Biotic stress limiting durum wheat production in Morocco - Hessian fly and the Russian wheat aphid: Surveys, loss assessment, and identification of sources of resistance

Lhaloui S., Nsarellah N., El Bouhssini M., Nachit M., Amri A.

in

Royo C. (ed.), Nachit M. (ed.), Di Fonzo N. (ed.), Araus J.L. (ed.).
Durum wheat improvement in the Mediterranean region: New challenges

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 40

2000
pages 373-379

Biotic stress limiting durum wheat production in Morocco – Hessian fly and the Russian wheat aphid: Surveys, loss assessment, and identification of sources of resistance

S. Lhaloui*, M. El Bouhssini, N. Nsarellah*, M.M. Nachit*** and A. Amri****
*Institut National de la Recherche Agronomique, INRA, P.O. Box 589, Settat, Morocco
**International Center for Agricultural Research in the Dry Areas, ICARDA,
P.O. Box 5466, Aleppo, Syria
***CIMMYT/ICARDA, P.O. Box 5466, Aleppo, Syria

SUMMARY – Hessian fly is the most destructive pest of wheat in the major cereal growing regions of the world. It is believed to have originated in West Asia which is the center of diversity of wheat, and has spread out to Europe, North Africa, and North America. Heavy populations are detected regularly in North America and western Mediterranean countries. In Morocco, grain yield losses have been estimated to 42 and 36% in bread wheat using insecticide control, and near isogenic resistant and susceptible lines respectively. In durum wheat, losses have been estimated to 32%. The most efficient and economic method of control of this pest is the genetic resistance via the use of resistant cultivars. In the USA, 29 genes of resistance have been characterized and named. Ten of these genes were selected as conferring resistance to Hessian fly in Morocco. The *H22* gene has been successfully introgressed into adapted Moroccan bread wheat cultivars. For a long period, no resistance was found in durum wheat, therefore, breeders have decided to transfer the genes *H5* and *H11,* located on the A genome, into durum wheat. Recently, the first source of resistance has been identified in durum wheat, CLM829. In addition to these genes, we have identified a large number of sources in wild relatives. The Russian wheat aphid has recently started getting serious on cereals in Morocco. The damage had first been seen in the highlands, but is now encountered over most of the cereal growing regions.

Key words: Hessian fly, durum wheat, survey, loss, varietal resistance.

***RESUME* –** *"Un stress biotique limitant la production de blé dur au Maroc – La mouche de Hesse et le puceron russe du blé : Etudes, évaluation des pertes, et identification de sources de résistance". La Mouche de Hesse est l'insecte le plus destructif du blé dans la majorité des régions céréalières du monde. Originaire de l'Asie de l'Ouest, centre de diversité du blé, l'insecte s'est propagé en Europe, Afrique du Nord, et Amérique du Nord. Des densités élevées sont détectées aux USA, et dans les pays situés à l'Ouest de la Méditerranée. Au Maroc, les pertes de rendement en grain ont été estimées à 42 et 36% chez le blé tendre, en utilisant respectivement un traitement insecticide, et des lignées isogéniques résistantes et sensibles. Chez le blé dur, les pertes ont été estimées à 32%. La lutte génétique, par le développement de variétés résistantes, est la méthode la plus efficace et économique. Aux USA, 29 gènes de résistance ont été nommés et caractérisés. Dix de ces gènes ont été sélectionnés comme conférant la résistance aux populations marocaines de cécidomyie. Le gène* H22 *a été introgressé avec succès dans les variétés marocaines de blé tendre. Cependant, pour une longue période, aucune source de résistance n'a été identifiée chez le blé dur ; donc, les améliorateurs ont décidé de transférer les gènes* H5 *et* H11, *localisés sur le génome A, dans le blé dur. Récemment, la première source de résistance a été identifiée chez un blé dur, CLM829. A côté de ces gènes, nous avons identifié un nombre important de sources de résistance dans le germoplasme sauvage. Le puceron russe a récemment commencé à être sérieux sur céréales au Maroc. Les dégâts ont d'abord été notés sur les régions de haute altitude, mais à présent, ils sont rencontrés dans la majorité des régions céréalières.*

Mots-clés : *Mouche de Hesse, blé dur, surveillance, pertes, résistance variétale.*

Introduction

Hessian fly, *Mayetiola destructor* (Say) is the most destructive insect pest of wheat (*Triticum* spp.) in the major cereal growing regions of the world. It is believed to have originated in West Asia which is the center of diversity of wheat, and has spread out to Europe, North Africa, and North America. Heavy populations are detected regularly in North America and western Mediterranean countries. In North Africa, especially in Morocco, grain yield losses have been estimated to 42 and 36% in bread wheat using an insecticide control method, and near isogenic resistant and susceptible lines respectively (Lhaloui *et al.,* 1992b; Amri *et al.,* 1992). In durum wheat, losses have been estimated to 32 % (Lhaloui *et al.,* 1992a), which is equivalent to losses estimated on bread wheat.

The most efficient and economic method of control of this pest is the genetic resistance via the use of resistant cultivars. In the USA, 29 genes of resistance have been characterized and named. Ten of these genes (*H5*, *H7H8*, *H11*, *H13*, *H14H15*, *H21*, *H22*, *H23*, *H25*, and *H26*) were selected as conferring resistance to Hessian fly in the field in Morocco (El Bouhssini *et al.,* 1996). Most of them are located on the A or the D genomes. The *H22* gene has been successfully introgressed into adapted Moroccan bread wheat cultivars. Also, the CIMMYT bread wheat resistant line L222 has been registered in the official catalogue. Both cultivars are now in the seed increase phase.

However, for a long period, no resistance was found in a durum wheat background, at the exception of the CLM826 introduction from CIMMYT. Therefore, breeders have decided to transfer the genes that are located on the A genome from bread into durum wheat. Thus, the *H5* and *H11* genes have been successfully transferred.

The Russian wheat aphid has recently started getting serious on cereals in Morocco. The damage had first been seen in the highland regions, but has now started to be noticed in the most of the cereal growing plains. No methods of control have yet been identified against this pest; seeking solid sources of resistance would be the best method.

The objective of this paper is to give an overview of what has been accomplished in the field of host plant resistance to these pests on durum wheat in Morocco.

Hessian fly

Surveys and diagnosis

In the plains

A five year survey was conducted over the 7 biggest cereal production provinces of Morocco, to determine the intensity and distribution of the pest infestations, compare the infestations on durum wheat to those on bread wheat and barley, observe annual variations in the infestations levels, and estimate yield losses due to these infestations.

This study showed that Hessian fly was very common throughout the major cereal growing areas of Morocco. It was also fairly persistant over the whole five year survey. 88, 85 and 80% of bread wheat, durum wheat, and barley fields respectively were infested. Economic levels of infestations (20% of tillers infested; Lafever *et al.,* 1980) were observed in 65, 55, and 55% of the bread wheat, durum wheat and barley fields, respectively.

The percent fields with economic infestations remained stable across years. Severe infestations (over 50% tillers infested) were observed in 27, 22 and 23% of bread wheat, durum wheat and barley fields, respectively (Lhaloui *et al.,* 1992a). These results explain clearly that Hessian fly is very widespread in Morocco, with high infestation levels in all the regions, and that durum wheat is as much infested as the other cereals.

In the regions of high altitude

A smaller scale survey, over two years only, was conducted in the highland regions of the Atlas mountains; this study showed that 72% of the bread wheat fields were infested with Hessian fly, and that the fields presented up to 27% of the tillers infested. For durum wheat, the percent of fields infested was equivalent to that of bread wheat, but tiller infestation was lower. As a comparison, it appeared that barley was almost free of this pest in the highland regions.

Estimates of yield losses

The estimate of yield loss test showed that yield increases between chemically protected and non protected varieties, averaged over a four year period of the test, 42, 32, and 45% for bread wheat, durum wheat and barley respectively (Table 1). In an average rainfall season, the percent loss was estimated to 35% of the yield. This indicates that losses caused by this pest on durum wheat are equivalent to those caused on bread wheat (Lhaloui *et al.,* 1992b).

Table 1. Mean percent grain yield loss due to Hessian fly infestations on mid season plantings estimated over 3 years in three different regions

Crop	Percent grain yield loss
Bread wheat	42
Durum wheat	32
Barley	45

Genetic control: Identification of sources of resistance and development of resistant cultivars

Host plant resistance has been widely utilized to limit the damage caused by insect pests over the world. Sources of resistance have been continuously sought and introgressed into adapted cultivars. This method presents many advantages:

(i) It is economical for the farmer as compared to the repeated use of chemicals, it does not cost him anything; everything is incorporated into the seed of the resistant cultivar.

(ii) It is safe for Man and animals: does not present any toxicity.

(iii) It is environmentally sound and safe, does not cause any pollution.

Methodology of screening

In the greenhouse and the growth chambers, the screening procedure we follow is similar to that described by Cartwright and LaHue (1944). The genetic material consists of collections of wild wheat relatives, and nurseries generated by breeders from crosses between identified sources of resistance, and adapted Moroccan varieties. The number of entries can vary from 5000 to 10,000 per year. Lines are seeded in standard greenhouse flats, containing a mixture of 2/3 soil and 1/3 peat, at a rate of one row per line, and 25 seeds per row. Each flat contains a susceptible (cv. Nesma) and a resistant (cv. Saada) check. When plants are in the two-leaf stage, flats are covered with a cheesecloth tent, and about one hundred females of newly emerged and mated Hessian fly are released in each flat. Females are allowed to lay eggs for two days. Three weeks later, plants are removed from the flats and checked for their resistance reaction. Plants that are stunted and had a dark green color were considered as susceptible, those that have normal growth, with a light green color are considered as resistant. Resistance is further confirmed by the presence of dead first instar larvae at the bases of stems.

Advanced breeding material is screened in the field, usualy at the Jemaa shaim experiment station which is considered as the hot spot of Hessian fly in Morocco. They are seeded in 3 meter lines, 50 cm spaced. The seeding date is chosen in late December to allow plants to get the maximum infestation by the second generation adults of Hessian fly. The screening is done visually in February after the infestations have occurred and plants had shown resistance or susceptibility reaction. The selection is made in April, at crop maturity, in collaboration with the breeding program.

Major results and accomplishments

At the beginning of the program, we screened all the existing Moroccan germplasm, unfortunately it was all susceptible. Then we screened the North American uniform Hessian fly nursery in 1984, and the results showed that 3 genes of this nursery gave a high level of resistance to the Moroccan populations of this pest. These were *H5, H11* and *H13.*

The *H5* gene existed in a south Dakota spring bread wheat germplasm SD8036. This line was tested in Morocco for yield performance, and released in 1989 as the first cultivar resistant to Hessian fly in Morocco, under the name of Saada. Later, in 1994, the first Moroccan breeder bread wheat cultivar, Massira, tolerant to the fly, was released.

The search for new sources of resistance continued, and we now have identified a total of 10 genes (*H5, H7H8, H11, H13, H14H15, H21, H22, H23, H25* and *H26*) (Table 2). Three other bread wheat lines were selected as presenting very high levels of resistance to the fly; these were L222, L254, and ADC14. Last year, the L222 was released as a cultivar under the name of Arrihane. Also, a Moroccan breeder bread wheat line carrying the *H22* was released under the name of Aguilal. Both lines are now in the seed increase phase, and will reach the farmer soon.

Table 2. Major wheat genes for resistance to Hessian fly in Morocco

Gene designation	Source	Genome/chromosome location
H5	*T. aestivum*	1A
H11	*T. turgidium*	1A
H13	*A. squarrosa*	6DL
H14H15	*T. turgidium*	5A
H21	*S. cereale*	2BS.2RL
H22	*A. squarrosa*	1D
H23	*A. squarrosa*	6D
H25	*S. cereale*	4AS.4AL-6RL.4AL
H26	*A. squarrosa*	4D

As for durum wheat, the screenings of thousands of accessions from all over the world did not reveal any resistance; only one accession, CLM829, was selected (Table 3). Thus, the breeders decided to transfer the *H5* and *H11* genes that are located on the A genome from bread to durum wheat varieties adapted to the Moroccan and the Mediterranean region. These varieties were used as recurrent parents in a back crossing program, with the bread wheat variety ‘Saada’, carrying the *H5* resistance gene. The F2 and subsequent generations are screened either in the field, under natural Hessian fly infestations, or in the greenhouse under controlled environmental conditions, and artificial infestation. Several promising lines (F10 to F12), carrying high levels of resistance to the fly, in addition to resistance or tolerance to other biotic and abiotic stresses, are available now. Four of them are currently proposed for registration after being subjected to advanced yield trials on experimental stations and to on-farm yield trials. They expected to be released soon.

Table 3. Cultivars with resistance to Hessian fly in Morocco

Line/cultivar	Source	Mechanism of resistance
Saada	*T. aestivum*	Antibiosis
Massira	*T. aestivum*	Tolerance
L222/L254	*T. aestivum*	Antibiosis
ADC14	*T. aestivum*	Antibiosis
Arrihane	*T. aestivum*	Antibiosis
Aguilal	*T. aestivum*	Antibiosis
CLM829	*T. durum*	Antibiosis
Four lines (*H5*)	*T. durum*	Antibiosis (to be released soon)

In addition, we have identified a large number of sources of resistance in wild relatives. Of the 91 accessions tested in a wild relatives collection, 49 showed resistance (54%); the highest percent of resistance was observed for *Aegilops ovata*, where 68.1% of the accessions tested had resistant plants, with 43.8% of the accessions homogeneous for resistance. Five out of the six accessions of *Ae.*

ventricosa tested were also resistant (83.3%). As for *Ae. triuncialis*, even though a high number of accessions was tested, none was resistant. The other species tested were represented by only few accessions each, their reactions varied from homogeneously resistant to susceptible (Table 4). This selected germplasm constitutes a very rich gene bank that we can turn to whenever the characterized genes are no longer effective.

Table 4. Reaction of an ICARDA collection of wild wheat relatives for resistance to Hessian fly in Morocco

Species and genomes		No. of accessions tested	No. of resistant accessions (R/H)[†]
Ae. biuncialis	(UM)	2	2 (H)
Ae. kotschyii	(US)	2	0
Ae. cylindrica	(CD)	2	2 (R)
Ae. caudata	(C)	2	1 (R)
Ae. ventricosa	(DUn)	6	5 (R)
Ae. ovata	(UM)	47	32 (14R, 18H)
Ae. triuncialis	(UC)	16	0
Ae. triaristata	(UM)	2	2 (H)
Ae. speltoides	(S)	4	1 (H)
Ae. squarrossa	(D)	1	1 (R)
Ae. umbellulata	(U)	2	1 (H)
Ae. uniaristata	(Mu)	1	0
Ae. geniculata	(Mu)	1	1 (R)
Ae. morocco		1	1 (R)
Agropyron IFG6		1	0
Total		91	49

[†]H = heterogeneous; R = homogeneous for resistance.

The Russian wheat aphid

The Russian wheat aphid (RWA) has recently started getting serious on cereals in Morocco. The damage has first been limited to regions of high altitude, but lately, the pest has spread out to all the cereal growing plains of the country. The heaviest populations are still found in the mountain regions where our surveys of 1996 and 1997 showed that 100% of the durum wheat fields were infested, with a mean of 49% of plants showing feeding symptoms of the pest (Table 5) (Lhaloui *et al.,* 1998). We are in the process of screening a CIMMYT/ICARDA collection of durum wheat for resistance to this pest, both in the field and under controlled environmental conditions, and the results of these screenings will be available at the end of this cropping season. The selected sources of resistance will be given to the breeders in order to incorporate this resistance into the durum wheat breeding program.

Conclusion

Overall, we have identified a large number of sources of resistance both in adapted durum wheat lines (CLM829), and several wild sources. The resistance that was identified is of the antibiosis type; plants were not stunted, had normal growth with light green color, and contained dead first instars of Hessian fly at the bases of their stems, which indicates that these larvae died when they started feeding on the plants (antibiosis reaction). Antibiosis is the most desirable form of resistance in the case of host plant resistance to Hessian fly as it is controlled by a gene for gene relationship.

The selected durum breeding lines were homogeneous for resistance and presented good agronomic characters. This indicates that lots of progress has been achieved as far as resistance to Hessian fly in durum wheat is concerned in Morocco.

Table 5. Infestation levels of RWA on durum wheat (DW) as compared with bread wheat (BW) in the regions of high altitude in Morocco (Lhaloui *et al.,* 98)

Crops/ regions	No. fields sampled		% fields infested		% plants infested	
	BW	DW	BW	DW	BW	DW
El Hajeb	1	1	100	100	100	10
Ifran/Azrou	3	1	100	100	64	30
Annoceur	3	0	100	–	100	–
Guigou	3	3	100	100	50	70
Boulmane	4	0	100	–	32	–
Midelt	1	3	100	100	10	67
Boumia	3	3	100	100	45	74
Aghbalou	0	2	–	100	–	60
Ait Ishaq	3	3	100	100	25	37
Zt. Cheick	0	1	–	100	–	30
El Ksibah	1	3	100	100	40	30
Ait Oukabli	1	4	100	100	50	42
Ouaouizaght	1	2	100	100	20	50
Azilal	1	1	100	100	30	90
Total/mean	25	27	100	100	47	49.2

However, because of the nature of Hessian fly genetics, and its ability to develop new more virulent biotypes, we need to stay continuously alerted, and ahead of biotype development. In fact, the speed of the rise of new more virulent biotypes depends on the size of the pest population, the number of generation, and acreage on which the resistant cultivar carrying a specific gene has been deployed. Hessian fly has large populations, with a fairly high number of generations per year, 2 to 3; thus a large genetic variability among individuals of the population which is the material needed for the selection pressure to act on. The development of these biotypes is even faster if the cultivar carrying the resistance is grown over a large acreage. This will be expected as improved, more productive varieties have always been adopted by farmers, and replaced older varieties. The durum wheat improvement program has to stay ahead of new biotypes by conducting surveys of deployed cultivars, and estimating the percent susceptibility in the released varieties; in other terms, the percent of virulence in the population.

On the other hand, the search for new sources of resistance to the developing biotype has to start very early and should not wait until the new biotypes erupt. Cultures of the new virulent individuals have to be kept in the laboratory, and used to search for new sources of resistance that should be used in the breeding program to develop resistant germplasm, and stay ahead of biotypes.

References

Amri, A., El Bouhssini, M., Lhaloui, S., Cox, T.S. and Hatchett, J.H. (1992). Estimates of yield loss due to Hessian fly (Diptera: Cecidomyiidae) on bread wheat using near isogenic lines. *Al Awamia,* 77: 75-87.

Cartwright, W.B. and LaHue, D.W. (1944). Testing wheats in the greenhouse for Hessian fly resistance. *J. Econ. Entomol.,* 37: 385-387.

El Bouhssini, M., Lhaloui, S., Amri, A., Jlibene, M., Hatchett, J.H., Nssarellah, N. and Nachit, M.M. (1996). Wheat genetic control of Hessian fly (Diptera: Cecidomyiidae) in Morocco. *Field Crop Res.,* 45: 111-114.

Lafever, H.N., Sosa, O. Jr., Gallun, R.L., Foster, J.E. and Kuhn, R.C. (1980). Survey monitors of Hessian fly population in Ohio wheat. Ohio Report on Research and Development. *Agriculture, Home Economics, Natural Resources*, 64(4): 51-53.

Lhaloui, S., Buschman, L., El Bouhssini, M., Amri, A., Hatchett, J.H., Keith, D., Starks, K. and El Houssaini, K. (1992a). Infestations of *Mayetiola* spp. (Diptera: Cecidomyiidae) in bread wheat, durum wheat, and barley: Results of five annual surveys in the major cereal growing regions of Morocco. *Al Awamia,* 77: 21-53.

Lhaloui, S., Buschman, L., El Bouhssini, M., Starks, K., Keith, D.L. and El Houssaini, K. (1992b). Control of *Mayetiola* species (Diptera: Cecidomyiidae) with carbofuran in bread wheat, durum wheat, and barley, with yield loss assessment and its economic analysis. *Al Awamia,* 77: 55-73.
Lhaloui, S., El Bouhssini, M. and Amri, A. (1998). *Survey of insect pests of cereals in the Highlands of Morocco in 1996 and 1997.* Annual Research Report, Centre Aridoculture, Settat, Morocco.