EXPRESSION OF GENES FOR RESISTANCE TO HESSIAN FLY (DIPTERA : CECIDOMYIIDAE) AT THREE TEMPERATURE REGIMES

AMRI, A.,* M. EL BOUHSSINI, * T.S. COX** and J.H. HATCHETT***

INTRODUCTION

Genetic resistance has been used effectively in the United States to protect common wheat, **Triticum aestivum** L., from Hessian fly, **Mayetiola destructor** (Say) attack (HATCHETT 1986). Several studies have shown that exposure of wheat plants to temperatures above 18° C causes a significant reduction in the expression of certain genes for resistance to Hessian fly (CARLSON et al. 1978, CARTWTRIGHT and LAHUE 1944, HATCHETT 1986, MAAS et al. 1987, SOSA 1979). The **H5** gene in "Abe" lost its effectiveness against biotype B after a 1-day exposure to 27°C (SOSA 1979). MAAS et al. (1987) concluded that the **H18** gene in 'Marquillo' was not expressed at temperatures above 18°C. The gene **H10** is sensitive to high temperature, but when it was combined with H9, as in the cultivar 'Elva', the resistance is complete at temperatures above 27°C (CARLSON et al. 1978, MAAS et al. 1989). TYLER and HATCHETT (1983)

* INRA : Centre Regional de la Recherche Agronomique de Doukkala Abda etChaouia, B.P.589, Settat, Marocco.

** Plant Science and Entomology Research, USDA-ARS, Departement of Agronomy, Kansas State University, Manhattan, KS 66506.

*** Plant Science and Entomology Research, USDA-ARS, Department of Entomology, Kansas State University, Manhattan, KS 66506.

demonstrated that plants homozygous for the gene **H13**, derived from **Aegilops squarrosa** L. [**Triticum tauschii** (Coss) Schmall], expressed resistance at temperatures up to 31°C, but that resistance in heterozygous plants was more sensitive to high temperatures. The third gene, **H16**, which was transferred from the durum wheat PI94587, and the genes **H14** and **H15** were less temperature sensitive than **H5** and **H11** (MAAS et al. 1989, PATERSON et al. 1988). The extent of the reduction in the expression of resistance at high temperatures was believed to depend on the biotype of Hessian fly (SOSA 1979). OLEMBO et al. (1966) found that resistance in the barley cultivar "Delta" was best explained as a single dominant gene at cool temperatures, while at high greenhouse temperatures, the resistance was best explained as two dominant genes with complementary epistasis.

The temperature effects on the expression of resistance by certain genes to the Great Plains biotype of Hessian fly, widely encountered in the hard red winter wheat area of North America, have not been investigated. The objectives of the present study were to determine the effect of different temperature regimes on the expression of resistance to Hessian fly for several genes for resistance, and to determine changes in the expression of the **H5** gene in two genetic backgrounds at different temperatures.

MATERIALS AND METHODS

The first test was conducted with 10 wheat lines or cultivars carrying different genes for Hessian fly resistance. Two susceptible check cultivars, 'Newton" and 'Nesma" were included to validate the level of infestation. The resistance genes **H1** through **H13**, with the exception of **H4**, were included in this study. Twenty-five seeds of each test line were planted in each of 2-ten cm rows, in a randomized complete block design in three sets of standard greenhouse flats (54 x 36 x 8 cm) containing soil. Plant infestations were conducted according to the techniques described by CARTWRIGHT and LAHUE (1944). When the plants were in the one Leaf stage, Great Plains (GP) biotype females were allowed to oviposit on the plants for two days. The infested flats were held at a temperature of 18°C for three more days to allow larvae to migrate to the base of the plant and then they were assigned randomly to one of three temperature regimes in growth chambers. The growth chambers were set for continuous 18°C, continuous 27°C, and alternating 27°C (12 hours day) and 18°C (12 hours night).

A second test was conducted to determine the effect of two temperature regimes (continuous 27°C and continuous 18°C) on two cultivars carrying the **H5** gene, 'Arthur 71' a winter wheat and 'Saada' (Butte/Arthur 71/Butte) a spring wheat. Each cultivar was planted in 3 randomly assigned rows in greenhouse flats.

In both tests plant reactions to Hessian fly infestation were determined 14 days after transfer to temperature treatments. Susceptible plants were stunted and dark green in color, resistant plants were light green in color and were not stunted and had dead larvae. The data are presented as the proportion of resistant plants per row. A separate analysis of variance was performed for the data for each temperature regime. Then a combined analysis was performed and the pooled error was used to calculate mean separations across temperature combinations.

RESULTS AND DISCUSSIONS

In the first test, the spring wheat check Nesma and the winter wheat check Newton both showed the symptoms of susceptibility to Hessian fly and were 100% infested. No escapes were detected on any of the cultivars tested. The analysis of variance for percent resistant plants, the interaction between temperature and cultivar was highly significant ($p<0.001$) (Table1). The resistance of cultivars Knox 62 (**H6**), Seneca (**H7H8**), and lines 812-24- 4-3 (**H9H10**) and KSH8998 (**H13**) was effective in all temperatures tested.

The resistance of Arkan (**H3**) was somewhat less effective at 27°C than at 18°C. The resistance of Big Club (**H1H2**) and the line 841453 (**H12**) was severely reduced by continuous 27°C, and was not fully expressed at 18°C either. Moderate reductions in percent of resistant plants with temperature increase were observed in the two cultivars 'Arthur 71' (**H5**) and '657CI23R' (**H11**), but the greatest decrease in resistance was observed in 'Brule' (**H18**).

The insensitivity of the genes **H9H10** and **H13** to high temperature, as observed in this study, is consistent with the conclusions of previous studies using the D biotype Hessian fly (CARLSON et al. 1978, TYLER and HATCHETT 1983). These results differ with results reported for the genes **H3**, **H5**, **H11**, **H6**, and **H18** in that the reduction in resistance was not as large (MAAS et al. 1987, MAAS et al. 1989, SOSA 1979). The continuous 27°C regime had a greater effect on the expression of the genes **H1H2**, **H12** and to a less extent **H11**, than did the 27°C/18°C regime. The **H18** gene was affected equally by these two regimes. This temperature sensitivity suggests that studies on inheritance and genetic relationship of Hessian fly resistance genes should always be conducted at temperatures lower than 18°C.

In the second test, the analysis of variance of percent resistant plants found the interaction between cultivar and temperature highly significant ($p<0.001$) (Table 2). In the cultivar, Arthur 71, percent resistant plants decreased 50% when the temperature increased from 18°C to 27°C. In the cultivar Saada percent resistant plants decreased only 17% at the same temperatures. Expression of H5 resistance was significantly less affected by high temperatures in the spring cultivar Saada than in the winter cultivar Arthur 71, the **H5** donor parent. A similar reaction was observed in the field in Morocco where Arthur 71 and the line carrying **H11** had higher numbers of susceptible plants than did Saada (unpublished data). The temperature sensitivity of **H5** is of special interest, because of the effectiveness of this gene in Morocco. The **H11** gene has shown behavior similar to **H5** in both the field and greenhouse. A partial sensitivity to temperature could extent the durability of a resistance gene, because there would be less selection pressure for virulent biotypes.

Differences in resistance to various biotypes, differences in genetic interrelationships, and differences in sensitivity to temperature could be used to differentiate between new sources of resistance. Resistance is also affected by the allelic dosage, as was demonstrated for the **H13** gene (TYLER et HATCHETT 1983) and the genetic background as was demonstrated for the **H5** gene in the present study. Cool temperatures at night, after a warm day, should reduce the number of susceptible plants, but normally the presence of such susceptible plants should not make a significant difference in yield.

ACKNOWLEDGMENT

This study was a cooperative investigation by: the National Institute for Agricultural Research (INRA), Rabat, Morocco: the MidAmerica International Agricultural Consortium (MIAC) from the University of Nebraska, USAID Morocco Projet No. 608-0136; the Agricultural Research Service, U.S. Department of Agriculture, and the Departments of Agronomy and Entomology, Kansas State University.

Table 1 : **Reaction of known genes for resistance to biotype Great Plains of Hessian fly at three temperature regimes.**

		Mean % resistant plants		
Cultivar	Gene (s)	18°C	27°C	27°/18°C
Newton	None	0	0	0
Nesma	None	0	0	0
Big Club	H1, H2	B 60.0 a	E 27.0 b	C 56.0 a
Arkan	H3	A 100.0 a	B 81.0 b	A 93.0 a
Arthur 71	H5	A 97.5 a	C 61.5 b	C 59.0 b
Knox 62	H6	A 100.0 a	A 97.5 a	A 95.5 a
Seneca	H7,H8	A 100.0 a	A97.5 a	A 100.0 a
812-24-4-3	H9, H10	A 100.0 a	A 100.0 a	A 98.0 a
657CI23R	H11	A 100.0 a	D 47.5 c	BC 66.0 b
841453	H12	B 62.5 a	F 12.5 b	C 54.5 a
KSH8998	H13	A 98.0 a	A 98.0 a	A 100.0 a
Brule	H18	A 96.0 a	F 10.0 b	D 12.5 b
Mean		A 91.4 a	C 63.2 b	B 73.5 c

Means followed by the same letters are not significantly different LSD at 5%. The LSD's are 9.0, 11.0 and 11.9 within the three temperature regimes (capital letters), respectively, and 6.7 across temperatures (small letters).

Table 2 : **Effects of two temperatures, 18°C and 27°C, on the expression of the H5 gene in Arthur 71 and Saada infested with the Great Plains biotype of Hessian fly.**

	Mean % resistant plants	
Source of H5	18°C	27°C
Arthur 71	98.3 a	48.7 b
Saada	100.0 a	83.3 b

Means followed by the same letters are not significantly different LSD at 5%. The LSD (5 %) was 4.5 across temperatures.

ABSTRACT

The objectives of this study were to determine the effects of fluctuating temperatures on the expression of these genes to the Great Plains biotype and to compare the temperature sensitivity of **H5** in two cultivars, 'Arthur 71' and 'Saada'. This is important because in Morocco the daily temperatures early in the growing season can reach 27°C, while the nights remain cool.

Results showed that the genes and gene combinations **H3, H6, H7 H8, H9 H10** and **H13** were the most stable under the three temperature regimes, whereas the genes **H5** and **H11** were intermediate, and **H18** in "Brule" was the least stable. Fluctuating temperatures had less effect on the expression of temperature sensitive genes than continuous 27°C treatment.

Genetic background affected the temperature sensitivity of **H5**, resistance was more stable in the spring wheat Saada than in the winter wheat Arthur 71.

KEY WORDS : Cecidomyiidae, **Mayetiola destructor**, **Triticum,** winter wheat, spring wheat, temperature sensitivity, resistance.

RESUME

Les températures journalières durant les premières décades de la saison agricole peuvent atteindre jusqu'à 27°C. L'expression de la résistance à la cécidomyie (**Mayetiola destructor** Say) conférée par certains gènes est affectée par les hautes températures. Cette étude se propose de déterminer les effets des régimes de températures fluctuants sur l'expression des gènes de résistance et de comparer la sensibilité aux températures élevées du gène **H5** dans deux cultivars 'Arthur 71' et 'Saada'. Les résultats ont montré que les gènes, **H3, H6, H7H8, H9H10**, et **H13** ont été les plus stables sous les trois régimes de températures, les gènes **H5** et **H11** ont été intermedaires dans leurs expressions, contrairement au gène **H18** dans le cultivar (Brule) dont l'expression a été très affectée par les hautes températures. Aussi, le régime fluctuant de température (27°C le jour/18°C la nuit) a affecté à un degré moindre l'expression des gènes sensibles à la température que le régime de 27°C continue.

Il apparait aussi que la composition génotypique peut affecter la sensibilité aux hautes températures du gène **H5** ; celui ci a été plus stable dans le blé de printemps 'Saada' que dans la blé d'hiver 'Arthur 71'.

MOTS CLES : Cecidomyiidae, **Mayetiola destructor**, **Triticum**, Blé d'hiver, Blé de printemps, Sensibilité à la température, Resistance.

ملخص

تهدف هذه الدراسة إلى تحديد تأثير التغيرات الحرارية على مدى فعالية بعض مصادر مقاومة دودة هس، ومقاومة حساسية الجين H5 الموجود في صنف القمح الشتوي ARTHUR 71وصنف القمح الطري الربيعي SAADA. وتبين النتائج على أن الجينات **H3، H6، H7**، **H9،H8**، **H10** و **H13** تحتفظ بمقاومة عالية تحت الأنظمة الحرارية الثلاثة 18 27، 27، 27 درجة نهارا و 18 درجة ليلا.

أما الجينات **H5** و **H11** ففعاليتها متوسطة بينما تكاد تنعدم هذه الفعالية في الجين **H18** في الحرارة المرتفعة. وقد اتضح أن تغييرات الحرارة (18 /17 درجة) لها تأثير أقل على فعالية الجينات الحساسة من النظام 27 درجة.

وقد اتضح كذلك أن تأثير الحرارة على فعالية الجين **H5** مرتبطة بالصنف الذي يحمل هذا الجين.

REFERENCES CITED

BROWDER, L. E. 1985. Parasite : Host : Environment specificity in the cereal rusts. Ann. Rev. Phytopathol. 23:201-22.

CARLSON, S. K., F. L. PATTERSON, and R. L. GALLUN. 1978. Inheritance of resistance to Hessian fly derived from **Triticum turgidum** L. Crop Sci. 18:10011-14

CARTWRIGHT, W. B., and L. E. COMPTON. 1946. Relation of temperature to the expression of resistance in wheats to Hessian fly. J. Am. Soc. Agron. 38:259-63.

CARTWRIGHT, W. B., and D.W LAHUE. 1944. Testing wheats in the greenhouse for Hessian fly resistance. J. Econ. Entomol. 37:385-87.

HATCHETT, J.H. 1986. Biology and genetics of the Hessian fly and resistance in wheats in the United States. Proc. Inter. Wheat Confereance, Rabat, Morocco.

MAAS, F. B. III, F.L. PATTERSON, J. E. FOSTER, and J. H. HATCHETT. 1987. Expression and inheritance of resistance of Marquillo wheat to Hessian fly biotype D. Crop Sci. 27 : 49-52.

MAAS, F. B. III, F.L. PATTERSON, J, E. FOSTER, and H. W OHM. 1989. Expression and inheritance of resistance of ELS6404-160 durum wheat to Hessian fly. Crop Sci. 29:23-28

OLEMBO, J. R., F. L. PATTERSON, and R. L. GALLUN. 1966. Genetic analysis of the resistance to **Mayetiola destructor** (Say) in **Hordeum vulgare** L. Crop Sci. 6: 563-66.

PATTERSON, F. L. , J. E. FOSTER , and H. W. OHM. 1988. Gene H16 in wheat for resistance to Hessian fly. Crop Sci. 28:652-54.

SOSA, O. Jr. 1979. Hessian fly : resistance of wheat as affected by temperature and duration of exposure. Enviro. Entomo. 8:280-81.

TYLER, J. M., and J.H. HATCHETT. 1983. Temperature influence on expression of resistance to Hessian fly (Diptera : Cecidomyiidae) in wheat derived from **Triticum tauchii.** J. Econ. Entomo. 76 : 323-26.

Photo 11. Experimental plots of the Hessian fly resistant variety "Saada". The Hessian fly pressure was so severe that the surrounding susceptible wheat breeding lines were not able to produce seed. (Photography by M. El Bouhssini).

Photo 12. Variety development in progress : experimental plots of three Hessian fly resistant lines in the Moroccan wheat breeding program. Note the stunted susceptible variety to the right. (Photograph by L.L. Buschman).