查各部位的物种和数量。2000 年 4 个小区面积各为 $0.03333hm^2$,喷药时间在 7 月 16 日,药后 1d 和 4d 分别进行调查,每小区 8 点取样,其它同 1999 年。

1.5　分析方法

(1) 生态位宽度值(Levins(1968))　$$Bn = 1/\sum_{i=1}^{s} P_i^2(s)$$

式中,B 表示生态位宽度值,P_i 表示物种在一个资源序列的第 i 个单位中所占的比例,s 表示每个资源序列的总单位数。

(2) 生态位的比例相似性(Schoener(1968))　$$C_{ij} = 1 - \frac{1}{2}\sum_{h=1}^{s} |P_{ih} - P_{jh}|$$

式中,C_{ij}为物种 i 与物种 j 的比例相似性,并且有 $C_{ij}=C_{ji}$,P_{ih}为物种 i 在资源 h 等级中所占的比例,

P_{jh}为物种 j 在资源等级 h 中所占的比例。

(3)蜘蛛捕食功能减退率评价法　采用功能法评价两种杀虫剂对各蜘蛛类群捕食功能的影响[6,7]:

$$FD_t = D_t + (1 - D_t)(F_{ck} - F_t)/F_{ck}$$

其中,FD_t 是 t 时刻天敌种群的功能减退率,D_t 为 t 时刻天敌的死亡率,F_{ck}为正常天敌的捕食功能,F_t 为药剂处理区存活天敌 t 时刻的捕食功能。同时,将田间各蜘蛛类群作为捕食性集团来考虑,则一次施用杀虫剂引起该集团的捕食功能减退率 FD 为:

$$FD = \sum_{i=1}^{s} a_i \times FD_t$$

其中,a_i 为该类群占该集团总捕食量的份额,可按下式获得:

$$a_i = (N_{a_i} \times B_i)/\sum_{i=1}^{n} N_{a_i}$$

其中,N_{a_i}为该类群蜘蛛个体在田间的平均捕食量,本研究中,以该类蜘蛛捕食褐飞虱功能反应的园盘方程中 $N=10$ 时的捕食量为其平均捕食量。B_i 为该类蜘蛛在集团中的相对丰盛度。

2　结果与分析

2.1　主要蛛虫空间生态位的季节动态

各蛛虫的空间生态位宽度值随季节而变(表 1),但不同的类群变化规律不同。其中微蛛和飞虱的生态位变化趋势在 8 月 22 日前比较一致,8 月 22 日以后趋势相反。狼蛛的生态位宽度值随时间的延续而缓慢增加,肖蛸和狼蛛生态位变化的总趋势相反,肖蛸在 8 月 22 日以前一直呈下降趋势,9 月 1 日出现一个上升高峰,随后又急剧下降。球腹蛛在 8 月底到 9 月上旬达最大值,水稻生长早期和后期均较小。

表 1　各蛛虫生态位宽度值的季节动态(江苏扬州,1999)

Table 1　Seasonal niche breadth of spiders and planthopper (Yangzhou, 1999)

物种类群 Taxa	调查日期(月.日) Sample date(Month. day)					
	07.13	07.21	08.10	08.22	09.01	09.10
飞虱 Planthopper	0.513	0.781	0.716	0.810	0.839	0.811
微蛛 Mictyphantidae	0.652	0.846	0.671	0.700	0.660	0.673
肖蛸 Tetragnathidae	0.889	0.710	0.663	0.591	0.895	0.708
狼蛛 Lycosidae	0.333	0.333	0.452	0.480	0.460	0.576
球腹蛛 Theridiidae	0.407	0.889	0.788	0.997	0.974	0.695
园蛛 Araneidae	0	0.415	0.641	0.817	0.333	0.333
跳蛛 Saltidae	0	0.600	0.333	0.600	0.600	0.585
蟹蛛 Thomisidae	0	0	0.333	1.00	0.333	0.333
管巢蛛 Clubionodae	0.333	0	0	0	0	0

2.2　主要蛛虫空间生态位的日变化

空间生态位在一日中的变化因物种类群而异(图 1～图 3)。飞虱和球腹蛛具有相似的日变化,早晨最宽,下午最窄;跳蛛早晨最窄,下午最宽;肖蛸和跳蛛在 7～8 月份较为类似,后期(9 月 10 日)则相反;与其它种类不同,狼蛛的生态位 7～8 月份早晨最窄,中午最宽,9 月中旬中午最窄;微蛛、园蛛的日变化比较复杂,无明显的规律性。空间生态位的这种日变化规律与它们各自的生态学习性有关,对喜凉类群,早晨具有较宽的生态位,飞虱和球腹蛛可能就是这样的类群,对喜温类群,如狼蛛、肖蛸和跳蛛,则中午、下午具有较宽的生态位。

2.3　各蛛虫空间生态位的比例相似性指数

比例相似性指数是反映种间利用资源相似性程度的一个重要指标,比例相似性指数越大,种间在资源序列上分布的相似性也就越大。狼蛛和其它蜘蛛类群的比例相似性指数较小,其它各类群间的比例相似性指数皆较高。微蛛和飞虱具有最大的比例相似性指数,其它蜘蛛和飞虱的相似性指数也较高(表 2)。表明蜘蛛对飞虱具有非常好的空间相遇机率。这与各类群的栖息部位有关(表 3)。狼蛛主要分布在基部,肖蛸主要分布在叶片和茎部,因此二者的生态位比例相似性指数最小,仅为 0.2576;除飞虱和微蛛外,其它类群主要

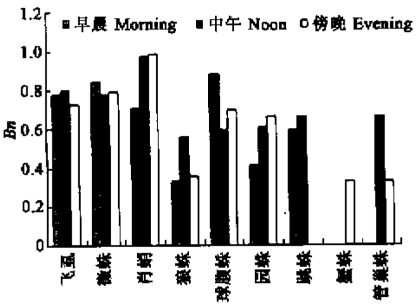

图 1　7 月 21 日空间生态位日变化

Fig. 1　Niche breadth of spiders and planthopper during early stage of rice (21 July)

图例同表 1 Taxa is the same as table 1

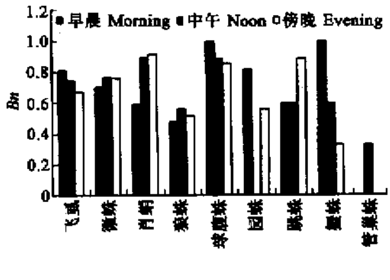

图 2　8 月 22 日生态位日变化

Fig. 2　Niche breadth of spiders and planthopper during middle stage of rice (22 August)

图例同表 1 Taxa is the same as table 1

分布在茎部，因此和狼蛛的生态位比例相似性指数也较小。

作为两大优势类群，狼蛛和肖蛸通过空间生态位的分离，相互之间对空间资源的竞争减小，增强了整体的控虫效果；而其它蜘蛛之间占据的生态位具有较大的相似性，竞争激烈，有可能削弱对飞虱的控制作用。

2.4　不同时间用药对飞虱和蜘蛛生态位的影响

杀虫双和甲胺磷分别在上午和下午喷药，对各蛛虫的生态位影响不同(表 4)。杀虫双上午喷施，微蛛和飞虱的生态位比对照宽，肖蛸、狼蛛则变窄；上午与下午相比，微蛛和肖蛸的生态位宽度值上午大于下午，狼蛛的生态位影响不大，球腹蛛下午变宽。甲胺磷下午喷施，微蛛、肖蛸和球腹蛛生态位宽度值比对照宽，并且比上午喷施宽，狼蛛和飞虱变窄。总体而言，甲胺磷对各类蜘蛛的空间生态位的影响要比杀虫双大，而飞虱则相反。这可能是因为甲胺磷对飞虱的杀伤力比杀虫双大，使得栖息在喷施过甲胺磷的稻株上的蜘蛛所能获得的猎物(飞虱)要比栖息在喷施过杀虫双的稻株上的蜘蛛所能获得的猎物少得多，只有通过扩大搜索范围来满足猎物需求。

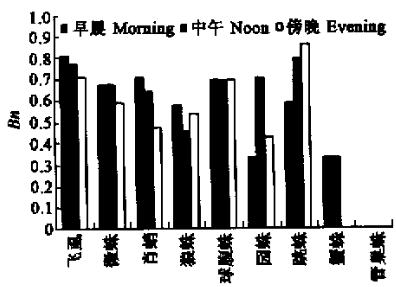

图 3　9 月 10 日空间生态位日变化

Fig. 3　Niche breadth of spiders and planthopper during late stage of rice (10 September)

图例同表 1 Taxa is the same as table 1

表 2　各蛛虫的比例相似性指数(江苏扬州，1999)

Table 2　Similarity indices of inter-taxa of spiders and planthopper (Yangzhou, 1999)

物种类群 Taxa	飞虱 Planthopper	微蛛 Mictyphantidae	肖蛸 Tetragnathidae	狼蛛 Lycosidae	球腹蛛 Theridiidae	园蛛 Araneidae	跳蛛 Saltidae	蟹蛛 Thomisidae
飞虱 Planthopper		0.8944	0.5682	0.6895	0.7591	0.7061	0.647	0.7025
微蛛 Mictyphantidae			0.5087	0.6437	0.8049	0.7519	0.6928	0.7483
肖蛸 Tetragnathidae				0.2576	0.6731	0.5906	0.6698	0.5726
狼蛛 Lycosidae					0.4486	0.3956	0.3364	0.3433
球腹蛛 Theridiidae						0.8645	0.8847	0.843
园蛛 Araneidae							0.9208	0.9784
跳蛛 Saltidae								0.9028
蟹蛛 Thomisidae								

2.5　不同时间用药对蜘蛛捕食功能的影响

两种农药不同时间施用对各类蜘蛛的捕食功能影响不同。杀虫双上午用药对微蛛、狼蛛和球腹蛛的影

响大于下午，肖蛸则相反；甲胺磷下午用药对微蛛、狼蛛和球腹蛛的影响大于上午，对肖蛸的影响则上午大于下午。对集团功能减退率的影响杀虫双上午用药大于下午，甲胺磷则相反。1999 年的结果与 2000 年相似，个别类型蜘蛛略有差异，但两种农药对集团功能减退率的影响完全与 2000 年相似。农药对各类蜘蛛捕食功能减退率的影响与各类蜘蛛空间生态位的日变化规律有关，从表 3 可以看出肖蛸和狼蛛的生态位在下午变宽，即表明下午分布在植株上部的肖蛸变少，狼蛛变多，从而使各自的农药接触量变化而产生上述的结果。杀虫双由于对蜘蛛的作用时间较长，在药后 1d 没有表现出这种现象，不过在药后 4d 则产生和甲胺磷相同的结果。由此可见，为使对天敌影响最小化，杀虫双以下午用药较好，甲胺磷则以上午为好。

表 3　飞虱和蜘蛛在稻株各部位的分布比例（江苏扬州，1999）

Table 3　Proportion of spiders and planthopper in different position rice plant (Yangzhou, 1999)

项目 Item	飞虱 Planthopper	微蛛 Mictyphantidae	肖蛸 Tetragnathidae	狼蛛 Lycosidae	球腹蛛 Theridiidae	园蛛 Araneidae	跳蛛 Saltidae	蟹蛛 Thomisidae	管巢蛛 Clubionodae
叶片 Leaf	0.106	0.047	0.538	0.026	0.212	0.129	0.208	0.111	0.200
茎杆 Stem	0.373	0.478	0.374	0.144	0.510	0.645	0.625	0.667	0.800
基部 Base	0.519	0.474	0.088	0.830	0.279	0.226	0.167	0.222	0.000

表 4　不同时间用药对飞虱和蜘蛛生态位（*Bn*）的影响（江苏扬州，1999）

Table 4　Effect of spraying at different time on spatial niche of spiders and planthopper (Yangzhou, 1999)

处理 Treatment		微蛛 Mictyphantidae	肖蛸 Tetragnathidae	狼蛛 Lycosidae	球腹蛛 Theridiidae	飞虱 Planthopper
杀虫双 Bisultap	上午 Morning	0.703	0.667	0.333	0.758	0.898
	下午 Afternoon	0.691	0.621	0.333	0.857	0.971
甲胺磷 Methamidophos	上午 Morning	0.632	0.867	0.517	0.857	0.691
	下午 Afternoon	0.742	0.903	0.333	0.926	0.644
用药前（对照）Before spraying (CK)		0.700	0.887	0.378	0.777	0.787

表 5　不同时间用药对优势蜘蛛类群存活率及捕食功能的影响（江苏扬州，2000）

Table 5　Effect of spraying at different time on survival rate and predation function of dominant spiders (Yangzhou, 2000)*

处理 Treatment			相对死亡率 Relative mortality rate				捕食功能减退率(%) Decrease rate of predation function				
			微蛛 Mictyphantidae	肖蛸 Tetragnathidae	狼蛛 Lycosidae	球腹蛛 Theridiidae	微蛛 Mictyphantidae	肖蛸 Tetragnathidae	狼蛛 Lycosidae	球腹蛛 Theridiidae	集团 Guild
药后 1d One day after spaying	杀虫双 Bisultap	上午①	34.20	17.39	29.73	36.67	59.97	40.70	63.74	61.47	62.33
		下午②	25.00	30.43	4.500	26.67	54.37	50.06	50.72	55.38	51.43
	甲胺磷 Methamidophos	上午	62.80	69.56	53.27	73.33	77.36	78.15	75.88	83.77	76.36
		下午	82.40	47.83	80.37	76.67	89.29	62.55	89.74	85.81	88.75
药后 4d Four days after spaying	杀虫双 Bisultap	上午	35.60	78.57	38.58	10.00	60.82	84.62	68.31	45.24	66.86
		下午	26.00	71.43	51.45	5.00	54.98	79.49	74.95	42.20	70.73
	甲胺磷 Methamidophos	上午	59.01	64.28	72.61	40.00	75.06	74.36	85.86	63.49	83.05
		下午	71.19	64.28	85.48	60.00	82.47	74.36	92.51	75.66	89.77

* 各类存活蜘蛛个体的捕食功能减退率引用徐建祥等（2000）的实验结果 Decrease rate of predation function of survived spiders after spraying was from Xu J. X, *et al* (2000); ① Morning　②Afternoon

3　讨论

协调好保护天敌与化学农药的使用仍是今后相当长时期内害虫综合治理研究的重要内容之一。现已报道许多杀虫剂的使用导致褐飞虱再猖獗[7～15]，再猖獗原因被认为主要是杀伤天敌[7,9,13,15]，且亚致死剂量刺激害虫生殖[11～13,15]。但即使是引起再猖獗的农药也不是在任何时间施用均导致再猖獗发生，例如在呋喃丹的各种使用方法中，叶面喷雾诱导再猖獗。再猖獗的程度受到用药时间的影响，甲基 1605 和 decamethrin 在水稻生长早期使用对再猖獗的发生影响不大，而栽后 50d 和 65d 使用在栽后 90d 左右的第 3 代发生再猖獗[8]。这表明农药的使用技术和使用时间的调节对减少农药的副效应是重要的。从田间捕食性天敌的空间

生态位的季节变化和日变化规律来协调保护天敌和化学防治的矛盾同样具有重要的理论和实践意义。有关稻田捕食性天敌空间生态位的静态情况已有一些报道[1,4,6]，但依据空间生态位的日变化规律，比较一天中不同时间用药对天敌空间生态位、杀伤天敌及天敌集团功能减退率的影响以寻找尽量减少对天敌的影响的研究尚无报道。实际上空间生态位的日变化反映了各蛛虫的行为、生态及对环境变化的适应性。对喜凉类群，早晨具有较宽的生态位，飞虱和球腹蛛就是这样的类群，对喜温类群，中午、下午具有较宽的生态位，如狼蛛、肖蛸和跳蛛。对捕食者来说，宽度值大表明搜索范围广，反之则窄。不同的种类又占据一定或特定的空间生态位。因而不同时间用药对各物种类群的影响不同。从蜘蛛集团功能减退率来看，杀虫双是下午用药要好于上午，甲胺磷则是上午好于下午。本试验上午和下午分别用两种不同的农药，产生相反的结果，且二年的试验结果相一致。可能与这两种农药具有不同的作用机制有关。杀虫双为神经毒剂，对天敌具有麻醉作用[5,6]；甲胺磷为触杀、胃毒和一定的熏蒸作用，因此下午温度高，毒性大，关于这个问题有待于进一步研究。当然是上午还是下午用药还应考虑对害虫的防效。在防效相差不大时，重点应考虑保护天敌。另外，尽管这两种杀虫剂有可能将被淘汰，但依据生态位的变化调整用药时间，对将来其它新农药的使用仍有方法和思路上的参考价值。

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