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Effect of Color Trap, Density and Pheromone Capsule Types on the Trapping Efficacy for the Red Palm Weevil (*Rhynchophorus ferrugineus*)

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Abstract – **The Red palm weevil (RPW), Rhynchophorus ferrugineus (Curculionidae: Coleoptera) is an indigenous species from South East Asia which has recently become one of the most dangerous pests of palms around the globe. Monitoring and mass trapping of weevils with synthetic male aggregation pheromone and food baited traps has been an important component of Integrated Pest Management (IPM) program against RPW. The aim of this study is to evaluate the effect of 3 parameters (trap color, trap density and type of pheromone) on trap effectiveness in catching Rhynchophorus ferrugineus. Food-baited pheromone traps were installed in the infested sites of Tunisia. Three trap colors were tested (black, white and yellow). Tested densities ranged from 1 to 8 and we compared two types of aggregation pheromone capsules (M2I and Atlas Agro). The highest weevil catch was achieved in the black traps. Moreover, these experiments showed that more traps per hectare are necessary to capture more adults in little time. Hence, our studies provide information for optimizing trap density using black traps combined with M2I capsule of pheromone for mass trapping program.**

Keywords – **RPW, Trap, Color, Density, Pheromone, Effectiveness.**

I. Introduction

The red palm weevil, Rhynchophorus ferrugineus (Olivier) (Coleoptera: Curculionidae) (RPW) is currently considered as the most damaging invasive palm pest worldwide ([1];[2];[3];[4]).

Rhynchophorus ferrugineus is native to southern Asia as described during the late nineteenth century on coconut palms. By the mid-1980's, the range of attack had spread through the Middle East and then it reached northern Africa by 1992 following a more quick spreading pattern. The rest of the Mediterranean countries were totally infested by 1994, eventually to report the pest attack in North America in 2009 [5]. The pest is reported to attack more than 20 species of palms worldwide. The latest report of an RPW invasion occurred in late 2011 in Tunisia where it was found infesting Phoenix canariensis. On this last species the weevil's infestation occurs on the top of the tree. Such an attack pattern is due to the massive pest presence throughout the whole year, the severe damage occurring within infested trees and the late onset of the symptoms' expression make their detection difficult. Four stages were defined, revealing the outcome of the attack on the leaves and the crown of P. canariensis. Stage 0 defined as an asymptotic palm (Figure 1), Stage 1 is caracterised by Some chewing symptoms in inner leaves (Figure 2), Second Stage is marked by Extensive chewing symptoms of ">" shape (Figure 3), Asymmetric inner leaf growth is clear in Stage 3 of an attack and on the last stage all the crown leaves collapsed into an "umbrella" shape (figure 5).

As the eggs of RPW are deposited inside concealed places of the stem, larvae (figure 6) hatch and start destructing reaching generally the apical growth area.

Fig. 1. Asymptotic palm

Fig. 2. Chewing symptoms in inner leaves

Fig. 3. Extensive chewing symptoms of shape

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Fig. 4. Asymmetric inner leaf growth

Fig. 5. All the crown leaves collapsed into an "umbrella" shape

Fig. 6. Red Palm weevil different larvae instars

Fig. 7. Red Palm weevil Nymphs and cocoon

Life cycle is than wholly sealed within the stem upon emergence of the adults from the cocoon (figure 7) which fly out and infest new palms or remain in the same palm and cause re-infestations at a new site [6].

An integrated pest management (IPM) program has been chosen as the most effective system recently developed in the countries concerned by the infestation.

Regular surveillance is the first necessary step for a swift detection even though palms in the early stages of attack are difficult to detect but can be cured with insecticide (stem injection). Palms in the later stages of attack often host several overlapping generations of the pest with a more severe tissue damage and have to be eradicated [2].

Preventive and curative methods were often based on chemical pesticides, until an extended alternative has been introduced involving the use of natural enemies ([7]; [8]). Considering that the RPW male produced aggregation pheromone, Ferrugineol (4-methyl-5-nonanol) which was identified and first synthesized in the early nineteen nineties ([7];[9]), a pheromone/food-based technology has been included in the management strategy against RPW for monitoring and mass trapping to reduce adult populations [2].

The trap design (figure 10) is important: depth of digging must be set so that entry holes, as close as possible to ground level, are easily accessible by weevils.

Used components are pheromones, semiochemicals and food attractants. Effect of trap Color is also highlighted to be significant as it has been reported that black designs fulfilled higher captures than red, yellow or white ones ([10]; [11]).

Moreover, for the success of IPM it is essential to know the optimum density of traps.

The aim of this study is to evaluate the repercussions of three trap colors, different pheromones and kairomones and several densities on the efficiency of mass trapping in numerous infected fields in the state of Tunis and its suburban area.

II. Materials and Methods

1. *Study Sites*

In this article we treated 4 experimental fields included within the regions concerned by the trapping compaign. Each site was marked by its population of stems and the density of plantation.

1.1 *Carthage*

The traps were placed in this site starting on February the 24th 2016 and their survey was carried on untill Mai the 26th 2016. In that period the infestation level was high.

There are 167 palms including 16 infested palms and the infestation by RPW was first reported from this region. We placed 20 traps whose densities are as follows: 2traps, 4traps, 6 traps and 8traps using AA Lure aggregation pheromone and Kairomone. In this field tested traps are black and white. In a second experiment black traps were used to compare the efficiency of two pheromones : M2I and ISCA.

1.2 *La Marsa*

1.2.1 *Saâda Park*

This trial was conducted in Saâda Park La Marsa on April the 28th 2016. The population was 184 canariensis palm trees among which 22 were infested. We followed *R.ferrugineus* placing 7 trap densities ranging from 1 to 7

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traps / ha. The pheromone trap used was AA Lure. In this site we compared the effectiveness of two colors of traps which are white and black.

1.2.2 *Embassy Residence of France*

In the residence, the trap density has been standardized to 6 traps/ha. We tested two parameters: color traps (black, white and yellow) and the type of pheromones (AA Lure and RhyncoPro M2I). 6 combinations of traps and pheromone type were tested and 8 replications were applied on 8 ha in area. The total number of placed traps was 48 traps (Figure 8). In the following the trapping effects of 2 types of pheromone were compared.

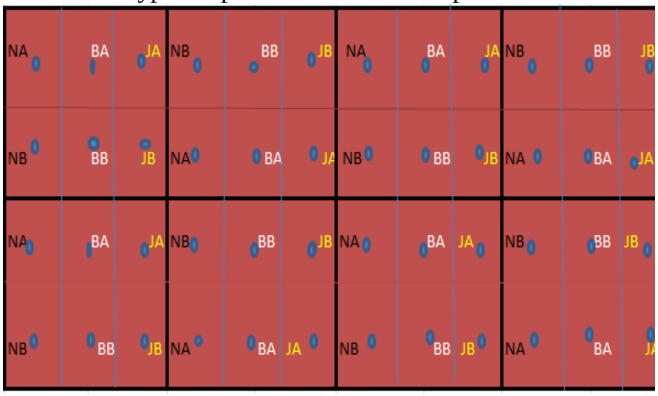

Fig. 8. Plan trapping showing the different combinations (**NA:** black/AA Lure, **NB:** black/M2I, **BA:** White/AA Lure, **BB:** White/M2I, **JA:** Yellow/AA Lure, **JB:** Yellow/M2I)

1.3. *INAT*

In this site there are a total of 142 palm trees among which 8 are infested. We tested the effectiveness of the black traps used with one of two pheromone types; M2I and ISCA. A total of 38 traps were placed on 6 hectares.

2. *Trap Design, Color and Installation*

In the current study, the trap color was the color of the plastic material itself. Three colors (figure 9) were tested: white, yellow and black.

The black and white traps are a 10 L plastic bucket. Trap height was 40 cm, and the diameter of the top and bottom was 18 cm. Each trap had four equidistant circular (5cm width) openings whose lower limits are tangent to the ground surface to allow R. ferrugineus entrance (Figure 9). The yellow trap or pitfall trap has a smaller size, a middle gap between the two parts of the trap allow the entrance of the pest (Figure 10).

Each trap contained one pheromone dispenser and one kairomone capsule that were attached to the lower surface of the trap lid by a wire.

For the bait and the fermentation substances dates and water were used respectively and were regularly changed every 15 days.

Fig. 9. Traps: Yellow(Y), Black(B), White(W)

Fig. 10. Trapping design: black white and yellow (Pitfall trap) traps are installed at ground level under the shadow of trees

3. *Types of Pheromone Tested*

Three aggregation pheromone lures were evaluated for RPW in this article (Figure 11).

Fig. 11. The 3 used pheromones for monitoring R. ferrugineus and mass trapping: **1: Atlas agro rubber septa AA Lure; 2: RynchoPro M2I and 3: ISCA**

Pheromone 1: AA Lure contains just the insect's aggregation pheromone and must be used with a capsule of Kairomone.

Pheromone 2: RhynchoPro classic dispensers contain the insect's pheromone and palm tree volatiles (kairomones) mimicking the odor of damaged palm. This combination of pheromone and synergists is highly attractive to both male and female weevils.

The content of the dispenser dissipates slowly and at a constant rate ensuring optimum evaporation over a period of 90 days.

4. *Trap Density*

Various trap densities were carried out ranging from 1 to 8 traps/ha. In each site were tested different trap densities as mentioned in paragraphs defining sites. The distance from a trap to a palm is between 1 and 2 m.

5. *Weekly Servicing and Data Collection*

All the traps were examined every week and RPW adults captured in each trap were recorded in both the experiments. After removing dead insects all traps were replenished with fresh date fruits/stem pieces, water and detergent. The Pheromone sachets were replaced with new ones in all traps after six weeks to eliminate any differences in available pheromone.

III. Results and Discussion

The results show that the RPW was active throughout the year. Nevertheless, at the start of the experiment (3/2/2016) we recorded a low number of captures (between 0 and 1) which then rose (between 0 and 11) at the end of the survey date. Furthermore, Figures (12, 13, 14, 15, 16 and 17) reveal that trap color, density and type of pheromone influenced weevil captures in food baited RPW pheromone traps.

Female weevils' captures dominated in the traps throughout the experimental period. From all dates, the mean proportion of captured males was 29.18% (lower bound-upper bound of the confidence interval: 25.16 %-33.55%) and 26.28% (19.97%-33.74%) respectively for black and white traps which corresponds to sex ratios (males/total adults) of 0.4119 and 0.3565.

Sex ratio was not affected by any of the trap color (pr> χ^2 =0.4791), the trap density (pr> χ^2 =0.7257) or the date (pr> χ^2=0.9152).

1. *Effect of Trap Color on the Trapping Number of RPW*

1.1. *Carthage*

There were significant differences between trap colors in the number of captured weevils. During the trapping period, a higher number of captures of *R. ferrugineus* was recorded in black traps (mean captures = 3.9421 adults/trap from all dates), which was significantly different from white traps (mean captures = 1.3576 adults/trap) for all the examination dates (figure 12).

1.2. *La Marsa*

1.2.1. *Embassy Residence of France*

The same results were found as for the Carthage experiment confirming the significant difference between dark traps' captures against white and yellow traps. From all dates, the mean number of captured weevils in black ones was 5.38±0.28. The respective means for white and yellow traps were only 2.01±0.17 and 1.96±0.17. These two light colored traps however haven't proven any significant difference. (figure 13).

1.2.2. *Saâda Park*

In this experimental site as well black traps have achieved a higher number of captures, with a mean of 10.95±0.34, compared to the white traps' captures (4.00±0.19) (figure 14).

2. *Effect of Trap Density on the Trapping Number of RPW*

Generally, in the case of trap density, it was very important to take in to account the total number of weevils trapped in a unit area with variable number of traps. The data were collected at weekly intervals and statistically analyzed.

Figure 15 illustrates the results on the adult weevils captures according to different densities in the site of Carthage; it was revealed that the number of captured adults is lower when 2 traps/ha were used instead of 4, 6 or 8 traps/ha. These 3 higher densities though didn't have any significant difference (some dates make an exception). Therefore, from all dates, the mean captures were as follows: only 1.3532 when 2 traps are installed on a hectare and respectively 2.5536, 2.9101 and 2.8482 for the 4, 6 and 8 traps densities.

For the experimental site of Saâda Park, the trend wasn't obvious for all the dates (figure 16). Nevertheless, it was revealed that number of captures was lower when only 3 or 4 traps per hectare were used (respective capture means of 5.29±0.37 and 5.97±0.48). The difference wasn't generally significant compared to the higher densities of 7, 6 and 5 traps/ha with respective adjusted means of 7.57±0.34, 7.97±0.37 and 6.66±0.36. The 6 traps density remains however the most recommended.

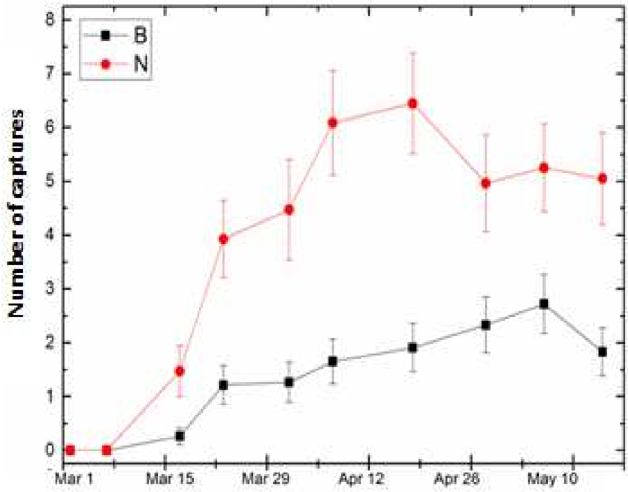

Fig. 12. mean captures of black traps (N) and white traps (B) in Carthage

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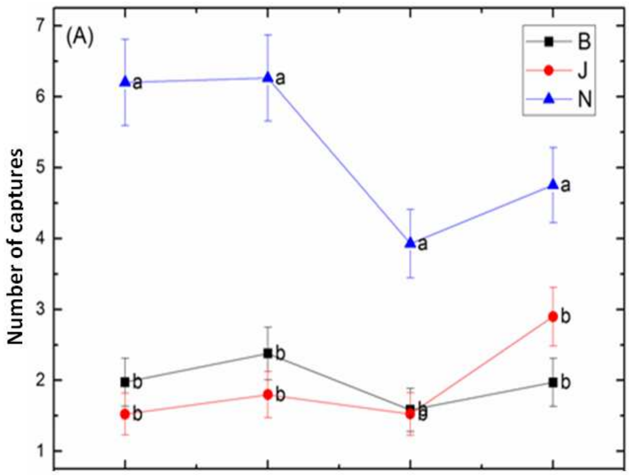

Fig. 13. Mean captures of black (N), white (B) and yellow (J) traps in the embassy's residence

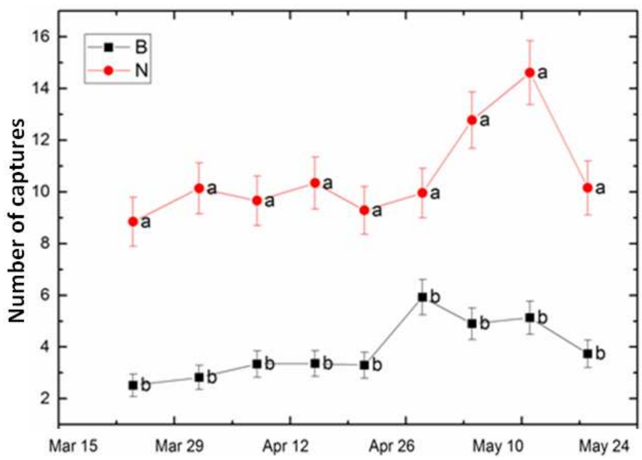

Fig. 14. Mean captures of black (N) and white (B) traps in Saâda Park

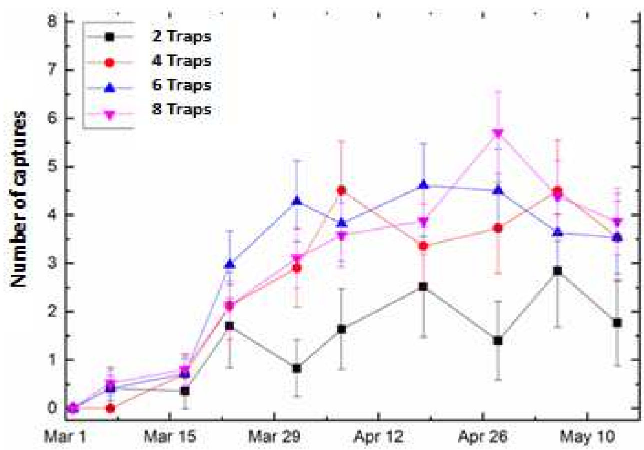

Fig. 15. Mean captures in different densities per hectare in Carthage

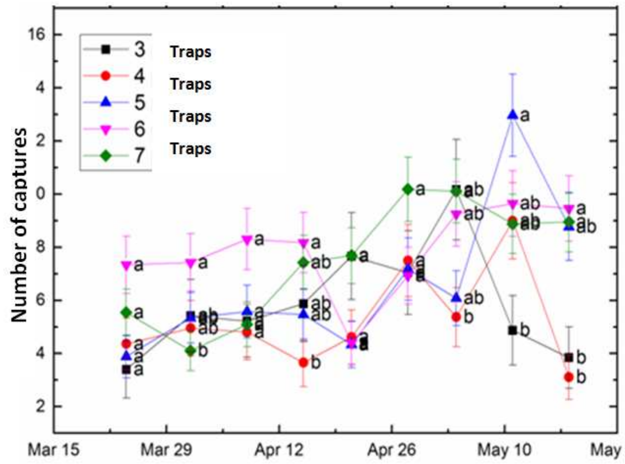

Fig. 16. Mean captures in different densities per hectare in Saâda Park (mean±SE)

3. *Effect of Pheromone type on the Captures of Weevils*

The pheromone type has been proven to have an effect on the number of captures (pr> χ^2 = 0.0023). Also, the interaction between pheromone type and capture date was significant which means that the effect of pheromone type depends on the date of capture. The other interactions (color/pheromone type and color/date of capture) were rejected for being non significant.

As described in figure 17, the number of captures in the embassy residence was significantly higher when B (M2I) type pheromone was used compared to the A (Atlas agro rubber septa AA Lure) type pheromone but only for 3 dates of the examination since during the fourth and the last date an opposite result was observed. The conclusion to be held from all dates support the significant higher capture efficiency for traps with B type pheromone (5±0.18 adults/ trap/ week) against the traps equipped with A type pheromone (2.36±0.15). Moreover, pheromone type doesn't have any significant effect on the sex ratio.

In the thermes of Carthage the ISCA type has been proven to have more efficient on capturing the weevils with a total of 92 captured adults against 27 captures in the traps with M2I type (figure 18).

In other M2I/ISCA comparison which was conducted in the Agronomic Institute (INAT) a significant higher capture of 65 weevils was cumulated within the ISCA traps, where only a total of 20 were found in the M2I traps (figure 19).

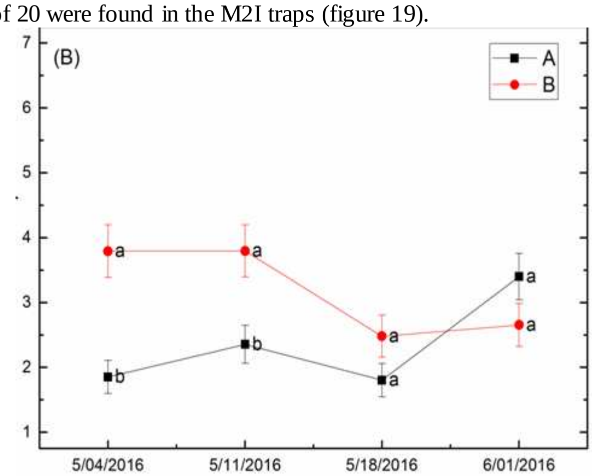

Fig. 17. Variation of mean captures using two types of pheromone (A and B)

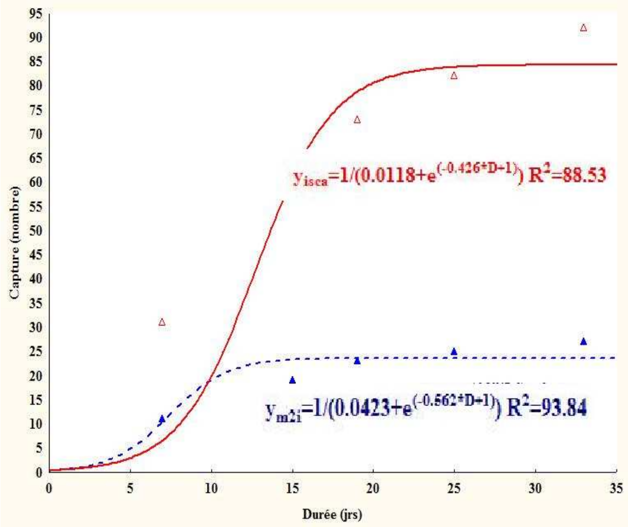

Fig. 18. Cumulated capture using ISCA (red) and M2I (blue) pheromones in Carthage

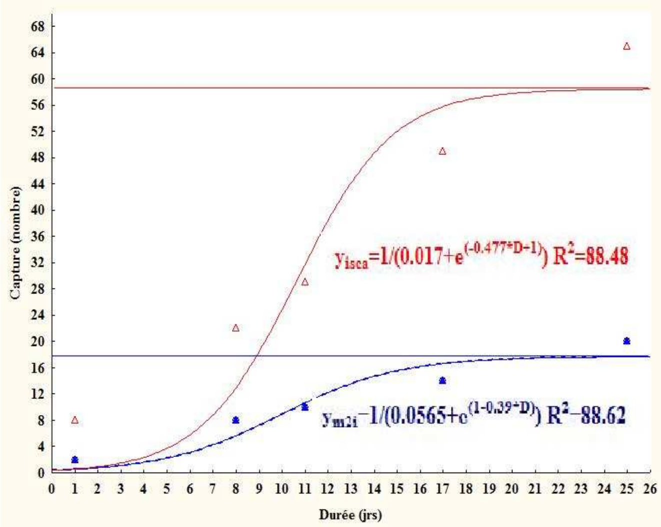

Fig. 19. cumulated capture using ISCA and M2I pheromones in INAT

IV. Conclusion

Pheromone baited traps have been successfully used to control rpw in several countries including Tunisia. Our studies comparing the effect of trap density, trap color and different types of pheromone revealed that the density of 6 traps/ha was necessary to capture the maximum number of adults. This result is confirmed by both the Carthage and the Saada Park trials. When it comes to trap color a major role was highlighted in the effectiveness of weevils trapping. Present results demonstrated that black traps were more effective than white and yellow traps for all the experimental sites. During the trapping period, the maximum number of rpw captured with traps using ISCA capsule as pheromone was significantly higher than Atlas Agro Capsule.

Based on the results presented above, we propose that using 4 to 8 black traps/ha instead of the commonly used white traps along with ISCA capsules would significantly enhance the efficacy of monitorig and mass trapping program of rpw in Tunisia.

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