CONTROL OF MAYETIOLA SPECIES (Diptera: Cecidomyiidae) WITH CARBOFURAN IN BREAD WHEAT, DURUM WHEAT AND BARLEY WITH YIELD LOSS ASSESSEMENT AND ITS ECONOMIC ANALYSIS

S. LHALOUI,* L. BUSCHMAN,** M. EL BOUHSSINI,* K. STARKS,*** D. KEITH**** AND K. EL HOUSSAINI*****

INTRODUCTION

Midges in the genus **Mayetiola** (Diptera: Cecidomyiidae) have been recognized as serious pests of cereals in Morocco for many years (MESNIL 1934, BALACHOWSKY & MESNIL 1935, JOURDAN 1937). In bread wheat (**Triticum aestivum** L.) and durum wheat (**Triticum turgidum** L. var. durum) the pest is recognized as the Hessian fly, **Mayetiola destructor** (Say). In barley (**Hordeum vulgare** L.) the pest has recently been recognized as **Mayetiola hordei** (Kieffer), the "barley stem gall midge" (GAGNÉ et al., 1991). **M.**

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

** MIAC/Moroc Project, B.P. 290, Settat, Maroc, and Department of Entomology; Kansas State University, 4500 E. Mary St., Garden City, KS 67846

*** Formerly MIAC/Moroc Project, B.P. 290 Settat, Maroc, Plant Science and Entomology Research, USDA-ARS, Department of Entomology, Oklahoma State Univ., Stillwater, OK 74078.

**** Formerly MIAC/Moroc Projet, B.P. 290, Settat, Maroc, and Department of Entomology, University of Nebraska, Lincoln, NE 68583-0816

***** Formerly MIAC/MAROC Projet, B.P. 290, Settat, Maroc.

destructor occurs in barley at very low frequency.

The **Mayetiola** spp. are serious pests of cereal throughout North Africa, but the most serious damage has been observed in Morocco, particulary in the west central semi-arid coastal region. A five year survey by LHALOUI et al. (1992) has documented that infestations are widespread in Moroccan cereals, almost 90% of bread wheat fields were infested and economically important infestations (more than 20% tillers infested) were present in 65 percent of them. Infestations in durum wheat and barley were only slightly lower than those in bread wheat.

There are generally two generations of **Mayetiola** spp. on wheat and barley in Morocco (DURAND 1967a, LHALOUI 1986). The first generation starts with oviposition by flies emerging from oversummering flaxseed after the first substantial rains of November or December. They attack the emerging cereal seedlings, killing the infested tillers. The second generation starts in January or February when flies develop from the first generation. They attack late planted cereals and late developing tillers, killing or stunting them. Both generations cause serious damage to cereal crops.

Yield losses associated with cecidomyiid infestations are not well documented, although the damage is obvious. Most attempts to quantify yield losses due to Hessian fly infestations have started by measuring the grain yield of infested versus uninfested tillers. HILL et al . (1943), the most cited reference, developed a table for calculating yield losses based on percent culms (tillers with heads) infested. The yield losses ranged from 0.027 to 10.5 Qx / ha for one to one hundred percent culms infested. However, he pointed out that these estimates were very low, since they account for only one of four types of Hessian fly damage.

Chemical control of **Mayetiola** spp. infestations is difficult. DURAND (1967b) found that the seed treatement with Lindane plus Chlordane (0.96 plus 2.0 gm AI / kg of seed) gave up to 60 percent control in Morocco, but that higher rates caused reduced seed germination. BENNANI and RIANY (1978) reviewed results of six years of chemical control trials in Morocco and concluded that of 19 insecticide treatments tested, only Lindane seed treatment (100 gm AI / 100 kg of seed) was both effective and presented minimal toxicity risk. Granular insecticides, especially phorate (Thimet), were effective (BENNANI 1968), but were considered too expensive and too toxic for use by farmers in Morocco (BENNANI 1972). Foliar treatments were not reliable (BENNANI 1968, BENNANI and RIANY 1978). In North America, MORRILL and NELSON

(1976) reported excellent Hessian fly control using carbofuran seed treatments or carbofuran spray treatments at planting and BUNTIN (1988) reported moderate control for broadcast applications of carbofuran granules. Carbofuran has not been tested on cereals in Morocco.

Our early trials (REGEHR et al., 1985, unpublished report) indicated that lindane seed treatments did not provide adequate control of **Mayetiola** spp., While in-furrow applications of granular carbofuran looked promising.

The following studies were conducted: 1. to determine the efficacy of different rates of carbofuran applied in-furrow to control first and second generation **Mayetiola** spp. infestation, 2. to determine the efficacy of carbofuran treatments broadcast during February to control second generation **Mayetiola** spp. infestation, 3. to measure yield responses of cereals to first and second generation **Mayetiola** spp. infestation, and 4. to compare yield reponses of three cereals, bread wheat, durum wheat and barley, to **Mayetiola** spp. infestations.

MATERIALS AND METHODS

Four experiments were conducted at Sidi El Aidi Experiment Station (SA) (1986-89), one at Ben Ahmed Agricultural School (BA) (1986) and two at Jemâa Shaim Experiment Station (JS) (1988-89). The six insecticide treatments were as follows: treatments 1, 2, 3, and 5 received carbofuran (Furadan 5G) in-furrow at planting time at the rates of 0.38, 0.75, 1.12 and 1.12 kg AI / ha, respectively, to control first generation **Mayetiola** spp. infestations, treatments 4 and 5 received carbofuran broadcast over the plots in February at 1.12 kg AI / ha to control second generation **Mayetiola** spp. infestations, and treatment 6 served as the untreated check. Treatment 5 received two insecticide applications to control both first and second generation infestations. The experiments were single factor (six insecticide treatments) randomized complete block designs with four replications. In 1986 and 1987 the tests were conducted in bread wheat only, but in 1988 and 1989, the tests were conducted in each of three cereals: bread wheat (variety 'Nesma'), durum wheat (variety 'Cocorit') and barley (variety '905'). The barley experiments were planted first, in mid-November before the first significant rainfall, and the wheat was planted within several weeks. The first two years, a single row cone planter was used to plant the seed. The planter was then adjusted to apply the insecticide in the same furrows. The third and fourth years, a 6-row cone planter (Winterstiger) was used to plant and apply the insecticide. The plots were 1.5 m with (6 rows) by 11 m long with 0.5

m boarders of bare ground around each plot. Fertilizer and weed control varied slightly across years and locations, but were applied uniformly across each experiment. Fertilizer applications included 50 kg / ha of ammonium sulfate (21% N) and 100 kg / ha of triple superphosphate (45% P). Weed control included use of herbicides, Printazol 75 and Glen, as well as hand weeding as needed.

First generation **Mayetiola** spp. infestations were determined by taking samples in late January or early February, and second generation infestations were determined by taking samples in late March to early May. In each plot, 20 to 30 plants were collected from the two outside rows and taken to the laboratory. There 20 plants were dissected to record the number of **Mayetiola** spp. (larvae plus flaxseed) on each tiller. The following variables were calculated: percent tillers infested and insects per plant. The first instar is the stage most likely to be affected by the insecticide treatments and should not be included in evaluations. In most samples, the insects were past this stage and this was not an issue, however, some first instars were present in the first generation samples from SA 88 and SA 89. Some first instars were included in percent tillers infested, but not in the other variables. The first generation samples from JS 88 included mostly eggs and first instars so the data have been excluded. At harvest, the plot ends were trimmed to eight meters and only the four middle rows were harvested. The first two years the plots were hand harvested, weighed, thrashed and the grain weighed, so that grain and straw yields could be calculated. The last two years the plots were harvested with a plot combine to give grain yield only.

Before statistical analysis, four data transformations were made : Taylor's power transformation (SOUTHWOOD, 1978) (p. values calculated from the 1988 and 1989 data), the square root of x + 1, logarithm of x + 1, and arcsin (square root x + 0.025)/100 (SOKAL and ROHLF, 1981). The STAT program of MSTAT-C (MSTAT Development Team, 1986) was used to determine the transformation producing the lowest skewness value. In the subsequent statistical analysis, Taylor's power transformation was used for first generation percent tillers infested and insects per plant and for second generation percent tillers infested, and the logarithm transformation was used with insects per plant and grain and straw yield.

The data for each of the fifteen tests were analyzed individually (ANOVA-2 program of MSTAT-C (MSTAT Development Team, 1985). There were seven bread wheat tests, four durum wheat tests and four barley tests. The LSD ($P \leq 0.05$) was used to separate means.

RESULTS AND DISCUSSION

The effect of treatment on first generation **Mayetiola** spp. was significant in 5 of the 15 tests, while the effect of treatment on second generation **Mayetiola** spp. was significant in 9 of the 15 tests (Tables 1-5). Although the effects of treatment were not always significant, the trends in treatment means were similar across the tests. The 1987 SA and 1989 SA tests suffered severe drought stress so the insecticide may not have been activated adequately. Low **Mayetiola** spp. populations were encountered in the 1988 JS barley test and in the 1989 SA and JS wheat tests which contributed to the lack of statistical significance in treatment main effects.

The effectiveness of carbofuran treatments is best examined by looking at percent control (Table 6). Although treatment differences were not significant for all tests, the trends are present across the tests. The percent control for 1987 SA bread wheat are inconsistent and have been omitted.

In all three cereals, percent control for both first and second generations increased with increasing rates of carbofuran (0.36 to 1.12 kg AI / ha) applied at planting (Table 6). In bread wheat, the mean percent control increased from 41 to 65% on first generation and 44 to 62% on second generation. The 1.12 kg AI / ha rate appears to be the most effective and consistent of the planting time treatments. In durum wheat, the mean percent control increased from 41 to 81% for first generation, but was erratic on second generation. In barley, the mean percent control increased from 18 to 67% on first generation and 27 to 51% on second generation.

Second generation broadcast treatments, alone (treatment # 4), gave 39, 39 and 45% control of **Mayetiola** spp. populations in bread wheat, durum wheat and barley (Table 6). Second generation broadcast treatments, together with first generation treatments (treatment # 5), increased control 9, 15, 3%.

In the four tests of 1988 and 1989, first generation **Mayetiola** spp. populations tended to be higher in bread wheat than in durum wheat, while populations in barley generally were similar to those in bread wheat. Second generation **Mayetiola** spp. populations also tended to be higher in bread wheat than in barley, while populations in durum wheat generally were intermediate between those in bread wheat and barley. In some durum wheat tests, there was little response of **Mayetiola** spp. populations to carbofuran treatments.

Yield responses to carbofuran treatments were significant in all tests (Table

RESULTS AND DISCUSSION

The effect of treatment on first generation **Mayetiola** spp. was significant in 5 of the 15 tests, while the effect of treatment on second generation **Mayetiola** spp. was significant in 9 of the 15 tests (Tables 1-5). Although the effects of treatment were not always significant, the trends in treatment means were similar across the tests. The 1987 SA and 1989 SA tests suffered severe drought stress so the insecticide may not have been activated adequately. Low **Mayetiola** spp. populations were encountered in the 1988 JS barley test and in the 1989 SA and JS wheat tests which contributed to the lack of statistical significance in treatment main effects.

The effectiveness of carbofuran treatments is best examined by looking at percent control (Table 6). Although treatment differences were not significant for all tests, the trends are present across the tests. The percent control for 1987 SA bread wheat are inconsistent and have been omitted.

In all three cereals, percent control for both first and second generations increased with increasing rates of carbofuran (0.36 to 1.12 kg AI / ha) applied at planting (Table 6). In bread wheat, the mean percent control increased from 41 to 65% on first generation and 44 to 62% on second generation. The 1.12 kg AI / ha rate appears to be the most effective and consistent of the planting time treatments. In durum wheat, the mean percent control increased from 41 to 81% for first generation, but was erratic on second generation. In barley, the mean percent control increased from 18 to 67% on first generation and 27 to 51% on second generation.

Second generation broadcast treatments, alone (treatment # 4), gave 39, 39 and 45% control of **Mayetiola** spp. populations in bread wheat, durum wheat and barley (Table 6). Second generation broadcast treatments, together with first generation treatments (treatment # 5), increased control 9, 15, 3%.

In the four tests of 1988 and 1989, first generation **Mayetiola** spp. populations tended to be higher in bread wheat than in durum wheat, while populations in barley generally were similar to those in bread wheat. Second generation **Mayetiola** spp. populations also tended to be higher in bread wheat than in barley, while populations in durum wheat generally were intermediate between those in bread wheat and barley. In some durum wheat tests, there was little response of **Mayetiola** spp. populations to carbofuran treatments.

Yield responses to carbofuran treatments were significant in all tests (Table

cereal in spring and are less likely to be affected by the planting time soil applications of carbofuran.

ACKNOWLEDGMENT

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

Table 1. : **Analysis of variance and means of first and second generation MAYETIOLA spp. populations in bread wheat after carbofuran applications at planting or at tillering and the resulting yields : three tests at two locations, 1986 and 1987.**

Treatment (kg AI/ha)	Gen. treat 1st 2 nd	First Generation: Percent tillers infest	First Generation: Insects per plant	Second Generation: Percent tillers infest	Second Generation: Insects per plant	Yield: Grain Qx/ha	Yield: Straw Qx/ha
	Bread Wheat ANOVA, 1986 Sidi El Aidi :						
	Treat (5df)[a]	2.78NS	2.21NS	9.35**	5.67**	11.14***	16.45***
	Error (15df)	0.657	0.108	0.25	0.058	0.001	0.001
	Treatment Means [b] :						
1	0.36 --	14.62 AB	1.59 AB	17.09 A	3.43 B	31.21 BC	45.99 B
2	0.75 --	11.27 B	0.96 AB	6.87 B	0.96 B	31.81 BC	46.64 B
3	1.12 --	7.23 B	0.66 B	5.83 B	1.34 B	32.50 B	60.24 A
4	-- 1.12	25.27 AB	2.54 AB	20.25 A	3.48 B	29.20 BC	46.10 B
5	1.12 1.12	7.24 B	0.45 B	2.67 B	1.36 B	38.81 A	58.98 A
6	-- --	42.84 A	4.79 A	29.37 A	10.64 A	28.92 C	44.92 B
	Bread Wheat ANOVA, 1986 Ben Ahmed :						
	Treat (5df)[a]	12.09***	11.94***	3.43*	3.84*	3.53*	13.91***
	Error (15 df)	0.381	0.064	0.078	0.025	0.002	0.002
	Treatment Means [b] :						
1	0.36 --	1.00 B	0.0590B	32.29 AB	18.19 AB	29.55 BC	45.56 C
2	0.75 --	0.06 BC	0.0004BC	32.64 AB	22.50 A	31.43 AB	44.92 C
3	1.12 --	0.00 C	0.0000 C	24.31 B	10.02 C	32.11 AB	56.15 B
4	-- 1.12	10.11 A	0.8240 A	40.14 A	23.55 A	28.17 BC	38.90 C
5	1.12 1.12	0.04 BC	0.0004BC	25.07 B	10.72 BC	35.06 A	68.98 A
6	-- --	14.63 A	0.9920 A	36.94 A	20.58 A	25.73 C	45.13 C
	Bread Wheat ANOVA, 1987 Sidi El Aidi :						
	Treat (5 df) [a]	0.56 NS	1.19 NS	0.90 NS	1.04 NS	-.-	-.-
	Error (15df)	0.225	0.064	0.297	0.052	-.-	-.-
	Treatment Means [b] :						
1	0.36 --	49.27 A	15.46 A	28.10 A	3.84 A	7.09 AB	3.72 AB
2	0.75 --	35.94 A	11.61 A	44.81 A	7.57 A	6.49 B	3.58 AB
3	1.12	38.31 A	6.89 A	33.37 A	3.68 A	7.42 AB	4.15 A
4	-- 1.12	43.04 A	7.28 A	26.64 A	3.16 A	4.20 C	2.78 BC
5	1.12 1.12	47.03 A	11.24 A	31.18 A	3.55 A	8.12 A	3.40ABC
6	-- --	35.91 A	11.56 A	27.47 A	3.39 A	4.67 C	2.31 C

[a] F - values : NS not significant at P≤ 0.05, * significant at P ≤ 0.05, ** significant at P ≤ 0.01, and *** significant at p ≤ 0.0001.

[b] Means within columns followed by the same letter are not significantly different (P ≤ 0.05) : least significant difference test. Note that not all mean separations are supported by a significant F-test.

Table 2. : **Analysis of variance and means of first and second generation MAYETIOLA spp. populations in bread wheat, durum wheat and barley after carbofuran applications at planting or at tillering and the resulting yields1988 Sidi El Aidi.**

Treatment (kg AI/ha)	Gen. treat 1st 2 nd	First Generation: Percent tillers infest	First Generation: Insects per plant	Second Generation: Percent tillers infest	Second Generation: Insects per plant	Yield: Grain Qx/ha
	Bread Wheat ANOVA :					
	Treat (5df)[a]	5.84**	7.96**	8.89**	9.56**	7.36**
	Error (15df)	0.387	0.051	0.295	0.041	0.001
	Treatment Means [b] :					
1	0.36 --	23.51 A	2.16 A	42.04 A	5.74 B	29.12 C
2	0.75 --	12.76 A	1.00 A	33.80 AB	4.20 BC	32.88 AB
3	1.12 --	9.45 A	0.92 A	17.49 BC	1.89 CD	34.81 A
4	-- 1.12	13.41 A	1.39 A	37.73 A	5.73 B	30.14 BC
5	1.12 1.12	0.59 B	0.01 B	8.41 C	0.77 D	35.97 A
6	-- --	16.17 A	1.88 A	58.66 A	12.80 A	27.11 C
	Durum Wheat ANOVA :					
	Treat (5df)[a]	8.64**	12.43***	2.63 NS	3.08*	9.82**
	Error (15 df)	0.296	0.033	0.340	0.041	0.001
	Treatment Means [b] :					
1	0.36 --	6.45 AB	0.36 AB	19.48 AB	2.96 AB	23.95 BC
2	0.75 --	5.11 AB	0.22 BC	9.92 B	1.16 BC	25.52 ABC
3	1.12 --	0.95 BC	0.04 C	12.91 B	1.07 BC	26.11 AB
4	-- 1.12	15.06 A	1.01 A	19.61 AB	2.09 ABC	23.20 CD
5	1.12 1.12	0.14 C	0.00 D	9.16 B	0.56 C	27.51 A
6	-- --	11.55 A	0.73 AB	30.52 A	3.43 A	20.69 D
	Barley ANOVA :					
	Treat (5 df) [a]	2.06 NS	1.49 NS	5.23**	4.25*	5.80**
	Error (15df)	0.193	0.045	0.198	0.013	0.003
	Treatment Means [b] :					
1	0.36 --	12.09 A	1.76 A	30.86 A	2.61 A	20.05 C
2	0.75 --	7.30 ABC	0.53 A	15.55 BC	1.54 ABC	25.42 AB
3	1.12	3.76 C	0.50 A	9.34 C	1.16 BC	28.92 A
4	-- 1.12	7.91 ABC	0.67 A	12.32 C	0.92 C	20.34 C
5	1.12 1.12	4.71 BC	0.65 A	9.50 C	0.86 C	29.45 A
6	-- --	10.97 AB	1.39 A	24.40 AB	2.17 AB	22.25 BC

[a] F - values : NS not significant at P≤ 0.05, * significant at P ≤ 0.05, ** significant at P ≤ 0.01, and *** significant at p ≤ 0.0001.

[b] Means within columns followed by the same letter are not significantly different (P ≤ 0.05) : least significant difference test. Note that not all mean separations are supported by a significant F-test.

Table 3. : **Analysis of variance and means of first and second generation MAYETIOLA spp. populations in bread wheat, durum wheat and barley after carbofuran applications at planting or at tillering and the resulting yields : 1988 Jemaa Shaim.**

Treatment (kg AI/ha)		First Generation		Second Generation		Yield
	Gen. treat 1st 2 nd	Percent tillers infest	Insects per plant	Percent tillers infest	Insects per plant	Grain Qx/ha
	Bread Wheat ANOVA :					
	Treat (5df)[a]	-.-	-.-	7.31**	3.06*	6.68**
	Error (15df)	-.-	-.-	0.132	0.071	0.002
	Treatment Means [b] :					
1	0.36 --	-.-	-.-	67.27 AB	15.19 AB	29.90 BC
2	0.75 --	-.-	-.-	59.04 AB	20.06 A	32.95 AB
3	1.12 --	-.-	-.-	48.79 AB	16.03 AB	34.61 AB
4	-- 1.12	-.-	-.-	68.02 AB	20.13 A	30.51 B
5	1.12 1.12	-.-	-.-	30.52 C	5.96 B	37.63 A
6	-- --	-.-	-.-	73.95 A	34.85 A	25.74 C
	Durum Wheat ANOVA :					
	Treat (5df)[a]	-.-	-.-	1.24 NS	0.55 NS	11.82***
	Error (15 df)	-.-	-.-	0.165	0.039	0.001
	Treatment Means [b] :					
1	0.36 --	-.-	-.-	58.59 A	14.96 A	25.23 BC
2	0.75 --	-.-	-.-	54.47 A	12.54 A	26.65 ABC
3	1.12 --	-.-	-.-	70.28 A	18.78 A	27.78 AB
4	-- 1.12	-.-	-.-	47.54 A	11.89 A	24.21 C
5	1.12 1.12	-.-	-.-	49.25 A	12.12 A	29.77 A
6	-- --	-.-	-.-	52.95 A	12.27 A	19.97 D
	Barley ANOVA :					
	Treat (5 df) [a]	-.-	-.-	6.70**	4.53**	26.09***
	Error (15df)	-.-	-.-	0.162	0.031	0.001
	Treatment Means [b] :					
1	0.36 --	-.-	-.-	51.54 AB	7.57 AB	29.24 C
2	0.75 --	-.-	-.-	46.90 AB	12.36 A	33.46 B
3	1.12	-.-	-.-	27.67 C	4.81 BC	36.77 AB
4	-- 1.12	-.-	-.-	37.48 BC	6.34 ABC	28.62 C
5	1.12 1.12	-.-	-.-	23.49 C	3.12 C	38.41 A
6	-- --	-.-	-.-	62.54 A	10.21 A	25.37 D

[a] F - values : NS not significant at P≤ 0.05, * significant at P ≤ 0.05, ** significant at P ≤ 0.01, and *** significant at p ≤ 0.0001.

[b] Means within columns followed by the same letter are not significantly different (P ≤ 0.05) : least significant difference test.

Table 4. : **Analysis of variance and means of first and second generation MAYETIOLA spp. populations in bread wheat, durum wheat and barley after carbofuran applications at planting or at tillering and the resulting yields : 1989 Sidi El Aidi.**

Treatment (kg AI/ha)		First Generation		Second Generation		Yield
	Gen. treat 1st 2 nd	Percent tillers infest	Insects per plant	Percent tillers infest	Insects per plant	Grain Qx/ha
	Bread Wheat ANOVA :					
	Treat (5df)[a]	0.58 NS	0.20 NS	0.83 NS	0.56 NS	12.22***
	Error (15df)	0.228	0.025	0.340	0.023	0.001
	Treatment Means [b] :					
1	0.36 --	8.02 A	0.43 A	8.93 A	0.66 A	17.23 C
2	0.75 --	7.82 A	0.39 A	8.70 A	0.86 A	18.37 BC
3	1.12 --	10.44 A	0.38 A	4.43 A	0.36 A	19.90 B
4	-- 1.12	11.54 A	0.46 A	5.33 A	0.62 A	18.16 BC
5	1.12 1.12	14.37 A	0.56 A	5.37 A	0.43 A	22.44 A
6	-- --	10.37 A	0.57 A	10.76 A	0.85 A	14.30 D
	Durum Wheat ANOVA :					
	Treat (5df)[a]	1.41 NS	0.84 NS	1.62 NS	0.54 NS	4.60**
	Error (15 df)	0.353	0.070	0.564	0.013	0.002
	Treatment Means [b] :					
1	0.36 --	1.98 AB	0.09 A	3.44 AB	0.39 A	19.24 C
2	0.75 --	2.00 AB	0.07 A	5.68 AB	0.42 A	20.64 ABC
3	1.12 --	1.14 AB	0.05 A	3.68 AB	0.69 A	23.06 AB
4	-- 1.12	5.28 A	0.29 A	6.02 AB	0.51 A	19.98 BC
5	1.12 1.12	0.52 B	0.02 A	1.14 B	0.33 A	23.55 A
6	-- --	3.54 AB	0.15 A	12.16 A	0.64 A	18.16 C
	Barley ANOVA :					
	Treat (5 df) [a]	4.98**	0.83 NS	1.23 NS	0.49 NS	16.79***
	Error (15df)	0.043	0.01	0.190	0.010	0.001
	Treatment Means [b] :					
1	0.36 --	13.47 A	0.66 A	2.83 A	0.36 A	20.37 C
2	0.75 --	7.06 B	0.57 A	5.21 A	0.45 A	23.06 B
3	1.12	8.87 B	0.53 A	4.12 A	0.38 A	23.04 B
4	-- 1.12	7.53 B	0.57 A	4.04 A	0.32 A	22.93 B
5	1.12 1.12	10.21 AB	0.68 A	3.43 A	0.42 A	26.44 A
6	-- --	14.29 A	0.91 A	8.14 A	0.67 A	16.05 D

[a] F - values : NS not significant at P≤ 0.05, * significant at P ≤ 0.05, ** significant at P ≤ 0.01, and *** significant at p ≤ 0.0001.

[b] Means within columns followed by the same letter are not significantly different (P ≤ 0.05) : least significant difference test. Note that not all mean separations are supported by a significant F-test.

Table 5. : **Analysis of variance and means of first and second generation MAYETIOLA spp. populations in bread wheat, durum wheat and barley after carbofuran applications at planting or at tillering and the resulting yields : 1989 Jemaâ Shaim.**

Treatment (kg AI/ha)		First Generation		Second Generation		Yield
	Gen. treat 1st 2 nd	Percent tillers infest	Insects per plant	Percent tillers infest	Insects per plant	Grain Qx/ha
	Bread Wheat ANOVA :					
	Treat (5df)[a]	1.54 NS	1.54 NS	5.24**	1.39 NS	2.18 NS
	Error (15df)	0.193	0.034	0.179	0.027	0.001
	Treatment Means [b] :					
1	0.36 --	5.85 AB	0.47 AB	7.55 AB	0.99 AB	44.48 AB
2	0.75 --	6.52 AB	0.52 AB	6.63 B	0.94 AB	40.83 B
3	1.12 --	3.69 AB	0.26 AB	7.79 AB	1.29 AB	43.89 AB
4	-- 1.12	7.44 A	0.64 A	8.58 AB	1.38 AB	40.28 B
5	1.12 1.12	2.29 B	0.13 B	1.56 C	0.56 B	46.05 A
6	-- --	7.38 A	0.58 A	14.70 A	2.03 A	39.88 B
	Durum Wheat ANOVA :					
	Treat (5df)[a]	0.91 NS	0.72 NS	0.69NS	1.23 NS	1.71 NS
	Error (15 df)	0.490	0.126	0.267	0.016	0.001
	Treatment Means [b] :					
1	0.36 --	0.67 A	0.03 A	7.80 A	1.25 A	53.27 AB
2	0.75 --	1.13 A	0.06 A	6.24 A	1.04 A	52.30 AB
3	1.12 --	0.05 A	0.00 A	5.92 A	0.97 A	50.81 AB
4	-- 1.12	0.82 A	0.05 A	4.71 A	0.76 A	52.60 AB
5	1.12 1.12	0.13 A	0.00 A	2.95 A	0.40 A	56.54 A
6	-- --	1.78 A	0.12 A	5.87 A	0.91 A	49.55 A
	Barley ANOVA :					
	Treat (5 df) [a]	7.19**	4.19*	7.68**	4.89**	4.60**
	Error (15df)	0.186	0.047	0.110	0.002	0.002
	Treatment Means [b] :					
1	0.36 --	9.34 AB	0.80 A	2.18 A	0.27 AB	19.24 C
2	0.75 --	3.51 BC	0.33 A	0.00 C	0.00 C	20.64 ABC
3	1.12	0.68 D	0.03 B	0.55 B	0.13 ABC	23.06 AB
4	-- 1.12	10.94 A	0.78 A	0.57 B	0.12 BC	19.98 BC
5	1.12 1.12	3.21 CD	0.26 AB	0.54 B	0.12 BC	23.55 A
6	-- --	11.06 A	1.09 A	1.52 AB	0.32 A	18.16 C

[a] F - values : NS not significant at P≤ 0.05, * significant at P ≤ 0.05, ** significant at P ≤ 0.01, and *** significant at p ≤ 0.0001.

[b] Means within columns followed by the same letter are not significantly different (P ≤ 0.05) : least significant difference test. Note that not all mean separations are supported by a significant F-test.

Table 6. : **Effectiveness, percent control, of carbofuran applications at planting or at tillering on first and second generation MAYETIOLA spp. populations.**

Treatment (kg AI/ha)	Gen. treated 1st	Gen. treated 2nd	Percent Control by Test [a] 86 SA	86 BA	87 SA	88 SA	88 JS	89 SA	89 JS	Mean
					First Generation					
	Bread wheat [b]									
1	0.36	--	67	94*	--	0	--	25	19	41
2	0.75	--	80	100*	--	46	--	32	10	54
3	1.12	--	86*	100*	--	51	--	33	55	65
4	--	1.12	47	17	--	26	--	19	0	22
5	1.12	1.12	91*	100*	--	99*	--	0	78	74
	Durum wheat [b]									
1	0.36	--	--	--	--	51	--	40	75	41
2	0.75	--	--	--	--	70	--	53	50	63
3	1.12	--	--	--	--	94*	--	67	100*	81
4	--	1.12	--	--	--	0	--	0	58	14
5	1.12	1.12	--	--	--	100*	--	87	100*	97
	Barley [b]									
1	0.36	--	--	--	--	0	--	28	27	18
2	0.75	--	--	--	--	62	--	37	70	56
3	1.12	--	--	--	--	64	--	42	97*	67
4	--	1.12	--	--	--	51	--	37	28	39
5	1.12	1.12	--	--	--	53	--	25	76	51
					Second Generation					
	Bread wheat [b]									
1	0.36	--	68*	12	--	55*	56	22	51	44
2	0.75	--	91*	0	--	67*	42	0	54	42
3	1.12	--	87*	51*	--	85*	54*	58	36	62
4	--	1.12	67*	0	--	55*	42	27	45	39
5	1.12	1.12	87*	48*	--	94*	83*	49	64	71
	Durum wheat [b]									
1	0.36	--	--	--	--	14	--	39	0	--
2	0.75	--	--	--	--	66	--	34	0	--
3	1.12	--	--	--	--	69*	--	0	0	--
4	--	1.12	--	--	--	39	--	20	16	--
5	1.12	1.12	--	--	--	84*	--	48	56	--
	Barley [b]									
1	0.36	--	--	--	--	20	26	46	16	27
2	0.75	--	--	--	--	29	0	33	100	41
3	1.12	--	--	--	--	47	53	43	59	51
4	--	1.12	--	--	--	58	38	52	33	45
5	1.12	1.12	--	--	--	60	69*	37	48	54

[a] SA = Sidi El Aidi, BA = Ben Ahmed and JS = Jemaa Shaim.

[b] Percent control calculated using data on insects per plant; "*" indicates numbers associated with means that were significantly different from the untreated check (not shown).

Table 7. : **Percent changes in grain associated with carbofuran applications at planting or at tillering to control MAYETIOLA,spp. populations.**

Treatment (kg AI/ha)	Gen. treated 1st	2nd	Percent Control by Test [a] 86 SA	86 BA	87 SA	88 SA	88 JS	89 SA	89 JS	Mean
	Bread wheat [b]									
1	0.36	--	8	15	52*	7	16	21*	12	19
2	0.75	--	10	22	39*	21*	28*	29*	2	22
3	1.12	--	12*	25*	59*	28*	35*	39*	10	29
4	--	1.12	1	10	0	11	19*	27*	3	10
5	1.12	1.12	34*	36*	74*	33*	46*	57*	15*	42
	Durum wheat [b]									
1	0.36	--	--	--	--	16*	26*	6	8	14
2	0.75	--	--	--	--	23*	33*	14	6	19
3	1.12	--	--	--	--	26*	39*	27*	3	24
4	--	1.12	--	--	--	12	21*	10	6	12
5	1.12	1.12	--	--	--	33*	49*	30*	14*	32
	Barley [b]									
1	0.36	--	--	--	--	0	15*	27*	6	12
2	0.75	--	--	--	--	14	32*	44*	14	26
3	1.12	--	--	--	--	30*	45*	44*	27*	37
4	--	1.12	--	--	--	0	13*	43*	10	17
5	1.12	1.12	--	--	--	32*	51*	65*	30*	45

[a] SA = Sidi El Aidi, BA = Ben Ahmed and JS = Jemaâ Shaim.

[b] Percent increase calculations based on yield of the untreated check ; "*" indicates numbers associated with means that were significantly different from the untreated check (not shown).

Table 8. : **Economic analysis of carbofuran applications on three cereals averaged over seven trials with associated benefit/cost ratios.**

	Treatments (kg AI/ha)		Bread Wheat		Durum Wheat		Barley	
			Benifit / cost [a] ratio	Break even [b] times	Benefit /cost [a] ratio	Break even [b] times	Benifit / cost [a] ratio	Break even [b] times
1	0.36	--	3.67	7/7	4.57	4/4	1.70	2/4
2	0.75	--	2.25	6/6	2.76	4/4	1.83	2/4
3	1.12	--	2.07	7/7	2.14	3/4	1.77	3/4
4	--	1.12	0.82	3/7	1.28	3/4	0.70	1/4
5	1.12	1.12	1.53	6/7	1.60	4/4	1.07	2/4

[a] Based on carbofuran at 560 DH for 1.12 kg AI/ha, Bread wheat at 208 Dh/Qx, Durum wheat at 247 Dh/Qx and Barley at 132 Dh/Qx.

[b] Yield of treatment at above prices covered cost of carbofuran for treatment.

ABSTRACT

Carbofuran (Furadan 5G) applied at three rates in-furrow at planting or broadcast in spring was evaluated for control of first and second generations of **Mayetiola** spp. A total of seven tests in bread wheat, four in durum wheat and four in barley were conducted over four years at Sidi El Aidi, Ben Ahmed and Jemâa Shaim. In all three cereals, percent control for both first and second generations increased with increasing rates of carbofuran (0.36 to 1.12 kg AI/ha) applied at planting. In bread wheat, the mean percent control increased from 41 to 65% on first generation and 44 to 62% on second generation. In durum wheat, the mean percent control increased from 41 to 81% for first generation, but was erratic on second generation. In barley, the mean percent control increased from 18 to 67% on first generation and 27 to 51% on second generation. The yields for planting time applications of carbofuran increased an average of 29, 24 and 37% for bread wheat, durum wheat and barley, respectively. Spring time

broadcast applications of carbofuran increased yield an average of 10, 12 and 17%, respectively for the three cereals. The yield increases for planting plus spring time applications averaged 42, 32 and 45%, respectively for the three cereals. The economic analysis of the carbofuran applications indicated that the benefit/cost ratios for the planting time treatments were well above 2.0 for bread wheat and durum wheat. The spring time broadcast treatments did not achieve the 2.0 benifit/cost ratio. Carbofuran applications on barley did not result in favorable benifit/cost ratios because the value of barley was so low.

KEY WORDS : Hessian fly, Diptera, Cecidomyiidae, Morocco.

RESUME

Le Carbofuran (Furadan 5G) appliqué en trois doses, localisé dans les sillons au moment de semis ou à la volée au printemps, a été évalué pour le contrôle de la première et deuxième génération de la Cécidomyie, **Mayetiola** Spp. Un total de sept essais de blé tendre, quatre de blé dur et quatre d'orge ont été conduits durant quatre années a Sidi El Aidi, Ben Ahmed et Jemâa Shaim. Pour les trois céréales, le pourcentage de contrôle de la première et de la deuxième génération a augmenté avec l'augmentation de dose de Carbofuran (0.36 à 1.12 kg AI / ha) appliqué au semis. chez le blé tendre, la moyenne des pourcentages de contrôle a augmenté de 41 à 65% pour la première génération et de 44 à 62% pour la deuxième. Chez le blé dur, la moyenne de contrôle a augmenté de 41 à 81% pour la première génération , mais a été irrégulière pour la deuxième. Chez l'orge, la moyenne des pourcentages de contrôle a augmenté de 18 à 67% pour la première génération et de 27 à 51% pour la deuxième. Les augmentations en rendements pour les applications du Carbofuran au semis ont été en moyenne de 29, 24 et 37% pour le blé tendre, le blé dur et l'orge, respectivement. Les augmentations en rendement pour les applications au semis et au printemps ont été en moyenne de 42, 32 et 45%, respectivement pour les trois céréales. L'analyse économique des applications du Carbofuran a indiqué que les rapports bénéfice/coût pour les traitements au semis ont été largement au dessus de 2.0 pour le blé tendre et le blé dur. Les traitements à la volée au printemps n'ont pas atteint le rapport bénéfice/coût de 2.0. Les applications du Carbofuran sur l'orge n'ont pas donné des rapports bénéfice/coût favorables parceque la valeur de l'orge a été trés faible.

MOTS CLES : Mouche de Hesse, Diptère, Cécidomyiidae, Maroc.

ملخص

لقد تمت معاينة آستعمال المبيد Carbofuran (Furadan 5G) في وقت الزرع بواسطة البذار أو يدويا في الربيع لمحاربة الجيلين الأول والثاني لدودة هس.ودامت هذه الدراسة، التي أجريت بسيدي العايدي، بن أحمد وجمعة سحيم، أربعة سنوات. بالنسبة للحبوب الثلاثة : (القمح الطري، القمح الصلب والشعير)،كما أن نسبة الوقاية من الجيل الأول والجيل الثاني لدودة هس ارتفعت مع آرتفاع نسبة المبيد (0.36 إلى 1.21 كلج من المادة المنشطة في الهكتار) المستعمل في وقت الزرع.

أما بالنسبة للقمح الطري فقد ارتفعت نسبة الوقاية ضد الجيل الأول من 41 إلى 65٪ ومن 44 إلى 62٪ ضد الجيل الثاني. ونسبة الوقاية ضد الجيل الأول بالنسبة للقمح الصلب ارتفعت من 41 إلى 81٪. أما الشعير فقد إرتفعت نسبة وقايته من الجيل الأول من 18 إلى 67٪ ومن 27 إلى 51٪ بالنسبة للجيل الثاني.

كما أن المحصول ارتفع بسبب آستعمال المبيد عند الزرع بنسبة 29٪ بالنسبة للقمح الطري، و24 بالنسبة للقمح الصلب و37٪ بالنسبة للشعير،إن استعمال المبيد يدويا في الربيع ساهم في إرتفاع المحصول بنسبة 10٪ بالنسبة للقمح الطري و12٪ بالنسبة للقمح الصلب و17٪ بالنسبة للشعير. أما آستعمال المبيد في وقت الزرع وفي فصل الربيع فقد ساهم في ارتفاع المحصول بنسبة 42٪ بالنسبة للقمح الطري، 32٪ بالنسبة للقمح الصلب و45٪ بالنسبة للشعير.وقد أظهر التحليل الإقتصادي لآستعمال المبيد Carbofuran أن الربح مقارنة مع المصاريف، بالنسبة لآستعمال المبيد في وقت الزرع، فاق الضعف بالنسبة للقمح الطري والصلب، لكن هذا لم يصل الضعف بالنسبة لآستعمال المبيد في الربيع. كما أن استعمال المبيد على الشعير لم يعط ربحا مشجعا نظرا لضعف ثمن الشعير.

REFERENCES CITED

BALACHOWSKY, A., and L. MESNIL. 1935. Les insectes nuisibles aux plantes cultivées, vol. 1. Busson, Paris.

BENNANI, S.A. 1968. Premiers resultats d'essais de lutte chimique contre les cecidomyies des céréales au Maroc. Al Awamia 26 : 75-96.

BENNANI, S.A. 1972. Lutte contre les cecidomyies des céréales. Al Awamia 44 : 1-9.

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

BUNTIN, G.D. 1988. Hessian fly control with granular insecticides applied at planting, 1985. Insecticide and Acaricide Tests 13 : 189 F.

DURAND, Y. 1967a. Observations sur le cycle evolutif des **Mayetiola** vivant sur orge et blé au Maroc. Al Awamia 24 : 1-15.

DURAND, Y. 1967b. Trois années d'essais de traitements en enrobage de graines pour lutter contre les larves de **Mayetiola** de première génération. Al Awamia 24 : 17-26.

GAGNÉ, R.J., J.H. HATCHETT, S. LHALOUI, and M. EL BOUHSSINI. 1991. The Hessian fly and the barley stem gall midge, two different species of **Mayetiola** (Diptera : Cecidomyiidae) in Morocco. Annals Entomol. Soc. Am. 84: 117-138.

JOURDAN, M.L. 1937. Observations sur la biologie de le cécidomyie destructive (**Mayetiola destructor** Say) au Maroc. Bull. Soc. Sci. Nat. Maroc 17 : 154-162.

HILL, C.C., E.J. UDINE and J.S. PINCKNEY. 1943. A method of estimating reduction in yield of wheat caused by Hessian fly infestation. US Dept. Agric., Circular No. 663.

LHALOUI, S. 1986. Effects of plant resistance, insecticide treatment, and planting dates on Hessian fly infestations in wheat in Morocco. Thesis submitted to Department of Entomology, University of Nebraska, Lincoln. 126 pp.

LHALOUI, S., L. BUSCHMAN, M. El BOUHSSINI, A. AMRI, J. HATCHETT, D. KEITH, K. STARKS and K. EL HOUSSAINI. 1992. Infestations of **Mayetiola** spp. (Diptera : Cecidomyiidae) in bread wheat, durum wheat and barley : Results of five annual surveys in some cereal growing regions of Morocco. Al Awamia 77 (in press).

MESNIL, L. 1934. Note préliminaire sur un nouveau parasite des céréales **Phytophaga mimeuri, n.sp.** Bull. Soc. Entomol. Fr. 39 : 245-247.

MORRIL, W.L. and L.R. NELSON. 1967. Hessian fly control with carbofuran. Journ. Economic Entomol. 69 : 123-124.

MSTAT DEVELOPMENT TEAM. 1988. MSTAT-C : A microcomputer program for the design, management, and analysis of agronomic reserch experiments. Michigan State University, East Lansing.

SOKAL, R.S., and F.J. ROHLF. 1981. Biometry : The principles and practice of statistics in biological research. 2nd Ed. W.H. Freeman and Company. San Francisco. 859 pp.

SOUTHWOOD, T.R.E. 1978. Ecological Methods. 2nd Ed. Chapman and Hall. New York. 524 pp.

Photo 5. first generation Hessian fly damage includes stunted tillers and plants. the plant at right is stunted while the plant at left is unstunted. Note the larger leaves and darker green color of the stunted plant. the stunted tillers will eventually die, but if growing conditions are favorable the plant may develop other tillers. (photograph by L.L. Buschman)

Photo 6. second generation Hessian fly damage includes weakened stems which lead to lodging at harvest and reduces harvest effeciency.Additional damage, not visible, includes stunted tillers, and reduced grain fill. (Photograph by J.H. Hatchett).