CITRUS TREE BORERS: (1) ALTERNATIVE MEANS OF CONTROL OF *HYPOTHENEMUS ERUDITUS* (COLEOPTERA: SCOLYTIDAE) BY HORTICULTURAL, MICROBIOLOGICAL AND LOCAL CHEMICAL TREATMENTS IN EGYPT

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Abstract

Non-conventional 10 means of control (horticultural, microbiological, and local chemical treatments) were evaluated in an infested citrus orchard located at Tokh district, Qalubia governorate during 1 and 2 successive years (December 2002 / to November 03 and/or 2003 / 04) against *H. eruditus*. The rate of reduction of infestation with winter pruning treatment averaged 40.53 and 59.32%, summer pruning treatment (17.80 and 23.29%), winter and summer pruning treatments (49.79 and 63.98%), fungal treatment (12.30 and 13.35%), bacterial treatment (9.67 and 10.87%), local spraying treatments (61.47 and 78.88%), local painting treatment (34.90 and 55.90%), winter and summer pruning and local spraying treatments together (78.15 and 91.30%), winter and summer pruning and local painting treatments together (68.42 and 82.30%), when applied for 1 and 2-successive years, respectively.

INTRODUCTION

In Egypt, the shot-hole bark beetle, *Hypothenemus eruditus* (Coleoptera: Scolytidae) is a serious pest attacking citrus tree species. Larvae bore tunnels inside the tree branches and stem, consume large amount of wood, causing weakness, reducing the production, and finally death of trees. Sweet lemon showed highest infestation with *H. eruditus*, while mandarin, lemon and kumquat showed high tolerance to infestation (Batt *et al.*, 1993).

Accordingly, borers are difficult to be controlled. In the meantime, chemical control programs with insecticides are the only available means of control in citrus orchards (Yuan and Huang, 1997, Machado and Raga, 1999 and Chatterjee and Ghosh, 2001). Therefore, the effectiveness of non-conventional means of control was evaluated in citrus orchards to check the ravages of *H. eruditus*. These means are safe, eliminate the environmental pollution, reduce the resistant biological races of the pest, and magnify the role of biological control agents (parasites, predators and pathogens).

Owing to the profitable income, citrus plantations are occupying the main horticultural area in Egypt, in old Delta lands as well as in the newly reclaimed lands. This study is a pioneer attempt to control one of the most economically important insect borers (*H. eruditus*) using non-conventional means of control for eliminating

yield losses due to this borer, the pesticide residues, prevent the outbreaks of secondary species, decrease the environmental pollution, magnify the role of the biological control agents and obtain better production of decontamination of fruits through using non traditional approaches for controlling *H. eruditus*.

MATERIALS AND METHODS

Trails on *H. eruditus* were carried out during the two successive years from December 2002 until November 2004 in an infested citrus orchard (5 feddans, 15 years old) at Tokh, Qalubia governorate. The following 10 horticultural, mechanical, microbiological, and local chemical treatments alone or in combination with each other were evaluated using completely randomized design with ten trees (replicates) each treatment:

A. Effect of one-year treatments:

1. **Winter pruning (Horticultural) treatment:** During December /January, the regular horticultural winter pruning was carried out including the infested branches and stubs using sharp saw.
2. **Summer pruning (Horticultural) treatment:** During July, the infested branches were also pruned.
3. **Winter and summer pruning (Horticultural) treatments:** The previous two treatments were conducted together.
4. **Bacterial (Microbiological) treatment:** The commercial bacterial compound "Diple 2X" (a.i. *Bacillus thuringiensis* var. *kurstaki* (Berliner), 3200 International Units Ak / mg) at the rate of 200 cc per 100 liters of water was locally sprayed on the stem, main branches and pruning sites four times each season. A compressed air knapsack sprayer was used in spraying at monthly intervals on May, June, July and August.
5. **Fungal (Microbiological) treatment:** The commercial fungal compound "Biofly FC" (a.i., *Beauveria bassiana*, 3×10^7 spores / mg) at the rate of 400 cc per 100 liters of water were locally sprayed on the stem, main branches and pruning sites four times each season. A compressed air knapsack sprayer was used in spraying at monthly intervals on May, June, July and August.
6. **Local painting (Local chemical) treatment:** Stemex insecticide (3% Anthracine + 18% Naphthalene) was used to paint the infested sites on the stem and main branches four times a year at monthly intervals during May, June, July, and August. Painting was applied by a brush.
7. **Local spraying treatment:** The recommended Basudin (Diazinon) 60% EC and Cidial L (fenthoate) 50% EC each at the rate of 300 cc / 100 liters water were locally sprayed alternatively four times a year at monthly intervals (May, June, July, and August). Spraying was directed mainly towards the infested sites on the stem and branches. A compressed air knapsack sprayer was used in spraying.

8. **Pruning and local painting (Combined) treatments:** Treatments number 3 and 6 were carried out altogether as mentioned before.
9. **Pruning and local spraying (Combined) treatments:** Treatments number 3 and 7 were carried out altogether as mentioned before.
10. **Untreated check:** Trees of this treatment did not receive any horticultural microbial or insecticidal treatments.

The previous treatments were conducted from December 2002/ November 2003 on 20 trees "replicates" each treatment. In the next season (2003/2004), the same previous treatments were repeated on another 10 trees "replicates" each treatment, in another orchard in the same locality with the same technique for confirmation.

B. Effect of two successive years treatments:

The same 10 previously mentioned one-year treatments of 2002/2003 were repeated on 10 of the previously year treated trees "replicates" (each treatment) in the same citrus orchard with the same technique during 2003/2004 seasons to evaluate the effect of the cumulative effect of two successive years.

The efficiency of the 1st year treatments was evaluated during December 2003 (before pruning treatment of the next year) in 10 trees "replicates" by counting the live larvae in 10 randomly distributed branches (25 cm each) on the treated and untreated trees. During December 2004, the efficiency of the two successive year's treatments was evaluated in the same way.

Statistical analysis:

The experimental design was completely randomized design, with 10 trees (replicate) each treatment. The efficiency of treatments was based on the percentage reduction of infestation (**Henderson and Tilton, 1955**) as follow:

$$\text{\% Reduction of infestation} = [(C - T) / C]^{-1} X\ 100$$

Where: C: Mean number of alive larvae in the untreated trees.

T: Mean number of alive larvae in the treated trees.

Analysis of variance (F test) and **Least Significant Difference (LSD) (Snedecor and Cochran, 1990)** were used for differentiation between treatments.

RESULTS AND DISCUSSION

The effect of alternative means of control with horticultural, microbiological, and local chemical treatments separately or in combination on the reduction of *H. eruditus* infestation was studied in citrus orchards at Tokh, Qalubia governorate during one and two successive years (2002/03 and 2003/04). Data concluded the following results:

A. Effect of one single year treatments (direct effect):

Statistical analysis of data of the mean number of live larvae per tree in citrus orchards indicated significant differences between the different treatments when applied for one year (Table, 1). However, some treatments showed insignificant differences between them.

a. Effect of horticultural treatments:

Statistically, there were insignificant difference between the winter pruning treatment and the treatments of winter and summer pruning together, but they significantly differed from summer pruning treatment.

1. **Winter pruning treatment** alone considerably reduced infestation reached 39.29-41.76 % (mean, 40.53%). This was due to the mode of the borer infestation that mainly attacked smaller branches, which included in the winter pruning.
2. **Summer pruning treatment** of newly infested branches was of some value as the percentage reduction in the borer infestation ranged 17.21-18.39 %, with a mean of 17.80%. This was because infestation with expanded all the year round.
3. **Winter and summer pruning treatments** remarkable reduced infestation when applied together. The mean increased percentages reduction reached 49.79 (range, 47.08–52.49%).

b. Effect of microbiological treatments:

Statistically, there were insignificant differences between the bacterial and fungal treatments. In the meantime, there were insignificant differences between the bacterial treatment and untreated check.

4. **Bacterial treatment** had slight effect may be because it was highly affected with the hot temperature and winds. Thus, the percentage reduction of infestation ranged 8.81-10.39% (mean, 9.67%).
5. **Fungal treatment** was rather higher than bacterial treatment, yet it was still of lower effect than other treatments. The percentage reduction of infestation reached 12.30% (range, 11.49-12.99%).

c. Effect of local chemical treatments:

From the statistical point of view, there were significant differences between the local painting and local spraying treatments. However, there were insignificant differences between the local spraying treatments and the combined treatments.

6. **Local painting treatment** reasonably reduced the borer infestation reached 33.77-36.02%, with a mean of 34.90%. This treatment hindered the borer to infest the tree stem and larger branches.
7. **Local spraying treatment** reduced the borer infestation approximated by 61.47% (range, 60.92-62.01%).

d. Effect of combined treatments:

8. **Winter and summer pruning together with local painting treatments** gave adequate results reached 67.86-68.97%, with a mean of 68.42% reduction of infestation.
9. **Winter and summer pruning together with local spraying treatments** achieved the maximum reduction in *H. eruditus* infestation magnified to 77.39-78.90%, with a mean of 78.15%.

Table 1. Effect of one single year treatments on the percentage reduction of *Hypothenemus. eruditus* infestation in citrus orchards at Qalubia governorate during 2002/03 and 2003/04 seasons.

Treatments	1st year 2002 / 03		2nd year 2003 / 04		Mean		
	No. of alive larvae / tree*	% R.I.	No. of alive larvae / tree*	% R.I.	No. of alive larvae / tree	Groups	% R.I.
A: Horticultural Treatments:							
1- Winter pruning	152±20.3 (118-192)	41.76	187±21.7 (135-212)	39.29	169.5	BC	40.53
2- Summer pruning	213±24.6 (174-259)	18.39	255±28.8 (181-296)	17.21	234.0	D	17.80
3- Winter & summer pruning	124±18.8 (105-165)	52.49	163±20.1 (127-206	47.08	143.5	BC	49.79
B: Microbiological Treatments:							
4- Bacterial	238±25.1 (153-286)	8.81	276±27.8 (205-342)	10..39	257.0	D	9.67
5- Fungal	231±23.7 (170-275)	11.49	268±26.3 (221-319)	12.99	249.5	D	12.30
C: Local Chemical Treatments:							
6- Local painting	167±19.5 (132-208)	36.02	204±20.8 (165-237)	33.77	185.5	C	34.90
7- Local spraying	102±17.6 (73-129)	60.92	117±16.1 (79-142)	62.01	109.5	AB	61.47
D: Combined Treatments:							
8- Treatments, 3+6	81±9.7 (63-104)	68.97	99±10.2 (76-114)	67.86	90.0	A	68.42
9- Treatments, 3+7	59±10.7 (41-89)	77.39	65±11.3 (49-92)	78.90	63.5	A	78.15
E: Untreated:							
10- Check	261±29.4 (198-311)	--	308±31.4 (254-372)	--	284.5 E		--

Values within a column followed by different letter are significantly different (P> 0.05), L.S.D. = 52

Duncan [1951 as described by Mstat, 1987] multiple ranges test.

% R.I.: Percent reduction of infestation.

From the statistical point of view, there were insignificant differences between the combined treatments of pruning, worming and local painting together and combined treatments of pruning, worming and local spraying together. Moreover, there were insignificant differences between the combined treatments and the local spraying treatment.

B. Effect of two successive year treatments (Cumulative effect):

Statistical analysis of data of the mean number of live larvae per tree in citrus orchards indicated significant differences between the different treatments when applied for two successive years (Table, 2). However, some treatments showed insignificant differences between them.

a. Effect of horticultural treatments (pruning):

Winter pruning treatment alone applied for two successive years somewhat reduced *H. eruditus* infestation (Table, 2). This relatively good percentage reduction of infestation (59.32%) was because the concentration of larval infestation in the smaller branches. Thus, winter pruning treatment, which included these branches, shared in the reducing of the borer infestation.

Summer pruning had slight effect on *H. eruditus* reduction of infestation although this treatment when repeated for two successive years. The percentage reduction of the borer infestation resulted in only 23.29%. Summer pruning treatment did not significantly share in the reduction of the borer infestation and should not include in the integrated control program of the pest.

Applying winter and summer pruning treatments together was of adequate effect on the reduction of *H. eruditus* infestation (63.98%), should this treatment applied year after another.

Statistically, there were insignificant difference between the winter pruning treatment and the treatments of both winter and summer pruning together, but they significantly differed from summer pruning treatment.

Table 2. Effect of two successive year treatments on the percentage reduction of *Hypothenemus eruditus* infestation in citrus orchards at Qalubia governorate during 2002 / 04 seasons.

Treatments	No. of alive larvae / tree*	Groups	% R.I.
A: Horticultural Treatments:			
1- Winter pruning	131±14.3 (104-162)	B	59.32
2- Summer pruning	247±11.9 (223-286)	C	23.29
3- Winter & summer pruning	116±8.6 (97-135)	AB	63.98
C: Microbiological Treatments:			
4- Bacterial	287±17.8 (241-326)	C	10.87
5- Fungal	279±18.2 (238-312)	C	13.35
D: Local Chemical Treatments:			
6- Local painting	142±12.5 (115-171)	B	55.90
7- Local spraying	68±10.6 (54-96)	AB	78.88
E: Combined Treatments:			
8- Treatments, 3 + 4 + 7	57±8.9 (42-75)	A	82.30
9- Treatments, 3 + 4 + 8	38±10.2 (26-61)	A	91.30
F: Untreated:			
10- Check	322±18.1 (274-358)	C	--

Values within a column followed by different letter are significantly different (P> 0.05), L.S.D. = 49
Duncan [1951 as described by Mstat, 1987] multiple ranges test.
% R. I. : Percent reduction of infestation.

b. Effect of microbiological treatments (bacteria or fungus):

Microbiological treatments whether with the pathogenic bacteria or fungus was relatively low when applied even cumulatively year after another because they were highly affected with the weather factors in the field.

Table (2) emphasized these results as the percentage reduction in *H. eruditus*

infestation reached 10.87 and 13.35%, when bacteria or fungus treatments were conducted for two successive years, respectively.

Statistically, there were insignificant differences between the bacterial and fungal treatments. In the meantime, they were significantly different from other treatments.

c. Effect of local chemical treatments (painting or spraying):

Local painting treatment with "Stemex" insecticide four times a year was not quite effective in the reduction of *H. eruditus* infestation in spite of repeating this treatment for two years. Local painting treatment for two successive years resulted in only 55.90 % reduction of the infestation (Table, 2).

Local spraying with Basudin 60% EC and Cidial L 50% EC alternatively four times a year was quite effective in the reduction of infestation should this treatment be repeated year after another. Table (2) indicated that local spraying treatment applied for two successive years resulted in higher percent reduction of the borer infestation reaching 78.88%.

From the statistical point of view, there were significant differences between the local painting and local spraying treatments. Moreover, there were insignificant differences between the local spraying treatment and the combined treatments.

d. Effect of combined treatments:

On the other hand, winter and summer pruning treatments, together with local painting treatment for two successive years maximized the percentage reduction in the borer infestation (82.30%) (Table, 2).

Moreover, winter and summer pruning treatments, together with local spraying treatment for two successive years also maximized the percentage reduction in the borer infestation (91.30%) (Table, 2). These combined treatments would resulted in more reduction in *H. eruditus* infestation should they applied yearly.

From the statistical point of view, there were insignificant differences between the combined treatments of pruning, worming and local painting together and combined treatments of pruning, worming and local spraying together. Moreover, there were insignificant differences between the combined treatments and the local spraying treatments.

Statistical analysis of variance (F test) and LSD resulted in the following groups:

Although the different treatments applied for different years ranked in the previously mentioned groups, yet an interaction were noticed between the treatments in the four groups.

A. The superior group (75 - 100% reduction of infestation):

1) **Winter and summer pruning and local spraying treatments together applied for two successive years** gave satisfactory effect on the reduction of infestation (91.30).
2) **Winter and summer pruning and local painting treatments together applied for two successive years** resulted in excellent control, showing 82.30% reduction of infestation.
3) **Local spraying treatment applied for two successive years** achieved a good percentage reduction of infestation reached 78.88%.
4) **Winter and summer pruning and local spraying treatments together applied for one year** was of great value due to its efficient action as well as reducing insecticidal application. The percent reduction of infestation reached 78.15%.

B. The moderate group (40 - 74% reduction of infestation):

1) **Winter and summer pruning and local painting treatments together applied for one year** gave moderate percentage reduction of infestation, averaged 68.42%.
2) **Winter and summer pruning treatments applied for two successive years** as an integrated environmentally safe pest control showed a very good effect on the reduction of infestation reached 63.98%.
3) **Local spraying treatment applied for one year** reduced the borer infestation with 61.47%.
4) **Winter pruning treatment applied for two successive years** reduced infestation by 59.32%. This treatment was easy to apply, reduce the quantity of insecticides used, and safe effort in addition to the reduction of crop pollution with insecticides.
5) **Local painting treatment applied for two successive years** reduced the borer infestation with 55.90%.
6) **Winter and summer pruning treatments applied for one year** reduced the borer infestation with 49.79%.
7) **Winter pruning treatment applied for only one year** reduced the borer infestation with 40.53%.

C. The less effective group (20 - 39% reduction of infestation):

1) **Local painting treatment applied for one year** showed 34.90% reductions of infestation.

2) **Summer pruning treatment applied for two successive years** showed 23.29% reductions of infestation.

D. The least group (less than 20% reduction of infestation):

1) **Summer pruning treatment applied for only one year** showed 17.80% reductions of infestation.
2) **Fungal treatment applied for two successive years** showed 13.35% reductions of infestation.
3) **Fungal treatment applied for only one year** showed 12.30% reductions of infestation.
4) **Bacterial treatment applied for two successive years** showed 10.87% reductions of infestation.
5) **Bacterial treatment applied for only one year** showed 9.67% reductions of infestation.

DISCUSSION AND CONCLUSION

It could be concluded that the effect of treatments varied from one treatment to another and of repeating these treatments year after another magnified the reduction of *H. eruditus* infestation in citrus orchards (Tables, 1 and 2). The effect of horticultural treatments alone resulted in 49.79% increased to 63.98% reduction of infestation. However, the majority of the effect was due to winter pruning (40.53% increased to 59.32%), since summer pruning showed (17.80% increased to 23.29%). Microbiological control with bacteria or fungus showed slight effect, as the results were 9.67 - 12.30% increased to 10.87 - 13.35%. Local painting and local spraying treatments varied much as they resulted in 34.90 increased to 55.90% and 61.47% increased to 78.88%, respectively. Combined applications (Integrated Pest Control) of winter and summer pruning treatments, together with local chemical treatments magnified the reduction of infestation 68.42 - 78.15% and greatly increased to when repeated year after another (82.30 - 91.30%). The horticultural treatments (winter and summer pruning) resulted in satisfied control if repeated year after another.

Table (3) indicated that repeating the different treatments year to another was sometimes of considerable values, but it was negligible in other cases. Repeating pruning increased the reduction of infestation with 14.2 % (the effect was mainly due to winter pruning). Repeating local chemical treatment increased the reduction of infestation with 17.4 - 20%. Repeating the combined treatments increased the reduction of infestation with 13.2 - 13.9 %. Repeating microbiological treatments negligibly increased the reduction of infestation (1.1 - 1.2%).

Table 3. General grouping of different treatments applied to control *Hypothenemus eruditus* larvae on citrus trees during one (1) and two (2) successive years (2002/03 and 03/04).

Treatment	Corrected mean no. of alive larvae	Corrected % R. I.	Ranked order	Groups
Pr + Local Spraying (2)	35.79	88.19	1	A
Pr + Local Painting (2)	53.68	82.30	2	AB
Local Spraying (2)	64.04	78.88	3	AB
Pr + Local Spraying (1)	67.68	77.68	4	BC
Pr + Local Painting (1)	95.93	68.37	5	CD
Pruning (2)	109.25	63.97	6	D
Local Spraying (1)	116.72	61.51	7	DE
Winter Pruning (2)	123.37	59.32	8	E
Local Painting (2)	133.73	55.90	9	EF
Pruning (1)	152.96	49.56	10	FG
Winter Pruning (1)	180.67	40.42	11	G
Local Painting (1)	197.73	34.80	12	G
Summer Pruning (2)	232.62	23.29	13	H
Summer Pruning (1)	249.42	17.75	14	HI
Fungal (2)	262.75	13.36	15	I
Fungal (1)	265.94	12.30	16	I
Bacterial (2)	270.29	10.87	17	I
Bacterial (1)	273.93	9.67	18	I
Untreated check	303.25	0	19	J

R. I.: Reduction of Infestation
Pr: Pruning (winter and summer)
L.S.D. = 30

Corrected percentages reduction of infestation in Table (3) showed significant differences between the 11 treatments. However, there were insignificant differences between the combined treatments of pruning together with local spraying or painting and local spraying alone when they were applied for two successive years. Furthermore, there were insignificant differences between the combined treatments of pruning together with local painting and local spraying alone when they were applied for two successive years, and pruning together with local spraying when they were applied for one year. Insignificant differences were between the combined treatments of pruning together with local spraying or painting when they were applied for one year. Pruning together with local painting and spraying applied for one year and pruning applied for two successive years were insignificantly different.

Local spraying applied for one year, winter pruning applied for two successive years, and local painting applied for two successive years were insignificantly different. Local painting applied for two successive years, and pruning applied for one year were insignificantly different. Pruning, winter pruning and local painting applied for one year were insignificantly different. Summer pruning treatment applied for one or two successive years showed insignificant differences between them. Insignificant differences were noticed between summer pruning applied for one year, fungal treatment and bacterial applied for one or two successive years.

Moreover, all the previous treatments were also insignificantly different from the untreated check control.

Accordingly, local spraying treatment and pruning (winter and summer) treatments are sufficiently effective application in controlling *H. eruditus* larvae on citrus trees when repeated year after another to increase their effectiveness.

Yuan and Huang (1997) found that the most effective method to control citrus borers was local painting of the trunk base by insecticides. Mote and Tambe (1990), Mani *et al.* (1990), and Li *et al.* (1995) tested several insecticidal treatments against the scolytid beetles and obtained promising results. Soil applications of granular systemic insecticides proved ineffective.

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حفارات أشجار الموالح: (١) الطرق البديلة لمكافحة خنافس قلف الموالح *Hypothenemus eruditus* باستخدام المعاملات البستانية والميكروبية والكيماوية الموضعية

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للحد من التلوث البيئي بالمبيدات، تم تقييم فعالية عشر طرق للمكافحة غير التقليدية وهي المعاملات البستانية والكائنات الحيوية الدقيقة والكيماوية الموضعية في حديقة موالح مصابة بخنافس قلف الموالح *H. eruditus* في منطقة طوخ محافظة القليوبية خلال عام واحد وعامين متتاليين (من ديسمبر ٢٠٠٢ إلي نوفمبر ٢٠٠٣ ،و ٢٠٠٣ / ٢٠٠٤). بلغ معدل تقليل الإصابة نتيجة للتقليم الشتوي ٤٠,٥٣ و ٥٩,٣٢%، ونتيجة للتقليم الصيفي ١٧,٨٠ و ٢٣,٢٩%، ونتيجة للتقليم الشتوي والصيفي معا ٤٩,٧٩ و ٦٣,٩٨%، ونتيجة للمعاملة بالفطريات الممرضة ١٢,٣٠ و ١٣,٣٥%، ونتيجة للمعاملة بالبكتيريا الممرضة ٩,٦٧ و ١٠,٨٧%، ونتيجة للمعاملة بالرش الموضعي ٦١,٤٧ و ٧٨,٨٨%، ونتيجة للمعاملة بالدهان الموضعي ٣٤,٩٠ و ٥٥,٩٠%، أما إجراء التقليم الشتوي والصيفي معا بالإضافة إلي الرش الموضعي فقد أدت إلي تقليل الإصابة بمعدل ٧٨,١٥ و ٩١,٣٠%، وإجراء التقليم الشتوي والصيفي معا بالإضافة إلي الدهان الموضعي فقد أدت إلي تقليل الإصابة بمعدل ٦٨,٤٢ و ٨٢,٣٠%، عندما أجريت هذه المعاملات خلال عام واحد وعامين متتاليين، علي التوالي.