A STUDY OF HESSIAN FLY, MAYETIOLA DESTRUCTOR (SAY), BIOTYPES AND RESISTANCE IN WHEATS IN MOROCCO

by

MUSTAPHA EL BOUHSSINI

B.S., National College of Agriculture (E.N.A.)
Meknes, Morocco, 1980

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

Approved by:

Gerald W. Wilde
Major Professor

I would like to dedicate this thesis to my mother and the rest of my family members.

I would also like to dedicate this to my wife, Rachida, for her help and encouragement during my studies.

TABLE OF CONTENTS

ACKNOWLEDGMENTS

I thank MIAC (MidAmerica International Agricultural Consortium) for the financial support made available to me for this work.

I extend special thanks to my research advisor, Dr. J. H. Hatchett, for his time, encouragement and patience; working with him has been very much a pleasure and a privilege. His knowledge, understanding and encouragement were vital in completion of this work.

I have very much appreciated the whole year I have spent with Dr. D. L. Keith in Morocco while conducting my research. I am indebted to him for his continuous assistance, helpful advice, and critical review of this manuscript.

I am grateful to Dr. G. E. Wilde, my major advisor, for his guidance and valuable instruction.

I also thank Dr. L. Croy for his reading and correction of this manuscript.

Thanks are also extended to Mr. Ken Oppenlander for his technical advice and assistance in the greenhouse.

I would like to thank Dr. R. J. Elzinga and Dr. R. G. Sears for serving on the advisory committee.

I am also grateful to Mrs. C. Kouriri for typing this thesis.

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

Cereals are very important in Morocco. Durum wheat, Triticum turgidum L., bread wheat, T. æstivum L., and barley, Hordeum vulgare L., are grown on almost 80% of the agricultural area. Because 65% of the rural population depends on these crops, stability and enhancement of yield are of major importance. Damage caused by the Hessian fly, Mayetiola destructor (Say), is one of the most important factors causing losses in wheat production in Morocco. While the insect is present in almost all wheat production areas of the country (El Bouhssini 1981, Hatchett et al. 1984), severity of damage is more pronounced in the dryland regions. The first published report of damage to cereals in Morocco was in 1932 (Anonymous 1932), and since then occasional losses of up to 100% in some areas have been observed (Anonymous 1939). Thus, it is critical to Moroccan cereal production that research be done on the control of this important pest. While entomologists from Morocco and elsewhere have experimented with chemicals for controlling Hessian fly, no one has been successful in finding an effective, economical or safe insecticide.

The fall generation of the Hessian fly seems to be the most damaging. First generation larvae feed on young plants and stunt them or kill them before they tiller. In winter wheat areas of the United States, fall infestations can be reduced or largely avoided by delayed wheat planting dates. However, this method is difficult to apply successfully under Moroccan climatic conditions because of hot, dry weather during the early part of the spring growing season. Thus, late planting of wheat delays maturity in the spring when soil moisture becomes critical during the grain filling stage. Typically, Moroccan farmers plant wheat just after the first fall rains. The rains encourage farmers to plant and also trigger development of the Hessian fly, which begins emerging about two weeks after significant rainfall.

Burning of straw and plowing under wheat stubble are not beneficial to Moroccan farmers, since they normally graze animals on stubble and weeds in the field after harvest. The most economical and practical long range solution to the Hessian fly problem is the development of resistant wheat cultivars. The entomology and wheat breeding projects of INRA (National Institute of Agronomic Research) have placed high priority on the development of Hessian fly resistant wheats.

The objectives of the present study were to:

1. Evaluate known sources of Hessian fly resistance in U.S. wheats to Hessian fly in Morocco;

2. Evaluate Moroccan, ICARDA, and U.S.D.A. Plant Introduction wheats, and Triticum monococcum and T. tauschii (Aegilops squarrosa) accessions for Hessian fly resistance in Morocco;
3. Evaluate full-season Hessian fly resistance levels of two winter wheats carrying H11 and H13 genes;
4. Evaluate full-season Hessian fly resistance levels of a spring wheat cultivar SD8036 carrying the H5 gene;
5. Determine the frequency of biotypes capable of infesting wheats carrying the H5, H11, or H13 resistance genes in Moroccan Hessian fly populations;
6. Evaluate the resistance of some Moroccan durum and bread wheats to three Hessian fly biotypes, GP, D, and J, in the United States.

Chapter II

REVIEW OF THE LITERATURE

Hessian Fly Biology in Morocco

Jourdan (1937, 1938) showed that rainfall is the main factor triggering emergence of adults of the aestivated summer generation. He also reported that the number of emerged flies is highly correlated with the quantity of rain and that the early emergence of the first generation in the fall influences the rest of the seasonal life-cycle. In 1965-66, in areas where the rain came early (end of September), the second flight (that of the first generation) began the second week of November on wheat, and in the first days of December on barley (Durand 1967a). In 1964-65, when the rain came late (beginning of November), emergence of the flies of the first generation was delayed until the end of January. Jourdan (1937, 1938) also reported that temperature influenced emergence because after the same quantity of rain, more emergence occurred when maximum and minimum temperatures were between 23.8°C-13.7°C respectively. Durand (1967a) showed that adult emergence from wheat occurred over almost 1 month, whereas emergence from barley was only for 2 weeks. Jourdan (1937, 1938) and Durand (1967a) indicated that two generations could develop on barley and three on wheat.

Jourdan (1938) determined the duration of each generation and of the different stages of the insect as follows:

First generation: 60 days from November - January

Second generation: 50 days from January - March

Third generation: 40 days from March - April

Adults usually live from 3 to 7 days, and they often begin ovipositing on the first day. Egg incubation takes 6 to 9 days, depending on the temperature. The insect has three larval instars; the first lasting 7 to 10 days, the second 10 to 20 days, and the duration of the third highly variable. During the rainy season, the third instar lasts 8 to 25 days. In the dry season, the larva enters aestivation from the beginning of summer to autumn. In this case, the third instar lasts at least 6 months. The pupal stage usually lasts from 7 to 12 days.

Jourdan (1938) also determined duration of the cycle of the insect under controlled temperatures. He found that when the temperature was uniformly maintained at 21°C, the cycle was 1 month long in November. On an average of 19°C (maximum and minimum of 25°C and 17°C) the cycle length was 33 days in February - March.

Damage Caused by the Hessian Fly to Wheat

Destruction of the main tiller often occurs when young plants become infested. Young, susceptible plants that are stunted are dark green in color, but later become chlorotic as they die. Tillering sometimes produces new shoots, which often are attacked by the second

or third generation. As a consequence of late infestation, there is a stunting of the internodes and many heads fail to emerge. Near maturity, infested stems usually break over at the nodes.

Control of the Hessian Fly

Cultural practices. Several cultural practices have been recommended by INRA for Moroccan farmers to use for reducing damage by the Hessian fly. These methods include late planting dates to escape the first generation, burning of straw just after harvest to kill aestivating larvae, summer plowing to bury infested stubble to prevent adult emergence, and destruction of volunteer cereals which serve as hosts for early-emerging flies before wheat emergence. Of these four recommendations, only the destruction of volunteer hosts after the first rain seems applicable and helpful to Moroccan farmers. Delayed planting dates, burning of straw, or summer plowing are usually not compatible with present farming practices.

Parasites. Several species of Hymenoptera have been reported as parasites of the Hessian fly in Morocco. The most abundant species, Platygaster hiemalis Forbes, is distributed all along the Atlantic Coast. Up to 50% parasitism by this species was observed by Bleton (1937). A similar percentage of parasitism was observed in the Fes region, but larvae also were parasitized by two other hymenopteran species, Eupelmus microzonus Forst and Tetrastichus nunctus Nees. These species were found to parasitize aestivating larvae and pupae of the third generation.

Insecticides. Bennani (1968, 1972, and 1978) showed that lindane used as a seed treatment gave good protection. Regehr et al. (1985) found lindane was not effective, but granular carbofuran (Furadan) applied in the seed furrow gave good control of the first generation and also reduced the second generation.

Resistance genes and use of resistant cultivars. Tegyey (1965) made the first attempt to select resistant germplasm to Hessian fly in Morocco. He screened some Moroccan wheats and found two durums, 0287 and 01554, less infested than the others. Durand (1967b) screened several cultivars and lines of durum and bread wheats and found some durums that showed low infestation. El Bouhssini (1981) screened 18 durum wheats, 23 bread wheats, and 16 barleys at seven locations in Morocco. All material tested had high infestation levels. In 1982, El Bouhssini (unpublished data) screened most of the known Moroccan wheats and barleys, including the native collections, introduced lines, and local cultivars. The test included 196 bread wheats, 795 durum wheats, and 147 barleys screened under natural conditions at three locations. Results were not encouraging since none of the wheats were found resistant.

Benyassine (1983) screened, in the field, selected durum and bread wheats and found that the bread wheat lines 41063 (U.S.S.R.), 2731 and 2336 (Portugal), and Portugal 90C7921 (Australia) were resistant. He also reported that the durum lines Ribeiro and Javardo had a very low percentage of infested plants. Benlhabib (1984) continued the

screening and reported 12 bread wheats to be resistant. A majority of the wheats were from Portugal and the others were from the Soviet Union.

In the United States, entomologists and plant breeders have made a major effort to develop Hessian fly-resistant wheat cultivars. Because of the continuous use of resistant wheats, damage by the Hessian fly has been reduced during the last 25 years (Hatchett et al. 1981). Thirteen major genes for resistance have been identified and designated H1 to H13. Other genetic factors for resistance include those derived from 'Marquillo' and 'Kawvale' (Painter 1951). Cartwright and Weibe (1936) found that the wheat cultivar 'Dawson' had two dominant genes for resistance which were later designated H1 and H2. An incompletely dominant gene, designated H3, was identified by Noble et al. (1940). Suneson and Noble (1950) reported the existence of a recessive gene designated h4 in the spring wheat 'Java'. Shands and Cartwright (1953) differentiated a fifth dominant gene conferring resistance which was designated H5. Allan et al. (1959) found a different gene, designated H6, for resistance in a wheat derived from a durum wheat PI 94587. Caldwell et al. (1966) concluded from crosses between PI 94587 and three Ethiopian durums that PI 94587 may have as many as four dominant genes. Patterson and Gallun (1977) identified two partially dominant genes in 'Seneca' wheat which were designated H7 and H8. Two dominant genes were identified in the durum wheat 'Elva', which were designated H9 and H10 (Stebbens et al. 1980, Stebbens 1981). A second dominant gene was identified from PI 94587 and was designated H11 (Stebbens 1981). A partially dominant gene H12 was identified from a common

wheat cultivar 'Luso' from Portugal (Oellermann et al. 1983). Hatchett et al. (1981) discovered a dominant gene, designated H13, in a synthetic hexaploid wheat derived from Triticum tauschii (Coss) Schmal., the donor of D-genome in common wheat. By using monosomic and genetic analysis, some genes have been located and mapped on wheat chromosomes. Chromosome 5A carries three genes, H3 - H6 - H9 (Stebbens, 1981). H11 and H5 genes have been identified on chromosome 1A (Roberts and Gallun 1984). The H13 gene has been identified on the long arm of chromosome 6D (Gill et al. 1986).

The mechanism of resistance conditioned by resistance genes is antibiosis, i.e., first instar larvae die after feeding on resistant plants.

Hessian Fly Biotypes in the United States

Because of deployment and use of resistance genes in wheat cultivars, development of Hessian fly biotypes has increased. Eight biotypes, GP, A, B, C, D, E (Gallun 1977) and J and L (Sosa 1981) occur in the field. Two more biotypes, F and G, have been synthesized and isolated in the laboratory (Wootipreecha 1971). The ten biotypes differ only in their ability to stunt and survive on wheats having different genes for resistance. Table 1 lists the reactions of wheats having different resistance genes to the known biotypes.

Genetic studies of biotype virulence have demonstrated a gene-for-gene relationship between virulence in the insect and resistance in the plant. This means that for every gene pair conferring resistance to the insect in the plant, there is a corresponding specific gene pair

Table 1. Reaction of wheats having different genes for resistance to Hessian fly biotypes.[1]

Biotype	Wheat Cultivars and Resistance Genes				
	Turkey (none)	Seneca H7H8	Monon H3	Knox 62 H6	Abe H5
GP	S	R	R	R	R
A	S	S	R	R	R
B	S	S	S	R	R
C	S	S	R	S	R
D	S	S	S	S	R
E	S	R	S	R	R
F	S	R	R	S	R
G	S	R	S	S	R
J	S	S	S	R	S
L	S	S	S	S	S

[1] R = resistant; S = susceptible

for virulence in the insect that can overcome the resistance in the plant (Hatchett and Gallun 1970). Of the biotypes that have been studied, the genes for virulence were found to be nonallelic and the allele for avirulence at one locus is dominant to the allele for virulence at the same locus. Only if a biotype carries double recessive alleles at a locus will it be virulent to a plant having a specific dominant gene for resistance (Table 2). Thus, with a gene-for-gene relationship, 16 possible biotypes could develop due to the existence of four different allelic pairs in the genotype of the insect that correspond to four in the plant.

Effect of Temperature on Expression of Resistance.

Cartwright et al. (1946) conducted an experiment to test whether temperature has an effect on the expression of resistance to the fly. All cultivars tested, except PI 94587, showed an increase in both the percentage of infestation and the number of surviving larvae as temperatures increased from a cooler (60-65°F) to warmer (75-80°F) temperature. Sosa and Foster (1975), by testing different cultivars to different biotypes, found that increased temperature decreased resistance regardless of the biotype used. The duration of exposure at high temperature also affected the expression of resistance. Sosa (1979), using the B biotype, found that the longer resistant plants are exposed to high temperature the higher the susceptibility. Tyler and Hatchett (1983) showed that plants heterozygous for H13 gene were more susceptible than homozygous resistant plants. Resistance of homozygous plants was significantly reduced only at 31°C. However, a great reduction of resistance was observed at 28°C in the heterozygous plants.

Table 2. Theoretical genotypes of Hessian fly biotypes based on a gene-for-gene relationship between resistance in wheat and avirulence in the insect.[1]

Biotype	Wheat Cultivars and Resistance Genes				
	Turkey (none)	Seneca H7H8	Monon H3	Knox 62 H6	Abe H5
GP	tt	S-	M-	K-	A-
A	tt	ss	M-	K-	A-
B	tt	ss	mm	K-	A-
C	tt	ss	M-	kk	A-
D	tt	ss	mm	kk	A-
E	tt	S-	mm	K-	A-
F	tt	S-	M-	kk	A-
G	tt	S-	mm	kk	A-
J	tt	ss	mm	KK	aa
L	tt	ss	mm	kk	aa

[1] Modified from Gallun (1977).

Chapter III

MATERIALS AND METHODS

Evaluation of the Known Sources of Resistance in U.S. Wheats to the Hessian Fly in Morocco

Field Test 1985. Entries of wheats carrying all known genes for resistance (Table 3) were planted the first week of December, 1984 at Sidi El Aydi, Guich, Marchouch and Sidi Kacem in rows one meter long and 25 cm apart. By the second week of January, 1985, only two locations (Guich and Sidi El Aydi) were ready for evaluation due to varying weather conditions. The other two locations, Marchouch and Sidi Kacem, were evaluated in March, 1985. Entries were planted in single rows (ca. 60 seeds per row) 1 m long with 20 cm between rows. Resistance evaluations were made when plants were in the 3- to 5-tiller stage. The method used for evaluations consisted of sampling in succession a maximum of 50 plants and determining the number of susceptible plants (stunted with dark blue-green leaves). (Some entries had <50 plants because of poor emergence.) Larval density also was estimated by counting the larvae on a maximum of 10 susceptible plants of each entry.

Greenhouse Test 1985. The test was conducted in the fall of 1984. Entries were subjected to Hessian fly infestations in the greenhouse and were evaluated for resistance in January, 1985. Twenty seeds/entry were planted. Newton was used as a susceptible

Table 3. Resistance genes in U.S. wheats evaluated for resistance to Hessian fly in Morocco, 1985.

Resistance genes Cultivar/line	Source/origin	Wheat Class[1]
None (Susc. check)		
Newton	Kansas	HRW
Bennett	Nebraska	"
Marquillo-Kawvale		
Parker 76	Kansas	HRW
KS 80-336	"	"
Brule	Nebraska	"
NE 82656	"	"
Colt	"	"
H1H1H2H2		
Big Club 60	California	SWS
H3H3		
Arkan	Kansas	HRW
Hart	Missouri	SRW
Pike	"	"
Monon	Indiana	"
Arthur	"	"
H5H5		
Oasis	Indiana	SRW
Arthur 71	"	SRW
Downey	"	"
W 11078	Missouri	"
SD 8036	South Dakota	HRS
H6H6		
Knox 62	Indiana	SRW
Auburn	"	"
Fillmore	"	"
Caldwell	"	"
Compton	"	"
W 11081	Missouri	"

Table 3 (cont.).

Resistance genes Cultivar/line	Source/origin	Wheat Class[1]
H7H7H8H8		
Seneca	Ohio	SRW
H9H9		
Ella (822-34)	Indiana	SRW
H10H10		
76529A5-3	Indiana	SRW
H9H9H10H10*		
Stella (812-24)	Indiana	SRW
H11H11		
658C1-23R	Indiana	SRW
H12H12**		
Luso	Indiana	SRW
H13H13		
KS 811152	Kansas (Manhattan)	HRW
KS 811156	"	"
KS 811167	"	"
KS 811261	"	"
KSH 8673	Kansas (Hays)	"
KSH 8700	"	"
KSH 8792	"	"
KSH 8976	"	"
KSH 8998	"	"
KSH 9036	"	"

[1]HRW - hard red winter, SRW - soft red winter, HRS - hard red spring, SWS - soft white spring.
* Field tests only.
** Greenhouse test only.

check. A Hessian fly culture from Marchouch was used to infest these entries. Methods of infestation and of determining resistance or susceptibility of plants were similar to those described by Cartwright and LaHue (1944). Presence of dead larvae was noted in resistant plants and number of larvae was recorded for all susceptible plants.

Field Test 1986. This experiment consisted of testing entries of the Great Plains Uniform Hessian Fly Nursery (UHFN) (Table 4), at two locations, Sidi El Aydi and Jemaa Shaim. Planting was in mid-November, prior to the first rain. Methods of planting, sampling and evaluation were identical to those used in the 1985 field tests.

In addition to the UHFN at Sidi El Aydi and Jemaa Shaim, entries (one entry per row, each 1 meter long) having H13, H11, H5, H7H8 and H9 were planted at the Guich Experimental Station. Evaluation methods were also similar to those used in 1985.

Evaluation of Moroccan, ICARDA, and U.S.D.A. Plant Introduction Wheats, and Triticum monococcum and T. tauschii Accessions for Resistance to Hessian Fly in Morocco.

In 1986, 160 advanced ICARDA wheat breeding lines (Table 14), 15 Moroccan bread wheats, and 10 durum wheats (Table 15) were tested at Ain Nzar Experiment Station, for resistance to the Hessian fly. Planting, sampling and evaluation techniques were similar to the other field experiments, except that in this experiment, 'Nesma' was used every 10 rows as a susceptible check. The T. monococcum and T. tauschii accessions and the U.S.D.A. Plant Introduction wheats

Table 4. Great Plains Uniform Hessian Fly Nursery 1986.

	Cultivar/Line	Resistance	Source
1.	Newton	Susc. Check	Kansas
2.	KS79238-2	Marquillo	Kansas
3.	Arkan	H3	Kansas
4.	KS82H4	H3	Kansas
5.	KSH8998	H13	Kansas
6.	Brule	Marquillo	Nebraska
7.	Brule 84	Marquillo	Nebraska
8.	NE82656	Marquillo	Nebraska
9.	NE82658	Marquillo	Nebraska
10.	Chisolm	Marquillo	Oklahoma
11.	Pike	H3	Missouri
12.	W11078	H5	Missouri
13.	W11081	H6	Missouri
14.	Newton	Susc. Check	Kansas
15.	Seneca	H7H8	Ohio
16.	Knox 62	H6	Indiana
17.	Caldwell	H6	Indiana
18.	6549	H3H6	Indiana
19.	Stella	H9H10	Indiana
20.	Ella	H9	Indiana
21.	76529A5-3	H10	Indiana
22.	657C1-23R	H11	Indiana

Table 4 (cont.).

Cultivar/Line	Resistance	Source
23. 841453 Composite	H12	Indiana
24. Arthur 71	H5	Indiana
25. Newton	Susc. check	Kansas

were planted at Sidi El Aydi Experiment Station, using the same experimental techniques with the susceptible check 'Newton' and the resistant check SD8036 (H5). At each of the two locations, a maximum of 30 plants were sampled to determine the percentage of plants susceptible, and only 5 susceptible plants were used to determine the number of larvae per susceptible plant.

Full-Season Evaluation of Hessian Fly Resistance Levels of Two Winter Wheats Carrying H11 and H13 Genes

The experimental design used was a randomized complete block with four replications, four rows, each 1 m long for each cultivar. Rows were spaced 30 cm apart. Newton was used as a susceptible check. The test was conducted at two locations, Jemaa Shaim and Sidi El Aydi. Two evaluations were made: January (first generation) and April (second generation) because only two full generations were produced in 1985-86. While some adult emergence was observed in April, which may have initiated a third generation, eggs were laid only on very late planted wheats and as such were of no consequence. From every row, a total of 30 plants were sampled, 10 successive plants from each end of the row and 10 from the middle. All plants (120) of the same cultivar were pooled. A subsample of 50 plants from each replicate was randomly selected and examined for larvae, as in the other experiments.

Full-Season Evaluation of Hessian Fly Resistance Levels of the Spring Wheat Cultivar SD8036 Carrying the H5 Gene

The experimental design was the same as that used in the previous experiment, except that the rows were 3 m long. Nesma was used as a susceptible check. This test was conducted at Sidi El Aydi and Jemaa Shaim. Evaluations were similar to those previously described and were also made only twice, for the first and second generation.

Determination of the Frequency of Biotypes in Moroccan Hessian Fly Populations Capable of Infesting Wheats Carrying H5, H11, and H13 Genes

Because of limited greenhouse facilities, only two populations from two different geographical regions, Jemaa Shaim and Sidi El Aydi, were studied. Thousands of infested plants were collected in late January, 1986 from many fields in each area to obtain a representative sample of the local Hessian fly population. Eight seeds each of SD8036 (H5), KS811261-8 (H13), 657C1-23R (H11), and Newton, were planted in clay pots (15/15 cm). After seedling emergence, plants were thinned to 4 per cultivar. When plants were in the one leaf stage, pots were covered with cheesecloth cages and a single female was placed inside each cage. Pots remained covered for 4 to 5 days to prevent contamination by other adults and to permit egg laying and incubation. Over 500 pots per location were planted and infested, but only 151 females from Sidi El Aydi and 140 females from Jemaa Shaim were successfully tested; i.e., plants were oviposited upon.

Evaluations were made three weeks after infestation and consisted of counting the number of live larvae on all susceptible plants. All the resistant plants were checked for dead larvae. Two susceptible plants and two larvae/susceptible plant were randomly chosen to measure the larval size. In this manner it was possible to compare the size of larvae on Newton and those that survived on plants carrying resistance genes.

Evaluation of Moroccan Durum and Bread Wheats to the Great Plains Biotype and Biotypes D and J of Hessian Fly in the United States

This experiment was carried out in the spring of 1985 at the USDA Hessian fly greenhouse in Manhattan, Kansas. The test consisted of 16 bread wheats and 24 durums, including 9 landraces (Table 5). Thirty seeds of each cultivar or line were seeded. However, only 20 seeds were used for each landrace since seed was limited. Wood flats were used with 24 rows/flat, including two rows of Newton as a susceptible check to both biotypes GP and D, and two rows of 'Arthur 71' as a resistant check to biotypes GP and D. Methods of infestation and of determining resistance or susceptibility of plants were similar to those described by Cartwright and LaHue (1944). The durum wheats, 'Haj Mouline', 'Jori', BD 0126, 1658 and 2909, which were homozygous resistant to GP and D, were also tested to biotype J. Arthur 71 was used as a susceptible check and 'Knox 62' was used as a resistant check.

Table 5. Moroccan wheats tested to biotypes GP and D in a greenhouse at Manhattan, Kansas, 1985.

Bread Wheats	Durum Wheats	Landraces (durum wheats)
908	Haj Mouline	BD 0114
5/70-32 Tegyey 32	EII 12	BD 0115
5/70-9 Tegyey 9	EII 13	BD 0116
1646 (Jouda)	EI 18	BD 0118
Marchouch	EI 15	BD 0119
1615	E 43	BD 0112
1708	ACSAD65	BD 0123
1709	EI 28	BD 0126
1710	Jori	BD 0258
1711	EI 43	BD 2909
1712	EI 29	BD 1658
Siete Cerros	2777	
Potam	Cocorit	
Nesma		
Pavon		
1618		

Chapter IV

RESULTS AND DISCUSSION

Evaluation of the Known Sources of Resistance in U.S. Wheats to Hessian Fly in Morocco

The reactions of the different genes tested at four locations in the field in 1985 are shown in Tables 6, 7, 8 and 9. Significant ($P < 0.05$) differences between resistance genes and between locations for both the percentage of plants susceptible and the number of larvae/susceptible plant were observed.

The means comparisons at $\alpha = 0.05$ of the different sources of resistance, for both the percentage of plants susceptible and the number of larvae, were significantly different ($P < 0.05$) between genes H5, H11, H13, H7H8 and H9 and the susceptible checks. Of these five genes, H5, H11 and H13 ranked highly resistant because of the very low (overall average, 4 locations) percentages of susceptible plants (H11: 3.0%, H5: 2.5%, H13: 4.8%), and low larval survival (H11: 0.8, H5: 1.2, H13: 1.3). Several dead larvae were recorded on plants carrying these genes, demonstrating a high level of antibiosis and confirming their resistance.

The H7H8 and H9 genes had only moderate levels of resistance, with 34.9% and 46.7% of the plants susceptible, and 2.5 and 1.8 mean number of larvae/plant, respectively. These results indicate that these two sources are resistant only to some of the biotypes in the populations and therefore probably should not be deployed separately

TABLE 6. Reaction of resistance genes in U.S. wheats to Hessian fly in field tests at Marchouch Station, Morocco, 1985.

	Marchouch Station			
Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	8	348	96.3	4.4
Marq.-Kawv.	7	299	91.6	3.6
H1H2	1	30	93.3	3.3
H3	6	217	90.8	3.8
H5	5	224	3.5	1.7
H6	7	267	94.9	3.6
H7H8	2	90	67.7	3.1
H9	2	79	79.9	1.9
H10	2	86	100.0	6.7
H9H10	1	41	92.7	4.3
H11	1	30	10.0	2.3
H13	21	753	9.8	1.8

Table 7. Reaction of resistance genes in U.S. wheats to Hessian fly in field tests at Sidi Kacem Station, Morocco, 1985.

	Sidi Kacem Station			
Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	8	237	83.4	3.7
Marq.-Kawv.	7	237	85.1	3.5
H1H2	1	24	45.8	4.4
H3	6	146	80.1	3.1
H5	5	163	4.7	1.4
H6	7	192	74.2	3.8
H7H8	2	78	18.0	1.8
H9	2	48	28.8	1.4
H10	2	70	85.8	2.7
H9H10	1	41	90.2	4.1
H11	1	46	2.2	1.0
H13	21	574	4.7	1.2

TABLE 8. Reaction of resistance genes in U.S. Wheats to Hessian fly in field tests at Sidi El Aydi Station, Morocco, 1985.

	Sidi El Aydi Station			
Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	8	375	93.0	4.9
Marq.-Kawv.	7	361	75.9	3.9
H1H2	1	35	82.9	2.7
H3	6	317	74.1	3.4
H5	5	265	1.8	1.5
H6	7	334	80.5	3.9
H7H8	2	91	12.3	2.3
H9	2	91	34.5	1.6
H10	2	103	83.4	2.9
H9H10	1	50	92.0	2.6
H11	1	47	0.0	0.0
H13	21	895	2.3	1.1

Table 9. Reaction of resistance genes in U.S. wheats to Hessian fly in field tests at Guich Station, Morocco, 1985.

		Guich Station		
Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	8	371	65.6	2.5
Marq.-Kawv.	7	341	50.4	3.2
H1H2	1	34	29.4	2.4
H3	6	279	60.8	2.7
H5	5	236	0.0	0.0
H6	7	339	63.7	2.7
H7H8	2	86	41.5	2.9
H9	2	99	43.5	2.1
H10	2	85	57.9	2.3
H9H10	1	50	60.0	2.8
H11	1	50	0.0	0.0
H13	21	852	2.5	1.2

against the fly. Those genes ranked highly resistant (H5, H11, and H13) should be of great value in breeding for Hessian fly resistance in Morocco. As mentioned, there was a location effect on the two measured variables. The H1H2 genes, for example, were only moderately susceptible at Sidi Kacem and Guich stations but were highly susceptible at the other two locations. H7H8 had a low percentage of susceptibility at Sidi El Aydi and Sidi Kacem. The H9 gene was more susceptible at Marchouch. The H11 gene had no plants infested at Sidi El Aydi and Guich, but was infested at Marchouch and Sidi Kacem. The H5 gene was not infested at Guich but had low infestation at the other locations. H13 had a few susceptible plants at all locations with slightly more at Marchouch. These variations in reactions of the different genes by location may indicate differences in virulence of the fly from one location to another.

Results of greenhouse tests generally supported the field data and distinguished H7H8, H9, H5, H11, and H13 from the other genes (Table 10). Only plants having H5, H11, and H13 genes were highly resistant. None of the plants having H11 or H5 were susceptible and only a few (1.2%) of the H13 gene plants were infested. Resistance was also confirmed by the presence of dead larvae on resistant plants. As in the field, H7H8 and H9 genes were moderately resistant and showed a substantially lower level of infestation than the susceptible checks. Some dead larvae were also found on resistant plants having these genes.

TABLE 10. Reaction of resistance genes in wheats to Hessian fly in Morocco. Greenhouse test - INRA Department of Plant Pathology and Entomology, Rabat, 1985.

Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	17	269	87.0	5.0
Marq.-Kawv.	2	32	81.3	6.3
H1H2	1	20	85.0	2.8
H3	2	29	72.4	5.0
H5	2	25	0.0	0.0
H6	3	47	70.2	4.8
H7H8	1	14	14.3	1.0
H9	1	16	18.8	0.7
H10	1	17	82.4	6.3
H11	1	13	0.0	0.0
H12	1	17	64.7	3.3
H13	21	338	1.2	5.5

The reaction of resistance genes represented in the Great Plains Uniform Hessian Fly Nursery to field infestation of Hessian fly at Jemaa Shaim and Sidi El Aydi is shown in Table 11. The comparative reaction of H5, H7H8, H9, H11, and H13 genes to infestation at Guich is shown in Table 12. Even though infestation levels were not as high in 1986 as in 1985, particularly at Sidi El Aydi, the general trends confirm 1985 field and greenhouse results. Marquillo, H3, H6, H10, H9H10, H3H6, and H12 genes were not effective. The H9 gene showed variable reactions, being more susceptible at Jemaa Shaim (54.0%) than it was at the other two locations (8.0% at Sidi El Aydi and 36% at Guich). H7H8 had low percent infestations, 21.0%, 20.0% and 16.0% at Sidi El Aydi, Jemaa Shaim and Guich, respectively. H5, H11 and H13 were highly resistant and easily distinguishable from the susceptible check and the other genes. Of these three genes, H11 was the only one free of larvae at all locations. H5 had a few susceptible plants, 2.0% at Sidi El Aydi, 4.0% at Jemaa Shaim and 10.0% at Guich. H13 also had a few susceptible plants, 2.0% at Sidi El Aydi, 8.0% at Jemaa Shaim and 3.7% at Guich.

A combined tabulation of 1985-86 field data from all locations (Table 13) clearly shows the high resistance levels of H5, H11, and H13. H11 appears to be the most effective gene with 1.7% plants susceptible and 0.5 larvae/susceptible plant. The H5 gene ranks second with 3.7% plants susceptible and 1.6 larvae/susceptible plant, while H13 was next with 4.7% susceptible plants and 1.8 larvae/susceptible plant.

Table 11. Reaction of resistance genes, represented in the Great Plains Uniform Hessian Fly Nursery, to Hessian fly in Morocco. Field tests at Sidi El Aydi and Jemaa Shaim Experiment Stations, 1986.

Resistance genes	No. of entries	Total no. plants sampled	Sidi El Aydi		Jemaa Shaim	
			Percent plants susc.	$\bar{X}$ no. larvae/susc. plant	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	3	180	58.7	2.7	91.3	3.8
Marquillo	6	300	21.3	1.9	72.0	3.4
H3	3	180	50.7	1.8	86.0	3.2
H5	2	100	2.0	1.2	4.0	1.3
H6	3	180	29.7	2.3	62.0	2.7
H3H6	1	50	32.0	1.9	86.0	4.4
H7H8	1	50	21.0	2.8	20.0	1.6
H9	1	50	8.0	1.0	54.0	2.2
H10	1	50	36.0	1.9	88.0	2.8
H9H10	1	50	20.0	1.4	86.0	3.9
H11	1	50	0.0	0.0	0.0	0.0
H12	1	50	50.0	2.0	78.0	2.9
H13	1	50	2.0	1.0	8.0	4.5

Table 12. Evaluation of H5, H7H8, H9, H11 and H13 resistance genes to Hessian fly in Morocco. Field test at Guich Experiment Station, 1986.

Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. Checks	1	50	96.0	5.2
H5	1	50	10.0	3.8
H7H8	1	50	16.0	1.4
H9	1	50	36.0	2.6
H11	1	50	0.0	0.0
H13	6	300	3.7	1.9

Table 13. Summary of reaction of resistance genes in U.S. wheats to Hessian Fly in Morocco. Field tests at all locations,[1] 1985 and 1986.

Resistance genes	No. of entries	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Susc. checks	39	1741	83.5	3.9
Marquillo	40	1838	66.0	3.2
H1H2	4	123	62.8	3.2
H3	30	1319	73.7	3.0
H5	25	1138	3.7	1.6
H6	34	1492	67.5	3.1
H3H6	2	100	59.0	3.1
H7H8	11	495	28.1	2.3
H9	10	467	40.7	1.8
H9H10	6	282	73.5	3.2
H10	10	444	75.2	3.2
H11	6	323	1.7	0.5
H12	1	100	64.0	2.4
H13	92	3474	4.7	1.8

[1] Sidi El Aydi, Guich, Marchouch, Sidi Kacem, Jemaa Shaim.

All three genes have been incorporated into Moroccan wheats. H13, due to its location on chromosome 6D, was transferred only to bread wheats. In addition to being present in some winter wheats, the H5 gene is also present in the South Dakota spring bread wheat, SD8036, a line being tested at several locations in Morocco. SD8036 shows promise, and if it proves disease resistant and is agronomically adapted, could be released as a variety.

Evaluation of Moroccan, ICARDA, and U.S.D.A. Plant Introduction Wheats, and Triticum monococcum and T. tauschii Accessions for Resistance to Hessian Fly in Morocco

All advanced breeding lines and cultivars of bread wheat that ICARDA has in trials at several locations in North Africa and elsewhere were tested to Moroccan Hessian fly in the hope of finding resistance genes. As shown in Table 14, none of these ICARDA cultivars have adequate resistance. Most of the wheats approached or even surpassed the infestation levels of Nesma, the susceptible check, with 86.1% plants susceptible and a mean number of 3.8 larvae/susceptible plant. However, Line No. 155 from Syria had fewer plants infested than the susceptible check (only 33.0 plants infested and 3.0 larvae/susceptible plant) and will be retested. Also, it would be of considerable benefit to test additional spring wheat germplasm from ICARDA and other sources. Therefore, if resistance is discovered, it will be easy for the breeder to rapidly develop such material.

Table 14. Evaluation of ICARDA Crossing Block bread wheats 1985-86 for resistance to Hessian fly in Morocco. Field test at Ain Nzar Experiment Station.

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
1. Kavko	Kenya	30	80.0	4.2
2. Ahgaf = Golan	India/Syria	30	100.0	4.6
3. Debeira = HD2172	India/Syria	30	100.0	4.8
4. Kasyon = FLK'S'/HORK'S' CM 39816-1S-1AP-0AP	Syria	30	97.0	4.0
5. Sham 2	Syria	-	-	-
6. Seri 82	Mexico	-	-	-
7. Castan	-	30	100.0	5.0
8. Vee'S' CM 33027-F-9M-1Y-4M-500Y-500M-502Y-0M	Mexico	30	97.0	2.6
9. Akraa	Pakistan/Syria	30	97.0	3.6
10. Bow'S' CM 33203-F-4M-4Y-1M-1Y-0M	Mexico	25	100.0	4.8
11. NWYT 11	Pakistan	30	100.0	6.4
12. Sakha 69	Egypt	25	100.0	5.0
13. Gv/Ald'S'	Lebanon/Syria	30	100.0	10.2
14. Nar.101/3/PJ/Gb/Tzpp/ kt12/4/Cal/Blo'S' CM 29958-1AP-5AP-0AP	Syria	30	97.0	4.0
15. Ana/Mon'S' CM 51743-S-2714-1G-2GM-0GM	Mexico/Egypt	-	-	-

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
16. Cc/Inia//Prl/Cno/5/ No/Bb/3/Cno//Nad/Chr'S' /4/7C CM 32972-2AP-1AP-0AP-5AP-0AP	Syria	30	87.0	3.4
17. Kvz/Pak 20	Turkey	30	83.0	3.2
18. Vee'S' CM 33027-F-15M-500Y-0M-18B-0Y-0ptz	Mexico	30	80.0	2.4
19. Wa 4767/391//560.81/ 14.53/1015.6410/3/ W-22/4/Ana	Syria	30	73.0	3.4
20. Vee'S' CM 33027-F-15M-500Y-0M-98B-0Y	Mexico	30	80.0	2.8
21. Bb/7C*2//Y50E/Kal*5 CM 29014-7S-2AP-1AP-2AP-0AP	Syria	26	85.0	3.2
22. Kal//Bb/Kal/3/Au// Y50E/Kal*3 CM 48418-A-3M-2Y-1M-3Y-0M	Mexico	30	77.0	3.0
23. P106/19//Soty/Jt*3	Lebanon/Syria	30	87.0	3.6
24. Kvz/Cgn	Turkey	30	100.0	6.0
25. K6290.9/4/Cno/K58N// Tob/Cno/3/We/Sx	Lebanon/Syria	30	97.0	3.4
26. Kvz/3/Cc/Inia//Cno/ ELGAU//Sn64	Turkey	30	87.0	2.0
27. P106/19//Soty/Jt*3	Lebanon/Syria	30	100.0	6.4
28. Ymh/Tob//Ron	Turkey	30	93.0	3.4

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
29. Wa 4767/391//56D.81/ 14.53/1015.6410/3/ W-22/4/Ana	Syria	30	100.0	3.8
30. S.84	-	30	93.0	6.2
31. Ti/Pch CM 27715-1AP-0AP-2AP-2AP-0AP	Syria	30	100.0	6.0
32. Cc/Kal/4/A267//Nad/ LR46/3/Bb/5/Pci'S' CM 32787-1AP-3AP-0AP-2AP-0AP	Syria	30	97.0	6.8
33. Kvz//Cno/Pj62	Mexico/Kenya	-	-	-
34. Prl'S' CM 25988-8Y-3Y-2Y-1M-1Y-0B	Mexico	30	100.0	3.6
35. Vee #9 CM 33027-F-12M-1Y-12M-1Y-2M-0Y	Mexico	30	93.0	4.2
36. Pf72640/Pf7326/ /Pf7065/Ald'S'	Brazil/Mexico	30	100.0	7.6
37. S.Sfm//Soty/Jn(3)	Lebanon/Syria	30	100.0	4.4
38. S.Sfm//Soty/Jn(3)	Lebanon/Syria	30	97.0	6.6
39. Kvz/Cgn	Turkey	25	100.0	4.0
40. Ald'S'/3/Cal//Bb/Cno67 CM 32595-5Y-2M-1Y-1M-1Y-0M	Mexico	30	77.0	6.6
41. Vee'S' CM 33027-F-12M-1Y-9M-0Y	Mexico	30	60.0	3.6
42. Kvz//Kal/Bb/3/Bon CM 33202-E-1M-2Y-0M	Mexico	30	77.0	5.8

Table 14 (cont.)

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
43. WRM/Ptm/Coc CM 43558-N-6Y-1M-1Y-8M-3Y-0B	Mexico	30	87.0	2.2
44. S.Sfm//Soty/Jn(3)	Lebanon/Syria	30	80.0	4.8
45. Ald'S' CM 11683-A-1Y-1M-2Y-0Y-2B-0Y-Optz	Mexico	30	80.0	3.4
46. Pvn'S'/Sprw'S' CM 46702-2AP-0AP-2AP-1AP-0AP	Syria	30	73.0	4.2
47. Pco/Pvn'S' CM 46710-1AP-1AP-1AP-1AP-0AP	Syria	30	97.0	2.4
48. Sannine/Ald'S'	Syria	30	80.0	5.2
49. Pvn'S'/Oln'S' CM 46693-1AP-1AP-4AP-1AP-0AP	Syria	30	77.0	3.2
50. BUC'S' CM 31678-R-4Y-2M-500Y-501M-500Y-500M-0Y	Mexico	30	67.0	3.2
51. Kea'S' CM 21335-C-9Y-3M-1Y-1Y-1Y-0B	Mexico	30	83.0	5.6
52. Vul'S' CM 36064-A-1M-1Y-0M-59B-0Y	Mexico	30	70.0	2.2
53. Nkt'S' CM 40454-11M-4Y-2M-3Y-0M	Mexico	30	93.0	6.7
54. Yd'S'/3/Tob/Era// Tob/Cno67 CM 42310-8Y-4M-5Y-1M-3Y-0B	Mexico	30	100.0	3.0

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
55. Jup/6/Pch/5/Kt54A/N10B// Kt54B/3/Nay59*2/4/Lfn	Syria	30	83.0	2.8
56. Bb/7C*2//Y50E/KAL*3 CM 29014-7S-2AP-1AP-4AP-0AP	Syria	30	87.0	2.8
57. Cno'S'/Pj//GLL/3/Emv'S' CM 35053-1L-1AP-0AP-2AP-1AP-0AP	Syria	30	77.0	3.4
58. Sdy/Cndr'S'	Syria	-	-	-
59. Cmh72-428/Mrc//FLK'S' CM 46869-2AP-0AP-3AP-1AP-0AP	Syria	30	97.0	7.0
60. K6290.9/4/Cno/K58N/ /Tob/3/We/Sx	Lebanon/Syria	30	100.0	2.6
61. P106.19//Soty/Jt*3	Lebanon/Syria	30	70.0	4.0
62. Inia'S'/Cc/4/12300/ Tdo//Jat/3/Pk20	Lebanon/Syria	30	73.0	3.2
63. Gv/4/D6301/Nai//Wrm/ 3/Cno*3/Chr	Lebanon/Syria	30	77.0	4.0
64. Nar/P1/3/Nar67//Cno/ Sn64/4/Yr'S'/3/Bb/ Cal//7C/Nad	Lebanon/Syria	30	100.0	5.0
65. Cal//Bb/Cno/3/7C/ Kt54/N10B	Lebanon/Syria	30	93.0	3.0
66. Sannine/Ald'S'	Lebanon/Syria	30	100.0	1.6
67. Skh8/4/Rrv/WW15/3/ Bj'S'//On*3/Bon	Syria	30	77.0	1.8
68. 7C/Nad63//Tob'S'/8156/ 3/Tob'S'/8156//Cc/Inia	Syria	30	90.0	3.6

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
69. Ti/Pch CM 27715-1AP-0AP-2AP-4AP-0AP	Syria	30	77.0	3.2
70. Kvz/Cgn	Turkey	30	83.0	5.8
71. Chat'S' CM 33090-N-1M-6Y-0M-4K-0K	Mexico/Kenya	30	87.0	2.2
72. Sprw'S'/4/Pato(R)/Cal/3/7C//Bb/Cno CM 35209-2AP-4AP-0AP-5AP-0AP	Syria	30	93.0	2.8
73. Ald'S'/WW 15 CM 39548-2AP-1AP-0AP	Syria	30	80.0	6.0
74. Mrs/Jup//Hork'S' CM 43462-D-3Y-2M-1Y-0M	Mexico	30	83.0	2.4
75. Wal/3/1154/45//Wal/Su92/4/Sol CM 46654-1AP-1AP-2AP-0AP	Syria	30	87.0	2.8
76. Cmh 72-428/Mrc//Flk'S' CM 46869-2AP-0AP-1AP-1AP-0AP	Syria	30	87.0	4.0
77. Carpentero/Carp	Syria	30	60.0	2.0
78. Pvn'S'/5/Fr/K58N//N10B/3/Gv55/4/Sn64//Tzpp*2/An CM 32828-4AP-2AP-0AP-2AP-0AP	Syria	30	70.0	2.6
79. Chr/4/Inia'S'/7C//Cno'S'/Gll/3/Pci'S'//Bb'Inia CM 46935-2AP-0AP-4AP-2AP-0AP	Syria	30	67.0	1.6
80. KIRAC 66	Turkey	30	80.0	3.0
81. NUGAINES	U.S.A.	30	63.0	1.4

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
82. MOLDOVA	Romania	30	73.0	1.8
83. S.Sfm//Soty/Jn(3)	Lebanon/Syria	30	80.0	5.4
84. SD648-5/5/Cc/Kal/4/ Az67//Nad/LR64/3/Bb CM 32669-3AP-1AP-OAP-1AP-OAP	Syria	30	93.0	3.0
85. Hahn'S' CM 33682-L-1Y-1Y-4M-4Y-100B-503Y-OM	Mexico	30	83.0	3.0
86. Tuc'S'/4/Tob/Cc//Pato/ HD832/Bb CM 32464-6AP-3AP-OAP-1AP-OAP	Syria	30	73.0	2.4
87. Ymh/Tob//Ron	Turkey/Kenya	30	70.0	2.0
88. Yd'S'/Bjy'S' CM 40456-12Y-1M-2Y-2M-OY	Mexico	30	90.0	2.6
89. Kvz/Cgn	Turkey/Kenya	30	73.0	2.4
90. Tol73/4/Pato(R)/Cal/ 3/7C//Bb/Cno CM 35412-4M-7Y-5M-1Y-1B-OY	Mexico	23	70.0	4.4
91. Chat'S' CM 33090-T-1M-4Y-OM-1B-OY	Mexico	23	87.0	3.4
92. Flycatcher'S' CM 43598-II-8Y-1M-2Y-4M-2Y-OB	Mexico	23	100.0	5.0
93. Y50E/Kal*3//Hork'S' CM 32111-1M-2Y-4M-1Y-OY	Mexico	23	100.0	6.0

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
94. SD648.511/SD648.5/5/8156/ Chr//Sn64/Kire/3/Bb/ 4/Zbz CM 32670-6S-1AP-1AP-2AP-0AP	Syria	23	70.0	2.8
95. 7C/Ald'S' CM 36581-1Y-3M-4Y-1M-0Y	Mexico	23	90.0	2.2
96. Vee'S' CM 33027-F-12M-1Y-4M-1Y-1M-0Y	Mexico	23	100.0	2.8
97. Sam68/Kal CM 39635-1AP-2AP-0AP-3AP-1AP-1AP-0AP	Syria	30	77.0	4.6
98. Jup/Ald'S' CM 34920-0M-10L-3L-1L-0L	-	18	89.0	3.0
99. Alondra 4546	Brazil	30	100.0	6.0
100. Mitacore	-	30	97.0	3.0
101. Laj 2484	Argentina	30	90	5.2
102. C182.24/C168.3/3/Cno *2/7C//Cc/Tob	Syria	30	100.0	6.4
103. Golan//Mxz/Tob	Syria	30	83.0	5.4
104. Cc//Cal/Sr/3/Kal/Bb	Syria	30	70.0	4.2
105. Ald'S'/WW15 CM 39548-2AP-1AP-0AP-3AP-1AP-2AP-0AP	Syria	30	83.0	2.4
106. Ald'S'/Hvac'S' CM 50366-3AP-3AP-1AP-1AP-0AP	Syria	30	100.0	6.4
107. Maya 74'S'/On//II 60.147 /3/Bb/GLL/4/Chat'S ' CM 58924-2AP-1AP-2AP-0AP	Syria	30	77.0	3.6

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
108. Gv/D6301//Ald'S'	Lebanon/Syria	30	97.0	6.4
109. Sannine/Ald'S'	Lebanon/Syria	29	79.0	4.2
110. Sannine/Ald'S'	Lebanon/Syria	30	73.0	3.2
111. Prl'S' CM 25988-8Y-3Y-2Y-1M-1Y-100B-0Y	Mexico	30	80.0	4.8
112. C183.24-C168.3/3/Cno /7C*2//Cc/Tob	Syria	30	83.0	2.6
113. Bow'S' CM 33203-K-12M-1Y-5M-5Y-0M	Mexico	24	100.0	6.0
114. C182.24-C168.3/3/Cno /7C*2//Cc/Tob	Syria	30	73.0	6.8
115. C182.24-C168.3/3/Cno /7C*2//Cc/Tob	Syria	30	93.0	5.0
116. Vee#4 CM 33027-F-12M-1Y-10M-1Y-3M-1Y-0M	Mexico	30	93.0	1.4
117. T.Aest/Mo//Nac CM 43367-E-3Y-1M-4Y-0M	Mexico	23	83.0	6.4
118. Kvz/Cgn	Turkey/Kenya	25	88.0	4.0
119. Sap'S'/Ald'S' CM 40403-3S-1AP-0AP	Syria	30	93.0	5.8
120. Hoopoe'S'	Mexico/Kenya	30	97.0	2.6
121. Condor'S'/Ald'S' CM 36903-1Y-1M-1Y-0M-3K-0K	Mexico/Kenya	30	87.0	2.4
122. Klt CM 33089-W-3M-7Y-1M-0Y	Mexico	30	80.0	3.2

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
123. Bch'S'/3/Bb/Nor67/ /Cno'S'/7C CM 35297-1L-3AP-OAP-2K-OAP	Syria	30	87.0	7.0
124. Yaco'S' CM 41195-J-7M-1Y-OM-13Y-OB	Mexico	30	73.0	3.4
125. 7C/Pvn'S' CM 36569-8Y-1M-1Y-2M-OY	Mexico	30	87.0	3.8
126. K 4500-2/Bjy'S' CM 40480-23M-2Y-2M-2Y-4M-2Y-OB	Mexico	30	93.0	5.0
127. Mnv'S' CM 37705-G-2Y-3M-1Y-OM	Mexico	30	93.0	4.8
128. Az 67/Pvn'S' CM 42398-24Y-1M-1Y-OM	Mexico	30	93.0	5.4
129. Cc/Kal/4/Az67//Nad/ Lr64/3/Bb/5/Pci'S' CM 32787-1AP-3AP-OAP-2AP-OAP	Syria	30	100.0	5.8
130. Anb'S' CM 20707-A-1Y-8M-1Y-0Y-4Ptz-OY	Mexico	30	83.0	2.8
131. Mai'S'/Pj//Emu'S' CM 33254-T-1M-1Y-6M-500Y-OM	Mexico	30	80.0	5.8
132. GH'S' CM 38795-H-6Y-1M-OY-1Ptz-OY	Mexico	30	87.0	4.8
133. Baya'S' CM 42374-1Y-1M-2Y-2M-1Y-OB	Mexico	30	100.0	5.8

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
134. Maringa	Brazil	23	57.0	3.6
135. Sap'S'/Pato(R)//BSY'S' CM 43646-H-1Y-3M-1Y-0M	Mexico	30	97.0	3.8
136. Cmt/Cdc//P10 CM 43473-J-1Y-1M-3Y-3M-0Y	Mexico	30	90.0	3.2
137. Pvn/Oln CM 46693-1AP-1AP-4AP-1AP-0AP	Syria	30	100.0	5.6
138. CMH72.428/Mrc//Flk'S' CM 46869-2AP-0AP-2AP-1AP-0AP	Syria	30	90.0	4.2
139. SK-7	-	30	87.0	6.2
140. 9D-27-262	-	26	73.0	3.0
141. Pvn'S'/Pam'S' CM 61932-1Y-4M-2Y-0M	Mexico	30	100.0	8.2
142. T.Aest//Kal/Bb/3/Ana CM 38236-G-6Y-4M-4Y-3M-1Y-0M	Mexico	30	83.0	3.8
143. Fengkang 15	China	-	-	-
144. Yd'S'/Pci'S' CM 35044-0L-7AP-1AP-1AP-0AP	Syria	30	60.0	5.4
145. Suweon 220	Korea	30	93.0	3.4
146. Chr/5/TP//Cno/Inia'S'/3/Sr'S'/4/Hork CM 46934-2AP-0AP-1AP-1AP-0AP	Syria	-	-	-

Table 14 (cont.).

Name or cross/ pedigree	Origin	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no.larvae/susc. plant
147. Arz/Sa 42	Syria	30	83.0	3.4
148. Ogosta	Bulgaria	30	90.0	3.8
149. Kvz/Gv	U.S.A.	30	87.0	3.4
150. Katya A-1	-	30	93.0	3.6
151. NS 15-89 A	-	30	87.0	5.0
152. WA 4767/391//56D.81/ 14.53/3/1015.6410/ 4/W22/5/Ana	Syria	30	87.0	3.6
153. 71 ST 2959 (from Romania)/Tob	Syria	27	93.0	6.4
154. Bb/Ron//Cno/No 66/4/Cno /Ven/3/Pj/Bb//Cno/Sn64 CM 32966-3AP-OAP-2AP- 2AP-2AP-OAP	Syria	30	87.0	3.6
155. Klle/Sn64/4/Cj//36896/ Gb54//3/Gb56/N53526/ 5/Hauc'S' CM 40554-4S-1AP-OAP- 3AP-1AP-OAP	Syria	30	33.0	3.0
156. Maya 74'S'/NR-Resel CM 40691-3K-1AP-OAP- 3AP-1AP-OAP	Syria	30	77.0	2.2
157. Pato/On//Maya 74/4/ Bb/3/Pato//Inia/Napo CM 40738-1S-3AP-OAP- 1AP-OAP	Syria	30	87.0	4.8
158. Emu'S'/Tjb84.1543	Syria	28	75.0	4.0
159. Ymh/Ald'S'	Syria	30	90.0	2.4
160. Ymh/Ald'S'	Syria	27	93.0	6.8
161. Nesma (susc. check)	-	435	86.1	3.8

The advanced bread wheat lines of the Moroccan breeding program and Moroccan bread wheats, including cultivars grown by farmers and newly released ones such as 'Jouda' and 'Marchouch 8', were tested in the field for resistance to the Hessian fly. The data summarized in Table 15 show that, except for the Jouda cultivar, all lines tested were susceptible. The percentage of plants susceptible approached or surpassed the susceptible check Nesma, with 89% plants susceptible. The cultivar Jouda, with only 37% plants susceptible and 4.4 larvae/plant, showed moderate resistance and should be retested in the greenhouse.

All lines of the durum wheats, except 1727, were susceptible and had fly infestations. The line 1727 had fewer plants susceptible (44%) and fewer larvae/susceptible plant as compared to Nesma, the susceptible check, with 78% plants susceptible and 3.2 larvae/susceptible plant. The line 1727 should be retested.

Table 16 summarizes the reactions of the U.S.D.A. Plant Introduction wheats to Moroccan Hessian fly. The infestation levels were high; all of the Newton plants sampled were attacked. Three lines, PI 321644, PI 134870, and PI 116231 were highly resistant and none of the plants were infested. Dead larvae were present on all plants. Two others, PI 134867 and PI 86202, had a similar level of resistance to that of SD8036 (H5). The SD8036 had 3% plants susceptible. PI 134807 and PI 86202 had 3% and 5% plants susceptible, respectively. PI 116311, with a few more plants susceptible (7%) than the others, also had dead larvae on the resistant plants. Because these plant introductions appear to have a high level of resistance to Moroccan

Table 15. Evaluation of Moroccan durum and bread wheats for resistance to the Hessian fly in Morocco. Field test at Ain Nzar Experiment Station, 1986.

Cultivar/line	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/ susc. plant
I. Bread wheat			
1. ACSAD 59	30	80.0	5.0
2. 5/70 - 9	30	83.0	4.2
3. 17/0	30	60.0	3.2
4. ACSAD 67	22	59.0	2.6
5. Potam	30	97.0	5.6
6. 1618	30	83.0	4.4
7. 1724	30	100.0	3.4
8. 1723	30	83.0	3.0
9. Jouda 1646	30	37.0	4.4
10. Marchouch 8	30	77.0	1.8
11. 1711	30	77.0	8.0
12. 1712	30	77.0	3.6
13. 1725	30	87.0	3.6
14. Tegvey 5/70-32	30	77.0	3.0
15. Nesma (susc. check)	41	89.0	8.2

Table 15 (cont.).

Cultivar/line	Total no. plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/ susc. plant
II. Durum wheat			
1. 1715	30	83.0	3.0
2. 1728	30	63.0	1.8
3. 1727	16	44.0	2.8
4. Kyperounda	30	70.0	2.2
5. 1726	30	97.0	4.2
6. 1718	30	97.0	4.6
7. E 28 "S"	24	71.0	3.0
8. Cocorit	-	-	-
9. ACSAD 65	20	100.0	8.8
10. Marzak	26	65.0	5.2
11. Nesma (susc. check)	18	78.0	3.2

Table 16. Reaction of U.S.D.A. Plant Introductions wheats to Hessian fly in Morocco. Field test, Sidi El Aydi Experiment Station, 1986.

Cultivar/ line	No. of entries	Total no.plants sampled	Percent plants susc.	$\bar{X}$ no. larvae/ susc. plant
PI 134867	1	30	3.0	3.0
PI 321644	1	30	0.0	0.0
PI 116311	1	15	7.0	4.0
PI 134870	1	30	0.0	0.0
PI 116231	1	30	0.0	0.0
PI86202	1	20	5.0	4.0
Susc. check (Newton)	1	30	100.0	3.6
SD8036 (H5)	1	30	3.0	2.0

Hessian fly, the genetics of resistance should be studied to determine whether they have new resistance genes.

Data summarizing the reaction of Triticum monococcum accessions to Moroccan Hessian fly are shown in Table 17. This test also had a high infestation level. Of the 69 Newton plants examined, all were infested and had an average of eight larvae per plant. Most of the 34 T. monococcum examined approached the susceptibility of Newton. Accession 4107 had a lower percentage of susceptible plants (21%) and a lower number of larvae (1.7) per susceptible plant than the other accessions and the susceptible check. This accession should be tested in the greenhouse and at several field locations to verify resistance.

The reactions of the T. tauschii accessions to Hessian fly in Morocco are given in Table 18. Again, a high level of infestation was present and all Newton plants were attacked. The number of larvae per plant was also high (8.8). All three accessions were highly resistant. TA 1651 and TA 1656 had zero plants infested and TA 1645 accession had a few infested plants (3%). These accessions appear to be excellent sources of resistance that wheat geneticists should transfer to bread wheats. The wild wheat, T. tauschii, may provide many new resistance genes to the Hessian fly, either here in Morocco or elsewhere in the world.

Full-Season Evaluation of Hessian Fly Resistance Levels of Two Winter Wheats Carrying H11 and H13 Genes in Morocco

Table 19 summarizes the data of two Hessian fly evaluations, one for the first generation at the end of January (Time 1) and the other

Table 17. Reaction of Triticum monococcum accessions to Hessian fly in Morocco. Field test, Sidi El Aydi Experiment Station, 1986.

Accession/ cultivar	No. of entries	Total no. plants sampled	Percent plants infested	$\bar{X}$ no.larvae/ susc. plant
4105	1	21	90.0	5.4
4108	1	30	70.0	3.4
4111	1	17	100.0	3.0
4112	1	30	83.0	2.4
4114	1	30	93.0	7.2
4115	1	27	78.0	5.2
4116	1	17	65.0	3.2
4112	1	30	100.0	4.0
4123	1	30	100.0	4.0
4124	1	30	83.0	4.4
Newton (susc. check)	3	69	100.0	8.0
SD8036 (H5)	3	90	0.0	0.0
4125	1	30	93.0	4.6
4127	1	30	100.0	4.6
4129	1	30	87.0	3.2
4131	1	30	43.0	2.4
4132	1	30	83.0	3.0
4135	1	30	93.0	2.0
4136	1	27	100.0	5.4

Table 17 (cont.).

Accession/ cultivar	No. of entries	Total no. plants sampled	Percent plants infested	$\bar{X}$ no.larvae/ susc. plant
4137	1	26	77.0	7.6
4138	1	10	100.0	2.8
4139	1	12	100.0	2.8
4141	1	30	43.0	3.2
4144	1	30	97.0	7.8
4145	1	30	70.0	4.6
4146	1	30	93.0	5.2
4147	1	24	88.0	6.4
4148	1	9	100.0	3.4
4133	1	29	52.0	3.4
4142	1	16	100.0	3.6
4106	1	7	100.0	4.0
4119	1	18	100.0	2.8
4109	1	12	75.0	2.4
4128	1	11	91.0	5.4
4107	1	14	21.0	1.7

Table 18. Reaction of *Triticum tauschii* accessions to Hessian fly in Morocco. Field test, Sidi El Aydi Experiment Station, 1986.

Accession/ cultivar	No. of entries	Total no. plants sampled	Percent plants infested	$\bar{X}$ no.larvae/ susc. plant
TA 1645	1	30	3.0	1.0
TA 1651	1	11	0.0	0.0
TA 1656	1	6	0.0	0.0
Newton (susc. check)	1	23	100.0	8.8
SD8036 (H5)	1	30	0.0	0.0

Table 19. Evaluation of first and second generation Hessian fly resistance levels of two winter wheats (H11, H13) compared to susceptible wheat, Newton, in Morocco. Field planting, two locations[1], 1986.

Cultivar/ gene	Total no. plants	First generation January		Second generation April	
		Percent plants susc.	$\bar{X}$ no. larvae/susc. plant	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
Newton	400	69.7	3.0	84.5	19.4
H11	400	0.7	1.0	2.2	3.3
H13	400	7.0	2.3	13.7	7.0

[1] Sidi El Aydi and Jemaa Shaim.

for the second during the first week of April (Time 2). Analyses of variance were made to test whether there is an effect of the buildup of the fly population from the first to the second generation on the two variables measured: percentage of plants susceptible and number of larvae per susceptible plant.

As indicated in Table 20, there was a highly significant ($P < .01$) difference between the number of larvae per susceptible plant at Time 1 and at Time 2 for the susceptible cultivar Newton. This number ranged from 3.0 larvae at Time 1 to 19.4 at Time 2. For the resistance genes H11 and H13, even though there were some increases in the number of larvae from Time 1 to Time 2, they were not significant. This is illustrated in Fig. 1. Table 21 shows that the percentage of plants susceptible increased from Time 1 to Time 2 on the susceptible check, Newton and the resistance genes (H11 and H13), but the difference was not significant. Fig. 2 illustrates these increases from Time 1 to Time 2.

Several explanations could be given for these increases in infestation levels from the first to the second generation. Perhaps the most logical explanation is that the high larval populations may have simply overpowered the resistant plants, allowing more larvae to survive. Also, in the second generation of the fly, new virulent genotypes may have resulted from the mating of the two heterozygous genotypes (previously avirulent). If the latter is the case, then the development of new biotypes may be rapid in Morocco. From the first generation to the next is a matter of just a few months, a good reason for entomologists to search for more sources of resistance and

Table 20. Means across blocks for specific treatment combinations of the number of larvae/susceptible plant.

	Cultivar/gene		
	Newton	H11	H13
Time 1	3.0	1.0	2.2
2	19.4	3.2	7.0

LSD (5%) = 8.9
LSD (1%) = 14.1

Table 21. Means across blocks for specific treatment combinations of the percent plants susceptible.

	Cultivar/gene		
	Newton	H11	H13
Time 1	69.7	.7	7.0
2	84.5	2.2	13.7

LSD (5%) = 22.1
LSD (1%) = 34.6

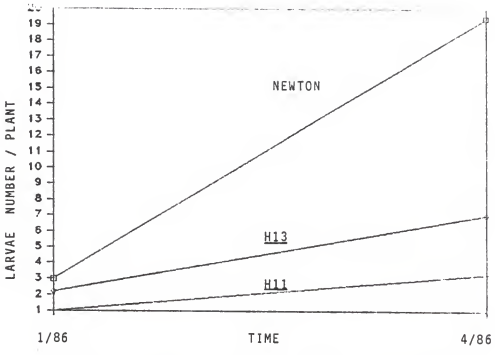

Fig. 1. Hessian fly larvae on Newton (susceptible), H11 and H13 (resistance genes) wheat cultivars from the first (1/86) to the second generation (4/86) in field tests at Sidi El Aydi and Jemaa Shaim, Morocco, 1986.

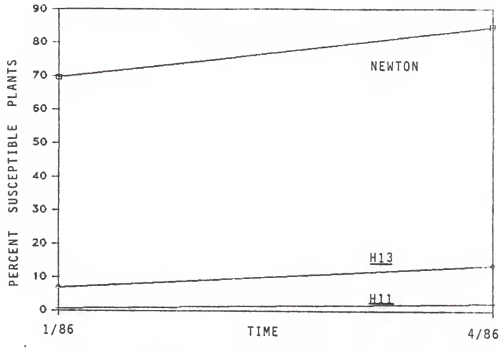

Fig. 2. Plants with Hessian fly infestation on Newton (susceptible), H11 and H13 (resistance genes) wheat cultivars from the first (1/86) to the second generation (4/86) in field tests at Sidi El Aydi and Jemaa Shaim, Morocco, 1986.

remain ahead of the problem. It would be worthwhile to repeat the work for more years in order to develop a model predicting the durability of a resistance gene in Morocco. Another plausible explanation for infestation differences (Times 1 and 2) is that they may have been due to the environment, mainly temperature, which is usually higher, on the average, after February. More precise tests, conducted in growth chambers, could give an estimate of the temperature sensitivity of these resistance genes.

In general, there were increases only in the number of larvae and not in the percentage of plants susceptible. This could be due to the aging (yellowing, etc.) of the plants, so that even if the number of ovipositing females of the first generation were high, there would be a reduced number of choices (younger and greener leaves preferred) for oviposition. However, for infested plants that remain attractive, a greater number of females would be available to oviposit, increasing the probability of a higher number of larvae per plant, but not necessarily increasing the number of infested plants. The latter might even decrease from the first generation to the next.

An important topic to consider is the comparative increase or decrease of the fly population on susceptible versus resistant cultivars. For example, at Jemaa Shaim, Newton, a winter wheat, was the susceptible check. The percentage of germination (evaluated at the 3-leaf stage) of Newton was 66 plants/linear meter of row. Since the spacing between rows was 0.30 m, plant density was 66 plants/0.3 m^2. Of these plants, 85% were infested, which did not change from the first to the second generation. Thus, there were 56 infested

plants/0.3 m^2, or 1,866,667 infested plants/ha. So for the first generation there were 1,866,667 infested plants x 4.08 larvae/plant = 7,616,000 larvae/ha. Using similar calculations for the second generation, there were 1,866,667 infested plants x 14.93 larvae/plant = 27,869,334 larvae/ha. This constitutes a tremendous buildup of the population on the susceptible cultivar. More adults means increased probability for some mating, which could produce new virulent genotypes. At Sidi El Aydi, following the same procedure, numbers of larvae increased from 2,372,400 larvae/ha for the first generation to 44,192,540 larvae/ha for the second generation. In this case, the number of larvae multiplied by almost 19 times from the first to the second generation. However, if we look at the resistance gene H11, we had 0 plants infested at Sidi El Aydi for the first generation. Theoretically, this means we have reduced the population by 2,372,400 flies. For the second generation the percentage of plants infested was 3.0. Following the same method of calculation, we had 2.23 plants infested/0.3 m^2 or 74,333 infested plants/ha. The total number of larvae is then 81,766. Therefore, we have reduced the potential fly population by 44,110,773 flies/ha. Considering the resistance gene H13 at the same location, there was a reduction in the fly population by 2,228,738 during the first generation and by 43,189,023 larvae/ha for the second. The results suggest that a large reduction of the fly would occur if the resistance genes H11 and H13 were deployed. Conversely, this also demonstrates that thousands of flies/ha may survive and reproduce on wheats having these resistance genes. Therefore, while hastening to deploy these

useful genes, they should not be relied on alone for long-term protection, since they will likely be rendered ineffective by virulent biotypes at some time in the future.

Full-Season Evaluation of Hessian Fly Resistance Levels of the Spring Wheat Cultivar SD8036 Carrying H5 Gene in Morocco

Two evaluations were made, one in January for the first generation (Time 1) and a second in April for the second generation (Time 2) (Table 22). As with H11 and H13, analyses of variance were made for the two variables: percentage of susceptible plants and the number of larvae/susceptible plant for the H5 gene.

Table 23 shows that there was a significant difference ($P < 0.01$) in number of larvae/susceptible plant from the first to the second generation only for Nesma, the susceptible check. This number increased from 3.3 to 12.9 larvae/plant. For the resistance gene (H5), this number decreased from 1.0 to 0.0 larvae/plant. Fig. 3 clearly illustrates the difference between Nesma and SD8036 (H5).

Table 24 indicates a slight but not a significant increase in the percentage of susceptible plants only for Nesma from Time 1 to Time 2. This is illustrated in Fig. 4. Following similar calculations to estimate comparative population increase on susceptible vs. resistant wheat, the mean percent germination of Nesma at the two locations was 68 plants/meter of row, or 68 plants/0.3 m^2. The mean percent infested plants at the two locations was 62.5, which calculates to 42.5 infested plants per 0.3 m^2 or 1,416,667/ha. The number of larvae/ha is then 4,675,000 for the first generation.

Table 22. Evaluation of first and second generation Hessian fly resistance levels of the spring wheat cultivar SD8036 (H5) compared to susceptible wheat Nesma in Morocco. Field planting, two locations[1], 1986.

Cultivar/ gene	Total no. plants	First generation January		Second generation April	
		Percent plants susc.	$\bar{X}$ no. larvae/susc. plant	Percent plants susc.	$\bar{X}$ no. larvae/susc. plant
SD8036 (H5)	400	0.7	1.0	0.0	0.0
Nesma	400	62.5	3.3	69.3	12.9

[1] Sidi El Aydi and Jemaa Shaim

Table 23. Means across blocks for specific treatment combinations of the number of larvae/susceptible plant.

		Cultivar/gene	
		SD8036(H5)	Nesma
Time	1	1.0	3.3
	2	0.0	12.9

LSD (5%) = 1.1
LSD (1%) = 2.1

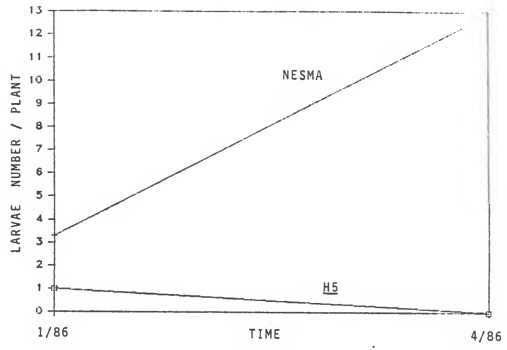

Fig. 3. Hessian fly larvae on Nesma (susceptible) and SD8036 (H5 resistant gene) wheat cultivars from the first (1/86) to the second generation (4/86) in field tests at Sidi El Aydi and Jemaa Shaim, Morocco, 1986.

Table 24. Means across blocks for specific treatment combinations of the percent plants susceptible.

		Cultivar/gene	
		SD8036(H5)	Nesma
Time	1	.7	62.5
	2	0.0	69.2

LSD (5%) = 40.9
LSD (1%) = 75.2

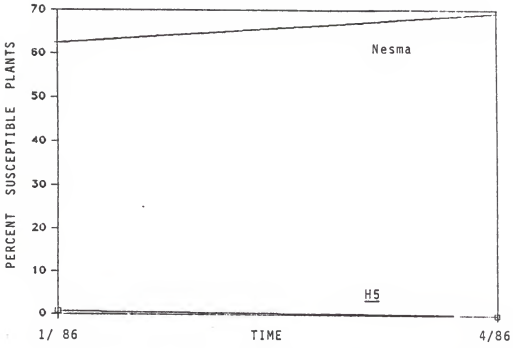

Fig. 4. Plants with Hessian fly infestation on Nesma (susceptible) and SD8036 (H5 resistant gene) wheat cultivars from the first (1/86) to the second generation (4/86) in field tests at Sidi El Aydi and Jemaa Shaim, Morocco, 1986.

At the second generation, the percent plants susceptible increased to 69.3, which increases the number of infested plants to 47/0.3 m^2 or 1,566,67 infested plants/ha. The number of larvae/ha is then 20,210,000, which is an increase of approximately 4.5 times from the first to the second generation on Nesma.

It appears that the resistance gene H5 reduced the fly population by 100%, since there were no plants infested by the second generation. The reduction is then 20,210,000 larvae/ha. It appears that millions of flies can be eliminated each year by growing resistant cultivars. Therefore, wheat production could be stabilized for some time by properly deploying different or new resistance genes when the frequency of virulent biotypes appears to be increasing as a result of selection by a resistance gene.

Frequency of Biotypes in Moroccan Hessian Fly Populations Capable of Infesting Wheats Carrying H5, H11, and H13 Genes

The different frequencies of virulence in the Sidi El Aydi Hessian fly population to the three resistance genes, H5, H11 and H13, are summarized in Table 25. The infestation levels on the susceptible check indicate a high average (7.4) number of larvae per susceptible plant. The mean larval length (3.5 mm) of live larvae on the Newton plants is indicative of normal larval development. The highest frequency of virulence (13%) occurred on the H13 gene, with 12% virulence only to H13 and 1% virulence to H11 and H13. Of a total of 20 virulent larval progenies, 17 gave heterogeneous reactions, one gave a homogeneous reaction on H13, and two gave

Table 25. Frequency of the virulent biotypes in Sidi El Aydi Hessian fly population that can survive on the three resistance genes H5, H11, and H13. Morocco, Greenhouse test, 1986.

Source	Frequency of virulence (%)		$\bar{X}$ no. larvae/ susc. plant	$\bar{X}$ larval length (mm)
	Homogeneous reaction[1]	Heterogeneous reaction[2]		
Newton (susc. check)	100.0	0.0	7.4	3.5
H5	1.0	1.0	10.5	4.3
H11	1.0	3.0	4.4	3.4
H13	1.0	11.0	7.3	3.7
H5 and H11	0.0	1.0	7.8	3.5
H5 and H13	0.0	0.0	-	-
H11 and H13	0.0	1.0	6.5	3.8
H5, H11, and H13	0.0	0.0	-	-

[1] All four plants of the same cultivar were susceptible.

[2] Some of the four plants were susceptible and the others were resistant (dead first instar larvae were present).

heterogeneous reactions on H11 and H13. In the case of heterogeneous reactions, the adults could either be both heterozygous or one heterozygous and one homozygous recessive. The homogeneous reaction of a progeny could result only by the mating of homozygous recessive adults. The number of live larvae on susceptible plants of the H13 gene (7.3) and the mean length of live larvae (3.7 mm) were similar to those of the susceptible check. Since there was no antibiotic effect of this resistance gene on the larval progenies, these adults would appear to be a true biotype virulent to the H13 gene. If the seeds of the line KS811261-8 (H13) are pure, then the frequency (13%) of virulence to this gene could be considered important. Since this much virulence exists, resistance may soon be lost after resistant cultivars having the H13 gene are widely grown in the country. Even though the frequency of virulence is low (1%), it seems that there is a true biotype developing in the Sidi El Aydi population that can attack the two resistance genes H11 and H13; the number of live larvae on these two genes was 6.5 and the length of live larvae was 3.8 mm.

The second highest frequency of virulence (6.0%) was on the H11 gene, with 4% virulence to H11 alone, 1% to H5 and H11, and 1% to H11 and H13. Only two females virulent to this gene gave homogeneous reactions; the others were heterozygous. The mean number of live larvae (4.4 for H11, 7.8 for H5 and H11, and 6.5 for H11 and H13) approached those of the susceptible check, indicating that this virulence may also be a true biotype that can develop on H11, H5 and H11, or H11 and H13 genes. No virulence to the combination of the three

genes (H5, H11, or H13) was detected in the Sidi El Aydi fly population.

The H5 gene had the lowest frequency of virulence (3.0%) with 1% of the progenies having homogeneous susceptible reactions and 1% having heterogeneous ones on H5 alone. On the H5 and H11 combination genes, 1% had heterogeneous reactions. The number of live larvae was quite high (10.5 for H5, and 7.8 for H5 and H11). Larval growth was also normal (4.3 mm for H5, and 3.5 mm for H5 and H11). These results indicate the presence of a true biotype capable of surviving on H5 and H5 and H11 plants.

In summary, the frequency of virulent biotypes in the Sidi El Aydi population is low for H11, H5, H11 and H13, and H5 and H11 genes, but quite high for the H13 gene.

Table 26 summarizes the data on biotypes in the Jemaa Shaim population. The infestation level of 7.8 larvae per susceptible plant on Newton, the susceptible check, was sufficient and the mean larval length (3.5 mm) was indicative of normal development. Again, at this location, the H13 gene had the highest frequency of virulence (13%). Of the population tested, 4% gave homogeneous reactions. A true biotype that can attack this gene is present at this location, since both the number of larvae per susceptible plant (6.5) and the larval length (3.7 mm) were similar to those of the susceptible check.

The frequency of virulence to the H11 gene at Jemaa Shaim was only 2%. Of the virulent progenies, 1% gave a homogeneous reaction and 1% gave a heterogeneous one. Although few larvae developed on

Table 26. Frequency of the virulent biotypes in Jemaa Shaim Hessian fly population that can survive on the three resistance genes H5, H11 and H13. Morocco, Greenhouse test, 1986.

Source	Frequency of virulence (%)		$\bar{X}$ no. larvae/ susc. plant	$\bar{X}$ larval length (mm)
	Homogeneous reaction[1]	Heterogeneous reaction[2]		
Newton (susc. check)	100.0	--	7.8	3.5
H5	0.0	0.0	-	-
H11	1.0	1.0	1.5	3.7
H13	4.0	9.0	6.5	3.7
H5 and H11	0.0	0.0	-	-
H5 and H13	0.0	0.0	-	-
H11 and H13	0.0	0.0	-	-
H5,H11, H13	0.0	0.0	-	-

[1] All four plants of the same cultivar were susceptible.

[2] Some of the four plants were susceptible and the others were resistant (dead first instar larvae were present).

the H11 plants, they exhibited normal larval growth (3.7 mm), demonstrating that they are probably a true biotype.

No virulence to the H5, H11 and H13, H5 and H13, or H5, H11 and H13 resistance genes could be detected at Jemaa Shaim, possibly due to insufficient sampling. In comparing the data from the two locations, it does not appear that the populations from the two areas differ in frequency of virulent biotypes. This would be expected since the same susceptible wheat cultivars are grown over the entire region.

Evaluation of Moroccan Durum Wheats and Bread Wheats to the Great Plains (GP) Biotype and Biotypes D and J of Hessian Fly in the United States

The results of the tests to biotype GP are presented in Table 27. Two durum cultivars (Haj Mouline and Jori), three landraces (BD 0126, 1658 and 2909), and two durum breeding lines (EI43 and E43) were homozygous resistant to biotype GP. Dead larvae were present on all resistant plants, confirming the resistance reaction. Most of the breeding lines, if resistant, were in the heterozygous condition. Because these lines were resistant to this biotype, they must have resistance genes; biotype GP cannot survive on any wheat having resistance genes.

All 16 bread wheat lines tested to GP biotype were susceptible and therefore cannot possess any resistance genes. A test of the Moroccan wheats to biotype D (Table 28) showed that only the cultivars Haj Mouline, Jori and the landraces BD 0126 and BD 2909 remained homozygous resistant. The resistance reaction was also confirmed

Table 27. Summary of reaction of Moroccan durum wheats to Hessian fly biotype GP, Manhattan, Kansas, 1984.

Entry	Biotype GP			
	No. plants		$\bar{X}$ no. dead larvae/ resist. plant	$\bar{X}$ no. larvae/susc. plant
	Resist.	Susc.		
Cultivars				
Haj Mouline	24	0	1.4	0
ACSAD 65	0	4	-	6
Jori	16	0	6	0
Cocorit	18	8	1.8	4
Landraces				
BD 0122	0	13	-	4.4
BD 0114	0	18	-	2.2
BD 0115	0	17	-	2.4
BD 0116	11	6	1.2	2.8
BD 0118	0	13	-	6.8
BD 0119	0	16	-	4.2
BD 0123	0	14	-	3.8
BD 0126	24	0	2.6	-
BD 0258	0	21	-	4.6
BD 1658	19	0	2.2	-
BD 2909	21	0	3.4	-

Table 27 (cont.).

Entry	Biotype GP			
	No. plants		$\bar{X}$ no. dead larvae/ resist. plant	$\bar{X}$ no. larvae/susc. plant
	Resist.	Susc.		
Breeding lines				
EII 12	13	9	2.6	5.8
EII 13	19	3	1.6	3.0
EI 15	9	11	0.8	4.6
EI 18	10	8	2.6	4.2
EI 28	0	13	-	3.8
EI 29	14	1	3.8	6.0
EI 43	28	0	2.0	-
E 43	24	0	2.8	-
Checks				
Newton (susc.)	0	22	-	3.4
Arthur 71 (resist.)	26	0	2.73	-

Table 28. Summary of reaction of Moroccan durum wheats to Hessian fly biotypes D and J, Manhattan, Kansas, 1984.

Entry	Biotype D				Biotype J	
	No. plants		$\bar{X}$ no. dead larvae/resist. plant	$\bar{X}$ no. larvae/ susc. plant	No. plants	
	Resist.	Susc.			Resist.	Susc.
Cultivars						
Haj Mouline	16	0	1.4	-	2	7
ACSAD 65	0	5	-	6.2	-	-
Jori	15	0	0.5	-	0	8
Cocorit	14	10	0.7	1.0	9	9
Landraces						
BD 01224	0	17	-	2.2	-	-
BD 0114	0	14	-	2.4	-	-
BD 0115	0	21	-	1.0	-	-
BD 0116	12	5	0.3	2.4	8	3
BD 0118	0	12	-	2.0	-	-
BD 0119	0	18	-	0.9	-	-
BD 0123	0	20	-	1.7	-	-
BD 0126	17	0	1.5	-	6	3
BD 0258	0	16	-	2.5	-	-
BD 1658	19	2	0.4	2.0	8	2
BD 2909	21	0	0.7	-	20	0

Table 28 (cont.).

Entry	Biotype D				Biotype J	
	No. plants		$\bar{X}$ no. dead larvae/resist. plant	$\bar{X}$ no. larvae/ susc. plant	No. plants	
	Resist.	Susc.			Resist.	Susc.
Breeding Lines						
EII 12	7	12	1.1	1.9	-	-
EII 13	14	5	1.6	6.2	5	3
EI 15	5	8	1.4	2.0	3	9
EI 18	9	13	1.1	1.9	9	13
EI 28	0	20	-	1.9	-	-
EI 29	12	9	1.2	2.1	-	-
EI 43	18	7	0.9	2.4	7	3
E 43	13	6	1.1	1.7	5	2
Checks						
Newton (susc.)	0	23	-	3.5	-	-
Arthur 71 (H5)	17	7	0.6	2.0	-	-
Arkan (H3)	-	-	-	-	0	21
Knox 62 (H6)	-	-	-	-	27	1

confirmed by the presence of dead larvae. Because these durum wheats were resistant to biotype D, they may have H5, H9, H10, H11, H12, or H13 genes. Biotype D larvae can infest wheats carrying H1, H2, H3, h4, H6, H7 and H8 genes but not wheats carrying H5, H9, H10, H11, H12, or H13. In a subsequent test of these lines resistant to biotype D against biotype J (Table 28), only the landrace BD 2909 was homozygous resistant. The landrace BD 0126 and the cultivars Haj Mouline and Jori may have the resistance genes H9, H10, or H12, which are susceptible in Morocco. The landrace BD 2909, resistant to biotypes D and J, therefore, cannot have the H5 gene, but may have a new gene for resistance to U.S. fly. Genetic studies should be carried out to confirm this hypothesis.

Chapter V

SUMMARY AND CONCLUSIONS

The results of 1985-86 research, in both field and greenhouse, strongly show the resistance of H5, H11, and H13 genes. H7H8 and H9 were moderately resistant. Presently, only H5, H11, and H13 appear useful in Moroccan breeding programs for developing resistant cultivars. H5 and H11 genes, both in the A genome, have been incorporated into both durum and bread wheats. H13, located in the D genome, has been transferred only to bread wheat. Low percentages of susceptible plants with these resistance genes indicate the possibility of future development of virulent biotypes.

Two cultivars, Haj Mouline and Jori, and two landraces, BD 0126 and BD 2909, were homozygous for resistance to biotype D in the U.S. Haj Mouline, Jori and BD 0126 may have the H9, H10, or H12 genes since they showed some resistance to biotype J. The landrace BD 2909, resistant to D and J, may have new gene(s) for resistance to the U.S. Hessian fly.

Of the 15 Moroccan bread wheats, 10 durum wheats, and 160 advanced ICARDA breeding lines tested, none showed resistance to the Moroccan Hessian fly. International centers like ICARDA should breed for Hessian fly resistance since they are working on wheat improvement in North Africa where the Hessian fly is a serious problem. Six wheats from USDA Plant Introductions were highly resistant to Hessian

fly in Morocco and should be used by wheat breeders. Except for accession 4107, which had few plants susceptible, all of the other 33 Triticum monococcum accessions tested were susceptible to Hessian fly in Morocco.

Three accessions of Triticum tauschii, TA1651, TA1651 and TA1656, were highly resistant and may contain new resistance genes. Wheat geneticists should work on this species, study the genetics of inheritance, and incorporate any new genes into adapted wheats.

Full-season evaluations of three winter wheats, Newton (the susceptible check), and the H11 and H13 resistance genes, showed that at two locations (Jemaa Shaim and Sidi El Aydi), a significant ($P < 0.01$) increase occurred in the number of larvae per susceptible plant from the first to the second generation. The increase of the percentage of Newton plants that were susceptible from the first to the second generation, was not significant. There were slight increases of the percentage of susceptible plants and the number of larvae per susceptible H11 and H13 plants from the first to the second generation, but these were not significant.

The full-season evaluation of the two spring wheats, SD8036 (H5) and Nesma indicated significant ($P < 0.01$) increases in the number of larvae per plant on Nesma from the first generation to the second. However, there was no significant increase in the percentage of susceptible Nesma plants. On the H5 gene, there was no increase.

To assess the potential impact of resistance on Hessian fly populations, computations were made to estimate the number of larvae

per hectare on resistant versus susceptible cultivars. At Sidi El Aydi, the number of larvae on Newton increased from 2,372,400 larvae/ha (first generation) to 44,192,540 larvae/ha (second generation). High density populations indicate a very large gene pool and a greater chance for the presence of virulence genes. Intermating among adults of such a large, genetically diverse population could rapidly produce new virulent biotypes that might overcome the resistance of deployed genes.

Because of multiple generations of the Hessian fly, it is important for entomologists to have accurate information on the levels of resistance expressed in wheat throughout the growing season. These evaluations would show the effects of high density populations, the environment, and temperature sensitivity of resistance genes. Temperature sensitivity may be indicated where there was a significant increase of the number of larvae per plant on the H13 gene. Temperatures were higher during the period of the second generation. With additional information on resistance genes, the wheat breeder may want to use mainly those resistance genes that are stable under both high insect population levels and high temperatures.

The determination of virulence in Hessian flies collected at Sidi El Aydi indicated that biotypes capable of infesting the H5, H11, H5 and H11, and H11 and H13 resistance genes were present at low frequencies in the populations. The virulence to H13 gene appears to be high (13%). Similar results were obtained in the Jemaa Shaim fly

population, except that no virulence to either H5 and H11 or to H11 and H13 was detected. The prevalent biotype at both locations was virulent to resistance genes H1H2, H3, H6, H7H8, H9, H10, and H12.

Although it appears that the frequency of biotypes virulent to H5, H11, and H13 resistance genes is low, biotypes are likely to increase in numbers when resistance genes are deployed over wide areas of Morocco for several years. Thus, deployment strategies for the use of these genes in bread and durum wheats and identification of new resistance genes will be critical for durable resistance against the Hessian fly. When resistant cultivars are available and are being grown, Hessian fly populations should be monitored closely for changes in the biotype composition so that new cultivars with a different resistance gene can be released.

REFERENCES

Anonymous. 1932. La Cecidomyie des cereales (Mayetiola destructor Say. Diptere), Defense des cultures, Memento No. 8, pp. 4.

Anonymous. 1939. La Cecidomyie destructive, Mayetiola destructor Say, Diptere: Cecidomyiidae, Memento No. 8, Defense de vegetaux, 15 pp. Rabat.

Allan, R. E., E. G. Heyne, E. T. Jones, and C. O. Johnston. 1959. Genetic analysis of ten sources of Hessian fly resistance, their interrelationships and association with leaf rust reaction in wheat. Kans. Agr. Exp. Sta. Tech. Bull. 104: 51 pp.

Bleton, C. A. 1937. Deux hymenopteres parasites de la cecidomyie destructive dans la region de Fes, Societe des Sciences Naturelles du Maroc. Memento No. 5, pp. 37-38.

Bennani, S. B. 1968. Premiers resultats d'essais de lutte chimique contre les cecidomyies des cereales au Maroc. Alawamia 26: 75-96.

Bennani, S. B. 1972. Lutte contre les cecidomyies des cereales. Alawamia 44: 1-40.

Bennani, S. B. and M. Riany. 1978. Resultats de quelques annees d'essais pratiques de lutte chimique contre les cecidomyies des cereales du genre Mayetiola sp. Alawamia 55: 1-24.

Benyassine, A. 1983. Etude preliminaire de la resistance a la cecidomyie (Mayetiola sp.) chez le ble dur (Triticum durum) et le ble tendre (Triticum aestivum). Memoire de Troisieme Cycle Agronomie.

Benlhabib, O. 1984. Etude de la resistance a la cecidomyie (Mayetiola destructor Say.) chez le ble dur, le ble tendre et l'orge. Memoire de Troisieme Cycle Agronomyie.

Cartwright, W. B. and G. A. Weibe. 1936. Inheritance of resistance to the Hessian fly in wheat crosses Dawson x Poso and Dawson x Big Club. J. Ag. Res. 52: 691-695.

Cartwright, W. B. and D. W. Lahue. 1944. Testing wheats in the greenhouse for Hessian fly resistance. J. Econ. Ent. 37: 385-387.

Cartwright, W. B. and R. M. Caldwell, and L. E. Compton. 1946. Relation of temperature to the expression of resistance in wheats to Hessian fly. J. Amer. Soc. Agron. 38: 259-263.

Caldwell, R. M., R. L. Gallun, and L. E. Compton. 1966. Genetics and expression of resistance to Hessian fly, Phytophaga destructor (Say). Proc. 2nd Int. Wheat Genetics Sym. 1963. Hereditas, Suppl. 2: 462-463.

Durand, Y. 1967a. Observations sur le cycle evolutif des Mayetiola vivant sur ble et orge au Maroc. Alawamia 24: 1-14, Rabat.

Durand, Y. 1967b. Etude du comportment dans la nature de quelques varietes de ble et d'orge vis-a-vis des attaques de cecidomyies des cereales. Alawamia 24: 27-40.

El Bouhssini, M. 1981. Rapport du stage, station centrale des cereales d'automne, INRA. Rabat.

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

Gill, B. S., J. H. Hatchett, and W. J. Raupp. 1986. Chromosomal mapping of Hessian fly resistance gene H13 in the D genome of wheat. J. Hered. (In Press).

Hatchett, J. H. and R. L. Gallun. 1970. Genetics of the ability of Hessian fly, Mayetiola destructor, to survive on wheats having different genes for resistance. Ann. Entomol. Soc. Amer. 63(5): 1400-1407.

Hatchett, J. H., T. J. Martin, and R. W. Livers. 1981. Expression and inheritance of resistance to Hessian fly in synthetic hexaploid wheats derived from Triticum tauschii (Coss) Schmal. Crop Sci. 21: 731-734.

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. Observations sur la biologie de la cecidomyie destructive (Mayetiola destructor Say) au Maroc, Bulletin de la Societe des Sciences Naturelles du Maroc. 17: 154-162.

Jourdan, M. L. 1938. Observations sur la biologie de la cecidomyie destructive (Mayetiola destructor Say) au Maroc (20 note). Bulletin de la Societe des Sciences Naturelles du Maroc, 18 (3-5), 161-169 p.

Noble, W. B., W. B. Cartwright, and C. A. Suneson. 1940. Inheritance of resistance to Hessian fly. J. Econ. Ent. 33: 580-581.

Oellermann, C. M., F. L. Patterson, and R. L. Gallun. 1983. Inheritance of resistance in Luso wheat to Hessian fly. Crop Sci. 23: 221-224.

Painter, R. H. 1951. Insect resistance in crop plants. Macmillan Co., New York. 520 pp.

Patterson, F. L. and R. L. Gallun. 1977. Linkage in wheats of the H3 and H6 genetic factors for resistance to Hessian fly. J. Hered. 68: 293-296.

Regehr, D., D. L. Keith, J. L. Hatchett and G. E. Wilde. 1985. Insecticides for Hessian fly control. Dryland Farming Applied Research Project- INRA - MIAC, Annual Technical Report 1984-85. p. 99.

Roberts, J. J. and R. L. Gallun. 1984. Chromosome location of the H5 gene for resistance to the Hessian fly in wheat. J. Hered. 75: 147-148.

Shands, R. G. and W. B. Cartwright. 1953. A fifth gene conditioning Hessian fly response in common wheat. Agron. J. 45: 302-307.

Sosa, O., Jr. and J. E. Foster. 1976. Temperature and the expression of resistance in wheat to the Hessian fly. Env. Ent. 5: 333-336.

Sosa, O. 1979. Hessian fly: resistance of wheats as affected by temperature and duration of exposure. Env. Ent. 8: 280-281.

Sosa, O. 1981. Biotypes J and L of the Hessian fly discovered in an Indiana wheat field. J. Econ. Ent. 74: 180-182.

Stebbens, N. B., F. L. Patterson, and R. L. Gallun. 1980. Interrelationship among wheat genes for resistance to Hessian fly. Crop Sci. 20: 177-180.

Stebbens, N. B. 1981. Interrelationships among wheat genes H3, H5, H6, H9, H10 and H11 for resistance to Hessian fly. Ph.D. Thesis, Purdue University, West Lafayette, IN.

Suneson, C. A. and W. B. Noble. 1950. Further differentiation of genetic factors in wheats for resistance to the Hessian fly. U.S. Dept. Ag. Tech. Bull. 1004: 8 pp.

Tegyey, 1965. Quelques observations sur l'amelioration des bles. Alawamia. 16: 23-42.

Tyler, J. M. and J. H. Hatchett. 1983. Temperature influence on expression of resistance to Hessian fly (Diptera: Cecidomyiidae) in wheat derived from Triticum tauschii (Coss) Schmal. J. Econ. Entomol. 76: 323-326.

Wootipreecha, S. 1971. Studies of genetic synthesis of new races of Hessian fly, Mayetiola destructor (Say). Ph.D. Thesis, Purdue University, W. Lafayette, IN. 187 pp.

A STUDY OF HESSIAN FLY, *MAYETIOLA DESTRUCTOR* (SAY), BIOTYPES AND RESISTANCE IN WHEATS IN MOROCCO

by

MUSTAPHA EL BOUHSSINI

B.S., National College of Agriculture (E.N.A.)
Meknes, Morocco, 1980

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

ABSTRACT

Hessian fly, Mayetiola destructor (Say), is one of the most important pests of cereals, mainly of common wheat, Triticum aestivum L., and durum wheat, T. turgidum L., in Morocco. Since no cultural control method for Hessian fly is compatible with present farming practices, genetic resistance appears to be the most practical method for long-term crop protection. In this regard, and because all wheat cultivars presently grown in Morocco are highly susceptible, a group of United States common wheats carrying all known resistance genes, except h4, were tested for resistance to Hessian fly in Morocco. Field and greenhouse tests conducted in 1985 and 1986 showed that the H5, H11, and H13 genes were highly effective in controlling infestations of Hessian fly. The three genes are being deployed by Moroccan wheat breeders in their national program to develop Hessian fly-resistant cultivars.

The screening of Moroccan bread and durum wheats to Hessian fly in the United States showed that the cultivars 'Haj Mouline' and 'Jori', and the durum landraces BD 0126 and BD 2909 were homozygous resistant to biotype D. When tested to biotype J, only the landrace BD 2909 was homozygous resistant. This indicates that Haj Mouline, Jori, and BD 0126 may have the H9, H10, or H12 genes, but BD 2909 may have a new gene for resistance to the U.S. Hessian fly.

No resistance was found in 15 Moroccan bread wheats, 10 durum wheats or 160 ICARDA wheat breeding lines tested in the field in Morocco.

Six wheats obtained from U.S.D.A. Plant Introductions were highly resistant to the Moroccan Hessian fly in a field test conducted in 1986.

Except for accession 4107, which only had a few susceptible plants, all other 33 T. monococcum accessions tested in the field in 1986 were highly susceptible.

Three accessions of T. tauschii, TA1645, TA1651 and TA1656, were highly resistant to the Moroccan Hessian fly.

Full-season evaluations of three winter wheats, 'Newton' (the susceptible check), and the H11 and H13 resistance genes showed a significant increase ($P < 0.01$) in the number of larvae per susceptible plant on Newton from the first to the second Hessian fly generation. There was no significant increase in the percentage of susceptible plants of Newton. Neither the number of larvae nor the percentage of susceptible plants increased significantly on H11 and H13 plants from the first to the second generation.

The full-season evaluation of the two spring wheats, SD8036 (H5 resistance gene) and 'Nesma', a susceptible cultivar, showed significant ($P < 0.01$) increases in the number of larvae per plant on Nesma but no significant ($P < 0.01$) increase in the percentage of susceptible plants. There was no increase in numbers of larvae on susceptible plants of the H5 gene.

A study of Hessian fly biotypes at two locations, Jemaa Shaim and Sidi El Aydi, showed that virulent biotypes were present in these two populations. Frequencies of biotypes virulent to H5 and H13, H11 and H13 (present only in the Sidi El Aydi population), H11 and H5 were still low, but the frequency of a biotype virulent to H13 was relatively high (13%). Because of the similar frequencies of biotypes at the two locations, it appears that they are similar populations. Only one prevalent biotype that can attack resistance genes, H1H2, H3, H6, H7H8, H9, H10, and H12, is present.