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The optimal use of some types of natural food attractive as a tool to reduce the prediction and limit the spread of red palm weevil *Rhynchophorus ferrugineus* Olivier.

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The red palm weevil, *Rhynchophorus ferrugineus* Olivier is the most severe insect of major cultivated palm trees. In the present studies, different experiments were carried out to evaluate the different sources of food baits compared with control (aggregation pheromone trap) in attracting RPW adults. Data recorded showed that the experiments that used aggregation pheromone and top soft trunk fresh tissues bait caught significantly more target adults pest (95.0 and 100.2 adults/ 2016 a year and 111.4 and 115.0 adults/ 2017 a year) compared with other treatments . The traps showed significant increase in weevils captured during the second season (2017) compared with the first season (2016). The top soft trunk tissues trap was the highest efficacy compared with the other baits (28.0% (2016) with all grand total a year 357.8 adults & 24.69% (2017) with all grand total a year 465.6 adults). Also our observations of captured weevils showed that the ratio of females to males captured was 1.3♀: 1.0 ♂ (2016) and 1.0♀:1.0♂ (2017). The synergistic effects of temperature and R.H. % with different bait traps were also recorded with significant effects for the temperature than the humidity. Three flight peaks were recorded during two experimental for years of study, April, July and September. Outcomes from this study may serve as basis for future proper formulation of red palm weevil trapping food baits which could be adapted to the Mediterranean Sea. The second aim from this study is useful in the utilization of farm date palm residues in attracting adults and saving resistance expenses and not using or importing chemicals.

Keywords: *Rhynchophorus ferrugineus;* Natural traps; Farm wastes ; Reduce the infestation; Date palm tree

INTRODUCTION

The red palm weevil *R. Ferrugineus* Olivier is widely considered to be one of the most dangerous pests that attack the palm plantations. Red palm weevil is the most destructive and notorious pest of palm trees in Egypt. The red palm weevil had expanded in more than 50 countries around the world. Some of the countries suffering from this pest are India (original habitat), Pakistan, Egypt and others. We can call the red palm weevil (the invisible enemy) as it spends its life cycle (oviposition, larvae, pupae and adult insects) in the trunk of the palm tree. In fact, the greatest concentration of larvae in the top of the palm tree causes a rise of internal temperature up to peaks of 50 ºC due to the fermentation. The red palm weevil has three different generations in the world , able to intermingle between it selves. As an internal tissue borer, detection of infested palm becomes extremely difficult in the early stage of attack (Abraham et al., 1998; Oehschlager , 1995 ; Salem, 2015). One of the main methods practiced to control adult weevils is monitoring and mass trapping with lures baited with aggregation pheromone (ferrugineol;4-methyl-5-nonanol) (Salem et al., 2009) and food bait traps (sugarcane, fermented dates).It is very difficult to detect the target pest in the early stages of infestation. Generally, it is detected only after the palm has been severely damaged. The destructiveness of this weevil is abetted by several traditional farming practices, including the removal of leaves or pruning of offshoots, which causes (kairomones) that attract male weevils (Gunawardena et al., 1998, Salem et al., 2015). Current tactics used to manage the red palm weevil are largely based on insecticide applications although there are now deep concerns about environmental pollution. In the recent years, there is a strong emphasis on the development of control methods based on different traps and biological control (Faleiro 2006 , Falerio and Kumar, 2008 , Oehlschlager et al., 1993; Hallett et al., 1999, Al-Sauod et al., 2010). Traps are mainly used for monitoring the insect, even though occasionally mass trapping has been employed to reduce adult populations (Soroker et al., 2005, El-Sayed et al., 2006). The colour of traps can play a role about the adult captures (Abuagla and Al-Deeb, 2012). The aim of this study was to evaluate five food bait traps used to monitor the target RPW as well as to monitor the insect population in the areas of reclaimed orchards cultivated with different fruit crops.

MATERIALS and METHODS

Monitoring and evaluation studies of curculionid weevil, *R. ferrugineus were* carried out in date palm orchard located at El-Sadat region ,Menofyia Governorate . Studies were conducted during two successive seasons using different bait traps from the first January 2016 until the end of December 2017.

A specially designed 5 litre plastic bucket with lid was used and 10 to 12 round holes (2-3 cm diameter) were made in each bucked at 10 cm height from its base for weevils entrance. Five traps were used as replicates for each tested materials. The attractant materials used are : (1) pheromone capsule obtained from Chem Tica international S.A., San Jose , Costa Rica , each capsule containing 700 mg/lure total mixture of both 4-methyl-5-nonanol and 4-methyl-5-nonanone (9:1) at 95% purity , the capsules replaced every 12-16 weeks (used as control for comparison with other traps) . (2) 500 gm. of top soft trunk tissue of date trees (named: El-gommar). (3) 500 gm. semidry dates with some water drops. (4) 500 gm. of apple fruit pieces. (5) 500 gr. of crushed sugarcane stem. Water was replaced every 2 weeks to maintain sufficient moisture in each trap and to avoid the growth of fungi or algae on the water surface (Al-Saoud et al., 2010). The water was mixed with detergent to kill the weevil and 10 ml. ethyl acetate was done every week to enhance the efficiency of the food baited pheromone trap. The total area used is about 5 Fed. (21000 m^2). Traps were located between date palms , as five traps / Fed. (4200 m^2). Traps were set under the shade of the plant canopy and not exposed to direct sunlight in order to obtain a sustained and uniform release of the chemical lure into the environment. The lures and food baits were changed every two weeks and the attracted weevils were sent to the laboratory for differentiation of sex and counted. The main weather factors; the month mean temperatures and the month relative humidity were considered. The weather data were obtained from meteorological institute, Minister Agriculture, Giza , Cairo. Data for the effects of temperatures and humidity on mean capture of traps were subjected to analysis of variance (ANOVA) using SPSS statistical package for (F) and (T) values and for percentage of variance. Analysis of variance was conducted for the data collected from 5 traps and the mean were separated by the least significant difference LSD procedure of the SAS statistical software (SAS 2001). To determine the direct effect of each weather factor on the adult activity, population counts were plotted against the corresponding weather data. The simple correlation coefficient "r" for the relationship between each weather factor and adults population was then worked out (Snedecor and Cochran 1990).

RESULTS and DISCUSSION

Results of these experiments confirm the existence of significant difference in the average number of red palm weevil caught in the five bait traps. These results were compatible with the objective of the study for the evaluation of the efficiency to these different sources of the baits under field conditions that represents different levels of infestation by RPW. The seasonal abundance of RPW in palm tree orchard during 2016 &2017 were tabulated in Tables (1 and 2). The food bait treatments with natural palm tree tissues and synthetic pheromone (as control) caught more red palm weevil adult specimens than treatments with other food baits alone.

Table (1): Attraction efficiency of the different bait food traps on the weevil date during 2016 season with the corresponding weather factors.

Month	Date of inspection	Mean number of weevil ♂& ♀ / Trap															Mean Temp. ºC	R.H. %
		Aggregation pheromone			Top soft trunk tissue			Semidry dates			Apple fruit pieces			Sugarcane pieces				
		♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month		
Jan.	1-15	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	18.8	62.0
	16-31	0.0	0.0		0.0	0.1		0.0	0.1		0.0	0.0		0.0	0.0			
Feb.	1-15	0.1	0.1	1.4	0.1	0.1	0.5	0.0	0.1	0.5	0.0	0.0	0.2	0.0	0.0	0.0	20.4	52.0
	16-28	0.5	0.7		0.1	0.2		0.1	0.3		0.1	0.1		0.0	0.0			
Mar.	1-15	2.1	2.4	9.5	2.9	2.9	12.6	2.0	2.5	9.3	1.4	1.5	7.0	0.1	0.2	1.2	23.7	66.0
	16-31	2.3	2.7		3.0	3.8		2.3	2.5		2.0	2.1		0.4	0.5			
April	1-15	3.8	4.6	18.0	4.0	5.2	19.1	2.6	2.4	11.5	2.5	2.5	10.2	0.9	1.0	5.1	28.0	68.0
	16-30	4.9	4.7		4.0	5.9		3.0	3.5		2.5	2.7		1.5	1.7			
May.	1-15	2.7	2.0	9.1	3.0	4.8	14.7	2.2	2.3	9.5	1.0	1.3	6.0	1.0	1.2	5.6	32.3	72.0
	16-31	2.5	1.9		2.9	4.0		2.0	3.2		1.7	2.0		1.5	1.9			
Jun.	1-15	2.3	2.0	9.6	2.0	3.2	9.2	2.0	2.5	7.2	1.6	1.7	5.1	1.4	1.5	4.6	34.0	76.0
	16-30	2.8	2.5		1.1	2.9		1.0	1.7		0.7	1.1		0.8	0.9			
July.	1-15	4.0	5.7	18.2	3.3	4.9	16.9	2.0	2.3	10.0	2.2	2.3	9.5	2.0	2.2	7.8	35.8	77.0
	16-31	3.9	4.6		3.0	5.7		2.2	3.5		2.0	3.0		1.7	1.9			
August.	1-15	0.2	0.2	0.6	1.0	2.2	5.1	0.5	0.9	3.0	0.3	0.7	2.2	0.4	0.8	2.6	34.0	79.0
	16-31	0.1	0.1		0.7	1.2		0.6	1.0		0.4	0.8		0.5	0.9			
Sep.	1-15	3.7	4.9	17.2	2.1	3.9	11.5	1.2	2.3	7.3	0.8	1.1	4.3	0.9	1.0	4.8	32.1	75.0
	16-30	4.0	4.6		2.6	2.9		1.3	2.5		1.0	1.4		1.2	1.7			
Oct.	1-15	2.3	2.4	8.8	1.7	2.4	8.1	1.3	2.5	7.6	1.0	1.2	4.8	1.0	1.5	5.6	28.8	73.0
	16-31	2.0	2.1		1.8	2.2		1.6	2.2		1.2	1.4		1.3	1.8			
Nov.	1-15	0.6	0.7	1.8	0.4	0.6	1.8	o.6	0.9	2.7	0.5	0.6	2.1	0.4	0.8	2.8	25.1	74.0
	16-30	0.4	0.1		0.3	0.5		0.4	0.8		0.3	0.7		0.5	1.1			
Dec.	1-15	0.3	0.2	0.8	0.2	0.3	0.6	0.2	0.3	1.1	0.1	0.2	0.4	0.3	0.5	0.9	21.0	68.0
	16-31	0.1	0.2		0.0	0.1		0.1	0.5		0.0	0.1		0.0	0.1			
Total/ year	------	45.6	49.4	95.0	40.2	60.0	100.2	29.2	40.6	69.8	23.3	28.5	51.8	17.8	23.2	41.0	-----	-----
Avg./ month	------	3.8	4.1	7.92	3.35	5.0	8.35	2.4	3.38	5.82	1.9	2.37	4.31	1.48	1.93	3.42	27.83	68.5

Table (2): Attraction efficiency of the different bait food traps on the weevil date during 2017 season with the corresponding weather factors.

Month	Date of inspection	Mean number of weevil ♂ & ♀ / Trap															Mean temp ºC	R.H. %
		Aggregation pheromone			Top soft trunk tissue			Semidry dates			Apple fruit pieces			Sugarcane pieces				
		♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month	♂	♀	Total/ month		
Jan.	1-15	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	19.8	66.0
	16-31	0.0	0.0		0.1	0.1		0.1	0.0		0.0	0.1		0.0	0.1			
Feb.	1-15	0.1	0.0	0.9	0.1	0.2	0.7	0.1	0.1	0.7	0.1	0.1	0.6	0.0	0.0	0.1	21.5	60.0
	16-28	0.3	0.5		0.2	0.2		0.3	0.2		0.2	0.3		0.1	0.0			
Mar.	1-15	2.7	2.9	12.5	3.3	3.4	14.7	2.2	2.7	13.4	1.1	1.6	8.4	0.1	0.2	1.6	24.1	62.0
	16-31	3.2	3.7		3.9	4.1		3.9	4.6		2.3	3.4		0.5	0.8			
April	1-15	4.4	5.6	22.1	4.8	4.1	20.0	5.1	5.9	22.5	4.0	3.3	14.4	0.7	0.7	4.8	28.1	64.0
	16-30	5.9	6.2		5.2	5.9		6.0	5.5		3.8	3.3		1.6	1.8			
May.	1-15	4.7	3.4	14.7	4.0	4.0	15.8	4.0	3.5	13.6	3.0	2.9	10.6	1.9	1.8	8.0	32.1	70.0
	16-31	4.0	2.6		4.1	3.7		3.1	3.0		2.0	2.7		2.4	1.9			
Jun.	1-15	3.5	3.0	11.4	3.2	3.0	11.1	2.6	2.9	10.4	1.3	1.9	6.6	1.6	1.4	6.6	34.6	75.0
	16-30	2.7	2.2		2.5	2.4		2.9	2.0		1.4	2.0		1.7	1.9			
July.	1-15	4.9	4.0	15.9	5.1	4.6	17.0	4.4	3.9	15.4	3.5	3.0	13.2	2.3	2.7	11.6	35.6	77.0
	16-31	3.7	3.3		4.3	3.0		4.0	3.1		3.6	3.1		3.1	3.5			
August.	1-15	2.2	0.4	3.1	3.0	2.0	5.3	2.4	2.0	4.6	2.2	2.0	4.4	2.0	2.2	4.9	33.4	79.0
	16-31	0.4	o.1		0.3	0.0		0.1	0.1		0.2	0.0		0.6	0.1			
Sep.	1-15	4.5	4.1	18.5	4.6	4.9	19.8	3.3	4.0	14.9	2.7	2.9	12.0	3.2	2.8	12.0	32.6	75.0
	16-30	5.1	4.8		5.3	5.0		3.7	3.9		3.4	3.0		3.0	3.0			
Oct.	1-15	3.3	3.1	10.6	2.9	2.4	9.4	2.2	2.1	8.4	2.1	2.1	6.9	2.4	2.1	7.2	29.1	71.0
	16-31	2.2	2.0		2.0	2.1		2.6	1.5		1.4	1.3		1.5	1.2			
Nov.	1-15	0.2	0.2	1.3	0.1	0.1	0.8	o.1	0.1	0.2	0.1	0.1	0.2	0.0	0.1	0.2	25.6	73.0
	16-30	0.5	0.4		0.3	0.2		0.0	0.0		0.0	0.0		0.0	0.1			
Dec.	1-15	0.2	0.1	0.4	0.1	0.1	0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	21.6	69.0
	16-31	0.1	0.0		0.0	0.0		0.0	0.1		0.0	0.0		0.0	0.0			
Total/ year	----	55.3	56.1	111.4	59.8	55.7	115.0	52.3	52.3	104.6	38.4	39.2	77.6	28.0	28.4	56.4	-----	----
Avg./ month	-----	4.6	4.7	9.28	4.98	4.64	9.58	4.35	4.35	8.69	3.2	3.25	6.45	2.3	2.4	4.75	28.17	70.08

During the two experimental seasons , the different traps attract 95% red palm weevil along with 5% of many other beetles as well as insects belonging to other orders which are not addressed further in this study. Traps using aggregation pheromone or top soft trunk tissues captured the highest number of red palm weevil (95.0 & 100.2 individuals respectively) and this number was significantly greater than the other treatments (aggregation pheromone 26.55%; top soft trunk tissues 28.0% , season 2016 . While in 2017 season the aggregation pheromone and the top soft tissues recorded 23.92 and 24.69% respectively. However, the significant differences in total adult catches were detected among other baits. Data pertaining to dispersion parameter are presented in Tables 1&2 , where it can be seen that the highest peaks of weevils captured during the first season (January - December 2016) were recorded during April , July and September with an average capture of 18.0 ±0.53 , 18.2±0.46 and 17.2±0.5 (aggregation pheromone traps) ; 19.1±0.52 ,16.9±0.52 and 11.5±0.56 weevils (top soft trunk tissues traps) ; 11.5±0.55 , 10.0±0.49 and 7.6±0.53 weevils (semidry dates traps) ; 10.2±0.57 ,9.5±0.51 and 4.8±0.46 weevils (pieces apple fruits traps) and 5.1±0.48, 7.8±0.51 and 5.6±0.57 weevils (pieces sugarcane traps) respectively .

In second season 2017, the data recorded in Table (2) explain the same trend concerning the number of peaks , which recorded three peaks (April ; July ; September) with some differences between the number of captured traps due to the changing in environmental condition in the area. In spite of different natural food baits used, the ratio of female to males captured recording was 1.3♀ : 1.0♂ (2016) and 1.0♀ : 1.0 ♂ (2017) during the experimental period.

Table (3) Showed that the average counts insects / traps /month as compared to average temperatures and R.H. %. The value of coefficient of correlation "r" was highly significant for the temperatures effects on adults captured with r=0.785 as compared with insignificant effects of R.H. with r=o.146 (2016) . Further, the same trend can be observed in the same Table (3) , r= o.654 (temp.) r= o.o99 (R.H) (2017). Wattanapongsin (1966) proved that red pal weevil can breed in a wide range of climates, and this is largely because the larvae feed and protected within their host palms. The statistical analysis shows that there is no significant recorded between the first two types of traps (aggregation pheromone and top soft trunk tissues) and other natural bait traps. Table (4) revealed that weevils were attracted to synthetic pheromones traps and top fresh trunk tissues trap more than other tested food traps used . The total of both sexes a year were 95.0 , 100.2 , 69.8 , 51.8 and 41.0 weevils (2016) , 111.4, 115.0 , 104.6 , 77.6 and 56.4 weevils (2017) represented pheromone traps, top soft trunk tissues , semidry dates , pieces apple fruits and pieces sugarcane natural food traps respectively. Table (4) clearly indicated that the efficiency percentages of different trap types used were as follow: 26.55 , 28.0 , 19.5 , 14.47 and 11.45 % (2016) while in (2017) were as follow : 23.95 , 24.73 , 22.49, 16.68 and 12.12% represent , aggregation pheromone , top soft trunk tissues, semidry dates with water drops , pieces apple fruit and pieces sugarcane traps respectively.

Under field conditions, the adults of target pest are revealed clear responses to synthetic pheromone or natural food baits (date palm tissues). According to Guarino et al., (2010) the trapping for RPW is often enhanced by the presence of synergistic palm volatiles (palm esters such as ethyl1 propionate , ethyl 1 butyrate, ethyl 1 isobutyrate, ethyl 1 lactate and ethyl 1 acetate) .

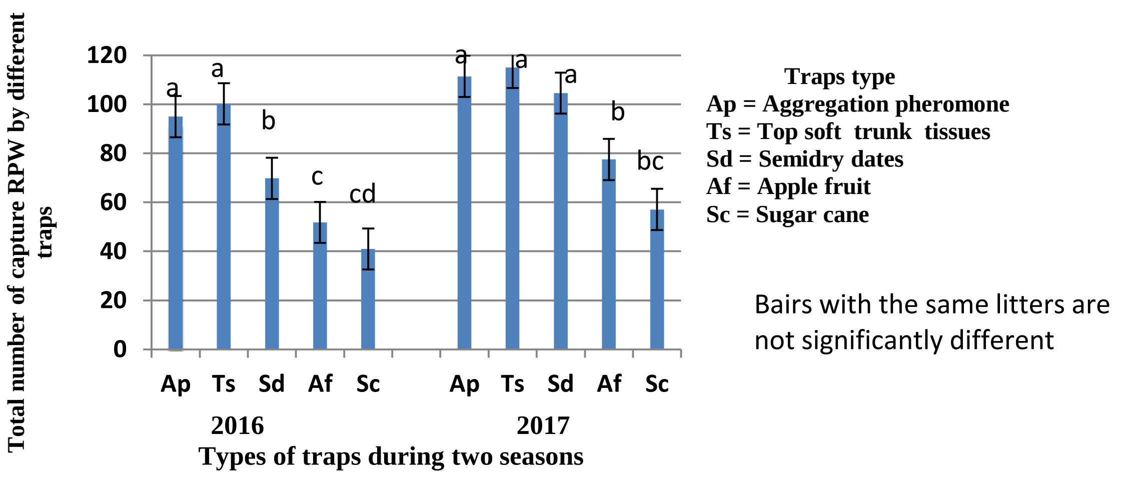
Table (3): The correlation "r" and regression coefficients between the mean numbers of RPW population in palm tree plantations and the corresponding day mean temperature and day mean R.H. calculated during 2016-2017 seasons of weevil activity.

Season	Period		Weather factor	Sample correlation "r"	Regression coefficient "b"
	From	To			
2016 N=12	1st January	End December	Day mean Temp.	0.785	0.02
			Day mean R.H.	0.146	0.173
2017 N=12	1st January	End December	Day mean Temp.	0.654	0.01
			Day mean R.H.	0.092	0.35

Table (4): Comparing Efficiency of different bait traps used during the two seasons 2016/2017.

Experimental seasons		Trap types									
		Aggregation Pheromone (Control)		Top soft trunk tissues		Semidry dates		Apple fruit pieces		Sugar-cane pieces	
		♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Total adult sexes/trap/year	2016	45.6	49.4	60.0	40.2	40.6	29.2	28.5	23.3	23.2	17.8
Total adult two sexes/trap/year		95.0		100.2		69.8		51.8		41.0	
Grand total/all traps/year		357.8									
Efficiency %/traps		26.55		28.0		19.5		14.48		11.46	
Total adult sexes/trap/year	2017	56.1	55.3	55.7	59.8	52.3	52.3	38.4	39.2	28.0	28.4
Total adult sexes/trap/year		111.4		115.0		104.6		77.6		56.4	
Grand total/all traps/year		465.0									
Efficiency %/traps		23.95		24.73		22.49		16.68		12.12	

Fig.(1): Efficacy of traps using different food baits as trapping RPW in the field from 1st Jan. 2016 to end Dec. 2017.



The data observed and recorded were agreement with finding of (Zada et al., 2002) , that the enhancement of oils is due to palm tissues that develop the fermentation processes that produce volatiles . The data recorded in the Tables indicated that the cycle of the weevils activity in date palm orchards were about 11 months. From the total counts of adults within the two experimental seasons (822.8 individuals), it can revealed that the infestation with the RPW changed during the two years from 29.8 weevils/month (2016) to 38.8 weevils/month (2017). The data recorded occurred may be due to climatic changes in addition to the numerical density of the larvae within the palm ,which leads to the temperature of the inside of the palm and increase the internal wine and eventually the exit of a large number of adults , which lead to an increase in injury rates.

CONCLUSION

In conclusion, the treatments consisting of pheromone or fresh tissues bait were the most effective in attractant and retaining the adult RPW compared with other food bait treatments. However, no significant differences in total RPW catches were detected among other different food baits used (pieces of apple and pieces of sugarcane) (Fig. 1). The results are in agreement with the finding by Conti et al., (2008), but in some cases pheromone traps failed to detect red pal weevil adults before damage occurred to the palms. From the obvious data, results confirm the fact that aggregation pheromone traps can be used effectively for a monitor and at the same time the releasing of volatiles (kairomones) from fresh trunk tissues or resulting of pruning processes together gave a good trend to suppression the RPW population when used through bait traps. Capture the main extracted from the study are: 1- The use of farm residues during the process of pruning palm trees as an attractive materials for the insect of red palm weevil. 2- Use the damaged fruits of the failing during the harvesting time after treatment with the appropriate pesticide with some water drops to ferment and release odour to attract insects . 3- The use of small palm trees which grow around the trees and should be disposed of in use (soft trunk tissues traps) to attract insects as an results of the emission of kairomone host plant (esters) and then kill. It is very important to detect the injury early so as not to increase the number of larvae and adults inside the tree, which leads to the exit of adults in large numbers and began new infections. Much work is needed to be done to optimize the use of mass traps /Fed. under field conditions, position of the traps to or on the trees and the duration of the trapping period.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Salem, S.A. designed and performed the experiments and also wrote the manuscript. Abd El-Salam, A.M.E. performed the treatments, data analysis and reviewed the manuscript and El-Kholy, M.Y. reviewed the manuscript, collection data, and also published it . All authors read and approved the final version.

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