Distribution and Grasshopper Transmission of Northern Jointvetch Anthracnose in Rice

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ABSTRACT

Yang, X. B., TeBeest, D. O., and Smith, R. J., Jr. 1994. Distribution and grasshopper transmission of northern jointvetch anthracnose in rice. Plant Dis. 78:130-133.

Surveys during 1990–1992 showed that northern jointvetch (*Aeschynomene virginica*) plants were distributed in patches of various sizes in rice fields. Plant density in individual patches varied from 0.5 to 8.4/m^2. Incidence and severity of anthracnose caused by *Colletotrichum gloeosporioides* f. sp. *aeschynomene* varied from 0 to 100% among individual patches, indicating that disease development within individual patches was independent of disease development in other patches. High mortality of northern jointvetch plants was observed in some patches. Grasshoppers frequently were observed feeding around or on anthracnose lesions of northern jointvetch. In eight separate experiments, about 20% of the grasshoppers collected from fields with diseased northern jointvetch were infested with the pathogen and transferred the pathogen to healthy plants after feeding. After pathogen-free grasshoppers fed on anthracnose lesions, 65–75% transmitted the pathogen to healthy plants. Grasshoppers (*Conocephalus fasciatus* and *Melanoplus differentialis*) may be important vectors in the dispersal of inoculum in northern jointvetch in rice.

Additional keywords: biological control

Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. in Penz. f. sp. *aeschynomene* incites an anthracnose of northern jointvetch (*Aeschynomene virginica* (L.) B.S.P.), a leguminous weed up to 2 m tall infesting rice and soybean fields in the southern United States. The weed competes with crop for space, nutrients, and light (3). Seeds of the weed are difficult to remove from rough rice in the milling process and can reduce rice quality (3). Collego, a commercial mycoherbicide, is a formulated product of this fungus used to control northern jointvetch (2). Because species of *Colletotrichum* are important agents in weed biological control (5), understanding the ecology of this fungus, especially its dispersal and distribution, is important to the development of new mycoherbicides.

The disease is endemic, which has hypothetically been attributed to the limited dispersal capacity of the pathogen and distribution of the weed in rice (7). Although inoculum distribution of numerous plant pathogens has been studied extensively for crop pathogens, information about the distribution and dissemination of weed pathogens used for biological control is limited. The distribution of northern jointvetch in rice and the distribution of anthracnose of the weed have not been investigated.

Wind-driven and splashing rain (8) and green treefrogs (9) have been identified as dispersal mechanisms for the pathogen. Grasshoppers have been observed feeding on anthracnose lesions on northern jointvetch plants and have been suggested since 1979 as possible vectors of the pathogen (7). However, grasshopper transmission has not been tested experimentally. The objectives of this study were to determine: 1) distribution patterns of northern jointvetch plants in rice, 2) distribution of anthracnose on the weeds, and 3) if grasshoppers could act as dispersal vectors for *C. g. aeschynomene*.

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Accepted for publication 6 October 1993.

MATERIALS AND METHODS

Weed and disease distribution. Surveys were conducted during the rice-growing seasons of 1990 through 1992 near Stuttgart, Arkansas, after emergence of northern jointvetch from the rice canopy. Rice fields with high infestations of northern jointvetch plants and without applications of Collego for weed control were selected. In 1990 and 1991, detailed data were not recorded for fields in which no diseased plants were observed. In 1992, data were taken from fields with and without diseased northern jointvetch plants. Five, two, and five fields were studied in 1990, 1991, and 1992, respectively. For each field, areas with and without northern jointvetch plants were recorded. Patches of northern jointvetch plants were considered as separate if the distance between the two patches was at least 3 m.

For each field, the number of northern jointvetch patches and the location of each patch were recorded. In 1990, the density of northern jointvetch plants of each patch was measured by defining quadrates of 1 m^2 across a patch and counting the number of plants per quadrate. At the same time, the number of diseased plants also was counted to determine the disease incidence for each patch. Disease severity, defined as portion of dead tissue caused by the disease, was estimated for each plant. The number of quadrates per patch varied from 12 to 50 and depended on the size of the patch. In 1991 and 1992, 10 quadrates were randomly chosen to determine the plant density in each patch. Twenty plants were removed randomly from each patch to determine the disease incidence and severity. The mean of plants per square meter, disease incidence, and disease severity of each field were calculated from patch means in the field.

Detailed weed maps were made for some rice fields in each growing season. The size and shape of each field were determined. The shape of individual patches was estimated from observations made from an elevated platform around the field's edge, and the length and width of the patches were measured in the field. The location of a patch in the field was determined by measuring the distance from the field border to the patch edge.

Grasshopper transmission. Two different experiments were performed to determine grasshopper transmission of *C. g. aeschynomene*. In the first experiment, shorthorn (*Conocephalus fasciatus*) and longhorn (*Melanoplus differentialis* and *Neoconocephalus crepitans*) grasshoppers were collected from commercial rice or soybean fields near Stuttgart. Grasshoppers were brought to the laboratory the same day they were captured. Each grasshopper was placed in a test chamber constructed of a transparent plastic bottle (10 cm in diameter and 22 cm in height) containing a healthy northern jointvetch plant approximately 3 wk old, and the chambers were placed under a light bench or in a growth chamber for 24 hr. Five insect-free test chambers were used as controls. Plants were moved first into a dark dew chamber for 24 hr at 28 C to induce infection, then into a growth chamber at 28 C for 4 days. Lesions on each test plant were counted, and grasshopper feeding marks were noted. The percentage of grasshoppers that carried inoculum and transferred the disease was calculated on the basis of the number of diseased plants. Grasshopper sampling number varied at each time because the insect population changed during the growing season. The experiment was repeated eight times during the growing season.

In the second experiment, grasshoppers were collected in northwestern Arkansas, where northern jointvetch and *C. g. aeschynomene* have not been reported. In each test, captured grasshoppers were first maintained on wheat seedlings for 1–2 days. Each grasshopper was placed into a glass tube (4 cm in diameter and 30 cm in height) containing a 2-cm stem segment of northern jointvetch with a lesion caused by *C. g. aeschynomene*. The insect was exposed to feed on the lesion for 24 hr. Each grasshopper then was moved into a plastic test chamber to feed on a healthy northern jointvetch plant as described in the first experiment. After 24 hr, plants were moved into a dew chamber for 24 hr at 28 C to induce infection and then kept for 4 days in a growth chamber at 28 C. The control treatment allowed the grasshoppers to feed on healthy stem segments before they were placed in contact with healthy northern jointvetch plants. The numbers of infected plants and lesions per plant were recorded. The experiment was repeated twice.

RESULTS

Northern jointvetch distribution. Northern jointvetch was distributed in patches in rice fields (Tables 1–3, Fig. 1). Patch size varied from field to field and from patch to patch in the same field. For example, in 1991, the largest patch in field 1, patch I, was about 700 m^2 and the smallest, patch L, was less than 100 m^2 (Fig. 1). A few individually distributed plants also were observed. Distances between patches varied from less than 5 m to more than 100 m, depending on the size of the fields. The northern jointvetch plant density varied from field to field and from patch to patch in a field. For example, in 1991, the northern jointvetch density varied from 2.4 to 8.4 plants per square meter in field 1 (Table 2, Fig. 1). Disease incidence also varied among patches in the field. For instance, in 1991, patch A in field 1 had 0 disease incidence while nearby patch B had 90% disease incidence. In 1990, patch A in field 1 had 100% disease incidence at rice heading stage (Table 1), and natural control of the weed in this patch was observed 2 wk later. A field with a high northern jointvetch plant density but with an estimated disease incidence of less than 5% also was observed in late September 1991, but no detailed data were taken for each patch. In 1992, two fields were observed with weed densities of about four plants per square meter, but no diseased plants were observed at heading stage (Table 3).

Grasshopper transmission. In rice fields, feeding wounds caused by grasshoppers were frequently observed around anthracnose lesions on northern jointvetch plants (Fig. 2). Grasshoppers transmitting *C. g. aeschynomeme* in these experiments were the longhorn grasshopper *M. differentialis* and the shorthorn grasshopper, both of which fed aggressively on northern jointvetch. In the first two experiments, approximately 10 longhorn *N. crepitans* grasshoppers were tested but did not feed on stems of northern jointvetch plants; this grasshop-

Table 1. Plant densities and incidence and severity of anthracnose, caused by *Colletotrichum gloeosporioides* f. sp. *aeschynomene*, in individual patches of northern jointvetch in rice fields, 1990

Field no.	Date	Rice growth stage	Patch	Plants/m^2	Incidence[a] (%)	Severity[b] (%)
1	1 August	Heading	A	1.4	100	30
			B	1.5	94	16
			C	1.1	26	5
			D	1.3	13	1
			E	1.4	36	9
			F	2.0	90	35
			Mean	1.5	60	16
2	14 August	Heading	A	1.3	29	22
			B	1.8	28	1
			Mean	1.6	29	12
3	15 August	NA[c]	A	2.2	100	63
			B	0.7	26	1
			Mean	1.5	63	32
4	23 August	NA	A	0.5	94	50
			B	0.8	100	85
			C	0.9	100	70
			Mean	0.7	98	68
5	23 August	NA	A	0.5	21	14
			B	0.5	70	66
			Mean	0.5	46	40

[a] Percentage of infected plants.
[b] Percentage of dead plant tissues caused by anthracnose.
[c] Not recorded.

Table 2. Plant densities and incidence and severity of anthracnose, caused by *Colletotrichum gloeosporioides* f. sp. *aeschynomene*, in individual patches of northern jointvetch in rice fields, 1991

Field no.	Date	Rice growth stage	Patch	Plants/m^2	Incidence[a] (%)	Severity[b] (%)
1	12 August	Flowering	A	8.4	0	0
			B	6.0	90	10
			C	5.5	15	2
			D	3.8	85	10
			E	2.4	65	12
			F	5.1	55	6
			G	2.9	35	6
			H	6.0	85	15
			I	2.6	50	10
			J	3.9	80	10
			K	5.9	35	5
			L	5.4	55	10
			Mean	4.8	54	8
2	12 August	Flowering	A	4.5	20	3
			B	3.0	40	6
			C	3.0	20	10
			D	3.5	20	4
			E	2.4	87	10
			Mean	3.3	37	7

[a] Percentage of infected plants.
[b] Percentage of dead plant tissues caused by anthracnose.

per species was not counted and was not used in later experiments. Lesions appeared within the feeding areas of stem pieces 3–4 days after insect feeding. Occasionally, lesions were observed on part of a stem where no insect feeding marks were noted, indicating that the insects also may spread the disease by contact. Among the five experiments in which grasshoppers were collected from rice, there was an increasing trend of disease incidence, with an average infection rate of 22% (Table 4). For experiment 8, in which grasshoppers from one soybean field were used, the infection rate was 40%. In the experiment in which grasshoppers acquired inoculum by feeding on segments with lesions, the infection rate was as high as 75%. No infections occurred in control treatments.

Table 3. Plant densities and incidence and severity of anthracnose, caused by *Colletotrichum gloeosporioides* f. sp. *aeschynomene*, in individual patches of northern jointvetch in rice fields, 1992

Field no.	Date	Rice growth stage	Patch	Plants/m²	Incidence[a] (%)	Severity[b] (%)
1	19 July	Heading	A	4.0	0	0
			B	4.5	0	0
			C	5.1	0	0
			Mean	4.5	0	0
2	19 July	Heading	A	3.6	0	0
			B	4.2	0	0
			Mean	3.9	0	0
3	18 August	Milk	A	2.0	20	4
4	18 August	Milk	A	1.3	10	7
			B	1.2	15	3
			C	1.0	15	3
			Mean	1.2	15	4
5	19 August	Milk	A	1.8	80	12
			B	2.0	30	8
			C	1.5	10	2
			Mean	1.8	40	7

[a]Percentage of infected plants.
[b]Percentage of dead plant tissues caused by anthracnose.

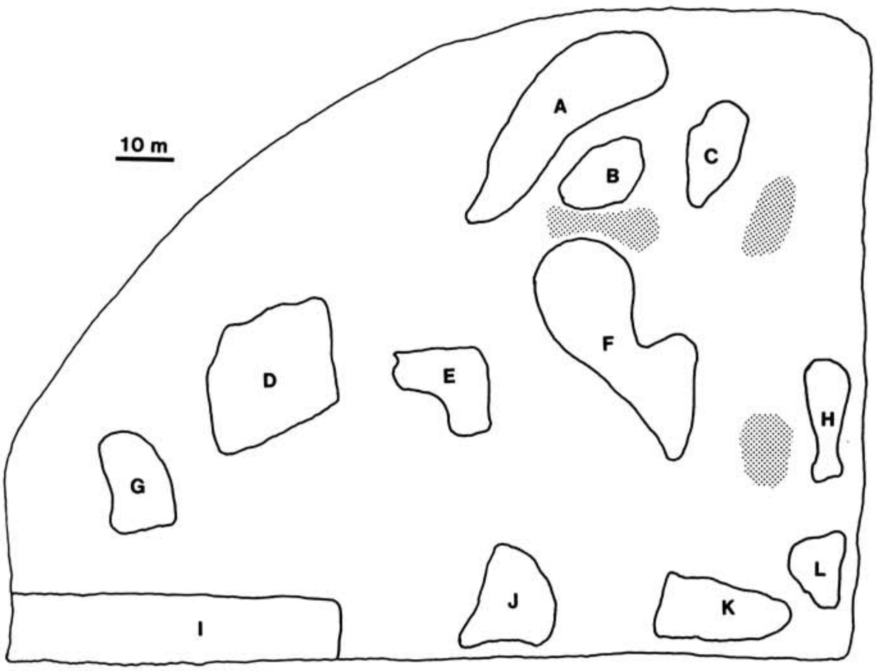

Fig. 1. Distribution of northern jointvetch plants in a rice field at Stuttgart, Arkansas. Letters are the codes for weed patches (Table 2, field 1), and shadowed areas represent weed densities lower than one plant per square meter.

DISCUSSION

The patchy distribution of northern jointvetch and the variation of disease severity among patches indicated that disease development within a patch may be independent of that of other nearby patches. Movement of inoculum among patches may be limited because the rice acts as a barrier to dispersal. Yang and TeBeest (8) demonstrated that dispersal distance of inoculum was about 1.5 m per rain episode in high rice density. The patchy distribution in rice fields, therefore, may be the major factor causing the endemicity of this disease on northern jointvetch.

The patchiness and difference in disease levels among patches also may be due to the nature of weed seed dispersal and pathogen overwintering. TeBeest and Brumley (6) reported that inoculum was carried on and in northern jointvetch seeds, with a diseased seed incidence as high as 25%. They suggested that the diseased seeds could be an inoculum source for natural infections. Because plant seeds are more likely to fall around or in the area of weed patches, diseased seedlings may serve as initial inoculum sources for the next season. The carryover of inoculum may result in an accumulation of inoculum over generations in each patch, resulting in differences in the initial amount of disease among patches. Because the pathogen has a limited capacity to spread between patches, development of the disease in one patch can be relatively independent of that in other patches.

Because the size of areas varied from patch to patch, the sample size of 10 quadrates per patch in 1991 and 1992

Fig. 2. Evidence of grasshopper feeding around an anthracnose lesion (arrow), caused by *Colletotrichum gloeosporioides* f. sp. *aeschynomene*, on a northern jointvetch plant.

Table 4. Infection of plants facilitated by either grasshoppers fed northern jointvetch with disease lesions or grasshoppers (*Conocephalus fasciatus* and *Melanoplus differentialis*) from rice fields with northern jointvetch infected by *Colletotrichum gloeosporioides* f. sp. *aeschynomene*

Test no.	Field	Rice growth stage	Number of grasshoppers tested	Percent infected plants	Lesions per plant
Field					
1	Rice	Heading	20	15	1.0
2	Rice	Flowering	27	20	1.0
3	Rice	Milking	12	17	2.0
4	Rice	Wax	4	25	1.0
5	Rice	Mature	9	33	1.3
6	Soybean	R5[a]	7	14	2.0
7	Soybean	R5	9	11	1.0
8	Soybean	R5	10	40	1.0
Lab					
1			20	65	1.6
2			16	75	3.8

[a]Seeds about 3 mm long.

represented different proportions for different patches, which made it difficult to statistically compare disease incidence or severity among the patches. Nevertheless, the sample method in our study still provided useful information on the spatial variation of disease among patches, as indicated by the consistent results during the 3 yr of this study. Methods to study weed diseases, especially the sampling method, need to be developed.

In this survey, the natural occurrence of the disease was much greater than in a survey done in the early 1970s in which only a few naturally diseased plants were observed in weed patches (4). The increase of natural occurrence may be due to the application of Collego over the past several years in the rice production region in Arkansas. The field in which patches with natural control were observed was a commercial field in which Collego was first tested experimentally and has received commercial application for many years. Despite the observed high incidence in the survey, disease severity was low in most fields. Natural dispersal mechanisms may not spread inoculum from one patch to other distant patches efficiently enough to provide high levels of natural infections early in the season, which was made evident by the patchy and uneven distribution of disease and the low disease severity in individual fields.

Insects can be major vectors in some plant pathosystems (1). However, transmission efficiency of the grasshoppers in this pathosystem may be influenced by several factors. Grasshopper populations vary from year to year and from field to field, resulting in variation in vector numbers. Therefore, the efficiency may vary from year to year and field to field, which is similar to that of green treefrogs. The efficiency also is determined by the preference of grasshoppers for feeding on disease lesions rather than on healthy portions of a plant. If there is no preference, the chance of grasshoppers acquiring inoculum would be a function of disease incidence. On the other hand, if grasshoppers actively search for disease lesions, their potential significance as vectors would be much greater. A future study of feeding preferences of the grasshopper species toward diseased and healthy tissue may help quantify their significance as vectors.

Grasshoppers and other vectors may be important factors to consider in biological risk assessment of mycoherbicides. Many species of *Colletotrichum* have been studied as potential mycoherbicides, and genetic engineering techniques are being investigated to enhance their efficacy (5). Eventually these engineered organisms will be subjected to field tests, and the presence of these vectors in test plots may increase the chances of unwanted dispersal. The distance of grasshopper movement is far greater than that of other physical dispersal mechanisms in this pathosystem.

ACKNOWLEDGMENTS

Published with the approval of the director of the Arkansas Agriculture Experiment Station. Research supported in part by USDA grant 92-34195-7162.

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