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Factors affecting on infestation of apple trees with pinhole beetle, *Hypothenemus eruditus* (Scolytinae: Curculionidae: Coleoptera) at Menoufia Governorate, Egypt

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Abstract:

Hypothenemus eruditus Westwood (Scolytinae: Curculionidae: Coleoptera) is considered the most widespread and abundant scolytine in the world. The aim of this is to study the effect of the factors, moisture content of apple branches, different heights from ground surface and dominant weather factors on infestation of apple trees with *H. eruditus*. The results indicated, these factors obviously detected the following:

1) The highest infestation was recorded for branches with 26.9% moisture content for cutting branches to 7days ago.
2)The highest number of entrance holes recorded for branches at height 150- 200cm.
3)Population fluctuation of H. eruditus beetle during activity periods revealed that the beetles are abundant all year. The number of attracted beetles to intact apple branches, estimated by number of entrance holes, appeared six and five peaks of population density during two successive years of study (2017 and 2018).
4)Seasonal activity of attracted beetles detected that the highest percentages of entrance holes were recorded during the summer followed by the spring or autumn then the winter. The highest monthly percentage of entranced beetles recorded 15.63% during July (2017) and 14.67% during August (2018), while the lowest percentage showed at January of both two seasons. Weather factors showed clear different effects on population fluctuation of beetles

Introduction

The pinhole beetle, *Hypothenemus eruditus* Westwood (Scolytinae: Curculionidae: Coleoptera) (tiny beetle) is considered a "super-generalist," recorded from an unusually broad range of host species and plant tissues and is abundant in most tropical and subtropical regions, and consequently, it is widely collected (Wood ,1982). It is one of the important

pests that attack many species of fruit and wooden trees. The infestation of *H. eruditus* beetles causes the death and dryness of infested branches and twigs, the color of tree branches become fading and reddish brown. In Egypt, Willcocks (1924); Batt(1999b) and Hashim (2009) reported that *H. eruditus* beetle infested mulberry, fig, mango and sesseban causing death to branches and twigs. As well as the pinehole borer, *H. eruditus* infested citrus trees, *Ficus* spp, *Poinciana* sp, *Acacia* sp, *Hibscus* sp, and *pitosoporum* sp (Hammad ,1961). Also, Girgis (1987) surveyed *H. eruditus* in Alexandria, Beheira, Gharbia, Menoufia, Qalubia and Minia Governoratesand he recorded this beetle on plum, apple, pear, *Fig sycomorus*, *Fig carica*, mango, olive, citrus, white poplar, lebbek, sessban, royal poinciana and mulberry trees. The same author found that *H. eruditus* attacked small branches (less than 6cm diameter) and preferred the weakened branches of several hosts comprising fruit and wood trees.

In addition to that Batt *et al*. (1993) recorded the *H. eruditus* beetles on sweet lemon, mandarin, lemon and kumquat trees; furthermore, they mentioned that the highest percentage of infestation recorded at Sharkia Governorate, while the lowest percentage of infestation was in Beni-Suef Governorate. The infestation percentages on pear, apple, plum, peach and apricot trees reached 37%, 28%, 19%, 13%, 3% respectively by *H. eruditus* beetles at Kafer alaem village, Berkt El-Saba district, Menoufia Governorate (Batt,1999 a).

In Germany, Blunck (1954) mentioned that *Ficus sp*., *Citrus* sp., *Vitis vinifera* (Grapevine) and *Acacia* sp. are host plants to *H. eruditus*. It is also attacked seedlings cocoa trees and caused the damage and death to them (Batt,1999a) and is *H. eruditu* spread in the area from Michigan (USA) to Argentina (Wood ,2007).

In Turkey, Akşit *et al.* (2005) recorded *H. eruditus* as a new pest on fig (*Ficus carica*) trees in Aydın province, while Tuncer *et al.* (2017) surveyed the bark beetle *H. eruditus* on hazelnut orchards in Aydın, Mersin, Samsun provinces. In India, Keshavareddy *et al.* (2007) recorded *H. eruditus* beetle for the first time on jack fruits *(Artocarpus heterophyllus*) trees.

Bastos and Lima (1981) found that *H. eruditus* [*H. obscures* (Miiller)] (beetles attack shoots of Manicoba (*Manihot glzivoii*), while Zelaya *et al*., 1984 stated that *H. eruditus* was trapped in plantations of (*Pinus oocarpa* and *Pinus caribaea*) in Barazil.

Beardsley (1990) and lÒbl and Smetana (2011) mentioned that some hosts such as coffee berries, nutmeg (Myristica fragrans Houtt.), macadamia nuts (Macadamia sp.), cocoa, tamarind, and jackfruit were attacked by *H. eruditus* (*H. obscures*) pest. Other authors had listed *H. eruditus* (*H. obscures*) infested coffee berries (eg.: Da Costa Lima (1956); Le Pelley (1968); Kathleen *et al.* (1994) and Constantino *et al*., 2011).

Previous studies on scolytid beetles (Coleoptera: Scolytidae) by many researchers such as Graham and Werner (1956); Chapman (1962) and (1963); Russo (1963); Charars (1976); Charars *et al.* (1978), Moeck *et al.* (1981); Girgis (1987) and Batt (1989) indicated that several factors play an essential part affecting on infestation by scolytids, these factors included weakened, dead or healthy branches, odors constituents of wood, volatile chemicals (primary attraction by terpenes give off by the tree), physiological conditions, excreta and chemical changes in the tree tissues by attack the first beetles, as well as moisture content which has important role in attraction of beetles to cut logs(branches) used as host trap for mechanical control of scolytid beetles. Other important factors have most influences on the infestation of orchards fruit trees with wood borers, these factors comprise the attack density of insect

population and meteorological conditions which include field temperature and relative humidity for surrounding air with the trees.

The objective of the present work is to study the effect of temperature, relative humidity, moisture content, height of attacked branches on infestation of *H. eruditus* beetles to apple trees at Menoufia Governorate, Egypt. As well as the possibility to use the apple branches as host traps (logs) to control of this pest.

Materials and Methods

Infested apple orchard (about 5 feddans, 12 years old) with pinehole beetles, *H. eruditus*, was chosen at Al-Khatatba location, Sadat district, Menoufia Governorate during October 2016. The experimental area not treated with any chemical treatments throughout the period of this work. The current study is interested with definition each of the suitable moisture content of apple branches, suitable height to attract the highest number of beetles, the determine the seasonal activity and population fluctuation of beetles under effects of field temperature and relative humidity.

To determine the suitable moisture content of apple branches for attract the beetles, intact apple branches of about 1.5 diameter were cut on different periods (28, 21, 14, 7,3 and 0 days) and divided to cuttings of 50cm length. One cutting from each period was gathered to making one group tied together. 20 groups were tied on the trunk of infested trees with *H. eruditus* (each group on infested tree), these groups were examined continually for 2weeks and the entrance holes in each cutting were recorded. The moisture contents corresponding with the number of days after cutting were determine using heat oven at 105 C° and percentage of moisture content (MC%) was calculated as follow:

$$MC\% = \frac{\text{Fresh wood weight} - \text{Dry wood weight}}{\text{Fresh wood weight}} \times 100$$

The suitable moisture content which attracted the highest number of beetles (entrance holes) used to definition the suitable timing for cut the intact apple branches as host traps.

The intact apple branches (1.5diameter) were cut and left to suitable timing to obtain required moisture content, the branches were divided to cuttings (50cm length). Each five cuttings were hanged on branches of tree at different heights of regions (0-50, 50-100,100-150, 150-200, 200-250 and 250-300cm) for 20 trees and left 2 weeks, the number of entrance holes at each height were recorded to definition the suitable height to attract the highest number of beetles.

After definition the suitable height, 20 groups from intact branches with suitable timing of cut (each group contain 5 cutting x 50cm length) were hanged on 20 infested trees at suitable height, these groups were replacing each 2 weeks. Continued examination was made, the weakly number of entranced holes was recorded throughout the period from the first of January 2017 to the ending December 2018.

The seasonal activity and population fluctuation of attracted beetles and the effect of dominant factors of field temperature and relative humidity on beetle population was studied. Statistical analysis of obtained data was made according **SAS program (2003).**

Results and discussion

1.The effect of moisture content of apple branches on number attracted beetles:

The number of attracted *H. eruditus* beetles was determined with number of entrance holes in apple branches cut on different periods as a result in the change of moisture content to attacked branches.The number of entrance holes at different moisture contents (corresponding number of days after cutting) was recorded in Table (1), the highest number of entrance holes was recorded at moisture content 26.9 % (seven days after cutting), while the least numbers of entrance holes were

recorded at moisture content at 50.98 % and 11.7% (0 and 28 days after cutting , respectively).

Statistical analysis for moisture contents of apple branches cut at different periods detected highly significant differences between obtained values of moisture contents of branches at different periods after cutting (F= 1714.9), six statistically groups were recorded for wood moisture contents (LSD= 0.88), Table (1). Also, highly significant differences between numbers of attracted beetles (entrance holes) to apple branches which cut at different periods (various moisture content), F =79.86, five statistically groups were observed between numbers entrance holes on apple branches, (LSD = 0.87), Table (1).

Table (1): Effect of moisture content of apple branches on initial infestation of *Hypothenemus eruditus* borer

Number of days after cutting	Wood moister content		Number of entrance	
	Mean ±SD	Range	Mean± SD	Range
0	50.98 ±1.60 a	48.8 - 53.6	3.4 ± 1. 96 c	0-6
3	41.4 ± 2.55 b	37.1 - 46.7	5.3± 1.75 b	3-8
7	26.9 ± 2.04 c	24.2 - 30.1	11.4 ±2.16 a	7-15
14	19.7 ±1.63 d	16.7 - 22.6	5.7± 1.75 b	4-11
21	14.6± 0.75 e	15.8 – 13.5	4 ± 1.41 c	1-7
28	11.7 ±0.69 f	10.4 – 12.7	1.8 ± 0.83 d	1-3
F	1714.9		79.86	
LSD	0.88		0.87	

These results were agreed with the obtained results by Okil (1982) who found that the suitable moisture content to infest *Poinciana regia* branches by *Sinoxylon sudanicum* Lesne. beetles were ranged from 13.6 to 35.6%. As well as, El-Sebay (1984) mentioned that the highest number of *Dinoderus bifoveolatus* Woll. beetles were attracted to bamboo wood at 39.4 % moisture content (at 0 day to storage period), while the lowest number of beetles was recorded at 9.4% moisture content (at 40 days to storage period). Also, Batt (1989) found that the percentage 32.12 % moisture content of plum branches showed the highest number of *scolytus amygdale* Guer. beetles at 7days after cutting, while the percentage 48.83% moisture content (at 0 day after cutting) attracted the lowest number of beetles. Whereas, Mohamad (2002) reported that the percentage 28.57% moisture content attracted the highest number of *Dinderus minutes* Fab. beetles, while the lowest number was recorded at moisture content of 37.68%

2. Effect of different heights on number of entrance holes in apple branches:

The number of entrance holes of *Hypothenemus eruditus* beetles attracted to apple branches on different heights was illustrated in Table (2). The highest number of entrance holes *H. eruditus* in apple branches was ranged 7-14 holes with a mean 11.4 ±1.93 holes, recorded at height 150-200cm, followed by 4-10 entrance holes with a mean 7.7 ±1.59 at the height 100-150cm then 5-9 entrance holes with a mean 7.2 ± 1.58 recorded at the height 200-250cm,1-7 entrance holes with a mean 5.5 ± 1.70 at the height 250 -300cm and 3-8 entrance holes with a mean 5.2 ± 1.40 at the height 50 -100cm, while the least number entrance holes ranged 1-5 entrance holes with a mean 2.7 ± 1.03 at the height 0-50cm.

Statistical analysis for numbers entrance holes recorded on different heights showed highly significant differences (F=70.36), four statistical groups were obtained between the number of entrance holes on different heights, (LSD = 0.83), Table (2).

Table (2): Number of entrance holes of *Hypothenemus eruditus* beetles attracted to apple branches trees (as host trap) on different heights.

Height cm.	Number of entrance holes		Statistical groups			
	Range	Mean ± SD				
0-50	1-5	2.7 ± 1.03				d
50-100	3-8	5.2 ± 1.40			c	
100-150	4-10	7.7±1.59		b		
150-200	7-14	11.4± 1. 93	a			
200-250	5-9	7.2 ± 1.58		b		
250-300	1-7	5. 5 ± 1.70			c	
F	70.36					
LSD	0.83					

Terren and De Simon (1983) reported that the most of scolytid beetles were caught at 1.5-2.5 m above the ground, while few of them at higher than 4m by using pheromone traps. The largest numbers of *H. eruditus* trapped were recorded at 1.5m, while the least number of beetles trapped were found at 0.5m on plum trees (Girgis ,1987). As well as, Batt (2008) showed that regions of 2m to 3m above ground on pear trees were preferred to attack *H. eruditus* beetles. Also, the largest numbers of *H. eruditus* beetles were found at the range of 100 to 150Cm above ground on *Pinus taeda* L trees in Santa Maria city, Rio Grande do Sul state, Southern Brazil (Machado and Costa, 2017).

3. Population fluctuation and seasonal abundance of *Hypothenemus eruditus* beetles:

3.1. Occurrence periods:

Data illustrated in Figure (1) show population fluctuation of *H. eruditus* beetles entranced in apple branches, in cultivated apple orchard at Al-Khatatba location, Sadat district, Menoufia Governorateduring 2017 and 2018. Activity of attracted beetles to apple branches showed that the beetles were abundant throughout the year, population density during 2017 appeared six occurrence periods and six peaks of entrance beetles recorded at the 2nd week of April, the 1st week of June, the 2nd week of July, the 2nd week of August, 3rd week of September and the 4th week of October, while during 2018 the number of entrance beetles detected five occurrence periods and five peaks of population density recorded at the 3rd week of April, the 2nd week of June, the 2nd week of July, the 3rd week of August and 3rd week of October**.** The occurrence periods of beetles detected different duration of activity periods during seasonal occurrence of beetles. In 2017 year, the highest duration was 19weeks recorded during the 1st occurrence period, from 1st week of January until the 3rd week of May, followed by 10 weeks recorded during 6th occurrence period, from the 3rd week of October until the 4th week of December, the durations of other occurrence periods ranged 4-5 weeks. In 2018 year, the highest duration of occurrence periods recorded 18 weeks observed through the 1st occurrence period extended from the 1st week of January until the 2nd week of May, followed by the 5th occurrence period which recorded 10 weeks occupied the period from 3rd week of October until the 4th week of December, while the lowest duration was 5weeks, recorded during the 3rd occurrence period extended from the 1st week of July to 1st week of August, Table (3). Girgis (1987) reported that the *H.eruditus* beetles had four occurrence periods on plum trees at Shibin El-Kom, Menoufia Governorate: the 1st occurrence appeared from late March to early June (11weeks) , the 2nd occurrence started from the end May to mid August (12weeks), the 3rd occurrence showed from mid August to early October (8weeks) and the 4th occurrence started from early October to early November (6weeks), while Girgis *et al.*, 1991 revealed that *H.eruditus* (*H obscures*) beetle had four generations on Mulberry trees at Shibin El-Kom, Menoufia Governorate started from early or late January and ended late December and showed four peaks of emerged beetles during (early or mid April), (early or mid June), (late July or early August) and (mid or late September).

Table (3): Seasonal occurrence periods of *Hypothenemu eruditus* beetle attracted to apple branches used as traps during 2017 and 2018 years

Occurrence periods				
2017 year				
No.	**From**	**To**	**Duration (week)**	**Peak time**
1	1st week of Jan.	3rd week of May	19	2nd week of April
2	4th week of May	4th week of Jun.	5	1st week of Jun.
3	1st week of Jul.	1st week of Aug.	5	2nd week of Jul.
4	2nd week of Aug.	2nd week of Sep.	5	2nd week of Aug.
5	3rd week of Sep.	2nd week of Oct.	4	3rd week of Sep.
6	3rd week of Oct.	4th week of Dec.	10	4th week of Oct
Total	-------	--------	48	--------
2018 year				
No.	**From**	**To**	**Duration (week)**	**Peak time**
1	1st week of Jan.	2nd week of May	18	3rd week of April
2	3rd week of May	4th week of Jun.	6	2nd week of Jun.
3	1st week of Jul.	1st week of Aug.	5	2nd week of Jul
4	2nd week of Aug.	2nd week of Oct	9	3rd week of Aug
5	3rd week of Oct.	4th week of Dec.	10	3rd week of Oct
Total	-------	--------	48	--------

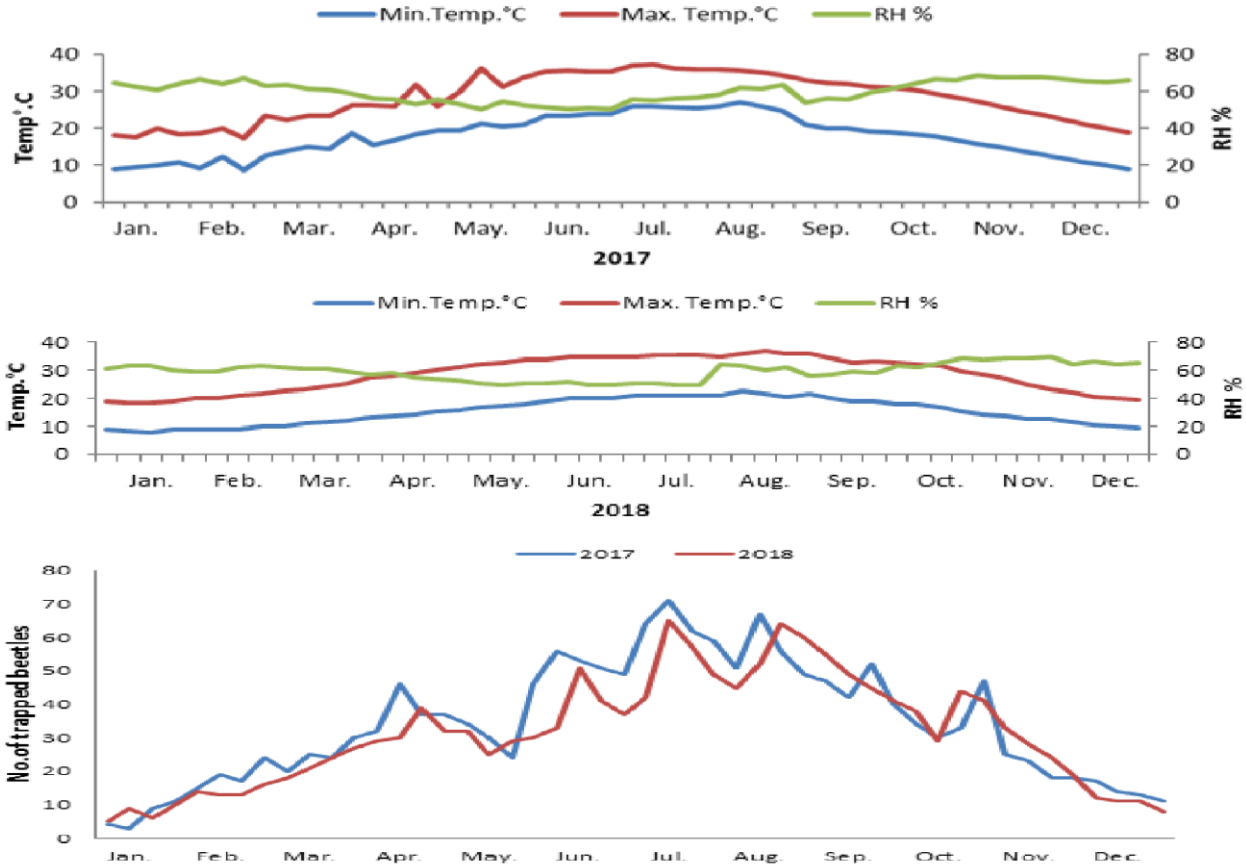

Figure (1): Seasonal flight activity of *Hypothenemus eruditus* estimated by number of attracted beetles to apple branches affected with changes in filed temperature and relative humidity during 2017 and 2018, years at Sadat district, Menoufia governorate.

3.2. Seasonal abundance:

The seasonal and monthly percentages of *H. eruditus* beetles attracted apple branches are cleared in Table (4). In 2017, highest percentage of entrance (40.29 %) was recorded during the summer followed by spring (30.22 % entrance), autumn (17.22 % entrance), while the lowest percentage was 12.27 % entrance recorded during winter. In 2018, highest percentage was 41.43 % entrance recorded also during the summer followed by spring (26.83 % entrance), autumn (19.79% entrance) while the lowest percentage (11.69 % entrance) recorded during the winter. The monthly abundance of entrance beetles in Table (4), during 2017 indicated that the highest entrance percentage was 15.63% recorded during July, followed by 13.61% entrance during August, 12.76%, 11.05%, 9.28%, 8.73%, 8.18%, 6.04%, 5.13 % entrance during, June, September, April, October, May, March and November respectively, while the lowest densities of entrance beetles recorded during February (4.58% entrance) December (3.36% entrance) and January (1.65% entrance) .

During 2018, the highest percentage of entrance during recorded during August (14.67% entrance), followed by 14.14%, 12.62%.10.76%, 10.09%, 8.63%, 7.44%, 6.91%, 5.98% entrance recorded during, July, September, June, October, April, May, November and March respectively, while the lowest entrance percentage showed during February (3.72% entrance) December (2.79 % entrance) and January (1.99 % entrance).

Table (4): Monthly population and percentages of *Hypothenemus eruditus* beetles attracted of apple branches during different seasons of 2017 and 2018 at Al-Khatatba, Menoufia Governorate.

Season	Months	2017		2018	
		Numbers of entrance beetles	Entrance percentage	Numbers of entrance beetles	Entrance percentage
Winter	Jan.	27	1.65	30	1.99
	Feb.	75	4.58	56	3.72
	Mar.	99	6.04	90	5.98
	Total	**201**	**12.27**	**176**	**11.69**
Spring	Apr.	152	9.28	130	8.63
	May.	134	8.18	116	7.44
	Jun.	209	12.76	162	10.76
	Total	**495**	**30.22**	**408**	**26.83**
Summer	Jul.	256	15.63	213	14.14
	Aug.	223	13.61	221	14.67
	Sep.	181	11.05	190	12.62
	Total	**660**	**40.29**	**624**	**41.43**
Autumn	Oct.	143	8.73	152	10.09
	Nov.	84	5.13	104	6.91
	Dec.	55	3.36	42	2.79
	Total	**282**	**17.22**	**298**	**19.79**
General total		1638	100	1506	100

4. The effect of whether factors on population fluctuation of attracted *Hypothenemus eruditus* beetles:

The effect of dominant factors (minimum and maximum temperatures °c and percent of Relative Humidity) on number of entrance *H. eruditus* beetles during different months, estimated by correlation "r", between different weather factors and population of attracted beetles to apple branches during the different activity periods detected highly significant and positive correlation between averages of both minimum and maximum temperatures with numbers of attracted beetles (r =0.933 and 0.904 respectively), while the correlation was negative between RH% and number of beetles (r = - 0.608) during 2017year. Also, the data obtained during 2018 year showed that the correlation was highly significant and positive, where the r values was 0.916 and 0.918 for minimum and maximum temperature, respectively; while no correlation was obtained between the relative humidity and population density of beetles (r = - 0.391), Table (5).

Table (5): Simple correlation (r) and simple regression (b) of the weather factors with the number of attracted beetles of Hypothenemus *eruditus* during 2017 and 2018 years.

year	2017		2018	
Weather factors	Simple correlation (r)	Simple regression (b)	Simple correlation (r)	Simple regression (b)
Min.Temp °c	0.933	2.942	0.916	3.242
Max.Temp°c	0.904	2.504	0.918	2.424
RH%	-0.608	-1.922	-0.391	-1.04

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