张秦风研究员论文集

李振岐题

陕西省农业科学院

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序

张秦风研究员，为我系毕业校友，也是我的好友。他自1955年毕业后迄今，一直在陕西省农科院植保所工作，从事植物病理学研究，主要研究粮食作物病毒病特别是麦类病害的发生规律及其防治，并且兼任中国植物病理学会理事、中国植物病理学会西北区分会理事、陕西省植物病理学会副理事长，历任陕西省自然科学系列（农业）高级科研职称评委、陕西省农科院学术委员会委员等职。他一向关心生产，思想敏捷，工作认真，善于钻研，学风严谨，业绩显著。他在谷子白发病、小麦黄矮病（BYDV）、小麦类菌原体（MLO）兰矮病（WMBD）、小麦梭条花叶病（WSSMV）、玉米黄矮病（BYDV）和水稻黄矮病（BYDV）等方面均有创造性研究成果，其中与朱象三研究员共同主持完成的“小麦黄矮病发生和防治技术研究”获农业部1987年科学技术进步二等奖和陕西省1988年科学技术进步一等奖；小麦黄矮病病毒株系鉴定、谷子白发病菌分生孢子系统侵染研究、小麦梭条花叶病鉴定研究、小麦黄矮病介体蚜虫个体带毒免疫电泳测试技术研究和小麦类菌原体兰矮病新病害鉴定均获陕西省农牧厅或陕西省农科院科学技术进步奖。

先后发表论文44篇以上，其中在《微生物学报》、《植物病理学报》、《植物保护学报》和《中国病毒学》上发表14篇；主要有《谷子白发病菌分生孢子系统侵染研究》、《小麦品种抗耐黄矮病性鉴定初步研究》、《类菌原体引起的小麦兰矮病》、《陕西省小麦梭条花叶病（WSSMV）鉴定研究》、《玉米感染小麦黄矮病（BYDV）初步研究》和

《水稻感染小麦黄矮病(BYDV)初步研究》等。研究解决了谷子白发病菌分生孢子系统再侵染的难题,填补了空白;最早鉴定出了我国小麦黄矮病毒(BYDV)主要株系为麦二岔蚜/禾谷缢蚜株系(GPV)和麦无网蚜/麦长管蚜株系(DAV);首次鉴定筛选出了大麦黄矮病毒(BYDV)的小麦抗源种质小偃麦中5与中4;发现了小麦黄矮病红穗症状与介体禾谷缢蚜对小麦黄矮病的传播能力的变异;试制成介体蚜虫传播小麦黄矮病个体带毒的免疫电泳测试技术;研究明确了西北及北方历史性冬小麦大面积"死亡"灾害的原因为类菌原体引起的小麦病害等问题。

在本论文集中选编的论文,多数是以他为主完成的。论文立论明确,文字简练,数据翔实可靠,创新性强,对读者很有启发和参考价值,对生产和进一步深入研究也有重要指导作用。

由于以上贡献,他1989年获陕西省科协"七五"优秀科技工作者称号;1994年获中共陕西省直属机关工委在建设四化、统一祖国、振兴中华事业中做出重大贡献的荣誉证书;1993年开始享受政府特殊津贴。

中国工程院院士、西北农林科技大学教授:

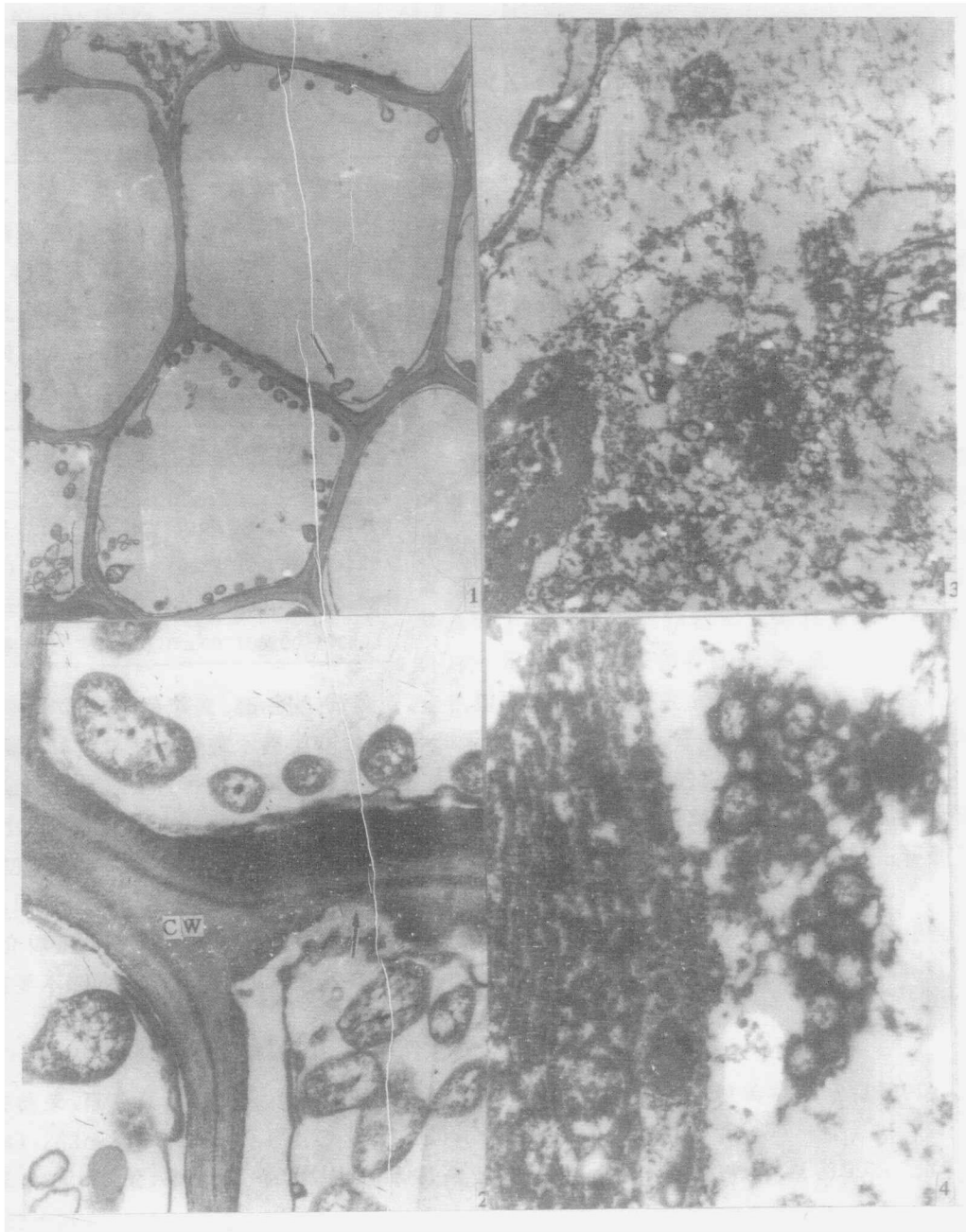
1999年10月7日

图版说明

Explanation of plate

1、2. 小麦蓝矮病株韧皮部筛管细胞的 MLO：1. 沿细胞壁分布 MLO，箭头示处于二分裂阶段(6000X)；2. 局部放大，箭头示细胞壁被侵蚀(30000X)。3、4. 介体条沙叶蝉唾液腺组织的 MLO：3. 唾液腺组织的 MLO(6000X)；4. 局部放大的 MLO. O(20000X)。

1,2. MLO of the sieve tube cell of the host phloem: 1. MLO is dispersed along cell wall. Arrow points to the binary fission stage of MLO; 2. Partial magnification. Arrow point to evoded cell wall. 3,4. MLO of the salivary gland of the vector Psammottix striatus; 3. MLO of the salivary; 4. MLO of partical magnification.



目　录

谷子白发病菌 *Sclerospora graminicola*(*sacc.*) *Schrot* 分生孢子系统侵染研究初报

张 秦 风

中国农业科学院陕西分院

提 要 谷子白发病菌分生孢子在一定湿度条件下，能从谷子的分生组织分蘖分枝幼芽、幼穗、幼叶、幼苗和胚芽上侵入而形成系统侵染发病；所产生的分生孢子与卵孢子侵染产生的分生孢子，在侵染致病特性上并无差异。在谷子各个生育阶段的病征也与卵孢子侵染完全一致，并丰产卵孢子。

由于分生孢子的系统侵染，因此陕西省陕北和关中地区谷子白发病在多雨年份比少雨年份、低湿田块比高燥田块田间发病显著严重。

白发病菌还可能通过分生孢子系统侵染而进行杂交产生新生理小种。

谷子白发病菌卵孢子系统侵染问题，国内早经肯定；而分生孢子只肯定是局部侵染，能否形成系统侵染，尚未定论[1,2]。在国外，曾提到谷子白发病菌分生孢子能系统侵染谷子，造成流行[4]。

陕北地区春谷种植时常常干旱缺墒。年雨量的二分之一以上都集中在7、8、9三月，此时正值谷子的幼苗阶段。根据群众经验，白发病在多雨年份比少雨年份显著严重，这可能与其分生孢子系统侵染有关。

又根据田间调查，在品种抗病性和环境条件基本一致的情况下，分蘖品种主茎和单秆品种发病率大致相同。但是，分蘖品种的无病主茎的分蘖及其分枝却大量发病或是分蘖、分枝在主茎普遍发病之后再大量发病。分蘖发病绝大多数都是次生弱小分蘖，分枝几乎全部发病。有些田块中，尽管主茎发病相差悬殊，但是，分蘖、分枝发病却相当一致。这些现象显然难以完全用卵孢子初侵染来说明。

由于上述的理由因此想到，谷子白发病菌除了卵孢子成为系统侵染的初侵染来源外，分生孢子似乎有引致分蘖、分枝、幼芽而形成系统侵染的可能。因此，自1961—1964年初步进行了分蘖幼芽、幼穗、幼叶、幼苗和胚芽等分生孢子接种试验。

实 验

发病指示品种系当地感病的分蘖品种九根齐、单秆品种大旗线和小黄谷。供试菌种* 分别采自九根齐、大旗线、小黄谷和辽东黄等品种。

以灭菌或无菌土壤播种灭菌种子，培育无病健苗。种子灭菌是用1∶300的甲醛液，浸种

* 在工作过程中，得到朱象三先生的大力支持和帮助，文稿承俞大绂、孙万祥教授、李振岐副教授和刘汉文先生审阅，特此一并致谢。

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20分钟或流水冲洗24小时。土壤灭菌是用40%甲醛，每立方米土壤施用1,300毫升。

田间小区面积，1963年为1×2米，重复1—4次，1964年为3×5米，重复1次。

接种方法：分蘖幼芽接种，即在分蘖分生期间，陆续以净毛笔蘸新鲜的分生孢子悬浮液，滴注于着生分生分蘖的第2、3个叶鞘内；幼穗接种，即在形成1—2毫米长的幼穗时，抽掉心叶，露出幼穗，于抽掉心叶的叶鞘内灌注分生孢子悬浮液5毫升，塞于脱脂棉球，保湿24小时后取掉；幼苗接种，即在幼苗开始出土时，灌足水、喷洒分生孢子悬浮液，每隔4小时喷洒1次，共3次，每次接种之后12小时内，加玻璃罩或玻璃箱保湿；胚芽接种，即在开始出芽后，喷洒分生孢子悬浮液，每隔4小时喷洒1次，共3次，每次接种后12小时内，加皿盖保湿。

以隔离播种、隔离置放、不接种为对照。为了防止自然传染，田间试验进行隔离保护，即在幼苗着生分蘖的第2、3个叶鞘部位，套一玻璃纸筒，顶端用药棉(0.08%硫酸铜液浸渍普通棉絮)环茎包扎一药带，每隔1周或雨后更换1次；分蘖拔节以后，每隔5天全株喷洒0.1%富民隆溶液一次，雨后补喷，至分蘖分生结束为止。

(一)接　种

1. 分蘖幼芽接种：供试品种为九根齐，分别于1963年4月11日、26日、5月11日和26日播种，在分蘖期间分批隔1、2日接种1次。分别于6月12日、18日、30日和7月1日始现"灰背"，进而呈现"白尖"、"枪杆"，极少"看谷老"，并丰产卵孢子。在谷子整个生长期，无论接种或对照，主茎均不发病，说明无病健苗是可靠的。9月1日末次检查结果(表1)，接种的分蘖发病显著，对照则无病，证明分生孢子可从分蘖幼芽形成系统侵染。

表1　分蘖接种发病试验(田间试验)

(1963年　延安)

处　理		株数	分蘖发病株数	发病%
Ⅰ	接　种	30	18	60.0
	不接种	34	0	0.0
Ⅱ	接　种	38	23	60.5
	不接种	36	0	0.0
Ⅲ	接　种	43	31	72.1
	不接种	40	0	0.0
Ⅳ	接　种	30	18	60.0
	不接种	37	0	0.0

表2　分蘖接种发病试验(庭院试验)

(1963年　延安)

处　理	株　数	分蘖发病株数	发病%
接　种	26	12	46.2
不接种	30	0	0.0

由于田间试验对照隔离不易彻底，因此，又在庭院进行重复试验。于5月12日播种，6月10日到7月15日每隔1、2日接种1次，7月15日始现灰背。9月1日末次检查发病结果(表2)，与田间试验一致。

表3　幼穗、顶叶接种发病试验(1963年延安)

处　理		茎　数	穗发病茎数	发　病%	顶叶发病茎数	发　病%	穗顶叶发病茎数	发　病%	总发病(%)
小黄谷	接　种	27	5	18.51	3	11.11	13	48.14	77.77
	不接种	16	0	0.00	0	0.00	0	0.00	0.00
九根齐	接　种	57	8	14.07	4	7.01	15	20.31	47.36
	不接种	33	0	0.00	0	0.00	0	0.00	0.00

2. 幼穗、幼叶接种：1963年供试品种为小黄谷和九根齐，小黄谷于5月2日播种，7月2日接种，27日开始现病；九根齐于5月11日播种，7月6日接种，29日开始现病。穗发病呈

现"看谷老",顶叶发病呈现灰背、白尖和枪杆。9月2日末次检查结果(表3),接种的穗、顶叶发病均极明显,对照则无病,证明分生孢子可以从幼穗、顶叶形成系统侵染。

1964年供试品种为九根齐,一次试验于5月6日播种,12日出苗,16日当2叶舒展、3叶冒尖时进行喷洒接种,28日新出叶片始现灰背,6月11日普遍显现灰背;另一次试验于3月30日播种,4月7日出苗,当6、7叶期时于5月23日抽掉心叶,在其叶鞘内灌注分生孢子悬浮液接种,6月8日始现灰背。两次试验于8月10日末次检查发病结果(表4),与1963年试验结果一致。

表4 幼叶接种发病试验(1964年武功)

处理		2叶舒展期接种			6、7叶期接种		
		苗数	发病苗数	发病%	苗数	发病苗数	发病%
I	接种	34	16	47.1	26	6	23.1
	不接种	36	0	0.0	29	0	0.0
II	接种	28	9	32.1	—	—	—
	不接种	29	0	0.0	—	—	—

3. 幼苗接种:1963年春谷播期多雨潮湿,发现田间个别幼苗叶上的局部叶斑扩大到叶面的一半甚至大半;7月11日发现延安专区农科所的晚播春谷比早播春谷发病显著严重,发病率成数十倍的增加。根据这一现象推想,可能分生孢子从开始出土的幼苗侵入而形成系统侵染。为了观察灰背和局部叶斑上不同来源的分生孢子侵染致病能力是否一致,进行了不同来源的分生孢子接种试验。

1963年供试品种为小黄谷和大旗线。局部叶斑上的分生孢子的接种试验于7月12日盆栽播种,15日幼苗开始出土,当日接种,20日始现灰背,22日普遍显现灰背,对照无病。灰背上的分生孢子接种试验于7月21日播种,23日幼苗开始出土,当日接种,28日始现灰背,31日普遍显现灰背,对照无病。表5结果指出,不同来源的分生孢子均可从开始出土的幼苗侵入形成系统侵染,致病能力并无差异,与卵孢子初侵染相同。

表5 幼苗接种发病试验(1963年延安)

处理		接种灰背分生孢子			接种叶斑分生孢子		
		苗数	发病苗数	发病%	苗数	发病苗数	发病%
I	接种	47	37	78.7	158	125	79.1
	不接种	267	0	0.0	162	0	0.0
II	接种	79	33	41.8	357	251	42.4
	不接种	—	—	—	341	0	0.0

表6 幼苗接种发病试验(1964年武功)

处理	苗数	发病苗数	发病%
接种	37	34	91.9
不接种	31	0	0.0

注:表列为6个重复的平均数。

1964年供试品种为九根齐,5月12日盆栽播种,15日出苗,16日接种,24日始现灰背,25日普遍显现灰背,对照无病,与1963年结果一致(表6)。

为了观察分生孢子侵染幼苗后的成株期病征,于6月2日移植幼苗接种发病的灰背幼苗于田间。观察结果,在14株发病幼苗中,有9株形成枪杆病株,有5株在灰背期后病征隐蔽而正常抽穗,后者可能主要与干旱有关。1963年在延安田间观察,幼苗发病的成株期亦大

都形成枪杆，极少看谷老。

4. 胚芽接种：1963 年供试品种为大旗线，7 月 23 日皿栽播种，25 日出芽，当日接种，30 日始现灰背，8 月 1 日普遍显现灰背，对照无病。1964 年供试品种为九根齐，5 月 12 日皿栽播种，13 日出芽，14 日接种，22 日始现灰背，23 日普遍显现灰背，对照无病(表 7)。说明分生孢子可从胚芽侵入形成系统侵染。

表 7　胚芽接种发病试验　（武功、延安）

处　理	1963 年			1964 年		
	幼芽数	发病幼芽数	发病 %	幼芽数	发病幼芽数	发病 %
接　种	118	92	78.0	66.0	49.0	74.2
不接种	167	0	0.0	73.0	0	0.0

注：1964 年为 3 个重复的平均数。

为了观察分生孢子侵染胚芽后的成株期病征，于 5 月 21 日移植接种胚芽于田间，结果 56 颗胚芽中形成 22 株灰背病株，其中 18 株为枪杆病株，4 株在灰背期后病征隐蔽而正常抽穗，这可能与干旱有关。

根据以上试验结果，证明分生孢子具有系统侵染的特性。

(二)单株系统发病观察

为了观察分生孢子系统侵染的系统发病情况，将九根齐进行幼苗接种，5 月 22 日发病的幼苗，于 6 月 10 日分别移植单株于庭院刺柏林带间，谷苗复元后，从 6 月 19 日起每隔 5—7天喷洒 500 倍的代森锌溶液一次，雨后补喷，直到所有植株的叶片发病终止为止，以防止外来的与本株上的分生孢子的再侵染。系统观察结果，移植处理的 10 株病苗均是由下而上的逐叶逐期发病，最后形成枪杆病株 。

此外，根据田间观察，后期次生弱小分蘖和分枝自然感病后即导致全部叶片发病。以上结果指出分生孢子可以系统侵染发病。

(三)田间自然传病试验

为了解田间条件下分生孢子系统侵染的情况，1964 年在武功进行如下 3 个分生孢子自然传病试验。供试品种为九根齐，菌种为九根齐上的菌株。

1. 3 月 27 日播种，在培育无病健苗区两侧接种卵孢子，作为繁殖分生孢子的菌源区，令其自然传病。菌源区 4 月 27 日始现灰背，5 月 3 日普遍显现灰背。无病健苗 5 月 7 日开始分蘖，28 日分蘖始现灰背，30 日新出幼叶始现灰背，6 月 24 日检查发病结果(表 8)，分蘖、幼叶普遍显现灰背，始现白尖，幼穗始现看谷老；设置在庭院内的无病健苗对照则无病。

表 8　田间传病试验

处　理		株　数	分蘖发病株　数	发病 %	幼叶发病株　数	发病%	穗发病株　数	发病%	分蘖幼叶发病株数	发病%	总发病(%)
传病	I	253	43	17.0	59	23.3	2	0.8	74	29.2	70.4
	II	273	54	19.8	64	23.4	1	0.4	46	16.8	60.4
不传病		139	0	0.0	0	0.0	0	0.0	0	0.0	0.0

2. 为了了解分生孢子系统侵染所产生的分生孢子的自然传病情况，在移植发病幼苗和接种胚芽区旁，又移植一批无病健芽，使其分生孢子再次自然传病。无病健芽长成的分蘖植

株5月29日分蘖始现灰背，7月2日普遍显现灰背，8月10日末次检查发病结果，30株分蘖植株中分蘖发病者24株，发病株率为80%，对照则无病。

3. 无病健苗5月11日播种，14日出苗，当2叶舒展后，于22日撒布灰背病叶于苗行间，令其分生孢子自然传病。6月3日幼苗始现灰背，7月6日普遍显现灰背，8月10日末次检查发病结果，18株无病健株苗中有12株发病(枪杆)，发病株率为66.66%；对照则无病。

根据以上自然传病试验结果，说明无论白发病菌卵孢子或分生孢子系统侵染所产生的分生孢子，在田间条件下均可造成显著的系统侵染。

讨论与结论

由上述人工接种、自然传病试验和单株系统发病观察所获得的结果，证知在谷子各个发育阶段凡是具有分生组织的幼嫩器官，均可被白发病菌分生孢子侵入而形成系统侵染。沙菲那[3]对御谷(*Pennisetum glaucum*)幼苗以分生孢子悬浮液浸泡接种后，在潮湿条件下获得类似结果。俞大纹所以未能肯定分生孢子可以形成系统侵染的原因[1,2]，可能是由于未进行分生组织的幼嫩器官的接种试验。白发病菌分生孢子究竟形成系统侵染抑是局部侵染，因病菌生理类型的致病性、侵染部位的发育阶段以及环境条件而异。这个问题尚需进一步研究。过去报导大都认为，干土、半干土适宜卵孢子的侵染；但田间观察却常常是低湿田块比高燥田块，多雨年分比少雨年分发病严重，可能是因为多雨低、湿的条件有利于分生孢子对分生组织幼嫩器官的系统侵染之故。作者认为，在不同地区的不同条件下，由于白发病的侵染的菌源不同而发病程度亦不同，在少雨年分和某些高燥地区，田间发病主要来源于卵孢子的初侵染，故发病轻；而在多雨年分和某些低、湿地区，除了卵孢子的初侵染外，还有分生孢子的不断系统侵染，不仅造成当年白发病严重发生，而且为来年积累了卵孢子初侵染菌源，使病害逐年加重。根据历年在不同地区调查，分生孢子系统侵染的不同类型中以分蘖分枝发病最为显著。

陕北比关中分生孢子系统侵染显著严重，由于陕北种植感病分蘖品种较多，谷子播种、分蘖分枝分生期限参差不齐，春谷与夏谷插茬配植，因而可以陆续产生、供给分生孢子菌源和可被侵染的分生组织的幼嫩器官，大大增加了分生孢子系统侵染的机率。

在自然条件下，分生孢子系统侵染的机率究竟有多少以及它在病害流行中的意义，这是一个复杂的问题。与谷子品种的抗病性、病原菌生理类型的致病性以及环境条件有关，需进一步研究。

分生孢子系统侵染在谷子各个生育阶段的病症，与卵孢子的初侵染完全一致，并且丰产卵孢子。不同生理小种的分生孢子混合侵染，给生理小种鉴定和抗病育种工作带来新的问题和困难。所以进一步探索白发病菌分生孢子系统侵染的致病性的遗传性，在理论上或者实践上均有着重要的意义。白发病菌的卵孢子，严格说来都是杂交体，不易获得纯系，致病性也不尽一致；而由分生孢子系统侵染所产生的卵孢子，则可获得致病性一致的纯系，因此适用于进行病菌生理小鉴定以及品种抗病性鉴定等工作。

此外，谷子白发病菌分生孢子，还可能以同样的动态侵染其它寄主。根据1963－1964年调查，陕北北部风砂区普遍生长的绿色狗尾草，其无病主茎的分蘖及其分枝，特别是次生分蘖分枝白发病也很严重，与谷子白发病菌分生孢子系统侵染类似。

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STUDIES ON THE SYSTEMIC INFECTION INDUCED BY SPORANGIA OF SCLEROSPORA GRAMINICOLA IN MILLET

Zhang Ching—fong

(Shensi Branch, Chinese Academy of Agricultural Sciences)

Field observations revealed that the severity of millet downy mildew varied from year to year with rainfall during seedling stage in Northern Shensi, and that the systemic infection occurred.

Artificial inoculation of all young organs possessing meristemic tissue with sporangia resulted a high percentage of systemic infection and the production of numerous oospores.

Trnasmission of Barley Yellow Dwarf Virus Strains from Northwestern China by Four Aphid Species

Q. F. ZHANG, W. N. GUAN, Z. Y. REN, and X. S. ZHU, Plant Virus Research Laboratory, Plant Protection Institute, Shaanxi Academy of Agricultural Sciences, Wugong, Shaanxi Province, People's Republic of China, and J. H. TSAI, Agricultural Research and Education Center, University of Florida, Fort Lauderdale 33314

ABSTRACT

Zhang, Q. F., Guan. W. N., Ren, Z. Y., Zhu, X. S., and Tsai, J. H. 1983. transmission of barley yellow dwarf virus strains from northwestern China by four aphid species. Plant Disease 67:895—899.

During a 3—yr period, 66 barley yellow dwarf virus (BYDV)—infected wheat plants were collected from 17 localities in Shanxi, Shaanxi, Gansu, and Henan provinces of the People's Republic of China. Four strains of BYDV (GPV, DAV, RPV, and GPDAV) were identified on the basis of differential aphid transmissions. the predominant strain was GPV, which was found in 77.3% of the 66 samples tested. GPV was transmitted nonspecifically by *Schizaphis gramimum* and *Rhopalosiphum padi*, but transmission by *S. graminum* was 36.8% more efficient than by *R. Padi*. *Macrosiphum avenae* rarely transmitted GPV. This strain was not transmitted by *Acyrthosiphon dirhodum*. DAV was found in 15.2% of the total 66 samples. DAV was transmitted nonspecifically by *S. graminum*, *M. avenae*, and *A. dirhodum* but was not transmitted by *R. Padi*. RPV was found in 4.5% of the samples, RPV was transmitted exclusively by R. Padi, and GPDAV was found in 3%of the samples. this strain was transmitted nonspecifically by all four aphid species. The vector specificity of GPV and DAV remained constant regardless of the number of aphids used in the tests. *S. Graminum* and *M. auenae* apparently acquired and inoculated GPV and DAV strains. respectively, in as short a time as 1 min. Increase in duration of acquisition and inoculation feeding time did not appreciably increase the rate of transmission. Both nymphs and adults of *S. Graminum* and *M. avenac* wew efficient transmitters of BYDV. The median latent period (LP_{50}) values in both vector species were about the same. The mean retention period of BYDV was 20.1days in *S. graminum* and 13.9 days in *M. avenae*. There were significant differences in varietal reaction to GPV and DAV among the 24 wheat cultivars tested, ranging from 0.0 to 85.7% infection.

Additional key word: luteoviruses

Barley yellow dwarf virus (BYDV) is the most common and widely distributed cereal virus in the world. It has been reported in Australia (4), Belgium (27), Canada (16), Czechoslovakia (31), England (33), Finland (12), Germany (18), India (15), Israel (11), the Netherlands (17), Sweden (14), adn the United States (1. 19). Its host range includes about 100 species of Gramineae; no dicotyledonous plants have ever been reported susceptible (24). Among the Gramineae, barley, oats, wheat, rice, corn, and rye are the most economically important hosts of BYDV. Transmission of BYDV is dependent on vector species, virus isolates, test plant species, source plants, and temperature (22). Five isolates of BYDV, namely PAV, MAV. RPV, RMV, and SGV, have been differentiated on the basis of vector specificity and serology in the United States during the past 20 yr (25). Similar isolates have been reported in Canada by Gill (7) and their relationships were based partly on results of aphid transmission tests and partly on cytological reactions (8,9).

BYDV has been known to occur in the People's Republic of China (PRC) for the last two decades (34). The disease reached epidemic proportions in 1966, 1970,1973 and 1978 over a vast area in China, including Shaanxi, Gansu, Shanxi, Henan, Hebei, and Shandong provinces as well as Ningxia and Nei Monggal (Inner Mongolia) autonomous regions. Other localized BYDV infestations during this period occurred in Liaoning, Jilin, Heilongjiang, Jiangsu, Anhui, Sichaun, Guizhou, and Qinhai provinces as well

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as Xingjiang and Xizang autonomous regions. Yield losses in wheat caused by BYDV have been estimated at 20—30%. As a result of the Cultural Revolution, no basic research on vector—virus—host relationships was encouraged during that 10—yr period. This paper reports identification of four strains of BYDV from wheat by differential aphid transmissions. We have tentatively designated these strains as GPV, DAV, RPV, and GPDAV. The transmission characteristics of two dominant strains of BYDV are also reported.

Materials and methods

Aphid species used in this study were *Rhopalosiphum padi* (L.), *Macrosiphum* (=*Sitobion*) *avenae* (Fabricius), *Schizaphis graminum* (Rondani), and *Acyrthosiphon dirhodum* (Walker). Each of these four species (RP, MA, SG, AD, respectively) represented progeny of a single viviparous female originating from Wugong in Shaanxi Province or Gangu in Gansu Province. All stock colonies of virus—free aphids were reared on caged wheat plants (*Triticum aestivum* L.) in an isolated room under 12—hr fluorescent illumination at about 23 C. A group of aphids from each species was also used as controls in the experiments.

A total of 66 infected plants showing BYDV symptoms was collected from 12 localities in Shanxi, Shaanxi, Gansu, and henan provineces. One to three leaves, from each of these 66 infected plants was each divided into four sections, and each section was placed in a separete petri dish containing a given test—aphid species. Four—to 5—wk—old plants inoculated in the first test were selected at random for subsequent tests with the four aphid species, this process was repeated for two to five cycles. All viruses were routinely maintained by serial transmissions by aphids to *Avena nuda* L. at 4 to 5—wk intervals. *A. nuda* seedlings in the two leaf stage were used as test plants for transmission trials. All insects were starved for at least 2 hr before each test in order to enhance the initiation of feeding.

For vector specificity tests, an acquisition access period of usually 2 days at 22±1 C was followed by transfer of two aphids by means of a camel's hair brush from each detached, infected leaf to each *A. nuda* test seedling for an inoculation access period (IAP) of 25 days at 22±1 C. In one test, transfers included five aphids per seedling and 10 aphids per seedling for comparison. In all trials, test insects and plants were sprayed with DDVP (2. 2—dichlorovinyl dimethyl phosphate) at the end of the inoculation access period, after which plants were placed on a greenhouse bench for at least 6 wk and observed for symptom development. Symptomatology was the only means used throughout this study to confirm the experimental results. Occasionally, a few symptomless plants resulting from various transmission trials were selected for aphid—acquisition checks. No transmission ever occurred.

To obtain a more precise comparison between virus strains and aphid species, individual insects were serially transferred to healthy seedlings at 2—hr intervals for 30 hr to determine the median latent period (LP_{50}) using Sylvester's method (28). Retention of BYDV inoculativity by aphids was determined by transfer of test insects, singly at daily intervals, until the death of the insects. For studying transmission characteristics of two dominant of BYDV, GPV and DAV, by their vectors *S. graminum* and *M. avenae*, vespectively, individual insects were carefully observed and precisely timed during various acquisition and inoculation feeding periods.

RESULTS

Results from 66 samples of BYDV—infected wheat collected from Shanxi, Shaanxi, Gansu, and Henan provinces during 1978—1981 are summarized in Table 1. Four distinct strains of BYDV were detected in northwestern China. The predominant strain was GPV, which was transmitted nonspecifically by both *S. graminum* and *R. padi*, but transmission by *S. graminum* (55. 3%) was more efficient than by *R. padi* (18. 5%). *M. avenae* rarely transmitted GPV and it was not transmitted by *A. dirhodum*. The second most

predominant strain was DAV, which was transmitted non specifically by *S. graminum*, *M. avenae*, *and A. dirhodum* (30.8, 38.1, and 25.0%, respectively) but was not transmitted by *R. padi*. The third strain was RPV, which was transmitted exclusively by *R. padi*. The fourth strain. GPDAV, was transmitted non-specifically by all four species of aphid tested.

Of the 66 samples tested, 77.3% contained a virus similar to GPV (Table 1). This strain was widely distributed in most plain areas of Shaanxi, southern Gansu, southern and central Shanxi, and central Henan provinces. DAV was only found in 15.2% of the samples and was distributed only in the samples and was distributed only in the high elevations of central Shaanxi, eastern Gansu, and northern Shanxi provinces. RPV and GPDAV were found in only three and two samples, respectively. Their distribution was rather limited; the former was found in the Taibei San Mountain and Meixian in Shaanxi Province and the latter was found in Taibei San Mountain and Longxian in Shaanxi Province.

Table 1. Summary of transmission of four strains of barley yellow dwarf virus by four aphid species during 1978—1981

Strain	Collection site	No. samples	No. test plants infected/no. plants infested by indicated aphid species*							
			SG	Percent	RP	Percent	MA	Percent	AD	Percent
GPV	Northern Shaanxi	3	47/62	75.8	15/69	21.7	2/63	3.2	0/71	0.0
	Central Shaanxi	39	501/883	56.7	159/907	17.5	50/861	5.8	0/880	0.0
	Southern Shaanxi	1	56/114	49.1	4/115	3.5	0/114	0.0	0/115	0.0
	Eastern Gansu	5	52/112	46.4	46/114	40.4	11/113	9.7	0/116	0.0
	Central Shanxi	1	19/31	61.3	15/30	50.0	0/27	0.0	0/33	0.0
	Northern Shanxi	1	43/93	46.2	10/90	11.1	0/94	0.0	0/97	0.0
	Central Henan	1	16/32	50.0	1/29	3.4	0/31	0.0	0/30	0.0
Total		51	734/1327	55.3	250/1354	18.5	63/1303	4.8	0/1342	0.0
Percent		77.3								
DAV	Central Shaanxi	4	32/157	20.4	0/169	0.0	79/161	49.1	49/158	31.0
	Eastern Gansu	5	34/109	31.2	1/112	0.9	42/112	37.5	28/108	25.9
	Northern Shanxi	1	56/130	43.1	0/130	0.0	30/123	24.4	21/126	16.7
Total		10	122/396	30.8	1/411	0.2	151/396	38.1	98/392	25.0
Percent		15.2								
RPV	Central Shanxi	3	0/32	0.0	20/31	64.5	0/32	0.0	0/31	0.0
Total		3								
Percent		4.5								
GPDAV	Central Shaanxi	2	17/32	53.1	9/41	22.0	21/30	70.0	19/21	90.5
Total		2								
Percent		3.0								
ealthy insects			0/236	0.0	0/228	0.0	0/230	0.0	0/233	0.0

*SG = *Schizaphis graminum*, RP = *Rhopalosiphum padi*, MA = *Macrosiphum avenae*, and AD = *Acyrthosiphon dirhodum*. A total of 656 healthy plants was used as uninoculated controls throughout this

test period; none of the control plants developed BYDV symptoms.
896 Plants Disease/Vol. 67 No. 8

To test the stability and distinctive nature of the predominant strains, GPVand DAV, we increased the number of test aphids from two to five and 10 per plant for each of the four aphid species, These results showed that the vector specificity of these two strains remained constant regardless of the numbers of aphids used(Table 2). *R. padi* transmitted GPV but not DAV, and *A. dirhodum* transmitted DAV but not GPV.

Because *S. graminum* and *M. avenae* were the most efficicnt vectors of GPV and DAV, respectively (Table 1), we conducted another series of experiments to elucidate the vector—virus—plant relationship. The transmission characteristics of GPV and DAV by these two aphid species are summarized in Table 3. It is interesting to note that both strains apparently were acquired and inoculated by their respective vectors in as little as 1 min. Increase in duration of acquisistion feeding period and inoculation feeding period did not appreciably increase the rate of transmission. Nymphs were as efficient vectors as adults in either species. There was a definite latent period of the virus in its vectors. The LP_{50} values in the vector species were 19. 4 and 17. 7 hr for nymphs and adults of *S. graminum* and 20. 8 and 16. 6 hr for nymphs and adults of *M. avenae*(Table 3). The virus could be retained until the death of the insect, with a mean of 20. 1 and 13. 9 days in *S. graminum* and *M. avenae*, respectively (Table 3).

Table 2. Comparative studies on the stability of two strains of barley yellow dwarf virus using different numbers of aphids allowed a 2—day acquisition access period

Strain	No. aphids per plant	No. test plants infected/no. plants infested by indicated aphid species[a]							
		SG	Percent	RP	Percent	MA	Percent	AD	Percent
GPV	2	14/22	63. 6	1/22	4. 5	0/9	0. 0	0/17	0. 0
	5	6/10	60. 0	0/9	0. 0	0/10	0. 0	0/8	0. 0
	10	20/30	66. 7	7/30	23. 3	1/28	3. 6	0/28	0. 0
Total		40/62	64. 5	8/61	13. 1	1/47	0. 2	0/53	0. 0
DAV	2	7/24	29. 2	0/19	0. 0	1/9	11. 1	6/20	30. 0
	5	11/15	73. 3	0/11	0. 0	3/11	27. 3	2/11	18. 2
	10	11/11	100. 0	0/11	0. 0	11/11	100. 0	10/11	90. 9
Total		29/50	58. 0	0/41	0. 0	15/31	48. 4	18/42	42. 9

SG=*Schizaphis graminum*; RP=*Rhopalosiphum padi*; MA=*Macrosiphum avenae*; AD=*Acyrthosiphon dirhodum*.

Another series of experiments was carried out in greenhouses to study the virus host plant relationships. Twenty—four cultivars of wheat were used for inoculation trials. Each test plant was inoculated by two or three aphids. The first 10 cultivars in Table 4 were commonly grown in northwestern China. The results of X^2 test showed that seven cultivars differed significantly in reaction to the main strains of BYDV (Table 4).

DISCUSSION

We have identified four strains of BYDV from infected wheat in northwestern China based on results of comparative transmission tests with four aphid species. Isolates similar to GPV were predominant in the major wheat growing areas. *S. graminum* was the predominant vector species throughout this region, This insect was not only the most numerous in this vast plain but also was the most efficient vector (Table 3). Therefore. it apparently played a major role in severe outbreaks of barley yellow dwarf in 1966, 1970, 1973 and 1978 when the weather was favorable in the preceding year (6). A similar isolate (SGV) was reported in Canada (7) and New York (13). This isolate was very rare in Canada because of low vector transmission efficiency; only 13% of individual *S. graminum* and 2% of *R. padi* transmitted SGV (7). Although *R. padi*