ESTIMATES OF YIELD LOSS DUE TO THE HESSIAN FLY (DIPTERA : CECIDOMYIIDAE) ON BREAD WHEAT USING NEAR-ISOGENIC LINES

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INTRODUCTION

The Hessian fly, **Mayetiola destructor** (Say), is the major pest of wheat (**Triticum aestivum** L.) in Morocco, and serious damage has been reported since 1937 (JOURDAN 1937, ANONYMOUS 1939, COUTIN et al. 1973). Surveys conducted since 1984 have shown that serious Hessian fly infestations were encountered in most of the cereal growing regions of Morocco (LHALOUI et al. 1992b). They documented that more than 50 percent of the bread wheat, durum wheat, and barley fields were moderately to heavily infested.

In North America, efforts have been made to estimate yield losses due to this insect. HILL et al. (1943) formulated a relationship between the level of

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infestation and the yield loss; i. e; 56 percent infestation corresponded to 182 kg ha^{-1} yield loss. This estimate was conservative compared to the loss of 309 kg ha^{-1} they obtained using cages to control levels of infestation. REDLINGER (1947), compared grain yield for infested and non infested culms, and found that the reduction in yield averaged more than 50 percent. PAINTER (1951) estimated the loss to be 25 percent, using the same approach. FOSTER and SOMSEN (unpublished data) did not find consistent yield loss trends in Illinois, partially because of compensatory growth of winter wheat, but they found that the weight of spikes decreased proportionately as the number of Hessian fly per culm increased.

In Morocco, total crop failure due to the combined effects of drought and Hessian fly attacks are frequently observed. Yield loss experiments have documented that two applications of the insecticide Furadan 5G (carbofuran), applied with the seed at planting and at jointing stage at the rate of 1.12 kg AI/ha, prevented losses of 33 and 35 percent in straw and grain yields, respectively (LHALOUI et al. 1992a). REGEHR and KEITH (1985) found that the Hessian fly caused reductions of 59 and 63 percent for grain and straw yields, respectively. In several studies both the number of spikes and the kernel weight were reduced by Hessian fly infestations (LHALOUI and KEITH 1986, PAINTER 1951, and REDLINGER 1947). EL BOUHSSINI et al. (1986) found that the resistant cultivar 'Saada' out yielded the susceptible cultivars 'Nesma' and 'Potam' by at least 50 percent and that the susceptible cultivars produced fewer spikes per square meter.

The present study, using near isogenic lines, was conducted to provide an alternative estimate of yield reduction caused by the Hessian fly in Morocco.

MATERIALS AND METHODS

Near-isogenic lines were obtained by backcrossing the susceptible bread wheat cultivar 'Sais' (TOB'S/NAPO//CC/INIA66/3/Cha) to a resistant winter bread wheat (TA1642/* 'Wichita'/TA 1642/Wichita) carrying an unnamed gene derived from **Aegilops squarrosa (Triticum tauschii** (Coss.) Schmal). Three backcrosses were made between Sais and the F1, the BC1F1, the BC2F1 and the BC3F1 plants. Eighteen resistant lines and eight susceptible lines, derived from a single BC3F2 heterozygous plant, were identified by testing them with biotype D Hessian fly in the greenhouse at Manhattan, Kansas, U.S.A.

Then all 26 lines and four checks, Saada (H5), a resistant cultivar, and the

susceptible cultivars Potam, Nesma and Sais, were evaluated at the Sidi El Aidi Experiment Station, Morocco, during the 1987-88 season. Each experimental unit consisted of one row 2m long and 0. 6m apart in which 60 seeds were sown. The experimental units were arranged in an augmented randomized complete block design with up to three replicates. The number of replicates of each line depended on seed supply. Each experimental line was bordered by rows of the susceptible check Nesma. The resistant parent was not included for comparison because of its vernalization requirement.

Ten plants per row were collected at heading stage to evaluate their reactions to the Moroccan Hessian fly. Susceptible plants were infested with live larvae, while resistant plants had dead larvae, indicating antibiosis. Total biomass, grain yield, number of productive spikes per square meter, height, and weight of 250 kernels were measured. These charateristics were also expressed as a percent of the average of adjacent rows of the check Nesma, to reduce part of the variation due to soil heterogeneity. Analysis appropriate for an augmented design was performed on all data using "SAS General Linear Models" (SAS INSTITUTE 1985).

During the 1988-89 cropping season two experiments were conducted at Douyet Experiment Station, in a higher rainfall area. The first experiment compared the performance of 9 resistant and 9 susceptible near-isogenic lines from the crosses described above. The second experiment compared four varieties, Saada, Potam, Sais and Nesma with and without the insecticide treatment to control the fly in treated plots. The insecticide, Furadan 5G (carbofuran), was applied at sowing at the rate of 1.12 kg AI/ha. For both experiments, the experimental unit consisted of six rows 3 meters long with 0.3 meter space between rows. There were two replications. Grain yield was estimated by harvesting the four central rows of each plot. Grain yield data was subjected to analysis of variance using "SAS General Linear Models" (SAS INSTITUTE 1985).

RESULTS AND DISCUSSIONS

The planting of both experiments in late November resulted in heavy infestations of Hessian fly when the plants were at the initiation of the first tiller. Three generations of the fly were observed during the 1987 season at Sidi El Aidi and two generations were observed at Douyet during the following season. All susceptible lines were 100% infested, while all resistant lines showed dead larvae. The reactions of the near-isogenic lines and the cultivars were similar to

reactions observed in the greenhouse with biotype D Hessian fly, Manhattan, Kansas. This indicates that the gene, transferred from the accession TA1642, which conditioned resistance to biolype D Hessian fly, also conditions resistance to the Moroccan Hessian fly.

In both experiments, the widely grown cultivar Nesma showed the highest number of insects per plant and lowest yields compared to most of the other susceptible genotypes (Tables 1 and 4). Nesma was also susceptible to most of other prevalent pests, such as leaf rust and SEPTORIA leaf blotch and did not show any level of tolerance as in case of the cultivar Potam.

The eighteen resistant lines did not differ from the susceptible lines or from the recurrent parent Sais for plant height or kernel weight, except for one resistant line that was taller (Table 1). This phenotypic similarity between the near isogenic lines suggested that three backcrosses provided sufficient homogeneity to conduct the yield loss estimates. Only 2 of the 18 resistant isolines yielded less grain than the highest yielding susceptible isoline, but none were significantly lower.

The expression of total biomass and grain yield as percentage of the values of the adjacent rows of Nesma, did not improve the coefficients of variation, which varied from 7 to 24 percent. Significant differences in total biomass, grain yield and number of spikes were found between resistant and susceptible isolines. The number of spikes per square meter and grain yield appeared to be the yield component most affected by the Hessian fly infestation. The yield loss was consistent with yield losses observed in other studies using exclusion cages or insecticides (HILL et al 1943, REDLINGER 1947, PAINTER 1951, LHALOUI and KEITH 1985, and LHALOUI et al. 1992a).

During 1987-88 season at Sidi El Aidi, the resistant cultivar Saada out yielded the three susceptible checks by an average of 39 and 21 percent for total biomass and grain yield, respectively (Table 2). The resistant near-isogenic lines out yielded the susceptible lines by an average of 35, 38 and 24 percent for biomass, grain, and number of spikes, respectively.

During 1988-89 season at Douyet, the grain yield loss was 23.4 percent using the near-isogenic lines approach (Table 3). The grain yield loss was 10 to 31 percent, depending on cultivar, using insecticide to control Hessian fly (Table 4). The cultivar Nesma had the largest yield decrease, followed by Sais. The cultivar Potam was not affected by the Hessian fly infestation.

Table 1 : **Means of total biomass, grain yield, number of spikes per square meter, 250-kernel weight, and plant height of the Hessian fly resistant and susceptible iso-lines and checks at Sidi El Aidi, Morocco, 1987-1988.**

Cultivar or line	Reac-tion	No. plots	Bio mass (kg ha^{-1})	Grain yield (kg ha^{-1})	Spikes m^{-2}	Plant height (m)	250 kernel wy (g)
Saada	R	3	12500	3720	216.7	100	10.7
Isoline	1 R	3	15000	4790	328.9	1.05	12.7
	2 R	2	13750	5860	463.3	1.02	13.7
	3 R	2	14170	4410	293.3	1.12	10.5
	4 R	1	15000	4480	410.0	1.10	11.4
	5 R	3	13780	3752	343.3	1.16	10.5
	6 R	1	13330	3620	133.3	1.00	9.8
	7 R	2	12500	4530	275.0	1.05	12.2
	8 R	1	10830	3190	320.0	1.05	10.3
	9 R	1	18330	4920	430.0	1.30	11.5
	10 R	1	10000	4540	420.0	1.00	12.1
	11 R	1	10000	2650	256.7	0.90	11.9
	12 R	3	14560	4490	185.5	1.02	11.9
	13 R	2	15830	5270	345.0	1.07	12.1
	14 R	1	14170	4810	96.7	0.91	11.1
	15 R	1	11670	3970	186.7	0.90	11.7
	16 R	1	13330	4690	156.7	0.90	9.6
	17 R	2	10830	4700	243.3	1.00	11.5
	18 R	1	15830	5220	406.7	1.25	12.7
	19 S	2	9170	2770	211.7	1.10	11.5
	20 S	2	10000	2970	268.3	1.07	12.1
	21 S	3	7220	3000	248.9	0.98	10.4
	22 S	1	9170	3120	176.7	1.00	9.1
	23 S	1	6670	1990	210.0	0.90	9.9
	24 S	1	8330	2920	213.3	1.00	13.7
	25 S	2	9830	3240	240.0	1.12	11.2
	26 S	3	7670	2230	192.2	0.93	10.1
SAIS	S	3	8030	3420	214.4	0.92	10.9
POTAM	S	3	8330	3390	280.0	1.02	11.5
NESMA	S	3	6390	1990	221.1	1.00	11.5
LSD (p =.05)			1910	630	62.0	ns	ns
CV			14.3	24.4	22.8	7.20	10.4

These results are in agreement with results for these cultivars at Sidi El Aidi, the previous year (Table 2). The cultivar Potam was relatively tolerant. The two most susceptible cultivars, Nesma and Sais, had an average yield loss of 25.5 percent, which is similar to the estimate obtained by the near-isogenic method (Table 4). The yield loss of the resistant cultivar Saada was 10 percent which suggests that Furadan might be controlling other insects in the plots. Reduction in yield due to Hessian fly attack depends on the level of infestation, the number of successive generations of the fly, the developmental stage of the plants at the time of infestation, and the degree of tolerance of a given cultivar. The effect of Hessian fly could be more pronounced in the semi-arid and arid zones than in higher rainfall areas where good climatic conditions enhance continuous tillering.

Table 2 : **Effects of Hessian fly damage on total biomass, grain yield, kernel weight, number of spikes per square meter, and plant height ; Sidi El Aidi, Morocco, 1987-88.**

Base of estimation	Total biomass ($kg\,ha^{-1}$)	Grain yield ($kg\,ha^{-1}$)	250 kernel wt. (g)	Spikes m^{-2}	Plant height (m)
Checks only					
R (1)	12500	3720	10.7	216	1.00
S (3)	7590	2930	11.1	238	0.98
Critical range (p=0.05)	186	700	ns	ns	ns
Iso-lines only					
R (18)	13110	4460	11.5	294	1.06
S (8)	8450	2780	11.2	224	1.02
Critical range (p=0.05)	1690	530	ns	62	ns

R = resistant ; S = susceptible

( ) = Number of lines per class used in comparison.

Table 3 : **Grain yield (qx/ha) of Hessian fly susceptible and resistant near-isogenic lines at Douyet during 1988-89 season.**

Group of near isogenic lines	Number	Average yield	Range	% loss
Susceptible	9	22.3	19.0-26.0	-
Resistant	9	29.3	25.0-32.0	23.4%

CV (%) = 22%.

Table 4 : **Percent grain yield loss due to Hessian fly on four bread wheat cultivars using insecticide control Douyet 1988-89**

Cultivars	Reaction to Hessian fly	Grain yield treated	Grain yield non treated	% yield loss
SAADA	Resistant	30.0	27.0	10.0
POTAM	Tolerant	24.0	24.0	0.0
SAIS	Susceptible	30.0	24.0	20.0
NESMA	Susceptible	32.0	22.0	31.2

CV (%) = 20 %

The yield loss estimates observed in this study were similar to those reported in previous studies (EL BOUHSSINI et al. 1986, LHALOUI and KEITH 1986, REGEHR and KEITH 1985 and LHALOUI et al 1992a). However, The near-isogenic line results probably provide the most reliable assessment of yield losses. Yield losses obtained from the use of insecticides could be confounded by the effects of the insecticide on other insects in the plots or by direct positive or negative effects on the plants. The estimates by HILL et al (1943), PAINTER (1951) and REDLINGER (1947) do not account for tillers killed, stunted or lodged due to Hessian fly damage. They underestimate the yield losses.

Total loss of grain yield was observed in adjacent plots which were planted much later. The stage of plant development at the time of Hessian fly infestation appears to have a critical influence on the extent of yield loss. Late planted wheat that is infested at the one-leaf stage will have much greater loss in yield than the 38 percent observed in this study.

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ABSTRACT

This study was designed to provide an alternative estimate of losses due to hessian fly, **Mayetiola destructor** (Say) using BC3F3 Hessian fly resistant and susceptible near-isogenic lines of bread wheat (**Triticum aestivum** L.). The trials were conducted at Sidi El Aidi (semi-arid) and Douyet (higher rainfall) during 1987-88 and 1988-89 seasons, respectively. At Sidi El Aidi, total biomass, grain yield, and number of spikes per square meter were reduced by 35, 38 and 24 percent, respectively. At Douyet, the grain yield losses were 23.4 percent in the test using near-isogenic lines and 0.0 to 31.2 percent, depending on cultivar, in the test using insecticide treatments.

KEY WORDS : Hessian fly, yield loss, Bread Wheat, Near-Isogenic Lines.

RESUME

Cette étude se propose de donner une meilleure estimation des pertes de rendement en utilisant les lignées presque-isogéniques BC3F3 de blé tendre résistantes ou sensibles à la mouche de Hesse, **Mayetiola destructor** (Say). Les essais ont été conduits à Sidi El Aidi (Semi-aride) et Douyet (bour favorable) durant les saisons agricoles 1987-88 et 1988-89, respectivement. Les réductions de biomasse totale, du rendement grain et du peuplement épis étaient de 35, 38 et 24 pour cent, respectivement, à Sidi El Aidi. A Douyet, les pertes de rendement grain s'élevaient à 23.4 pour cent en utilisant les lignées presque isogéniques et variaient entre 0 et 31.2 pour cent, selon le niveau de tolérance des variétes, quand le Furadan fût utilisé pour le contrôle de l'insecte.

MOTS CLES : Mouche de Hesse, Pertes de rendement, Blé tendre, Lignées presque-isogéniques.

ملخص

تهدف هذه الدراسة إلى تقدير خسائر محصول القمح الطري الناتجة عن الإصابة بدودة هس. وقد استعملت طريقتان :

استعمال المبيد للحد من تأثير الدودة ، والمقارنة بين السلالات المقاومة والغير المقاومة للدودة. أجريت هذه التجارب في محطة سيدي العايدي خلال الموسم 87 ـ 1988 و بمحطة الضويات بسايس خلال الموسم 88 ـ 1989.

وتوضح نتائج سيدي العايدي أن المحصول العام انخفض بنسبة 35٪ ومحصول الحب ب 38٪ ،وعدد السنابل في المتر المربع ب 24٪ ، أما في محطة الضويات فمردودية الحب تقلصت ب 23٪ في حالة مقارنة السلالات وما بين 0 و 31٪ حسب الصنف في حالة استعمال المبيد .

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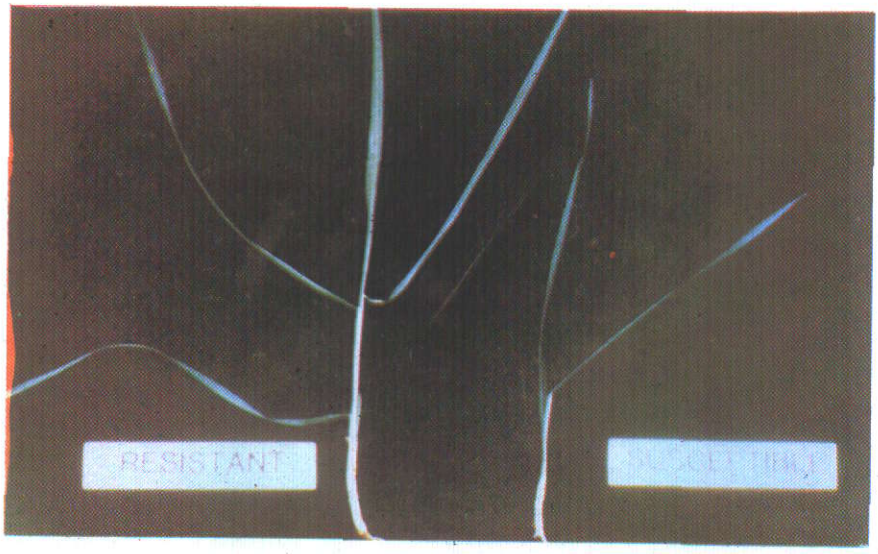

Photo 7. an unstunted resistant plant, on the left, and a stunted susceptible plants, on the right. Note the darker green color of the stunted plant. (Photograph by J. H. Hatchett)

Photo 8. Dead reddish first instars of Hessian fly at the base of a tiller of a resistant plant. Presence of dead first instars is confirmation of resistance (antibiosis) of this specific plant. (Photograph by J.H. Hatchett)