NEW SOURCES OF RESISTANCE IN WHEAT TO HESSIAN FLY, MAYETIOLA DESTRUCTOR (Say), (Diptera : Cecidomyiidae) IN MOROCCO

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

INTRODUCTION

The Hessian fly, **Mayetiola destructor** (Say), is a major pest of wheat in most of the world's wheat producing areas. In the U.S.A., this pest has been a serious problem on wheat since its introduction in the late 1700's. The Hessian fly is also the most serious insect pest of wheat in North Africa and Southern Europe. The pest is distributed throughout the wheat growing zones of Morocco (El BOUHSSINI, 1981; HATCHETTet al., 1984), but severity of damage is more pronounced in the dryland regions. Damage caused by the insect can result in total loss of the crop if high infestations occur on the young stages of the crop. LHALOUI (1986), using the insecticide FURADAN 5G, and AMRI(1989), using near-isogenic resistant and susceptible wheat lines, estimated Hessian fly losses in specific years at 39% and 36%, respectively.

The Hessian fly undoubtedly has been in Morocco for many years, although reports on its damage did not appear until the 1930'S (ANONYMOUS, 1932).

* INRA : Centre Regional de la Recherche Agronomique de Doukkala Abda et Chaaouia, B.P. 589, Settat, Maroc.

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

Since that time, researchers have concentrated their efforts mostly on the insect's biology (JOURDAN, 1937, 1938; DURANT, 1967) and insecticide treatments as a means of control (BENNANI and RIANI, 1978). However, due to the high cost of chemicals, insecticides have not been used by farmers.

The most practical control method for Hessian fly has been the use of resistant cultivars. In the U.S.A., 20 resistance genes (designated **H1** to **H20**) and two unnamed genes derived from **Triticum tauschii** have been identified as effective against the Hessian fly (AMRI, 1989; AMRI et al., 1990). All of these wheat resistance genes have been tested for resistance to Hessian fly in Morocco and only **H5**, **H11**, and **H13**, genes and the two unnamed genes derived from. T. Tauschii were found to be effective (EL BOUHSSINI et al., 1985; GALLAGHER et al., 1987; EL BOUHSSINI et al., 1988; AMRI, 1989). The mechanism of resistance is antibiosis, i.e., first instar larvae die after feeding for two to three days on resistant plants.

All the resistance genes effective against Moroccan Hessian fly have been incorporated into Moroccan breeding lines. The single gene deployment strategy has been adopted, since it has been shown theoretically to provide as durable resistance as other more complex strategies, such as multiline or gene pyramiding (COX and HATCHETT, 1986).

In addition to its presence in winter wheat 'Arthur 71', the **H5** gene is also present in a spring wheat germplasm 'SD8036' (CHOLICK et al., 1987). 'SD8036' has recently been released in Morocco as the cultivar 'Saada' and is targeted mostly for production in the southern region of the country where Hessian fly is the most damaging.

Because of the gene-for-gene specificity between the resistance genes and virulence genes (HATCHETT and GALLUN, 1970), biotypes have developed in the U.S.A. as the result of selection pressure by resistant cultivars. Eight biotypes have been identified from field populations and are designated Great Plains (GP), A, B, C, D, E, J, and L (see GALLUN, 1977 for review; SOSA, 1981).

The objectives of this study were to evaluate a diverse group of wheat germplasm in an attempt to identify new sources of resistance to Hessian fly in Morocco and to monitor changes in populations for virulence against effective genes, **H5**, **H11**, and **H13**.

MATERIALS AND METHODS

In 1986, six USDA Plant Introductions were screened at the Sidi el Aidi Experiment Station for resistance to Hessian fly. Planting was in mid-November, prior to the first rain. Entries were planted in rows 1 m long and 0.3 m apart. 'Newton' and 'SD8036', which has the **H5** gene, were used as susceptible and resistant checks, respectively. When symptoms indicating plant susceptibility (plants dark green in color and stunted) were observed, 50 consecutive plants were sampled from each entry to estimate the percentage of susceptible plants. Ten of the susceptible plants were dissected to estimate larval density.

In 1987, 25 irradiated bread wheat-rye lines developed by the later Dr. E. E. Sebesta, USDA-ARS, were tested for Hessian fly resistance at Sidi el Aidi and Jemaâ Shaim. 'TAM 101', 'TAM 106', and 'Vona' were used as susceptible checks. Saada (**H5**) was used as the resistant check. Methods of planting and evaluation were similar to those used in the first experiment. In addition, 24 accessions of **Triticum tauschii** obtained from the Kansas State University Wheat Genetics Resource Center were screened for resistance to Hessian fly at the same two locations. Entries were planted in single rows, each 3 m long and spaced 0.3 m apart. All resistant plants were examined for presence of dead first instars to confirm resistance reaction.

In 1988, two CIMMYT F4 lines, 222 (Buc "S" / Charc "S"/PRL"S" / 3 / PVN"S", and 254 (BAV"S" / PRL"S"/VEE) were screened in a greenhouse during the winter at Manhattan, Kansas, against the Great Plains biotype and biotypes D and L and at Settat, Morocco, against Moroccan Hessian fly. 'Nesma' and 'SD8036' were included as susceptible and resistant checks, respectively. Greenhouse temperatures were maintained between 18 and 24° C. These two lines were first identified as being resistant at Jemaa Shaim in 1987 where they showed good field resistance compared to all the other susceptible lines (El Bouhssini, unpublished data).

A uniform Hessian fly nursery comprised of wheats carrying resistance genes, **H5, H7H8, H9, H11,** or **H13** and Newton as the susceptible check, was planted in several locations to field-monitor any changes in virulent biotypes. In 1987, only three resistance genes, **H5, H11,** and **H13** and Newton, the susceptible check, were evaluated at Sidi El Aidi, Jemaa Shaim, and Guich. The methods of planting and evaluation were similar to those described for the other field experiments. In 1986 or 1987, the genes were evaluated at six locations, Sidi El Aidi, Jemaa Shaim, Dar Bouazza, Guich, Marchouch, and Fez. Body lenghts of larvae on susceptible plants of resistant genotypes were measured and compared with those on susceptible checks.

RESULTS AND DISCUSSION

Table 1 shows the reactions of the USDA Plant Introduction wheats to Hessian fly. Three lines, PI 321644, PI 134870, and PI 1162231, were highly resistant and none of the plants were infested. Dead larvae were present on all plants. PI 134867 and PI 86202 had a level of resistance similar to that of SD 8036 (**H5**). SD 8036 had 3 % plants susceptible. PI 134807 and PI 86202 had 3% and 5% plants susceptible, respectively. PI 116311, with 7% plants susceptible, also had dead first instars on the resistant plants. These plant introductions showed a high level of resistance and may be new sources of resistance for bread wheat in Morocco. The genetics of resistance should be studied to determine whether they carry the same genes.

Table 1 : **Reaction of U.S.D.A. Plant Introduction wheats to Hessian fly in Morocco. Field test, Sidi El Aidi Experiment Station, 1986.**

Cultivar/ line	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/ susc. plant
PI 116231	30	0.0	0.0
PI 321644	30	0.0	0.0
PI 134870	30	0.0	0.0
PI 134867	30	3.0	3.0
PI 86202	20	5.0	4.0
PI 116311	15	7.0	4.0
SD8036 (H5)	30	3.0	2.0
Susc. check			
(Newton)	30	100.0	3.6

The two CIMMYT lines showed a high percentage of plants resistant to the Moroccan Hessian fly and to biotype GP and D Hessian fly in the U.S., but were susceptible to biotype L (Table 2). Resistant plants had dead first instars which confirmed their resistance reaction. Because the level of resistance of these two lines is similar, they may have the same gene (s). Because these two lines are F4 they may still be segregating for resistance. Also, since they were resistant to the Moroccan Hessian fly and to biotypes GP and D, but susceptible to L, they may have the **H5** gene. Thus, the genetics of these two lines also should be studied to determine if they are carrying new resistance genes. The white kernel color of the lines is also desirable since white kernel is preferred by Moroccan farmers. Because C222 and C254 may be valuable sources of resistance for bread wheat breeding, breeders should make selections from these lines based on Hessian fly resistance and white kernel color, in addition to other agronomic characteristics.

Table 2. : **Reaction of two CIMMYT bread wheat lines to Hessian fly in the U.S and Morocco, greenhouse test, 1988-89.**

	Percent Plants Resistant			
Cultivar/ Line	Moroccan Hessian fly	Biotype GP	Biotype D	Biotype L
C 222	81.8	83.3	75.0	0.0
C 254	83.3	50.0	75.0	0.0
Nesma (Susc. check)	0.0	0.0	0.0	0.0
SD 8036 (Resist. check)	100.0	100.0	100.0	0.0

Table 3 summarizes the reaction of the irradiated wheat-rye lines to Hessian fly. Based on the susceptible checks, there was a high infestation at Jemaa Shaim (96%), but only a moderate infestation at Sidi el Aidi (74%). Most of the irradiated lines had a much lower percentage of plants infested and fewer larvae per plant at Jemaa Shaim, and from 0 to less than 10% and 0 to 1 larva per plant at Sidi El Aidi. All the resistant plants had dead first instar larvae, which confirmed their resistance reactions. These wheat-rye lines also are effective against the most virulent biotypes in the U.S.A. (Hatchett, unpublished data) and

Table 3. : **Reaction of irradiated wheat-rye lines for resistance to Hessian fly in Morocco, 1986-87** [a]

	Number of plants sampled		% plants infested		Avg. no. larvae/ infested plant [b]	
Entry	JS	SEA	JS	SEA	JS	SEA
49 368-B	31	18	3	5.5	1.0	1.0
50 369-B	30	22	17	22.5	4.4	1.0
55 374-B	35	24	9	0	2.0	0
61 379-B	50	24	6	0	1.3	0
64 381-B	43	23	5	4.3	1.0	1.0
67 382-B	40	24	3	0	1.0	0
71 386-B	50	20	4	10.0	3.0	1.0
74 387-B	42	24	12	8.3	1.6	1.0
75 388-B	50	12	10	8.0	2.4	1.0
87 394-B	33	24	9	0	2.0	0
132 479-B	43	25	9	20.0	1.7	1.0
133 480-B	38	24	3	0	1.0	0
134 481-B	33	22	6	0	3.5	0
165 509-B	36	8	14	0	1.5	0
343 658-B	21	21	10	4.0	1.5	1.0
356 661-B	20	19	5	5.0	1.0	1.0
381 667-B	21	22	5	0	3.0	0
410 683-B	23	23	4	4.3	6.0	1.0
427 691-B	10	21	10	4.7	1.0	1.0
450 699-B	14	25	14	0	1.5	0
465 719-B	5	10	0	20.0	0	1.0
485 731-B	12	16	25	6.0	1.3	1.0
489 734-B	18	27	0	7.0	0	1.5
494 737-B	12	26	0	0	0	0
529 751-B	22	15	18	6.0	2.2	1.0
TAM-W101	50	30	100	66.6	7.4	2.0
TAM-106	50	36	98	63.8	6.4	2.0
Vona	50	25	96	92.0	8.0	2.6

[a]JS = Jemaa Shaim; SEA = Sidi El Aidi

[b]The columns refer to live larvae. All wheat-rye lines had dead first instars on resistant plants.

have been shown to carry a wheat-'Balbo' rye chromosomal translocation. Another wheat-rye line carrying a 2BS/2RL chromosome translocation from 'Chaupon' rye (FRIEBE et al., 1990) also has been shown to be effective against the Moroccan Hessian fly (Amri, unpublished data). Backcrosses are being made to transfer these new genes derived from rye into Moroccan bread and durum wheats.

Because of poor seed germination of the **Triticum tauschii** accessions, and because of the similar level of resistance at both Sidi El Aidi and Jemaa Shaim, the data were combined from both locations (Table 4). All accessions that germinated were highly resistant at both locations; no plant was susceptible and dead first instars were found on all plants. Thus, these **T. tauschii** accessions may provide additional genes for use against future virulent biotypes. So far, three resistance genes, **H13,** and two unnamed genes,have been derived from **T. tauschii** and all are effective against the Hessian fly in Morocco and against the most virulent biotype of Hessian fly in the U.S. (HATCHETT and GILL, 1983; AMRI, 1989; EL BOUHSSINI et al., 1988).

As shown in Tables 5, 6, and 7, the resistance reactions of wheats carrying **H5, H11,** or **H13** genes, found earlier (EL BOUHSSINI et al., 1988) were confirmed throughout the six locations and two years of testing. The level of Hessian fly infestation was high on susceptible checks throughout the testing period, 1985 (EL BOUHSSINI, 1986), 1986 and 1987 (Table 8). There was some variability in infestations across locations. As in 1985 (EL BOUHSSINI, 1986), no virulence to **H11** wheat gene was detected at Guich during subsequent years (Tables 5 and 7), but some virulance to **H11** was detected at Sidi El Aidi and Jemaa Shaim in 1987/88. We did not detect any virulance to the **H11** gene at Dar Bouazza, Marchouch or Fez. These data indicate that the initial virulence frequency to the **H11** gene is still low in populations, as shown in 1985 (EL BOUHSSINI, 1986). The virulance to **H13** wheat gene also was still low in most populations, except with 17.5 infestation at Marchouch and 19.5% infestation at Jemaâ Shaim in 1987. The **H5** gene in 'Saada', a spring wheat, was expressed differently than in 'Arthur 71', a winter wheat (Table 6). The percentage of plants infested was much lower in Saada. The difference could be due to temperature sensitivity. Sosa and Foster (1976) showed that temperature sensitivity of Hessian fly resistance genes was biotype dependent. For instance, **H5** in Arthur 71 was not effective against biotypes B and D at 27°C. In Morocco, it is common to have temperatures of about that magnitude starting from March.

Table 4.: **Reaction of <u>Triticum tauschii</u> accessions for Hessian fly resistance at Sidi El Aidi and Jemaa Shaim, 1986-87.**

Accession	No. plants sampled	Percent plants resistant [a]
TA 1634	15	100.0
TA 1645	40	100.0
TA 1651	36	100.0
TA 1656[c]	11	100.0
TA 1664	9	100.0
TA 1666	10	100.0
TA 1667	12	100.0
TA 1669	13	100.0
TA 1670	19	100.0
TA 1671	14	100.0
TA 1674[b]	5	100.0
TA 1677	13	100.0
TA 1678[c]	8	100.0
TA 1687	14	100.0
TA 1691	7	100.0
TA 1692[c]	6	100.0
TA 1707	9	100.0

[a]No plant had live larvae but dead larvae were found in all accessions.

[b]Plants established only at Jemaa Shaim.

[c]Plants established only at Sidi El Aidi.

Table 5. : **Field monitoring of the Hessian fly virulence to wheats having H5, H7, H8, H9, H11, or H13 resistance genes in M‹rocco, 1986-1987.**

Resistance genes	Location					
	Sidi El Aidi		Jemaa Shaim		Guich	
	% plants infested	X no-lar/plt	% plants infested	X no-lar/plt	% plants infested	X no-lar/plt
H5 (Arthur 71)	2.0	1.2	4.0	1.3	10.0	3.8
H7H8	21.0	2.8	20.0	1.6	16.0	1.4
H9	8.0	1.0	54.0	2.2	36.0	2.6
H11	0.0	0.0	0.0	0.0	0.0	0.0
H13	2.0	1.0	8.0	4.5	3.7	1.9
Susc. check (Newton)	58.7	2.7	91.3	3.8	96.0	5.2

Table 6. : **Field monitoring of Hessian fly virulence to wheats having H5, H11, or H13 resistance genes in Morocco, 1987-1988.**

Resistance genes	Location								
	Sidi El Aidi			Jemaa Shaim			Dar Bouazza		
	% plants infested	X no-lar/plt	X larval leng (mm)	% plants infested	X no-lar/plt	X larval leng (mm)	% plants infested	X no-lar/plt	X larval leng (mm)
H5 (Arthur 71)	9.8	5.8	3.6	16.7	13.7	3.7	10.5	3.3	4.0
H5 (Saada)	0.2	3.5	4.0	0.0	0.0	0.0	0.0	0.0	0.0
H11	0.5	1.5	1.7	1.7	3.2	4.1	0.0	0.0	0.0
H13	6.3	5.1	3.4	19.5	9.0	3.7	5.5	5.3	3.8
Susc. check (Newton)	82.7	13.1	3.8	97.9	35.3	5.4	94.6	9.5	4.0

Table 7. : **Field monitoring of the Hessian fly virulence to wheats having H5, H7 H8. H9, H11, or H13 resistance genes in Morocco, 1987-1988.**

Resistance genes	Location: Guich % plants infested	Guich X no-lar/plt	Guich X larval leng (mm)	Marchouch % plants infested	Marchouch X no-lar/plt	Marchouch X larval leng (mm)	Fez % plants infested	Fez X no-lar/plt	Fez X larval leng (mm)
H5 (Saada)	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0	2.9
H7H8	20.0	2.4	4.0	90.0	**102**	3.8	92.0	8.7	3.2
H9	38.0	2.5	4.3	76.0	5.0	4.0	36.0	7.1	3.2
H11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H13	6.0	2.0	3.7	1[illegible].5	4.4	3.7	0.0	0.0	0.0
Susc. check (Newton)	52.0	4.1	4.1	86.0	14.8	4.3	100.0	8.2	3.70.0

Table 8. : **Field monitoring of the Hessian fly virulence to wheats having H5, H7H8, H9, H11, or H13 resistance genes in Morocco, 1985-1988.**

Resistance genes	1985-86		1986-87		1987-88	
	% plants infested	X no-lar/plt	% plants infested	X no-lar/plt	% plants infested	X no-lar/plt
H5	2.5	1.2	0.9	1.6	4.6	6.1
H7H8	34.9	2.5	21.0	2.8	67.3	7.1
H9	46.7	1.7	8.0	1.0	50.0	4.9
H11	3.0	0.8	0.0	0.0	0.4	2.3
H13	4.8	1.3	2.0	1.0	9.1	5.2
Susc. check (Newton)	84.6	3.9	81.2	11.2	85.3	12.3

a Mean of all locations, Sidi el Aidi, Jemaa Shaim, Dar Bouazza, Guich, Marchouch, and Fez.

As in 1985 (EL BOUHSSINI, 1986), the **H9** gene was only moderately effective throughout the locations and the years of testing. The **H7H8** genes exhibited a wide range of variability and were mostly ineffective at Marchouch and Fez (Table 7), but were more effective at Sidi El Aidi, Jemaa Shaim and Guich (Table 5).

The variability of Hessian fly infestations of wheats having resistance genes, **H5, H11, H13, H7H8**, and **H9** across locations indicate differences in biotype frequencies over the cereal production zone of the country. As in 1985 (EL BOUHSSINI, 1986), larval length measurements (Table 6 and 7) suggest that virulence does in fact exist in populations at different locations. The size of larvae on susceptible checks was similar to that of larvae on resistant plants, indicating there was no antibiotic effect and larvae developed normally on infested plants. These results indicate that additional sources of resistance will be needed to stay ahead of biotype evolution in Morocco. Virulence of the Moroccan Hessian fly appears to be much greater than that of Hessian fly in the U.S.A. Only three (**H5, H11**, and **H13**) of the 20 named resistance genes were effective in Morocco. Thus, wild species such as **Triticum tauschii** and rye (**Secale cereale**) should be exploited further for resistance since resistance genes derived from these wheat relatives may be more durable. Once several genes are available, deployment of resistance genes that allow for larval survival on resistant plants may also slow biotype development, since there will be less selection pressure on Hessian fly populations. Hessian fly populations in all the cereal production areas should be monitored closely for changes in virulence as resistance genes are deployed. This monitoring should be continued through the use of a uniform Hessian fly nursery and resistance tests conducted in environmental chambers. Biotypes virulent against specific resistance genes should be isolated in the greenhouse and used to screen for new sources of resistance. The genetic interaction between resistance genes in wheat and virulence genes in the Hessian fly must be studied on a continuing basis so entomologists and breeders can stay ahead of biotype occurrence in nature.

ACKNOWLEDGMENT

We thank KHALIL EL HOUSSAINI and ABDELKADER CHAKIR for their technical assistance. This study was a cooperative investigation by: the National Institute for Agricultural Research (INRA), Rabat, Morocco : the Mid America 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.

ABSTRACT

Several new sources of resistance to Hessian fly were identified in field and greenhouse evaluations of a diverse group of wheat germplasm in Morocco. Eight USDA Plant Introduction bread wheats showed high levels of resistance in the field. Two F4 CIMMYT bread wheat lines also had acceptable levels of resistance to Moroccan Hessian fly and to Hessian fly biotypes GP and D in the U.S.A. when tested in a greenhouse, but their susceptibility to biotype L indicated that the lines may have the **H5** resistance gene. Seventeen accessions of **Triticum tauschii** were highly resistant to the Moroccan Hessian fly in the field. Several of 25 wheat-rye lines carrying putative rye-wheat chromosomal translocations also exhibited a high level of resistance in Morocco. One wheat-rye line (498-737-B) had no plants infested at either Sidi El Aidi or Jemaa Shaim.

A uniform Hessian fly nursery comprised of the effective resistance genes, **H5**, **H11**, and **H13** was used to field monitor changes in virulence of the Hessian fly. Results from 1986, 1987, and 1988 corroborate those of 1985 which showed that virulence of the Hessian fly to **H5**, **H11**, and **H13** genes is low in most populations. However, variation in the frequancy of virulence against the resistance genes exists across different biotypes.

KEY WORDS : Insecta, **Mayetiola destructor, Triticum**, Plant resistance, Biotype.

RESUME

Plusieurs nouvelles sources de résistance, représentant un groupe diversifié de germoplasme de blé, ont été identifiées par des évaluations au champ et en serre au Maroc. Six introductions (USDA) de lignées de blé tendre ont montré des niveaux de résistance élevés au champ. Deux lignées (F4) de blé tendre provenant du CIMMYT avaient des niveaux de résistance acceptables en serre contre la mouche de Hesse Marocaine et les biotypes GP et D aux U.S.A. Mais leur sensibilité au biotype L a indiqué que ces lignées pourraient avoir le gène **H5**. Dix sept accessions de **Triticum taushii** étaient très résistantes au champ contre la mouche de Hesse Marocaine. Plusieurs des 25 lignées blé-seigle, ayant des translocations des chromosomes blé-seigle, ont aussi un niveau de résistance élevé au Maroc. La lignée blé-seigle (498-737-B) n'avait aucune plante infestée dans les deux stations Sidi El Aidi et Jemaa Shaim.

Une pépinière mouche de Hesse composée des gènes de résistance efficaces, **H5**, **H11**, **H13** a été utilisée pour surveiller les changements de la virulence de la mouche de Hesse au champ. Les résultats de 1986, 1987, et 1988 corroborent ceux de 1985 en montrant que la virulence de la mouche de Hesse, dans la plupart des populations, pour les gènes **H5**, **H11**, et **H13** est encore faible. Cependant, l'existence de variabilité de fréquence de virulence contre les gènes de résistance, à travers les différentes zones de production du blé, indique la présence de différents biotypes.

MOTS CLES : insecte, **Mayetiola destructor**, **Triticum**, Résistance, Biotype.

ملخص

عدة أنواع جدد من أنواع مختلفة من القمح الطري المقاومة لدود"هس **(Mayetiola destructor)** قد تم اكتشا فها بعد تجارب في الحقل والمنازل الزجاجية .

ثمانية أنواع مستوردة من أمريكا أظهرت مقاومة عالية في الحقل . نوعان من القمح الطري تم جلبها من المركز الدولي لتحسين القمح والذرى أظهرا كذلك مقاومة لا بأس بها لدودة هس المغربية والأمريكية (G P and D biotypes)

لكن عدم مقاومة هذين النوعين ل (biotype L) تدل على أنها تحتوي على جين المقاومة H 5 .سبعة عشرة أنواع من **(Triticum tauschii)** أظهروا مقاومة عالية ضد دودة "هس" في الحقل . عدة أنواع من 25 نوع من القمح الطري الحاملين لجزء من rye chromosome أظهرت هي الأخرى مقاومة عالية ضد هذه الحشرة بالمغرب .واحدة من هذه الأنواع (B . 737 . 498) لم تصب قط بدودة هس وكان بالمحطتين التجريبيتين سيدي العايدي وجمعة سحيم .

بواسطة تجربة حقلية تضم جينات المقاومة H 5، و H11 ، و H13 لدراسة تغييرات دودة "هس". تأكدت نتائج 1985 والتي أظهرت أن قدرة هذه الحشرة على إصابة القمح الحامل لهذه الجينات (H 5 ، H11 و H13)لازالت ضعيفة . لكن التغييرات في القدرة على الإصابة من منطقة لأخرى تدل على وجود أنواع مختلفة (Biotypes) لدودة "هس" بالمغرب .

REFERENCES CITED

AMRI, A. 1989. In heritance and expression of resistance to Hessian fly (**Mayetiola destructor**) in wheat (Ph. D. dissertation). Manhattan, Kansas : Kansas State University, 122p.

AMRI, A., T. S. COX, B. S. GILL, and J. H. HATCHETT. 1990. Chromosomal location of the Hessian fly resistance gene **H20** in 'Jori' durum wheat. J. of Hered. 81 (1) : 71-72.

BENNANY, S.A. and M. RIANY. 1978. Resultats de quelques années d'essais pratiques de lutle chimique contre les Cécidomyies des Céréales du genre **Mayetiola** sp. Al Awamia 55 : 1-24.

COX, T. S., and J. H. HACHETT. 1986. Genetic model for wheat Hessian fly (Diptera : Cecidomyiidae) interaction : Strategies for deployment of resistance genes in wheat cultivars. Environ. Entomol. 15 (1) : 24-31.

CHOLICK, F.A., J.H. HATCHETT, D. K. STEIGER, and D. L. KEIM. 1987. Registration of SD 8036 Hessian fly resistant hard red spring wheat germplasm. Crop Sci. 27 : 373-374.

DURAND, Y. 1981. Observation sur le cycle evolutif des **Mayetiola** vivant sur orge et blé au MAROC. Al Awamia 24: 1-15.

EL BOUHSSINI, M. 1981. Rapport de stage, Station Centrale des Céréales d'Automne, Institut National de la Recherche Agronomique, Rabat, Morocco.

EL BOUHSSINI, M., A. AMRI, and J.H. HATCHETT. 1985. Three wheat resistance genes, **H5, H11, H13,** effective against the Hessian fly, **Mayetiola destructor** (Say), in Morocco. Rachis 5: 23-25.

EL BOUHSSINI, M. 1986. A study of Hessian fly, **Mayetiola destructor** (Say), biotypes and resistance in wheats in Morocco. M.S. Thesis, Department of Entomology, KSU, 85 pp.

EL BOUHSSINI, M., A. AMRI, and J.H. HATCHETT. 1988. Wheat genes conditioning resistance to the Hessian fly (Diptera : Cecidomyiidae) in Morocco. J. Econ. Entomol. 81 : 709-712.

FRIEBE, B., J. H. HATCHETT, R. G. SEARS and B. S. GILL. 1990. Transfer of Hessian fly resistance from 'Chaupon' rye to hexaploid wheat via a 2BS/2RL wheat-rye chromosome translocation. Theor. Appl. Genet. 79 : 385-389.

GALLAGHER, L. W., A. BENYASSINE, O. BENLHBIB, and M. OBANI. 1987. Sources of resistance to **Mayetiola destructor** in bread wheat and durum wheat in Morocco. Euphytica 36 : 591-602.

GALLUN, R. L. 1977. Genitic basis of Hessian fly epidemics. Ann. N. Y. Acad. Sci. 287 : 223-229.

HATCHETT, J. H. , and R. L. GALLUN. 1970. Genetics of the ability of the Hessian fly, **Mayetiola destructor**, to survive on wheats having different genes for resistance. Ann. Entomol. Soc. Am. 63 : 1400-1407.

HATCHETT, J. H., and B. S. GILL. 1983. Expression and genetics of resistance to Hessian fly in **Triticum tauschii** (Coss) Schmal., pp. 807-811. In Proceedings of the 6th International Wheat Genetics Symposium, Kyoto University, Kyoto, Japan.

HATCHETT, J. H., D.L. KEITH, J.H. HILL, J. E. FOSTER, and G. E. WILDE. 1984. Assessment of cereal pests in Morocco. Incidence and damage, research priorities, needs and recommendations. MIAC Project Report, pp. 24.

JOURDAN, M. L. 1937. Observation sur la biologie de la Cécidomyie destructive (**Mayetiola destructor** say) au Maroc. Bul. de la. Soc. des Sciences Naturelles au Maroc 17 : 154-162.

JOURDAN, M. L. 1938. Observations sur la biologie de la Cécidomyie destructive (**Mayetiola destructor** Say) on Maroc (2 note), Bul. de la Soc. des Sciences Naturelles au Marod 18 : 161-169.

LHALOUI, S. 1986. Effects of plant resistance, insecticide treatment, and planting dates on Hessian fly infestations in wheat in Morocco. (M. S. Thesis), University of Nebraska, 126p.

SOSA, O., Jr., and J. E. FOSTER. 1976. Temperature and the expression of resistance in wheat to the Hessian fly. Environ. Entomol. 5 : 333-336.

SOSA, O., Jr. 1981. Biotype J and L of the Hessian fly discovered in an Indiana wheat field. J. Econ. Entomol. 74 : 180-182.

Photo 9. Seed heads of wild **Triticum tauschii** with several wheat heads. ***T. tauschii*** *is the source of several Hessian fly resistance genes, such as H13, H22* and H23, which have been incorporated into Moroccan bread wheats. Variety development is in progress. (Photograph by J.H. HATCHETT)

Photo 10. Triticale, on the right, derived from a wheat-rye cross and a susceptible wheat, on the left being inspected by interested agricultural personel. Two unnamed rye genes for Hessian fly resistance have been incorporated into Moroccan bread and durum wheats. Variety development is in progress. (Photograph by M. El Bouhssini).

FRIEBE, B., J. H. HATCHETT, R. G. SEARS and B. S. GILL. 1990. Transfer of Hessian fly resistance from 'Chaupon' rye to hexaploid wheat via a 2BS/2RL wheat-rye chromosome translocation. Theor. Appl. Genet. 79 : 385-389.

GALLAGHER, L. W., A. BENYASSINE, O. BENLHBIB, and M. OBANI. 1987. Sources of resistance to **Mayetiola destructor** in bread wheat and durum wheat in Morocco. Euphytica 36 : 591-602.

GALLUN, R. L. 1977. Genitic basis of Hessian fly epidemics. Ann. N. Y. Acad. Sci. 287 : 223-229.

HATCHETT, J. H. , and R. L. GALLUN. 1970. Genetics of the ability of the Hessian fly, **Mayetiola destructor**, to survive on wheats having different genes for resistance. Ann. Entomol. Soc. Am. 63 : 1400-1407.

HATCHETT, J. H., and B. S. GILL. 1983. Expression and genetics of resistance to Hessian fly in **Triticum tauschii** (Coss) Schmal., pp. 807-811. In Proceedings of the 6th International Wheat Genetics Symposium, Kyoto University, Kyoto, Japan.

HATCHETT, J. H., D.L. KEITH, J.H. HILL, J. E. FOSTER, and G. E. WILDE. 1984. Assessment of cereal pests in Morocco. Incidence and damage, research priorities, needs and recommendations. MIAC Project Report, pp. 24.

JOURDAN, M. L. 1937. Observation sur la biologie de la Cécidomyie destructive (**Mayetiola destructor** say) au Maroc. Bul. de la. Soc. des Sciences Naturelles au Maroc 17 : 154-162.

JOURDAN, M. L. 1938. Observations sur la biologie de la Cécidomyie destructive (**Mayetiola destructor** Say) on Maroc (2 note), Bul. de la Soc. des Sciences Naturelles au Marod 18 : 161-169.

LHALOUI, S. 1986. Effects of plant resistance, insecticide treatment, and planting dates on Hessian fly infestations in wheat in Morocco. (M. S. Thesis), University of Nebraska, 126p.

SOSA, O., Jr., and J. E. FOSTER. 1976. Temperature and the expression of resistance in wheat to the Hessian fly. Environ. Entomol. 5 : 333-336.

SOSA, O., Jr. 1981. Biotype J and L of the Hessian fly discovered in an Indiana wheat field. J. Econ. Entomol. 74 : 180-182.