第 23 卷第 11 期
2003 年 11 月

生 态 学 报
ACTA ECOLOGICA SINICA

Vol. 23, No. 11
Nov., 2003

豚草卷蛾与苍耳螟的资源生态位研究

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摘要：引进的豚草卷蛾和本地的苍耳螟是取食豚草的重要天敌昆虫。为了进一步明确两种天敌种间的竞争作用，定量研究了豚草卷蛾和苍耳螟在寄主植物种类和空间上的生态位指数。结果表明，在寄主植物种类上，豚草卷蛾只取食豚草和苍耳；苍耳螟可取食豚草、苍耳、黄花蒿、向日葵、万寿菊、国庆菊、菊芋、麦杆菊；苍耳螟的生态位宽度指数(Hurbert 标准值 0.228)明显大于豚草卷蛾(0.069)，两者的食物资源生态重叠程度较小(Horn's 指数 0.318)；豚草卷蛾和苍耳螟对常用资源的利用率分别为 93.5%(豚草)和 59.3%(苍耳)。在相同寄主植物上，两种天敌的空间生态位表现为：随着寄主植物的生长发育，两种天敌的生态位重叠程度减小；高龄幼虫的生态位宽度指数大于低龄幼虫。在食物生态位上，豚草卷蛾主要取食新发生的幼嫩枝，并且一旦蛀入形成虫瘿后很少发生转移，而苍耳螟除低龄幼虫喜蛀食幼嫩枝外，高龄幼虫的取食部位常常发生转移，从枝型较细的幼嫩枝转向枝型较粗的老龄枝。两种天敌对豚草和苍耳实际选择作用以及对常用资源利用率存在明显差异，因此，形成竞争的程度较小，在对豚草的控制机制上形成互补作用。

关键词：豚草卷蛾；苍耳螟；资源生态位；风险评价

Resource use overlap between *Epiblema strenuana* and *Ostrinia orientalis*: two biocontrol agents against *Ambrosia artemisiifolia* and *Xanthium sibiricum*

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Abstract: The imported ragweed borer *Epiblema strenuana* (Lepidoptera: Tortricidae) and local Siberian cocklebur stem borer *Ostrinia orientalis* (Lepidoptera: Pyralidae) are important biocontrol agents against ragweed (*Ambrosia artemisiifolia*) and have similar feeding characteristics. In order to evaluate interspecific interactions between these two biocontrol agents, food and spatial overlap were evaluated quantitatively in 2001 in the Field Experimental Station of Hunan Agricultural University, Changsa City,

基金项目：国家自然科学基金资助项目(39770510)；"十五"国家攻关课题资助项目(2001BA611B-06-1-5)

收稿日期：2002-10-01；**修订日期**：2003-05-10

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感谢 Dr. Gábor Lövei 对本文英文摘要的审阅和修改 The authors are grateful for Dr. Gábor Lövei for linguistic revision on the English abstract and many comments on the text

Foundation item: National Natural Science Foundation of China (No. 39770510); State Fenth Five-year plan, Funded by MOST (2001 BA 611B-06-1-5)

Received date: 2002-10-01; **Accepted date**: 2003-05-10

Biography: MA Jun, Ph. D., Associate professor, main research field: Integrated pest manageinent and risk assessment of GMOS and IAS.

Hunan province, Central China. In this area, *E. strenuana* had 5 generations (peak periods for the 2nd～4th generations were middle to late June, middle to late July and middle to late August, respectively) and *O. orientalis* had 4 generations (peak periods for the 2nd and 3rd generations were middle to late July and middle to late August, respectively). The first generation of *E. strenuana* occurred one month earlier than *O. orientalis*. The two insect species overlapped temporally from middle June to early September. Populations of the first one to two generations of both species were relatively low. For the field survey, 9 plant species (including 6 varieties of *Helianthus annus* and 4 cultivars of *Dendranthema morifolium*) from the family Compositae were tested. *D. morifolium* were potted (three plants per pot, 35～40cm in height) and put between the ragweed plant lines. Other plants were transplanted or seeded into 30 randomly distributed plots (2～3 plots per species, 20～50 m^2/plot, depending on the amounts of plant seeds or seedlings available) during May～June. During the whole growing season, galls caused by the two insect species on the 17 test plant species and other surrounding weed plants were recorded at 7-day intervals from middle June to early September. At the same time, 3 plants of both *A. artemisiifolia* and *X. sibiricum* were taken back to the laboratory and dissected to check the presence of the two insect species in different-sized stems and branches. For the spatial overlap, only 7 samples, collected between 11 July and 22 August were taken into account, during which both species were present at high densities and developmental stages of both species overlapped. From the 9 Composite species (including varieties and cultivars) and other surrounding weeds plants, *E. strenuana* only utilized *A. artemisiifolia* and *X. sibiricum* as host plants. *O. orientalis* could feed on 8 host plant species: *A. artemisiifolia*, *X. sibiricum*, *Artemisia annua*, *Helianthus annus*, *Tagetes erecta*, *Dendranthema morifolium* (cv. Guoqing), *Helianthus tuberosus*, and *Helichrysum bracteatum*. These two insect species had significantly different preferences on the tested plant species. *E. strenuana* preferred *A. artemisiifolia* and 93.5% galls were found on ragweed. *O. orientalis* preferred *X. sibiricum*, with 59.3% galls distributed on cocklebur and others on the other 7 plant species. The Hurlbert's niche width index of *O. orientalis* was 0.228, higher than that of *E. strenuana* (0.069). Horn's niche overlap index value between the two insects was relatively small (0.318). Body size and feeding behavior of the two insect species were different. Larval *E. strenuana* was smaller and mainly fed on newly grown twigs from its early age, and it seldom transferred to other twigs after a gall was formed. However, old larvae of *O. orientalis* were bigger and usually changed feeding sites from small, newly grown twigs to fully-grown branches. When feeding on ragweed, *E. strenuana* larvae mainly feed on tender branches of no more than 6mm in diameter. Old larvae (5th～6th instar) distributed wider (niche width value 0.34) than young 1st～4th instar larvae (0.25). Young *O. orientalis* larvae (1st～3rd instar) mainly feed on tender ragweed branches of no more than 8mm in diameter, while its old larvae (4th～5th instar) mainly on branches of more than 12mm in diameter. Old larvae also distributed wider (niche width value 0.37) than young ones (0.31). When feeding on cocklebur, *E. strenuana* larvae mainly feed on tender branches of no more than 6mm in diameter, and young larvae distributed wider (niche width value 0.53) than old ones (0.37). Young *O. orientalis* larvae mainly feed on tender cocklebur branches of no more than 6mm in diameter and niche width value was 0.27, while its old larvae distributed widely on all size branches from 2mm to over 16mm in diameter and niche width value was 0.67. Comparing the niche width values of the two insect species, *E. strenuana* larvae always distributed wider on ragweed than those of *O. orientalis*. Either on stems and branches of *A. artemisiifolia* or on those of *X. sibiricum*, the overlap of the two insect species decreased as the host plant grew. On different-sized branches, the overlap between *E. strenuana* and *O. orientalis* was higher for young larvae (overlap index value 0.69 on *A. artemisiifolia*, and 0.94 on *X. sibiricum*, respectively) than

for old larvae (0.37 on *A. artemisiifolia*, and 0.72 on *X. sibiricum*). Young *O. orientalis* larvae and old *E. strenuana* larvae had higher overlap (index value 0.94 on *A. artemisiifolia*, and 0.97 on *X. sibiricum*) compared to other combinations. Within the two host plant species, no matter which two larval stages (old larvae and young ones) were compared, there was a higher overlap on *X. sibiricum* plants than on *A. artemisiifolia*. As the actual selection and utilization rate for host plant resources between *E. strenuana* and *O. orientalis* differed significantly, the authors conclude that the conflict between these two biocontrol agents would rarely occur in the filed. The two species could coexist and provide a more efficient control of the target weed species, *A. artemisiifolia*.

Key words: *Epiblema strenuana*; *Ostrinia orientalis*; resource use overlap; risk assessment; *Ambrosia artemisiifolia*

文章编号:1000-0933(2003)11-2232-07 **中图分类号**:Q958.12^{+} **文献标识码**:A

外来生防作用物可通过多种方式影响生态系统,其释放定殖必然占据一定的生态位,从而与其它物种可能产生竞争[1]。豚草卷蛾(*Epiblema strenuana*)是一种钻蛀茎杆并形成虫瘿的外来杂草天敌[2]。我国从澳大利亚引进该天敌并在湖南释放用于控制豚草(*Ambrosia artemisiifolia*)[3]。在释放地,豚草卷蛾可同时取食豚草和当地杂草—苍耳(*Xanthium sibiricum*),而苍耳上的本地蛀茎性天敌—苍耳螟(*Ostrinia orientalis*)亦可同时蛀食豚草[4]。为了评价豚草卷蛾与本地天敌苍耳螟的竞争作用,作者从生态位的角度对这两种昆虫的种间关系作了研究,以明确两种间竞争性风险程度。

1 材料与方法

1.1 调查方法

豚草卷蛾和苍耳螟为田间自然种群。实验设在湖南农业大学教学实验场内。根据以往的测定结果[5],选择豚草卷蛾可能取食并与豚草近缘或具有重要经济意义的植物作田间栽种测定。田间栽培供试植物有:豚草、苍耳、6个向日葵品种(*Helianthus annus* var.:内蒙1号、内蒙2号、白97-1、寸嗑、天委1号、天委F_2)、麦杆菊(*Helichrysum bracteatum*)、万寿菊(*Tagetes erecta*)、孔雀草(*T. patula*)、4个菊花变种(Dendranthema morifolium *cv.*:硫花菊、富士雪、国庆菊和黄莲)、菊芋(又名洋姜,*Helianthus tuberosus*)和黄花蒿(*Artemisia annua*)共17种。

以上植物(除菊花)先后于2001年5月至6月移栽或直播于实验地,每种小区面积20~50m^2不等,重复2~3次,随机排列。4个菊花变种为盆栽(直接购于园艺花圃),每盆3株,每品种3~6盆,苗高35~40cm,随机摆放于豚草空行内。

在供试植物的整个生育期,每隔7d调查一次豚草卷蛾和苍耳螟在各供试植物及实验地周边杂草和作物上的发生量,并且每次分别采回豚草和苍耳整株3株左右,在室内按不同株型和枝型大小分别剥查两种昆虫在各种类型枝上的虫量,共调查12次。

1.2 生态位表示方法

(1)Hurlbert标准化生态位宽度指数[6]

$$B'_A = \frac{B' - a_{\min}}{1 - a_{\min}} \qquad 其中, B' = \frac{1}{\sum_{j=1}^{n} \frac{p_j^2}{a_j}}$$

式中,p_j为利用资源j的个体的比例,a_j在资源j中可利用的项目的比例($\sum a_j = 1.0$),$a_{\min}$是资源中最小者。

(2)Horn's重叠指数[7]

$$R_0 = \frac{\sum_{i=1}^{n}(P_{ij} + P_{ik})\ln(P_{ij} + P_{ik}) - \sum_{i=1}^{n}P_{ij}\ln(P_{ij}) - \sum_{i=1}^{n}P_{ik}\ln(P_{ik})}{2\ln(2)}$$

式中 R_0＝Horn 种类 k 对种类 j 的生态位重叠指数；P_{ij}＝由种类 j 所利用的整个资源中第 i 种资源所占比例；P_{ik}＝由种类 k 所利用的整个资源中第 i 种资源所占比例，n＝资源状况总数。

2 结果与分析

2.1 豚草卷蛾和苍耳螟的食物生态位

根据 2001 年对同一田间试验地及其周围共 37 种植物调查结果，表明豚草卷蛾在田间条件下仅取食豚草和苍耳，其平均单株虫瘿量分别为：豚草（67.2）和苍耳（4.5）；苍耳螟可取食 8 种植物，单株虫瘿量分别为：豚草（1.7）、苍耳（17.3）、黄花蒿（3.3）、向日葵（3.4）、万寿菊（1.0）、国庆菊（1.4）、菊芋（0.8）、麦秆菊（0.3）。生态位宽度指数的测定结果表明，豚草卷蛾的 Hurlbert 标准值为 0.069，以豚草作为常用食物的资源利用率达 93.5%，表明有很强的寄主专一性；而苍耳的 Hurbert 标准值为 0.228，以苍耳为常用食物的资源利用率为 59.3%。两者的生态位重叠 Horn's 指数较低，为 0.318。

2.2 豚草卷蛾和苍耳螟在寄主植物豚草及苍耳上的空间生态位

2.2.1 豚草 长成的成熟株，其枝的分级一般为 3 级，少量植株可达 4 级。按不同分级枝划分，当豚草植株近基部主茎直径小于 1.0cm 时，两种天敌昆虫在各级枝条上的空间生态位宽度指数和重叠指数相似（表 1），两者均以主茎和分枝（一级枝）作为常用食物资源，而且重叠程度较高，但在利用率上豚草卷蛾倾向于分枝，而苍耳螟则偏于主茎。当主茎大于 1.0cm 时，苍耳螟的生态位宽度指数大于豚草卷蛾，而在常用资源利用上两者有所分化，豚草卷蛾仅以分枝（一、二级枝）为主，而苍耳螟同时以主茎和分枝（一级枝）为主；生态位重叠指数较前两种株型有所减小，表明随着植株增大重叠程度有所降低。

表 1 豚草卷蛾和苍耳螟在豚草上的生态位宽度、重叠度指数及对主茎与枝条的利用率

Table 1 Niche breadth and overlap indices for *Epiblema strenuana* and *Ostrinia orientalis* and utilization rate on plant stems and branches of *Ambrosia artemisiifolia*

主茎直径 Plant stem (Ø,cm)	种类 Species	生态位宽度 Niche width	生态位重叠 Niche overlap	资源利用率 Resource utilization rate (%)	
				主茎 Stem	分枝 Branches
0.2～0.5	*E. strenuana*	0.593	0.952	43.6	56.5
	O. orientalis	0.666		57.1	42.9
0.51～1.0	*E. strenuana*	0.642	0.941	35.3	64.7
	O. orientalis	0.621		57.9	42.1
≥1.01	*E. strenuana*	0.357	0.825	4.4	95.59
	O. orientalis	0.528		36.7	63.3

按照枝条直径大小划分，豚草卷蛾低龄幼虫（1～4 龄）和高龄幼虫（5～6 龄）在不同大小枝上的生态位宽度指数均小于苍耳螟幼虫，与上述不同大小株型上的生态位指数相似（表 2），而在同一种虫内，高龄幼虫的生态位宽度均大于低龄幼虫。这种现象一方面反映了两种幼虫的虫体大小差异，也反映了两种天敌的取食行为特征。如苍耳螟不仅虫体大于豚草卷蛾，而且移动性也大于豚草卷蛾，尤其是苍耳螟的高龄幼虫（5～6 龄）取食部位不固定，移动性更强，细小枝不但难以满足其食量需要，而且虫体无法蛀入。豚草卷蛾幼虫的移动性相对较小，一旦形成虫瘿后则很少发生转移，但若幼虫的取食刺激不能使枝茎形成虫瘿，则往往迫使幼虫发生转移，这在豚草植株间因竞争激烈或植株进入花穗期以后表现得尤为明显。从常用资源的利用率看，豚草卷蛾各龄幼虫主要利用直径在 6.0mm 以内的幼嫩枝；而苍耳螟低龄幼虫取食枝的直径主要在 6.0mm 以下，随着虫龄的增大，明显趋向利用较粗的老龄枝，并且常用资源利用范围扩大，高龄幼虫（4，5 龄）主要取食枝的直径大于 12.0mm。两种天敌的生态位重叠测度指数表明，两种天敌间，除低龄幼虫之间的重叠指数较高外，高龄幼虫间的重叠指数明显减小，苍耳螟低龄幼虫与豚草卷蛾高龄幼虫重叠度较高（表 3）。

2.2.2 苍耳 苍耳枝的分级最多为 3 级，偶尔叶柄也可成为这两种天敌的钻蛀对象。在不同分级枝和叶柄上的空间生态位，当主茎直径小于 1.2cm 时，豚草卷蛾的生态位宽度指数明显大于苍耳螟，原因在于豚草卷蛾可选择主茎和分枝（一级枝）作为常用利用资源，而苍耳螟仅以主茎作为常用资源。当苍耳主茎直径

大于1.2cm时,两种天敌的生态位宽度指数十分接近,但豚草卷蛾仅以分枝(一、二级枝)作为取食资源,苍耳螟同时以主茎和分枝(一级枝)为主,同样反映两种天敌对取食枝型的选择差异性,即豚草卷蛾明显趋向于寄主的幼嫩枝条,而苍耳螟主要取食较大的老龄枝。两种昆虫在苍耳上的生态位重叠指数小于豚草,表明两者对苍耳不同分级枝的取食空间选择差异性大于豚草(表4)。

表2 豚草卷蛾和苍耳螟不同龄期的幼虫对豚草不同枝条的利用率

Table 2 Utilization rate of different larval stages of *Epiblema strenuana* and *Ostrinia orientalis* on different size branches of *Ambrosia artemisiifolia*

种类 Species	幼虫龄期 Larval stage	生态位宽度 Niche width	枝条直径(mm)与利用率(%)之间的关系 Relationship between branch diameters (mm) and utilization rate (%)							
			≤2	2.1～4	4.1～6	6.1～8	8.1～10	10.1～12	12.1～14	≥14.1
豚草卷蛾 *Epibelma strenuana*	1～4龄 1st～4th instar	0.25	66.6	21.6	9.9	1.7	0	0	0.3	0
	5～6龄 5th～6th instar	0.34	26.5	42.5	18.9	8.9	0.8	0.5	1.3	0.5
苍耳螟 *Ostrinia orientalis*	1～3龄 1st～3rd instar	0.31	10.5	49.1	13.2	21.1	2.6	0.9	1.8	0.9
	4～5龄 4th～5th instar	0.37	0	7.4	3.2	7.4	1.1	4.2	42.1	34.7

表3 豚草卷蛾和苍耳螟不同虫态在不同大小豚草枝条上的生态位重叠指数

Table 3 Niche overlap indices of different larval stages of *Epiblema strenuana* and *Ostrinia orientalis* on different size branches of *Ambrosia artemisiifolia*

种类 Species	幼虫龄期 Larval stage	豚草卷蛾 *E. strenuana* 1st～4th instar	豚草卷蛾 *E. strenuana* 5th～6th instar	苍耳螟 *O. orientalis* 1st～3rd instar	苍耳螟 *O. orientalis* 4th～5th instar
豚草卷蛾	1st～4th instar	1.00	0.86	0.69	0.21
E. strenuana	5th～6th instar		1.00	0.94	0.37
苍耳螟	1st～3rd instar			1.00	0.44
O. orientalis	4th～5th instar				1.00

表4 豚草卷蛾和苍耳螟在苍耳上的生态位宽度、重叠度指数及对主茎与枝条的利用率

Table 4 Niche breadth and overlap indices for *Epiblema strenuana* and *Ostrinia orientalis* and utilization rate on plant stems and branches of *Xanthium sibirium*

主茎直径 Plant stem (Ø,cm)	种类 Species	生态位宽度 Niche width	生态位重叠 Niche overlap	资源利用率 Resource utilization rate (%) 主茎,Stem	资源利用率 Resource utilization rate (%) 分枝,Branches
0.2～0.8	*E. strenuana*	0.667	0.7536	28.6	71.4
	O. orientalis	0.192		84.2	15.8
0.81～1.2	*E. strenuana*	0.358	0.646	17.2	82.8
	O. orientalis	0.202		83.3	16.7
≥1.21	*E. strenuana*	0.279	0.597	0	100
	O. orientalis	0.272		54.9	45.1

在苍耳不同大小枝型上,豚草卷蛾各龄幼虫主要以直径6.0mm以内的幼嫩枝作为常用利用资源(表5),其低龄幼虫的生态位宽度指数大于苍耳螟的低龄幼虫,但高龄幼虫明显小于苍耳螟的高龄幼虫。苍耳螟的生态位宽度指数随虫龄增大明显增大,虽然低龄幼虫也主要利用直径6.0 mm以下的幼嫩枝,但高龄幼虫常用枝的直径范围自2.1 mm至超过16.0mm以上。生态位重叠测度指数表明,两种天敌在苍耳不同大小枝上的重叠程度大于豚草(表6),原因在于长成的苍耳植株其枝的分级程度少于豚草,可利用的变异枝不如豚草。与豚草相似的是,两种天敌间,低龄幼虫之间的生态位重叠程度较高,高龄幼虫间的重叠程度

较低，苍耳螟低龄幼虫与豚草卷蛾高龄幼虫生态位重叠程度较高。

表 5　豚草卷蛾和苍耳螟不同龄期的幼虫对苍耳不同枝条的利用率

Table 5　Utilization rate of different larval stages of *Epiblema strenuana* and *Ostrinia orientalis* on different size branches of *Xanthium sibirium*

种类 Species	幼虫龄期 Larval stage	生态位宽度 Niche width	枝条直径(mm)与利用率(%)之间的关系 Relationship between branch diameters (mm) and utilization rate (%)							
			2.1～4	4.1～6	6.1～8	8.1～10	10.1～12	12.1～14	14.1～16	≥16.1
豚草卷蛾 *Epibelma strenuana*	1～4 龄 1st～4th instar	0.53	51.7	46.7	1.6	0	0	0	0	0
	5,6 龄 5th～6th instar	0.37	41.7	47.5	10.1	0.7	0	0.7	0	0
苍耳螟 *Ostrinia orientalis*	1～3 龄 1st～3rd instar	0.27	45.6	40.5	6.3	3.0	3.0	1.3	0.4	0
	4,5 龄 4th～5th instar	0.67	22.9	25.3	2.4	15.7	9.6	6.0	3.6	14.5

表 6　豚草卷蛾和苍耳螟在不同大小苍耳枝条上的生态位重叠 Horn's 指数

Table 6　Niche overlap indices of *Epiblema strenuana* and *Ostrinia orientalis* on different size branches of *Xanthium sibirium*

种类 Species	幼虫龄期 Larval stage	豚草卷蛾 *E. strenuana*		苍耳螟 *O. orientalis*	
		1st～4th instar	5th～6th instar	1st～3rd instar	4th～5th instar
豚草卷蛾	1st～4th instar	1.00	0.96	0.94	0.68
E. strenuana	5th～6th instar		1.00	0.97	0.72
苍耳螟	1st～3rd instar			1.00	0.81
O. orientalis	4th～5th instar				1.00

3　结论与讨论

生态位宽度和重叠指数测度表明，豚草卷蛾和苍耳螟所取食的食物种类生态位差异较大，在同一寄主上的取食空间生态位也同样具有一定的差异性，说明两者发生种间冲突的程度较低。两者发生种间竞争的可能主要在于，当只有豚草或苍耳单一寄主存在时，两种天敌昆虫发生竞争的可能性较大。这种竞争表现在：一是寄主枝条的顶芽部位均是两种低龄幼虫选择蛀食部位，在调查时发现，同一取食部位很少出现两头以上幼虫的同时蛀食；二是豚草卷蛾一旦在适当取食部位形成虫瘿后很少转移，而苍耳螟则随虫龄的增大常常由细枝转向粗枝，以满足食量的需要。苍耳螟高龄幼虫蛀食后往往造成蛀孔处枝条断裂，引起断口后的枝条死亡，使豚草卷蛾死于枯枝中。

就田间的实际情况而言，生态位的竞争性风险程度与两种天敌的实际作用强度(种群数量)有关。豚草卷蛾与苍耳螟两者出现竞争冲突的可能性应当较低，除了生态位的差异性外，原因还在于：第一，在自然条件下两者对寄主植物的种类和各自嗜好寄主的选择数量存在明显差异[4]。豚草卷蛾在供试植物种类中仅取食豚草和苍耳，其中以豚草为主；苍耳螟的食物种类生态位明显大于豚草卷蛾，其中以选择苍耳为主。第二，在寄主空间分布上，豚草卷蛾主要选择枝型较小的细嫩枝，而苍耳螟随虫龄增大则选择枝型较粗的枝条，两者取食部位互有差异。第三，在低龄幼虫期，虽然两种天敌均以取食细嫩的新枝为主，但由于低龄幼虫的食量小，而且新枝数量多，每一叶位和顶芽均可作为取食位点，因此竞争性较小。另外，在豚草生长前期，按照物候学发生的时序性，在湖南豚草卷蛾第一代的发生要比苍耳和苍耳螟的发生早一个月左右，加上两种天敌的第一、二代种群数量较少，因此两者在寄主苗期难以发生生态位竞争。由于两种天敌对豚草和苍耳实际选择作用以及对常用资源利用率存在明显差异，因此，两者在某种程度上对豚草的控制机制上反而可形成互补作用。

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