

# 中国的日本松干蚧雌成虫性信息素 对日本的日本松干蚧和美国的 红松干蚧雄成虫吸引力观察 (同翅目: 蚧总科: 珠蚧科)

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珠蚧科松干蚧属 (*Matsucoccus*) 的种类鉴定常是混淆的。在形态上相似的种类, 它们的区别主要是量级的。在英国松干蚧 [*Matsucoccus pini* (Green)] 和可能还有其他的种类, 不幸的是, 越冬世代和夏季世代也有显著差异 (Boratynski, 1952)。这个问题在区分种类时很少受到考虑, 因此被认为是一个重要的混淆因素。Boratynski (1952) 做过这属最全面的研究, 但没有包括所有的种类, 而且主要根据发表的描述, 没有对一系列标本作过实际观察。

近些年来, 在中国和美国的科学家们对于松干蚧所造成的危害关切日增。日本松干蚧 [*Matsucoccus matsumurae* (Kuwana)] 在中国毁坏大面积的赤松、马尾松、油松和黑松 (杨平澜等, 1976), 红松干蚧 (*Matsucoccus resinosae* Bean et Godwin) 在美国东北部一些地区是美国红松致命的一种害虫 (McClure, 1983 a)。因为红松干蚧的毁坏性和缓慢地扩散蔓延, 它曾被推测为引进美国的种类。McClure (1983 b) 推测它是当 1939 年纽约世界博览会时从日本引进外国松树品种被带到美国的。中国的日本松干蚧来源说法不一。有的说是从日本传入的 (McClure, 1983 b)。杨平澜 (在印刷中) 认为它也可能原产中国, 因为 (1) 它的猖獗并非由于近来传入中国, 而是广泛喷药防治松毛虫措施所引起的。杀虫剂杀死天敌引起日本松干蚧的猖獗。(2) 它在中国的发现是零乱的, 不象一种引入的害虫呈扩散发生的图景。它常在风景区或林区经过普遍应用杀虫剂之后才被发现。它在中国已经存在, 如果不造成灾害, 就没有人去注意。(3) 在中国、日本和朝鲜自然界的生物都属盛行的亚洲生物区系, 要在中国和日本之间说起源于何处是困难的。

能确定它的产地因而能得到天敌至少也是很有兴趣的。这些生物防治潜力的发现首要的是对日本松干蚧种团——包括苏联松干蚧 (*Matsucoccus insignis* Borchsenius)、日本

松干蚧(中国、日本和朝鲜种群)、英国松干蚧和红松干蚧——在分类状况方面有一个全面的了解。我们现正对这个种团部分的或全部的成员进行行为及形态等三方面的研究, 研究结果将发表一系列报告。这个报告是第一部分, 其余还有在精子形态和玻片标本的外部形态等方面的分类特征。

在松干蚧属存在雌成虫性信息素是 Doane (1966) 首先在红松干蚧发现的。1983 年祁云台等开始研究中国的日本松干蚧雌成虫性信息素。他们应用一套性信息素提取法, 并在室内和田间进行了初步行为试验。杨平澜和祁云台(1983)应用日本松干蚧和马尾松干蚧 (*Matsucoccus massoniana* Young et Hu) 雌成虫性信息素抽提液测定它们雄成虫的反应以鉴定性信息素的种特异性。虽然两种雄成虫都有交叉反应, 但种内的反应要强烈得多。

本文报告美国的红松干蚧雄成虫和日本的日本松干蚧雄成虫对于中国的日本松干蚧雌成虫性信息素反应试验的数据。美国和日本雄成虫的强反应将支持中、日、美三个种群是同种的证据。

## 方 法

日本松干蚧和马尾松干蚧雌成虫性信息素用祁云台等(1983)描述的气体收集法收取, 日本松干蚧在山东 1983 年 5 月间收集, 马尾松干蚧在浙江 1983 年 2 月间收集, 保存在己烷液内。日本松干蚧性信息素己烷溶液 0.1 毫升相当于 5 头雌成虫性信息素量(5FE), 马尾松干蚧性信息素己烷溶液 0.05 毫升相当于 5 头雌成虫性信息素量(5FE)。性信息素溶液封在安瓿瓶内带到美国和日本, 测定时现开现用。试验用直径 10 厘米培养皿, 室内在房顶上用荧光灯照明。培养皿底铺一层滤纸, 在滤纸上用铅笔标明试验的类别。分别用 1 毫升注射针筒吸取相当于 5FE 的性信息素溶液放到直径 1 厘米的圆形滤纸片上。让滤纸片上的己烷挥发后, 放到培养皿内的指定位置。用作对照的圆滤纸片也用等量己烷处理。红松干蚧性信息素圆滤纸片的制备, 是用直径 1 厘米的滤纸片放入小指管底部, 再放入 5 头处女雌成虫, 经 24 小时后取出圆滤纸片进行测试。试验用虫采自林野, 放在室内羽化。雌成虫从收集的无肢若虫期羽化, 保证是未经交配的。雄成虫从收集的雄茧羽化的。1984 年红松干蚧采集地点是康涅狄格州的 Saybrook (八月十三日和十四日)和 Litchfield (八月十五日)。1984 年日本的日本松干蚧采集地点是京都大学的试验林场(八月十四日)。

试验以三种形式进行。如果比较两种信息素或在一种信息素和对照之间比较, 试验区划为二半, 每半边放一个直径 1 厘米供试的圆滤纸片。如果将三种相比较, 试验区一分为三, 每一份放直径 1 厘米供试的滤纸片。如果比较四种成份, 则试验区划为四块, 每块放一个直径 1 厘米供试的圆滤纸片。在放完圆滤纸片后, 将雄成虫一一放入培养皿的中央。由于红松干蚧雄成虫数量有限, 每次试验仅用 6 头雄成虫。日本的日本松干蚧用 10 头雄成虫。在放入全部雄成虫经过 2 分钟后, 开始计数接触圆滤纸片的雄虫数。每隔 2 分钟计数一次, 共历时 20 分钟。试验仅限于培养皿底部, 如果有雄虫爬到培养皿壁上, 则用镊子小心将雄成虫移到培养皿中央。

## 结 果

一共进行八种试验，在美国用红松干蚧做过5种(第I组)，在日本用日本松干蚧做过3种(第II组)：

### 第 I 组

试验 1. 比较中国的日本松干蚧雌成虫性信息素  $\delta$ FE (0.1 毫升) 和己烷对照二圆滤纸片之间用 6 头红松干蚧雄成虫的行为。

经历时间 (分)	实 验 1		实 验 2	
	日本松干蚧滤 纸片上雄虫数	己烷滤纸片 上雄虫数	日本松干蚧滤 纸片上雄虫数	己烷滤纸片 上雄虫数
2	6	0	3	0
4	6	0	2	0
6	6	0	4	0
8	6	0	4	0
10	6	0	5	1
12	5	0	4	0
14	5	0	3	0
16	6	0	3	0
18	5	0	4	0
20	5	0	5	0
%	93.3	0	61.6	1.6
总平均%	日本松干蚧 77.5	己烷 0.8		

试验 2. 比较由 5 头红松干蚧雌成虫爬过 24 小时的滤纸片和己烷对照滤纸片之间 6 头红松干蚧雄成虫的行为。

经历时间 (分)	实 验 1		实 验 2	
	红松干蚧滤纸片上雄虫数	己烷滤纸片上雄虫数	红松干蚧滤纸片上雄虫数	己烷滤纸片上雄虫数
2	4	0	4	0
4	4	0	5	1
6	3	0	5	0
8	4	0	6	0
10	4	0	4	0
12	3	0	5	0
14	3	0	5	0
16	3	0	5	0
18	2	0	4	0
20	2	0	5	0
%	53.3	0	80.0	1.6

总平均% 红松干蚧66.7 己烷 0.8

试验 3. 比较马尾松干蚧雌成虫性信息素 5FE (0.05 毫升)和己烷对照之间分别用 3 头(实验 1)及 6 头(实验 2)红松干蚧雄成虫的行为。

经历时间 (分)	实 验 1		实 验 2	
	马尾松干蚧滤纸片上雄虫数	己烷滤纸片上雄虫数	马尾松干蚧滤纸片上雄虫数	己烷滤纸片上雄虫数
2	1	0	0	0
4	0	0	0	0
6	1	0	0	0
8	1	0	1	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	1
20	0	0	1	0
%	10.0	0	3.3	1.6

总平均% 马尾松干蚧 6.7 己烷 0.8

试验 4. 比较中国的日本松干蚧雌成虫性信息素 5FE (0.1 毫升) 滤纸片、5 头红松干蚧雌成虫爬过 24 小时的滤纸片、马尾松干蚧雌成虫性信息素 5FE (0.05 毫升) 滤纸片和己烷对照滤纸片四片之间 6 头红松干蚧雄成虫的行为。

经历时间 (分)	实 验 1				实 验 2			
	日本松干蚧 滤纸片上 雄虫数	红松干蚧 滤纸片上 雄虫数	马尾松干蚧 滤纸片上 雄虫数	己 烷 滤纸片上 雄虫数	日本松干蚧 滤纸片上 雄虫数	红松干蚧 滤纸片上 雄虫数	马尾松干蚧 滤纸片上 雄虫数	己 烷 滤纸片上 雄虫数
2	5	0	0	0	0	4	0	0
4	5	0	0	0	0	3	0	0
6	4	0	0	0	1	2	0	0
8	6	0	0	0	1	1	0	0
10	5	1	0	0	1	3	0	0
12	4	1	0	0	0	1	0	0
14	4	1	0	0	1	2	0	0
16	4	1	0	0	1	3	0	0
18	4	1	0	0	1	1	1	0
20	3	1	0	0	0	2	0	0
%	73.3	10.0	0	0	10.0	36.6	1.6	0
总平均%	日本松干蚧 41.7		红松干蚧 23.3		马尾松干蚧 0.8		己烷 0	

试验 5. 比较中国的日本松干蚧雌成虫性信息素 2.5FE (0.05 毫升) 滤纸片和 5 头红松干蚧雌成虫爬过 24 小时滤纸片之间 6 头红松干蚧雄成虫的行为。

经历时间 (分)	日本松干蚧滤纸片上雄虫数	红松干蚧滤纸片上雄虫数
2	1	5
4	2	3
6	1	3
8	1	3
10	1	3
12	2	4
14	1	4
16	0	5
18	0	4
20	0	5
%	15.0	65.0

## 第 I 组

试验 1. 比较中国的日本松干蚧雌成虫性信息素 5FE (0.1 毫升) 和己烷对照滤纸片之间用 10 头日本的日本松干蚧雄成虫的行为。

经历时间 (分)	实 验 1		实 验 2		实 验 3	
	中国样品	己烷对照	中国样品	己烷对照	中国样品	己烷对照
2	9	0	7	0	9	0
4	8	0	8	1	10	0
6	9	0	6	0	9	1
8	8	0	7	0	10	0
10	9	0	9	0	9	0
12	10	0	7	0	9	0
14	10	0	9	0	10	0
16	9	0	8	0	9	0
18	7	0	7	0	10	0
20	7	0	9	0	10	0
%	86.0	0	77.0	1.0	95.0	1.0
总平均%	中国样品 86.0		己烷对照 0.7			

试验 2. 比较日本的日本松干蚧 5 头雌成虫爬过 24 小时的滤纸片, 用 0.1 毫升己烷处理的对照滤纸片和不用己烷处理的对照滤纸片用 10 头日本的日本松干蚧雄成虫的行为。

经历时间 (分)	实 验 1			实 验 2			实 验 3		
	日本样品	已烷对照	无己烷对照	日本样品	已烷对照	无己烷对照	日本样品	已烷对照	无己烷对照
2	5	0	0	7	0	0	5	0	0
4	8	0	0	6	1	0	7	0	0
6	6	0	0	5	0	0	4	0	0
8	7	0	1	6	0	0	5	0	0
10	8	0	0	5	0	0	7	0	0
12	8	0	0	4	0	0	4	0	0
14	6	0	0	6	0	0	7	0	0
16	7	0	0	4	0	0	8	0	0
18	5	0	0	5	0	0	6	0	0
20	6	0	0	6	0	0	6	1	0
%	66	0	1	54	1	0	59	1	0

总平均%                      日本样品 59.7    己烷对照 0.7    无己烷对照 0.3

试验 3. 比较中国的日本松干蚧雌成虫性信息素 5FE (0.1 毫升)及 2.5FE (0.05 毫升)滤纸片、日本的日本松干蚧雌成虫 5 头爬过 24 小时的滤纸片及己烷 0.1 毫升对照滤纸片用 10 头日本的日本松干蚧雄成虫的行为。

经历时间 (分)	实 验 1				实 验 2				实 验 3			
	中国样品 5FE	中国样品 2.5FE	日本样品	己烷对照	中国样品 5FE	中国样品 2.5FE	日本样品	己烷对照	中国样品 5FE	中国样品 2.5FE	日本样品	己烷对照
2	5	2	3	0	4	1	2	0	6	3	1	0
4	7	1	1	0	6	2	2	0	5	2	3	0
6	7	2	1	0	5	2	3	0	4	1	2	1
8	7	1	2	0	6	1	3	0	5	1	3	0
10	6	1	2	1	5	2	2	0	4	2	2	1
12	7	2	1	0	6	1	2	0	5	1	2	1
14	6	2	2	0	5	2	2	1	4	3	3	0
16	7	1	2	0	6	1	1	0	5	2	2	0
18	6	1	2	0	5	2	2	0	5	1	3	0
20	7	2	1	0	6	1	3	0	5	1	3	0
%	65	15	17	1	54	15	22	1	48	17	24	3

总平均%                      中国样品 5FE 55.7    中国样品 2.5FE 15.7    日本样品 21.0    己烷 1.7

## 讨 论

根据第 I 组试验 1 的结果,非常清楚的是红松干蚧雄成虫强烈地被中国的日本松干蚧雌成虫性信息素吸引。杨平澜和祁云台(1983)用中国不同地区的日本松干蚧在种内所做的试验,被吸引到雌成虫性信息素 5FE 滤纸片上的雄成虫数平均达 84%。在第 I 组试验 1,有 77.5% 的红松干蚧雄成虫被吸引到中国的日本松干蚧雌成虫性信息素 5FE 滤纸片上。用日本的日本松干蚧做的试验得到相同的结果。在第 II 组试验 1,有 86% 的日本雄成虫被吸引到中国的样品上。

饶有兴趣的是,日本的日本松干蚧雄成虫被吸引到中国样品上的百分比(86%,第 I 组试验 1)高于被吸引到日本样品上的百分比(59.7%,第 II 组试验 2)。在康涅狄格的试验结果也有同样的情况。红松干蚧雄成虫被吸引到中国的日本松干蚧雌成虫性信息素样品有 77.5%(第 I 组试验 1),而被吸引到红松干蚧雌成虫性信息素样品仅有 66.7%(第 I 组试验 2)。这种现象可能是由于收集信息素的方法不同而引起的。用 5 头雌成虫在滤纸上收集到的信息素之量不可能与祁云台等(1983)所采用的气体收集法所收之量相等。这可从第 II 组试验 3 和第 I 组试验 4 实验 1 找到根据,其中雄成虫处于种内雌成虫性信息素污染过的样品及从中国采用气体收集法所收的样品。被吸引到中国样品上的雄虫数总是多于被吸引到日本的日本松干蚧样品或红松干蚧样品的雄虫数。在第 I 组试验 5,中国的日本松干蚧雌成虫性信息素之量减成一半,红松干蚧雌成虫性信息素之量保持不变,红松干蚧雄成虫被吸引到红松干蚧雌成虫性信息素样品上的个体数大于被吸引到中国的日本松干蚧雌成虫性信息素样品的个体数。在第 II 组试验 3,日本的日本松干蚧雄成虫被吸引到日本性信息素样品上的个体数几乎和被吸引到 2.5FE 中国样品上的个体数相等,而被吸引到 5FE 中国样品上的个体数则很大。这表明是样品浓度的作用。但是在第 I 组试验 4 实验 2 的结果和以上的情况并不一致,被吸引到红松干蚧样品的雄虫数(36.6%)大于被吸引到 5FE 中国样品的雄虫数(10.0%)。这显然表明在这试验里有某种异常,因为被吸引的雄虫总数几乎是实验 1 的一半。我们对这异常现象还无从解释。

我们应用马尾松干蚧雌成虫性信息素所得的结果,和杨平澜、祁云台(1983)所得的结果也不相同。他们的结果表明种间的吸引力相当大。被马尾松干蚧样品吸引的日本松干蚧雄成虫达 21%,被日本松干蚧样品吸引的马尾松干蚧雄成虫还要多(约 50%)。在我们的试验里,被马尾松干蚧雌成虫性信息素吸引的红松干蚧雄成虫仅有 6.7%。

## 结 论

我们的试验结果清楚地表明:红松干蚧雄成虫和日本的日本松干蚧雄成虫对于中国的日本松干蚧雌成虫性信息素有强烈的反应。日本的日本松干蚧有二个实验以及红松干蚧有一个实验,被吸引到中国的日本松干蚧性信息素样品上的雄虫数,比杨平澜、祁云台

(1983)所得到的日本松干蚧种内试验结果还要高。而且中国的日本松干蚧信息素样品对于红松干蚧雄成虫的吸引力，似乎和红松干蚧信息素样品对于红松干蚧雄成虫有一样的吸引力。这些结果可能表明红松干蚧和日本松干蚧是一个种类。

然而，在作出同种异名决断之前应考察到若干潜在的复杂性。(1)可能在相近的种类具有相同的性信息素。昆虫在其他类群的已知种间有交叉反应(Inscoe, 1982),特别在鳞翅目昆虫是如此。松干蚧种间交叉反应已由杨平澜、祁云台在试验中表明过。已经弄清信息素化学结构的两种蚧虫近缘种是红圆蚧(Roelofs 等, 1977)和黄圆蚧(Gieselmann 等, 1979)。研究结果表明,在这些几乎相同的种类,其信息素非常不同。在 Rotundo 和 Tremblay (1975)研究形态上非常相近的桔臀纹粉蚧和无花果臀纹粉蚧的信息素种间特异性中,发现其特异性很强,但他们没有做其化学结构。(2)我们的试验设计可能在行为研究方面有某些不足,以致造成结论上的失误。因此,我们在决断同种异名之前还要收集它们的其他资料。我们正进行精子结构和初孵若虫、无肢若虫、雌成虫和雄成虫的形态研究。

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ATTRACTIVITY OF THE FEMALE SEX PHEROMONE OF CHINESE  
*MATSUCCUS MATSUMURAE* (KUWANA) TO MALES OF *M.*  
*MATSUMURAE* IN JAPAN AND TO MALES OF *M. RESINOSAE*  
BEAN AND GODWIN IN THE UNITED STATES  
(MARGARODIDAE, COCCOIDEA, HOMOPTERA)

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The identity of species of the margarodid genus *Matsucoccus* frequently has been confused. In morphologically similar species, differences primarily are quantitative. Unfortunately, in *Matsucoccus pini* (Green) and probably in other species, the overwintering and summer generations have significantly different numbers and sizes of certain taxonomically important structures (Boratynski 1952). This problem only rarely has been taken into consideration when attempting to distinguish among *Matsucoccus* species and therefore is believed to be an important confounding factor. The most comprehensive study of the genus was undertaken by Boratynski (1952), but his study did not include all species and was based principally on information taken from published descriptions not on actual observations of a series of specimens.

In recent years, scientists in China and the United States have become increasingly concerned about the damage caused by *Matsucoccus* species to certain native pines. In China *Matsucoccus matsumurae* (Kuwana) (Japanese pine bast scale) causes significant damage in large stands of *Pinus densiflora*, *P. massoniana*, *P. tabulaeformis*, and *P. thunbergiana* (Young et al. 1976), and in certain areas of the northeastern United States *Matsucoccus resinosae* Bean and Godwin (red pine scale) is a lethal pest of *Pinus resinosa* (McClure 1983a). Because of the destructiveness and slowly expanding distribution of *Matsucoccus resinosae* and some convincing historical evidence, it has been surmised that the species was introduced into the United States. The species apparently arrived on exotic pines brought to the United States from Japan for the 1939 New York World Fair (McClure 1983b). The origin of the Chinese population of *M. matsumurae* also is open to speculation. There is some historical evidence suggesting that the species was introduced into China from Japan (McClure 1983b). Indeed, in Japan where *M. matsumurae* apparently is native, the species generally is innocuous, whereas in China the species is a serious pest. However, Young (in press) reported that *M. matsumurae* also may be indigenous to China for the following reasons. (1). He sug-

gested that the pine bast scale has become a pest in China not because of its recent introduction, but because of the extensive spray programs used in the forests against the pine lappet caterpillar, *Dendrolimus spectabilis* Butler. The insecticides apparently killed natural enemies and allowed *M. matsumurae* to reach pest status. (2) Discovery of the species in China was sporadic and did not occur in an expanding pattern as might be expected of an introduced pest. It usually was found in ornamental situations or in forests after the general use of insecticides. Young believes that the species was always in China but was not collected until it caused damage. (3) The pattern of natural occurrence of organisms in China, Japan, and Korea is prevalent throughout the Asian biota and would not be considered unusual.

There is considerable interest in ascertaining at least parts of the indigenous area of the species so that natural enemies can be located. Basic to discovery of these potential biological control agents is a comprehensive understanding of the taxonomic status of the *Matsucoccus matsumurae* complex, i.e., *M. insignis* Borchsenius, *M. matsumurae* (populations from China, Japan, and Korea), *M. pini*, and *M. resinosa*. We currently are studying three different aspects of the behavior and morphology of some or all components of the complex and these results will be published in a series of papers. Results of the first study are reported here. The remaining studies examine taxonomic characters found in sperm morphology and in external morphology of slide-mounted specimens.

The occurrence of a female sex pheromone was first demonstrated in *Matsucoccus* by Doane (1966) in *M. resinosa*. In 1983 Qi et al. began research on the female sex pheromone of Chinese populations of *M. matsumurae*. They developed methods for collecting the pheromone and performed preliminary behavioral experiments in the laboratory and in the field. Young and Qi (1983) collected female sex pheromone of *M. matsumurae* and *M. massoniana* Young and Hu and tested the responses of males of each species to determine the specificity of the pheromones. Although *M. massoniana* males did react to the female pheromone of *M. matsumurae*, and vice versa, the reaction was considerably less than in any of the intraspecific tests.

The purpose of this paper is to present data on the reaction of adult males of *M. resinosa* in the United States and of adult males of *M. matsumurae* in Japan to the female sex pheromone of Chinese populations of *M. matsumurae*. A strong reaction by the United States and Japanese males would be evidence supporting the hypothesis that all three populations are conspecific.

## METHODS

The female sex pheromone of *M. matsumurae* and *M. massoniana* was obtained by collecting the gases after they were passed over virgin adult females as described by Qi et al. (1983). Specimens used for gathering the pheromones were collected in Shandong in May 1983 and in Zhejiang in February 1983, respectively. The pheromone was in a solution of hexane; for *M. matsumurae*, 0.1 cc of the hexane solution was equal to five female equivalents (5FE) of the pheromone, and for *M. massoniana* 0.05 cc of the hexane solution was equal to 5 FE. The pheromone was transported to the United States and mailed to Japan in sealed ampules which were opened just before

conducting the experiments. Experiments were carried out in 10 cm diameter petri dish arenas in a room with overhead, florescent lights. The bottom of each petri dish was covered with filter paper and was marked with pencil to indicate the kind of experiment being conducted. An equivalent of 5 FE was applied to 1 cm filter paper disks using disposable tuberculin 1 cc syringes. The 1 cm disks were allowed to dry and were placed in the arena. Control disks were made using hexane only. Pheromone disks of *M. resinosa* and Japanese *M. matsumurae* were made by placing a 1 cm disk in the bottom of a small vial which also contained five virgin adult females. The females were left in the vials which were closed with a cotton plug for 24 hours. Control disks in experiments with *M. resinosa* sex pheromone also were treated with hexane; the correct control disk should have been a filter paper disk with no solvent. Control disks in the tests with intrapopulational female pheromone of Japanese *M. matsumurae* used both kinds of disks to determine if the reaction of the males was different to either kind of control; fortunately, there was no difference.

Specimens for the experiments were collected in the field and allowed to emerge as adults in the laboratory. Females were isolated as cysts in covered petri dishes and were left attached to small pieces of the host. Males were kept in separate dishes as cocoons and either were removed from the host or were left attached. Collecting sites of *M. resinosa* in 1984 were Saybrook (August 13 and 14) and Litchfield (August 15), Connecticut. Collecting sites for Japanese *M. matsumurae* in 1984 were in Kamigamo Experimental Forest of Kyoto University, Kyoto (August 14).

The experiments were carried out in three ways. If tests were conducted comparing two pheromones or a single pheromone against a check, then the arena was divided in half and a 1 cm disk was placed in each half of the arena. When tests were conducted comparing three compounds, the arena was divided into thirds and a 1 cm disk was placed in each section. When tests were conducted comparing four compounds, the arena was divided into four quarters and a 1 cm disk was placed in each quadrant. After the disks were in place, the adult males were introduced into the center of the arena one at a time. Because of the small number of *M. resinosa* males available, only six were used for each experiment. Ten males were used in each of the experiments with Japanese *M. matsumurae*. Beginning two minutes after the sixth or tenth male was first introduced into the arena, counts were made of the number of males in contact with each 1 cm disk. Counts were taken every two minutes for 20 minutes. Only the bottom half of the petri dish was used for the experiments, and males that climbed on the side of the dish were picked up with forceps and were placed in the middle of the arena again.

## RESULTS

The following eight experiments were conducted; five with *M. resinosa* in the United States (Group I) and three with *M. matsumurae* in Japan (Group II):

### GROUP I:

Experiment 1. By examining the behavior of six adult males of *M. resinosa* we compared a disk containing 5 FE (0.1 cc) of Chinese female sex pheromone of *M. matsumurae* with a disk treated with an equal amount of hexane alone.

Time elapsed in minutes	Trial 1		Trial 2	
	Males on <i>M. matsumurae</i> disk	Males on hexane disk	Males on <i>M. matsumurae</i> disk	Males on hexane disk
2	6	0	3	0
4	6	0	2	0
6	6	0	4	0
8	6	0	4	0
10	6	0	5	1
12	5	0	4	0
14	5	0	3	0
16	6	0	3	0
18	5	0	4	0
20	5	0	5	0
%	93.3	0	61.6	1.6
Total mean %	<i>M. matsumurae</i> 77.5		Hexane 0.8	

Experiment 2. By examining the behavior of six adult males of *M. resinosa* we compared a disk exposed to five virgin adult females of *M. resinosa* for 24 hours with a disk treated with 0.1 cc of hexane.

Time elapsed in minutes	Trial 1		Trial 2	
	Males on <i>M. resinosa</i> disk	Males on hexane disk	Males on <i>M. resinosa</i> disk	Males on hexane disk
2	4	0	4	0
4	4	0	5	1
6	3	0	5	0
8	4	0	6	0
10	4	0	4	0
12	3	0	5	0
14	3	0	5	0
16	3	0	5	0
18	2	0	4	0
20	2	0	5	0
%	53.3	0	80.0	1.6
Total mean %	<i>M. resinosa</i> 66.7		Hexane 0.8	

Experiment 3. By examining the behavior of three adult males in trial 1 and six adult males in trial 2 of *M. resinosa* we compared a disk containing 5FE (0.05 cc) of female sex pheromone of *M. massoniana* with a disk treated with an equal amount of hexane alone.

Time elapsed in minutes	Trial 1		Trial 2	
	Males on <i>M. massoniana</i> disk	Males on hexane disk	Males on <i>M. massoniana</i> disk	Males on hexane disk
2	1	0	0	0
4	0	0	0	0
6	1	0	0	0
8	1	0	1	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	1
20	0	0	1	0
%	10.0	0	3.3	1.6
Total mean %	<i>M. massoniana</i> 6.7		Hexane 0.8	

Experiment 4. By examining the behavior of six adult males of *M. resinosa* we compared a disk containing 5 FE (0.1 cc) of Chinese female sex pheromone of *M. matsumurae* with a disk exposed to five virgin adult females of *M. resinosa* for 24 hours with a disk containing 5 FE (0.05 cc) of female sex pheromone of *M. massoniana* with a disk treated with 0.1 cc of hexane.

Time elapsed in minutes	Trial 1				Trial 2			
	Males on <i>matsumurae</i> disk	Males on <i>resinosa</i> disk	Males on <i>massoniana</i> disk	Males on hexane disk	Males on <i>matsumurae</i> disk	Males on <i>resinosa</i> disk	Males on <i>massoniana</i> disk	Males on hexane disk
2	5	0	0	0	0	4	0	0
4	5	0	0	0	0	3	0	0
6	4	0	0	0	1	2	0	0
8	6	0	0	0	1	1	0	0
10	5	1	0	0	1	3	0	0
12	4	1	0	0	0	1	0	0
14	4	1	0	0	1	2	0	0
16	4	1	0	0	1	3	0	0
18	4	1	0	0	1	1	1	0
20	3	1	0	0	0	2	0	0
%	73.3	10.0	0	0	10.0	36.6	1.6	0
Total mean %	<i>M. matsumurae</i> 41.7	<i>M. resinosa</i> 23.3	<i>M. massoniana</i> 0.8		Hexane 0			

Experiment 5. By examining the behavior of six adult males of *M. resinosa* we compared a disk with 2.5 FE (0.05 cc) of Chinese female sex pheromone of *M. matsumurae* with a disk exposed to five virgin adult females of *M. resinosa* for 24 hours.

Time elapsed in minutes	Males on <i>M. matsumurae</i> disk	Males on <i>M. resinosa</i> disk
2	1	5
4	2	3
6	1	3
8	1	3
10	1	3
12	2	4
14	1	4
16	0	5
18	0	4
20	0	5
%	15.0	65.0

## GROUP II

Experiment 1. By examining the behavior of ten adult males of Japanese *M. matsumurae* we compared a disk containing 5 FE (0.1 cc) of Chinese female sex pheromone of *M. matsumurae* with a disk treated with an equal amount of hexane alone.

Time elapsed in minutes	Trial 1		Trial 2		Trial 3	
	Chinese	Hexane	Chinese	Hexane	Chinese	Hexane
2	9	0	7	0	9	0
4	8	0	8	1	10	0
6	9	0	6	0	9	1
8	8	0	7	0	10	0
10	9	0	9	0	9	0
12	10	0	7	0	9	0
14	10	0	9	0	10	0
16	9	0	8	0	9	0
18	7	0	7	0	10	0
20	7	0	9	0	10	0
%	86.0	0	77.0	1.0	95.0	1.0
Total mean %	Chinese 86.0		Hexane 0.7			

Experiment 2. By examining the behavior of ten adult males of Japanese *M. matsumurae* we compared a disk exposed to 5 virgin adult females of Japanese *M. matsumurae* for 24 hours with a disk treated with 0.1 cc of hexane, with a disk treated with nothing.

Time elapsed in minutes	Trial 1			Trial 2			Trial 3		
	Japanese	Hexane	Nothing	Japanese	Hexane	Nothing	Japanese	Hexane	Nothing
2	5	0	0	7	0	0	5	0	0
4	8	0	0	6	1	0	7	0	0
6	6	0	0	5	0	0	4	0	0
8	7	0	1	6	0	0	5	0	0
10	8	0	0	5	0	0	7	0	0
12	8	0	0	4	0	0	4	0	0
14	6	0	0	6	0	0	7	0	0
16	7	0	0	4	0	0	8	0	0
18	5	0	0	5	0	0	6	0	0
20	6	0	0	6	0	0	6	1	0
%	66	0	1	54	1	0	59	1	0
Total mean %	Japanese 59.7			Hexane 0.7			Nothing 0.3		

Experiment 3. By examining the behavior of ten adult males of Japanese *M. matsumurae* we compared a disk containing 5 FE (0.1 cc) and one containing 2.5 FE (0.05 cc) of Chinese female sex pheromone of *M. matsumurae*, with a disk exposed to five virgin females of Japanese *M. matsumurae* for 24 hours with a disk treated with 0.1 cc of hexane.

Time elapsed in minutes	Trial 1				Trial 2				Trial 3			
	Chinese		Japanese	Hexane	Chinese		Japanese	Hexane	Chinese		Japanese	Hexane
	5FE	2.5FE			5FE	2.5FE			5FE	2.5FE		
2	5	2	3	0	4	1	2	0	6	3	1	0
4	7	1	1	0	6	2	2	0	5	2	3	0
6	7	2	1	0	5	2	3	0	4	1	2	1
8	7	1	2	0	6	1	3	0	5	1	3	0
10	6	1	2	1	5	2	2	0	4	2	2	1
12	7	2	1	0	6	1	2	0	5	1	2	1
14	6	2	2	0	5	2	2	1	4	3	3	0
16	7	1	2	0	6	1	1	0	5	2	2	0
18	6	1	2	0	5	2	2	0	5	1	3	0
20	7	2	1	0	6	1	3	0	5	1	3	0
%	65.0	15.0	17.0	1.0	54.0	15.0	22.0	1.0	48.0	17.0	24.0	3.0
Total mean %	Chinese 5FE 55.7				Chinese 2.5FE 15.7				Japanese 21.0 Hexane 1.7			

## DISCUSSION

Based on the results of experiment 1 (Group I), it is quite clear that adult males of *M. resinosa* are strongly attracted to the adult female sex pheromone of Chinese populations of *M. matsumurae*. In similar experiments with conspecific populations of Chinese *M. matsumurae*, Young and Qi (1983) were able to attract an average of 84% of the adult males to filter paper disks containing 5 FE of female sex pheromone of *M. matsumurae*. In Experiment 1 (Group I), 77.5% of the males of *M. resinosa* were attracted to filter paper disks containing 5 FE of female sex pheromone of *M. matsumurae* from China. Experiments performed with Japanese populations provided similar results. In Experiment 1 (Group II), 86% of the adult males of Japanese *M. matsumurae* were attracted to the sex pheromone of the Chinese adult females of *M. matsumurae*.

It is interesting to note that a higher percentage of males of Japanese *M. matsumurae* were attracted to the Chinese female pheromone (86%) (Experiment 1, Group II) than were attracted to the female pheromone of Japanese *M. matsumurae* (59.7%) (Experiment 2, Group II). Similar results were found in the Connecticut experiments where 77.5% (Experiment 1, Group I) of the males of *M. resinosa* were attracted to the Chinese female pheromone and only 66.7% (Experiments 2, Group I) of the males were attracted to the female pheromone of *M. resinosa*. This phenomenon probably is a reflection of the lack of comparability of the methods of collecting the pheromone. There is no reason to expect that the quantity of pheromone deposited by five virgin females over a 24 hour period will be the same as that collected by the "aeration" method of Qi et al. (1983). This premise is supported by the results of Experiments 3 (Group II) and 4 (Trial 1) (Group I) where males were exposed simultaneously to pheromone from intrapopulation females and to Chinese pheromone. More adult males were attracted to the Chinese *M. matsumurae* disks than to either the Japanese *M. matsumurae* or to the *M. resinosa* disks. In Experiment 5 (Group I), the quantity of Chinese female sex pheromone of *M. matsumurae* was reduced by half while the quantity of *M. resinosa* pheromone was kept constant. At these concentrations the *M. resinosa* female pheromone was more attractive to males of *M. resinosa* than was the Chinese *M. matsumurae* pheromone. In Experiment 3 (Group II), males of Japanese populations were found to be approximately equally attracted to disks containing pheromone of adult females from Japan and to disks containing 2.5 FE of Chinese pheromone; whereas, they were considerably more attracted to disks containing 5 FE of Chinese pheromone. These data suggest that there is a concentration effect. However, the results of Experiment 4 (Trial 2) (Group I) are inconsistent with these findings since more males were attracted to the *M. resinosa* disk (36.6%) than to the disk that contained 5 FE of Chinese *M. matsumurae* (10.0%). It is obvious that something different occurred during this trial, since total male attraction was approximately half of Trial 1. Unfortunately, we do not have an explanation for this inconsistency.

It also is of interest to note that our results with the adult female pheromone of *M. massoniana* are quite different from the findings of Young and Qi (1983). Their results showed a considerable amount of interspecific attractiveness. They found that about 21% of the adult males of *M. matsumurae* were attracted to female pheromone of *M. massoniana*. An even higher percentage of attraction was found between adult males of *M. massoniana* and female pheromone of *M. matsumurae* (about 50%). In our experiments only 6.7% of the adult males of *M. resinosa* were attracted to female pheromone of *M. massoniana*.

### CONCLUSION

The results of our experiments clearly demonstrate that adult males of *M. resinosa* and of Japanese *M. matsumurae* are strongly attracted to the sex pheromone of adult females of Chinese populations of *M. matsumurae*. In two trials Japanese *M. matsumurae* males and in one trial *M. resinosa* males showed a stronger attraction to the female pheromone of *M. matsumurae* than did any of the conspecific males tested by Young and Qi (1983). Furthermore, the Chinese pheromone seemed to be as attractive to males of *M. resinosa* as the female pheromone of *M. resinosa*. The results of this research provide evidence that *M. resinosa* may be a junior synonym of *M. matsumurae*.

However, there are several potential complications that need to be considered before a decision can be made concerning this synonymy. (1) It is possible that closely related species may have identical sex pheromones. Cross attraction among different species is known in other insect groups (Inscoc 1982), particularly the Lepidoptera, and has been demonstrated here and in the experiments by Young and Qi in *Matsucoccus*. The only research that has deciphered the chemical structure of the pheromones of two closely related scale-insect species involved *Aonidiella aurantii* (Maskell) (Roelofs et al. 1977) and *A. citrina* (Coquillett) (Gieslmann et al. 1979). Results of this research demonstrated that these virtually identical species have pheromones that are strikingly different. A study by Rotundo and Tremblay (1975) examined the specificity of the pheromones of the nearly morphologically identical mealybugs *Planococcus citri* (Risso) and *P. ficus* (Signoret), but they did not investigate the chemical structure of the pheromones. Their bioassays demonstrated a high degree of pheromone specificity. (2) The experimental design of our tests may have been set up in such a way that certain behavioral requisites were prohibited causing our conclusions to be misleading. Therefore, we believe that it is essential for us also to gather information from other data sources before reaching a conclusion about synonymy within this group. We currently are conducting research on the taxonomic characters of the sperm and of the external morphology of the first instars, cysts, adult females, and adult males.

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