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Full Length Research Paper

Effects of the soil texture and the burying depth of the larvae on some biological parameters of *Ceratitis capitata* (Diptera: Trypetidae).

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We have studied the effect of the soil texture and the different depths on the emergence rate, the duration of pupation and the sex-ratio of the Mediterranean fruit fly, *Ceratitis capitata*. Three different texture of soil have been tested: clay loam, silty clay loam and sandy loam. As far as the depth of burying of the larva is concerned, we have tested six varied depths from 2 to 20 cm.The results have shown that the silty clay loam texture reduces the emergence rate of *C. Capitata* but the sandy loam soil favours the pupation. The tested depths of burying revealed a significant effect on the emergence rate. The lowest depths (from 2 to 10 cm) permit a high emergence rate. However, the sex-ratio seems to be not influenced by the nature of the soil and less by the depth of burying.

Key words: *Ceratitis capitata*, depth of burying, emergence, pupation, sex-ratio, soil texture.

INTRODUCTION

Among the insects pests, *C. capitata* (Diptera: Tephritidae), is considered to be as one of the most species of the Mediterranean countries menacing the fruit trees. According to Oukil et al. (2002), it constitutes the major problem to production and exportation of the fruits in Algeria.

The females deposit their eggs under the epidermis of the fruit host and the larvae feed themselves from the pulp. At the end of their development, the larvae, at the third stage, leave the fruit by a brusque relaxation and sink into the soil in order to pupate (Chrystenson and Foote, 1960).

According to Harris (1984) the medfly has a high faculty of adaptation and a high biotic potential. It attacks more than 260 plants and the favourite hosts vary according to the areas. For Hendrichs (1990), it presents a remarkable capacity of selection of the fruit hosts. The control of this devastator is essentially chemical in spite of the conesquences it has on the biological balances and on the insect itself which develops resistant phenomena.

Among the recommended chemical treatments figure the dimethoate, the fenthion, the malathion and phosphamidon (Lekchiri, 1982).

The autocide struggle by releases of sterile males was successfully applied in particular in the south of Mexico where it permitted the reduction of populations of his devastator (Riba and Silvy, 1989). ElMoubariki (2005) has obtained promising results in Morocco by using the system Match Medfly RB03. Interesting researches on the biological activity of the inhibitors of proteases have been recently undertaken (Araujo et al., 2005).

The cultural practices, as the choice of plants hosts which is less important, can be efficient in the reduction of this predator's populations (Balachowsky and Mesnil, 1935). Moreover, Liaropoulos (1978) recommends the soil shallow labouring, notably a turn up ploughing in order to reduce the populations of Tephritides which pupation occurs in the soil.

It is in this contexc that our study is undertaken, which consists in choosing the implantation of orchards on the appropriate soils in order to reduce the populations of the medfly. In fine soil texture, the penetration of this devastator is difficult and sometimes the formation of pupae takes place on the soil surface. However, in unrefined soil texture, the penetration of the larvae is rapid and deep.

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According to Seguy (1950), the nature of the soil and its chemical composition has a great importance in the dipteran's development which is a part of the endogen fauna.

MATERIALS AND METHODS

The soil

The soils were collected from fruit orchards, which consists of plantations of meddler, fig trees and of patch trees situated in two localities of Tizi-ouzou town, which is 100 Km far from the south–east of Algiers. The soil texture is determined by the international pipette method (Baise, 2000). An air dried soil, sieved with a 2mm riddle is treated first with H_2O_2 at heat temperature to destroy the organic matter, then with HCl to eliminate calcareous. Natrium hexametaphosphat is added to disperse the soil particules. The whole is completed to 750 ml and shaked mecanically for an hour. The suspension is let in a 1l test tube for sedimentation. A volume of this suspension is taken using the Robinson pipette twice; after 4mn 48 seconds and 8 hours, dried at room temperature and weighed to obtain the weighs of the mixcures: thin silt +clay + Natrium hexametaphosphat (P_1), clay+ thin silt+Natrium hexametaphosphat (P_2) and clay+Natrium hexametaphosphate (P_3) respectively.The weight (P_4) of Natrium hexametaphosphate is obtained after drying the same volume of this solution. The weight of sand (P_5), is obtained by pouring the suspension remaining in the test tube on a 50 µ riddle and drying it. The rates of clay, thin silt and sand are calculated and taken away from100%.

The pupae

In order to have the maximum of pupae in this study, we have sampled infested fruits in an orchard of fig trees of different varieties. The infested fruits are picked up from the trees or collected on the soil.

Fruits are sampled twice a week during all the month of September, this period coincides with the maturation of figs. They are put in strainers which are placed for their part in bowls which bottoms' contain layers of sand of 2 cm for the burying of the larvae during the pupation. Each strainer is covered with muslin which stitches' diameter is inferior to 2 mm to prevent the penetration of the drosophila which is attracted by the fruits' fermentation. After that, the pupae are recuperated by sieving the sand.

Experimental protocol

Six depths were tested for each type of soil: D_1 (2 cm), D_2 (5 cm), D_3 (8 cm), D_4 (10 cm), D_5 (15 cm) and D_6 (20 cm).

Ten pupae were placed in the bottom of flasks of 10 cm high and diameter of 3.4 cm for the first four depths, and in the bottom of glass jars of 22.7 cm high and diameter of 9.2 cm for the two last depths and are buried under a sand of varied highs from 2 to 20 cm. We have realised 5 replicates per depth and per type of soil; in laboratory conditions at a temperature of 30.5 ± 1°C and a relative humidity of 50 ± 5%.

From the first emergence, the number of adults is daily counted in order to assess the rate of emergence and the duration of pupation which corresponds to the period of time from the formation of the pupae till the exit of the adult flies. The sex-ratio which is a good indicator of populations' dynamic is determined by the following formula: Number of female flies / Number of total flies.

A control lot was realised without soil and consists of 10 pupae per flask for each tested depth.

Statistical analysis

The statistical software was used to perform the statistical analyses. First, the analysis of variance and standard deviation of the means were used to determine the significance (P=0.05) of difference between treatments using Newman and Keuls test. Second, in order to compare the différent tests to their respective controls, we have appealed to the Dunnett test (Dagnelie 1975).

RESULTS AND DISCUSSION

Soil texture

According Base (2000), with use of English texcural diagram, the soil S_1 is a clay loam, the soil S_2 is a silty clay loam and the soil S_3 is a sandy loam texture (Table 1).

Table 1. Some properties of three soils studied.

Soils	S1	S2	S3
Clay (%)	25	20	15
Silt (%)	25	65	30
Sand (%)	50	15	55
Carbon rate (%)	0.31	0.42	0.73
Humidity (%)	1.01	5.93	2.04

Texture and depth soil effects on the emergence rate of adult flies

There is no significant difference in the rate of emergence concerning controls of the three soils (Table 2).

Table 2. Rate of emergence in the control soils (C= control).

Controls	Rate of emergence (%) (mean ± SD)	ANOVA		
		DF	F	P
C1	60.0 ± 10.9	2	2.17	0.1475
C2	70.0 ± 0.0			
C3	48.3 ± 4.0			

The analysis of the results (Table 3) reveals a very highly significant difference between the rates of emergence for the three soils. As well as a very high significance of the action of the factor of depth on this biological parameter was noticed. The difference is also very highly significant concerning the two provided factors.

Soil texture effect

The highest mean rate of emergence (63%) is obtained in the sandy loam soil (S3). However in the silty clay loam soil (S2), this rate is only of 23.6% (Table 3). These results confirmed by Cavalloro and Delrio (1978) who sti-

Table 3. Emergence rate of C. capitata according the type and depth of soil (Means following by different letter are significantly different, P = 5%).

Factors	Types	Emergence rate (mean ± SD)	ANOVA		
			DF	F	P
Soil	S_3	63.00 ± 25.8 (a)	2	47.92	0.0000
	S_1	44.00 ± 32.4 (b)			
	S_2	23.67 ± 22.6 (c)			
Depth	D_1	69.33 ± 22.1 (a)	5	23.34	0.0000
	D_2	58.00 (21.4 (b)			
	D_4	54.00 (40.1 (b)			
	D_3	32.00 (242 (c)			
	D_5	25.33 (18.0 (c)			
	D_6	22.67 (28.1 (c)			
Interaction soil-depth	D4S3	92 (8.3 (a)	10	7.90	0.0000
	D1S1	84 (8.9 (ab)			
	D1S3	82 (8.3 (ab)			
	D2S1	68 (4.4 (abc)			
	D2S3	68 (17.8 (abc)			
	. D4S1	66 (20.7 (abc)			
	D6S3	58 (19.2 (bc)			
	D1S2	42 (13.0 (cd)			
	D3S2	42 (25.8 (cd)			
	D5S3	40 (18.7 (cd)			
	D2S2	38 (22.8 (cd)			
	D3S3	38 (25.8 (cd)			
	D5S1	24 (15.1 (de)			
	D3S1	16 (15.1 (de)			
	D5S2	12 (8.3 (de)			
	D6S1	6 (5.4 (e)			
	D4S2	4 (5.4 (e)			
	D6S2	4 (5.4 (e)			

pulate that he pupation doesn't depend on the soil's chemical composition, but on its texture.

According to the control, the soil's texture has an influence on the variation of the rate of emergence. The soils S1 and S2, have presented low mean rates of emergence comparing to their controls respectively (44% and 23.6%). However, using soil S1 we have obtained relatively a higher rate of emergence which is near to that of the third control. Comparing the two preceding soils, the silty clay loam soil influences negatively the emergence rate. It seems to be inappropriate to the med fly's development, when we compare it to the control and the two other types of soil.

We have also noticed an important death rate, at some centimetres, from the surface of this soil. This mortality is probably due to the size of the silty particles' which prevent adults from arriving to the surface and traverse easily the imposed depths.

The type of soil-temperature interaction can also be at the origin of the mortality of individuals.

In fact, according to Hooper (1987), there is no difference concerning the pupation of *C. capitata* at 20 and 25°C, but the pupation in sand at 20°C causes a high mortality while it has no effect at 25°C.

Depth of larvae burying effect

The statistical analysis shows that the rate of emergence is significantly reduced when the depth of burying of the larvae increases. The highest rates, more than 50%, were obtained with the lowest depths (2.5 and 10 cm) (Table 3).

Rigamonti (2004) noticed that the pupae of *C. capitata* are formed at a depth inferior to 10 cm, and that 90% of the obtained pupae are concentrated in the five upper centimetres that is what coincides with our results; we have in fact recorded that the higher rate of emergence, 69.3%, corresponds to 2 cm depth.

For other diptera as *Dacus oleae*, Liaropoulos (1978) determined that the pupation's preferential depth is situa-

ted between 0 and 4 cm. This layer of soil is easily penetrated by the larvae as a result of human activities (soil farming) and the presence of plants' roots. Dimou et al. (2003) reported that the majority of the larvae of *D. oleae* start pupation in the upper three centimetres and the depth of pupation differ with the variation of humidity and the type of soil in addition to the interaction temperature-type of soil-humidity.

Concerning the soil S_3, the depth of 20 cm revealed a high rate of emergence of the med fly, result confirms, that this soil is favourable to the development of this fly. This is in accordance with the results of Delmas and Thermes (1953), who reported that the pupae of *C. capitata* artificially buried at 25 cm in the soil, gave birth to adults. By comparing the results obtained for the tested depths and those of the three controls, we record a significant difference.

Effect of the Two factors together (texture and depth of soil)

The test of variance analysis (Table 3) classifies the different depths of the three soils, according to the rate of emergence into many homogeneous groups (Newman and Keuls test).

The first one groups the first four depths of the two soils S_1 and S_3 (excepting the depth 8 cm) with a rate of emergence between 66 to 92 %.

This result confirms those obtained previously with the same test by studying each factor apart. The last group is that which groups the lowest values, from 4%, for the fourth and sixch depth of the soil S_2, to 6% for the sixch depth of the soil S_1. According to this test, we can confirm that the sandy clay loam soil allows the best rates of emergence for the lowest depths. The soil of a clay loam texture allows too important rates of emergence but are inferior than those obtained in the sandy loam soil, contrarily to the silty clay loam soil which limits the population of C. *capitata* by reducing emergences for all the tested depths (rate of emergence < 5%).

The presence of the sand in the two first cited soils makes the texture more friable and easy to be traversed by the adults in the stage of emergence. Hooper (1987) observed that the larvae of *C. capitata* pupate better in a soil giving a quite elevated rate of emergence.

Comparison between tests and controls

Dunnett's test allows the comparison of the results obtained for the different tested depths for each soil with those of their controls. To apply this test, the number of repetitions for the control must be equal to the number tested depths. So we have compared the five depths: 2 cm, 5 cm, 10 cm, 15 cm and 20 cm.

Dunnett's test for the soil (S_1)

The results obtained concerning the soil S_1 are as follows:

$P.P.D.S_d = 22.18$ $X_1 = 60$

$X\ Pf_1 - Xc = 24 > P.P.D.S_d$

$X\ Pf_2 - Xc = 8 < P.P.D.S_d$

$X\ Pf_4 - Xc = 6 < P.P.D.S_d$

$X\ Pf_5 - Xc = 36 > P.P.D.S_d$

$X\ Pf_6 - Xc = 54 > P.P.D.S_d$

Comparing to the control, there is no significant difference for the depths 5 and 10 cm but for the others, the rate of emergence is significantly different.

Dunnett's test for the soil S_2

The results obtained are as follows:

P.P.D.Sd = 21.17 Xc=70

X Pf1 - Xc = 28 > P.P.D.Sd

X Pf2 - Xc = 32 > P.P.D.Sd

X Pf4 - Xc = 66 > P.P.D.Sd

X Pf5 - Xc = 58 > P.P.D.Sd

$X\ Pf_6 - Xc = 66 > P.P.D.S_d$

For this soil, the differences are significant for all the tested depths. This soil isn't appropriate to pupation and therefore evokes a high mortality and a low rate of emergence.

Dunnett's test for the soil S_3

$P.P.D.S_d = 31.28$ $Xc = 48$

$X\ Pf_1 - Xc = 34 > P.P.D.S_d$

$X\ Pf_2 - Xc = 20 < P.P.D.S_d$

$X\ Pf_4 - Xc = 44 > P.P.D.S_d$

$X\ Pf_5 - Xc = 08 < P.P.D.S_d$

$X\ Pf_6 - Xc = 10 < P.P.D.S_d$

Contrarily to the soils $S_1$and S_2, this test proves that the rates of emergence for the depth 2 cm and 10 cm differ significantly from the control. For the other depths, the difference is not significant (P=5%).

Effects of soil nature and depth of burying on the duration of pupation

There is significant difference between the isolated factors "nature of soil" and "Depth of burying" but there is no significant difference for the two factors together at the threshold of P = 5% (Table 4).The highest duration of pupation was recorded in the soil S_3 of a sandy loam texture and the soil S_1 of a clay loam texture; it varies from 7 to 8 days. For the silty clay loam soil, the duration of pupation is shorter.

The durations of pupation are shorter than those observed for *D. oleae*; 88% of the pupae, placed in air conditioned room, give birth to adults after 10 to 17 days (Laudeho et al., 1979). The influence of temperature on the duration of pupation is reported by many authors, Shoukry and Hafez (1979) obtained a mean duration of

Table 4. Duration of pupation (mean ± SD) according to the texture and the depth of soil (means following by different letter are significantly different, P = 5%).

Factors	Types	Duration of pupation (days)	ANOVA		
			DF	F	P
Controls	C_1	9.0 ± 1.2	2	0.22	0.8057
	C_2	8.7 ± 0.5			
	C_3	8.7 ± 0.4			
Soil	S_3	8.4 ± 0.3 (a)	2	9.8	0.0002
	S_1	7.6 ± 2.3 (a)			
	S_2	6.0 (3.4 (b)			
Depth	D2	8.4 (0.6 (a)	5	4.6	0.0011
	D3	8.3 (0.2 (a)			
	D1	8.0 (1.6 (a)			
	D5	7.7 (2.1 (a)			
	D4	6.5 (3.3 (ab)			
	D6	5.4 (3.9 (b)			
Interaction	D1S1	7.7 (2.9	10	1.53	0.1472
	D1S2	7.5 (0.0			
	D1S3	8.9 (0.0			
	D2S1	8.8 (0.2			
	D2S2	7.5 (0.0			
	D2S3	8.9 (0.2			
	D3S1	8.3 (0.2			
	D3S2	8.2 (0.2			
	D3S3	8.4 (0.2			
	D4S1	8.0 (0.0			
	D4S2	3.2 (4.3			
	D4S3	8.4 (0.2			
	D5S1	8.2 (0.2			
	D5S2	6.6 (3.6			
	D5S3	8.3 (0.2			
	D6S1	4.8 (4.3			
	D6S2	3.4 (4.6			
	D6S3	8.0 (0.0			

pupation of 7 days at 30°C. This latter is 11 days at 25°C and 9 days at 27°C. Hooper (1978) also noted duration of 9 days at 29 ± 0.4°C. According to Shoukry and Hafez (1979), the humidity has no influence on the duration of pupation. However, the composition of the breeding environment of the larvae has an incidence on the pupation (Feron and Sacantanis, 1957).

The texture could not be the cause of this difference if we make reference to the results obtained in the controls of the three soils (Table 5).

As far as the depth of burying is concerned, results of the Newman and Keuls test reveals 3 homogeneous groups. In the first group are included the depths D_1 (2 cm), D_2 (5 cm), D_3 (8 cm) and D_5 (15 cm) which engendered high mean durations of pupation. The last group contains the depth D_6 (20 cm) with the lowest value.

This test proves that the higher duration of pupation corresponds to the depth of 5 cm, whereas the shorter duration was obtained with 20 cm depth (Table 4).

The pressing exercised by the weight of soil can explain this result. Other factors can also interfere like the porosity and consequently the availability of oxygen which can be a limit factors for the larvae distribution (Dajoz, 1975).

Variance analysis of the two factors, soil texture and depth of burying of the larvae, reveals that there is no significant difference. This permits us to say that the effect of one of the two factors is severally affected by the effect of the second parameter.

In order to determine the presence of a difference between the durations of pupation, we have applied the Dunnett test.

Table 5. Duration of pupation (means following by different letter are significantly different, (P ≤ 5%).

Type of Soil	Duration in controls (days)	Duration in tested soils (days)
S_1	9 ± 0	7 ± 1 (a)
S_2	8 ± 1	6 ± 1 (b)
S_3	8 ± 1	8 ± 1 (a)

Soil 1

$P.P.D.S_d = 3.07$ $Xc = 9$
$X\ Pf_1 - Xc = 1.3 < P.P.D.S_d$
$X\ Pf_2 - Xc = 0.2 < P.P.D.S_d$
$X\ Pf_4 - Xc = 1.0 < P.P.D.S_d$
$X\ Pf_5 - Xc = 0.8 < P.P.D.S_d$
$X\ Pf_6 - Xc = 4.2 > P.P.D.S_d$

According to the results obtained by this test, there is no significant difference between the duration of pupation for each depth comparing to the control, except the depth 6 which gave a shorter duration comparing to the control, so favourable to the pupation.

Soil 2

The results are the following

$P.P.D.S_d = 0.73$ $Xc = 8.7$
$X\ Pf_1 - Xc = 1.2 > P.P.D.S_d$
$X\ Pf_2 - Xc = 1.2 > P.P.D.S_d$
$X\ Pf_4 - Xc = 5.5 > P.P.D.S_d$
$X\ Pf_5 - Xc = 2.1 > P.P.D.S_d$
$X\ Pf_6 - Xc = 5.3 > P.P.D.S_d$

For all depths, the duration of pupation differs significantly from the control lot which is longer. This soil has then a positive influence on the duration of pupation of *C. capitata*,

Soil 3

The results are

$P.P.D.S_d = 0.63$ $Xc = 8.7$
$X\ Pf_1 - Xc = 0.2 < P.P.D.S_d$
$X\ Pf_2 - Xc = 0.2 < P.P.D.S_d$
$X\ Pf_4 - Xc = 0.3 < P.P.D.S_d$
$X\ Pf_5 - Xc = 0.4 < P.P.D.S_d$
$X\ Pf_6 - Xc = 0.2 < P.P.D.S_d$

This soil not seems having any significant influence on the duration of pupation whatever the depth considered.

Sex-ratio

The results obtained are variable according to the nature and the depth of soil (Table 6). The sex-ratio is calculated from a complement which varies from one soil to another, from 5 to 46 individuals.

According to Debouzi (1977), the sex-ratio varies between 0.4 and 0.5 which agrees with the majority of the obtained results. The sex-ratio is in favour of the males, for almost all the tested depths. According to Causse (1974), the maximum of the couplings is reached when the number of males is inferior to the number of females. The phenomena can be explained by the pronounced sexual maturation of the males. For Albajes et al. (1980), the proportion of sex is favourable to the females at the high-test temperature. The soil texture and the depth of burying of the larvae have no influence on the sex-ratio.

Table 6. Sex-ratio of *C. capitata* according to texture and depth of the soil (C: control).

Depth (cm)	Soils	Sex-ratio
2	S_1	0.4
	S_2	0.4
	S_3	0.4
	C	0.5
5	S_1	0.4
	S_2	0.5
	S_3	0.4
	C	0.5
8	S_1	0.3
	S_2	0.5
	S_3	0.4
	C	0.5
10	S_1	0.3
	S_2	0.5
	S_3	0.4
	C	0.5
15	S_1	0.4
	S_2	0.5
	S_3	0.4
	C	0.5
20	S_1	0.3
	S_2	0.0
	S_3	0.6
	C	0.5

The latter can depends on the larvae's origin and their number in the breeding environment which leads to a competition, influencing by that the sex-ratio. It can also depend on the period of maturation of the fruits hosts, thus the temperatures.

Conclusion

Through this study we have confirmed the important activity of the devastator in our region, notably by the high number of the pupae we have obtained.

Influence of the texture studied has shown that the 3 types of soil influence differently on the rate of emergence and on the duration of pupation.

The silty clay loam texture reduces the rate of emergence than the populations of *C. capitata*. The san-dy loam texture favours adults' ascent when emerging. This effect is also noticed at the level of the clay loam texture but with a lower mean rate of emergence. We deduce that the important amount of sand in the soils S_1 (50%) and S_3 (55%) makes the texture weaker and facili-tates the burying of the larvae (L_3) and the emergence of adults. But the presence of 65% of silt in the soil S_2 makes it more compact and consequently less adequate to pupation and emergence.

The depth of burying of the larvae has a significant effect on the rate of emergence of the adult flies, the lowest depths, 2 and 10 cm permitted high rates of emergence. It is for this reason that the sandy loam soil, which proved to be favourable to the emergence of *C. capitata*, must be avoided for the fruit arboriculture.

We must as well avoid concentrating fruit cultures in the same place, especially species of successive maturations in the year, to avoid a permanent activity of the med fly.

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