Surveillance and Early Detection of RPW

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Abstract:

Although meaningful intercontinental trade involving Southeast Asia can be traced to back at least a millennium the Red Palm Weevil, *Rhynchophorus ferrugineus*, remained located in Southeast Asia until the late 1980's. In the last quarter century, the range of this insect has spread from Southeast Asia, through the Arabian Peninsula, to the European shores of the Mediterranean, North Africa and the Caribbean Islands. This rapid spread is due to international trade in infected hosts coupled with the absence of reliable techniques to detect infestations in the hosts. The most frequently transported host carrying the weevil across international borders is mature date palm trees. National responses to this weevil have been varied and only Israel has successfully implemented a program that brought the rate of date palm infestation to zero. The key to Israel's success is that it determined it had acquired RPW from a neighboring country and quickly developed a surveillance method and containment strategy. The surveillance method of choice has almost always been pheromone trapping. The containment strategy has been to trap extensively in areas known to be infested and trap sparingly in areas into which the insect might be transported and initiate infestation. This paper will present data to show the important features of an effective surveillance trap. As an example of a national program of surveillance against an invasive pest this paper will present the strategy used by the US in combating another tree pest (emerald ash borer).

The RPW (*Rhynchophorus ferrugineus*) was first identified in 1790 by Oliver and for the next two centuries it was confined to the Indian Subcontinent and neighboring countries including Pakistan and Indonesia. Despite heavy trade between this region and the Arabian Peninsula it was not until the mid 1980's that the RPW was transported to the Arabian Peninsula. Although the exact process of importation has not been defined it is considered most likely that it was transported to its new range inside infested palms. Since its arrival in the Arabian Peninsula it has spread to nearly all countries bordering the Mediterranean and has now been reported in the Caribbean. In the view of all that have traced the spread of the RPW. The most remarkable leap of the RPW was probably between 1992 and 1993. In 1992 it was reported in northern Egypt, brought there from Saudi Arabia in infested palms given to the government of Egypt. A year later several life states were found in Spain. Figure 1 shows the approximate distribution of the most important species of weevils of the genus *Rhynchophorus* infesting palms.

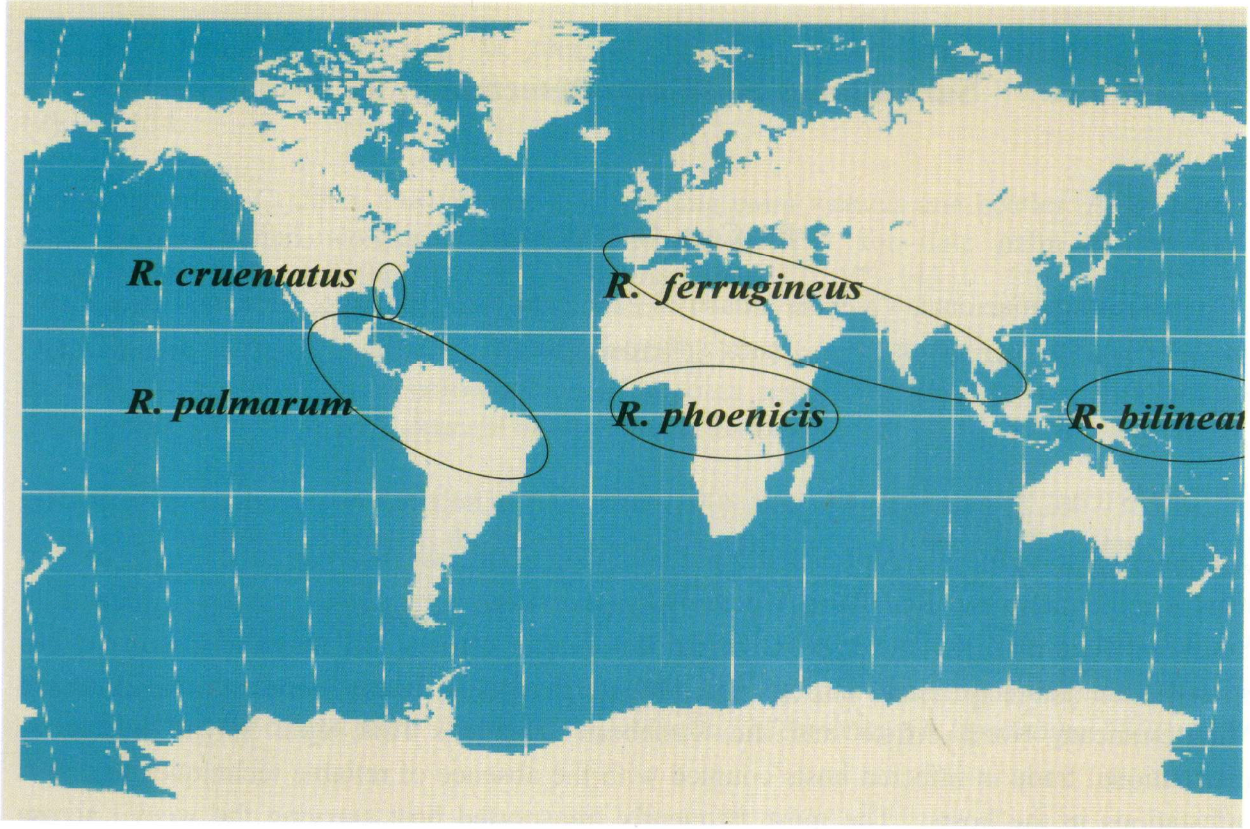


Figure 1. Approximate distribution of palm infesting Rhynchophorus palm weevils.

Surveillance and early detection of RPW can be done by tree inspection or by trapping the weevil. The inspection of trees will detect infestation only after the weevil has been present for at least one life cycle which is close to one year. In this method of surveillance one seeks to find soft tissue by probing the outer tissue of the palm. Often soft tissue near the base of date palm or in the frond bases of Canary palms is located which on further inspection yields large cavities containing larval tunnels, pupal chambers and perhaps even adults. This consultants visit to Morocco indicated that tree inspection is carried out properly and that the signs of RPW infestation are known to inspectors. Treatment of infested palms is carried out carefully in Morocco and currently all infested palms are destroyed. Since infested palms can be rescued by killing larvae, pupae and adults inside trees training needs to be conducted so that Morocco can save some of its infested trees. Tree inspection with good pictures is well documented on the internet at www.redpalmweevil.com

Because tree inspection detects a weevil population in an area no sooner than one life cycle after the weevil has arrived and traps will detect the presence of the weevil much sooner this consultant has chosen to concentrate on trapping.

The RPW is very similar in life cycle, behavior and host to other weevils in the same genus. The semiochemistry of this weevil also is very similar to other weevils of the same genus. Males of all studies species of palm weevils produce a pheromone that attracts both males and females. Although the pheromone is weakly attractive for each species when presented alone it is strongly attractive when presented with wet food. Below is shown Figures 2-6.

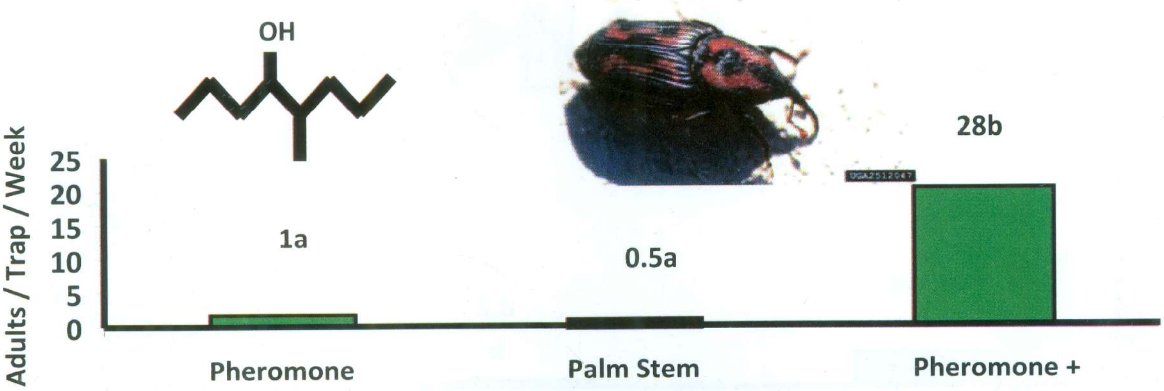


Figure 2. Captures of *R. cruentatus* in bucket traps baited with pheromone (5-methyl-4-octanol), palm stem or pheromone + palm stem in palmetto palm R. H. Hallett, A. L. Perez, G. Gries, R. Gries, H. D. Pierce, Jr., J. Yue, A. C. Oehlschlager, L. M. Gonzalez & J. H. Borden, J. Chem, Ecol., 21, 1549, 1995.

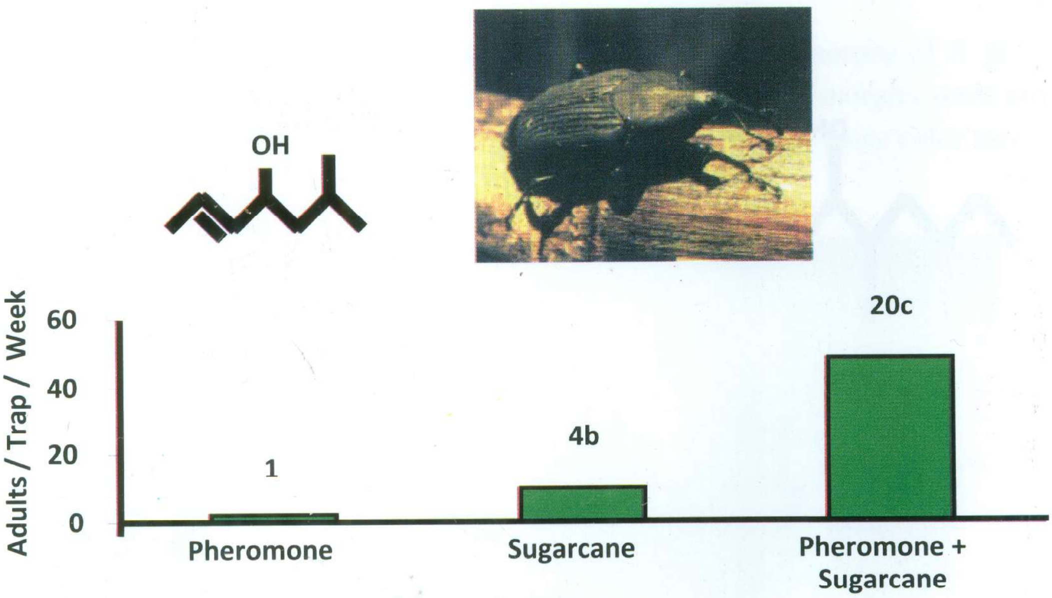


Figure 3. Captures of *R. palmarum* in bucket traps baited with pheromone (2-methylhept-5-en-4-ol), sugarcane or pheromone + sugarcane in oil palm A. C. Oehlschlager, C. M. Chinchilla & L. M. Gonzalez, PORIM Congress Proceedings, 1993, p A645-A660

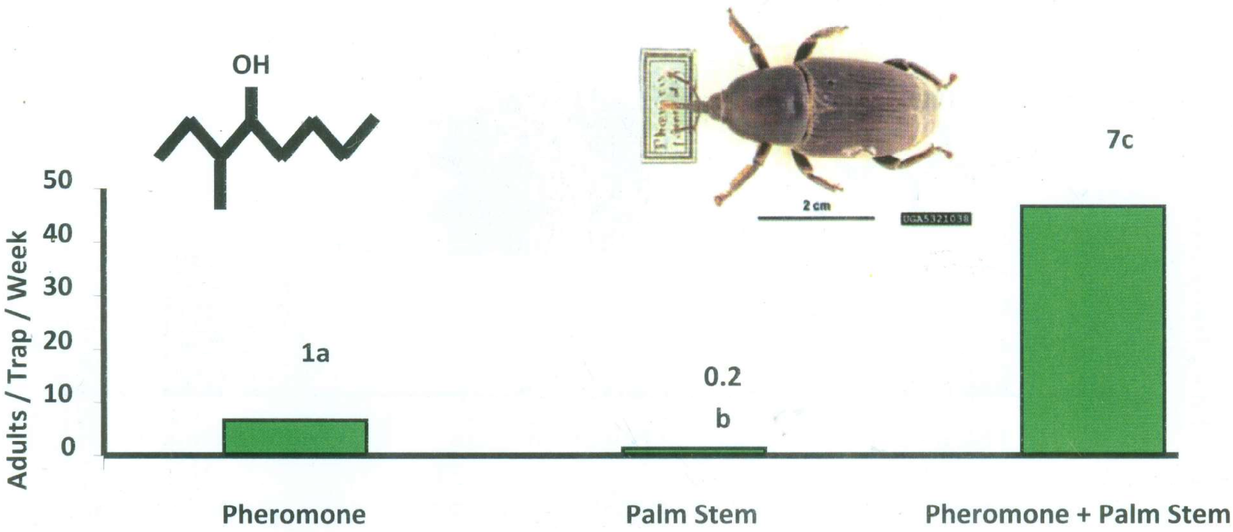


Figure 4. Captures of *R. phoenicis* in bucket traps baited with pheromone (3-methyl-4-octanol), palm stem or pheromone + palm stem in oil palm G. Gries, R. Gries, A. Perez, A. C. Oehlschlager, L. M. Gonzalez, H. D. Pierce, Jr., M. Zebeyou & N Nanou. Naturwiss., 80. 91-91, 1993

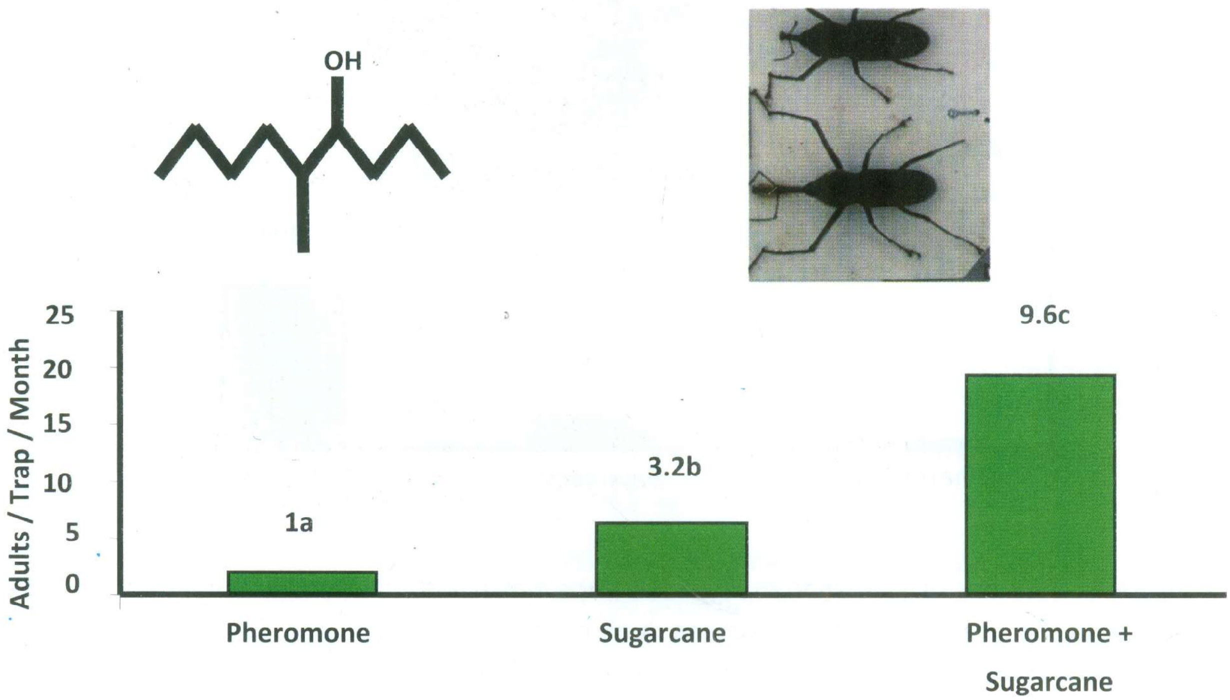


Figure 5. Captures of *R. bilineatus* in bucket traps containing pheromone (4-methyl-5-nonanol), sugarcane or both in coconut palm, n = 10 A. C. Oehlschlager, R. N. B. Prior, A. L. Perez, R. Gries, G. Gries, H. D. Pierce, Jr., S. Laup, J. Chem. Ecol. 21, 1619, 1995.

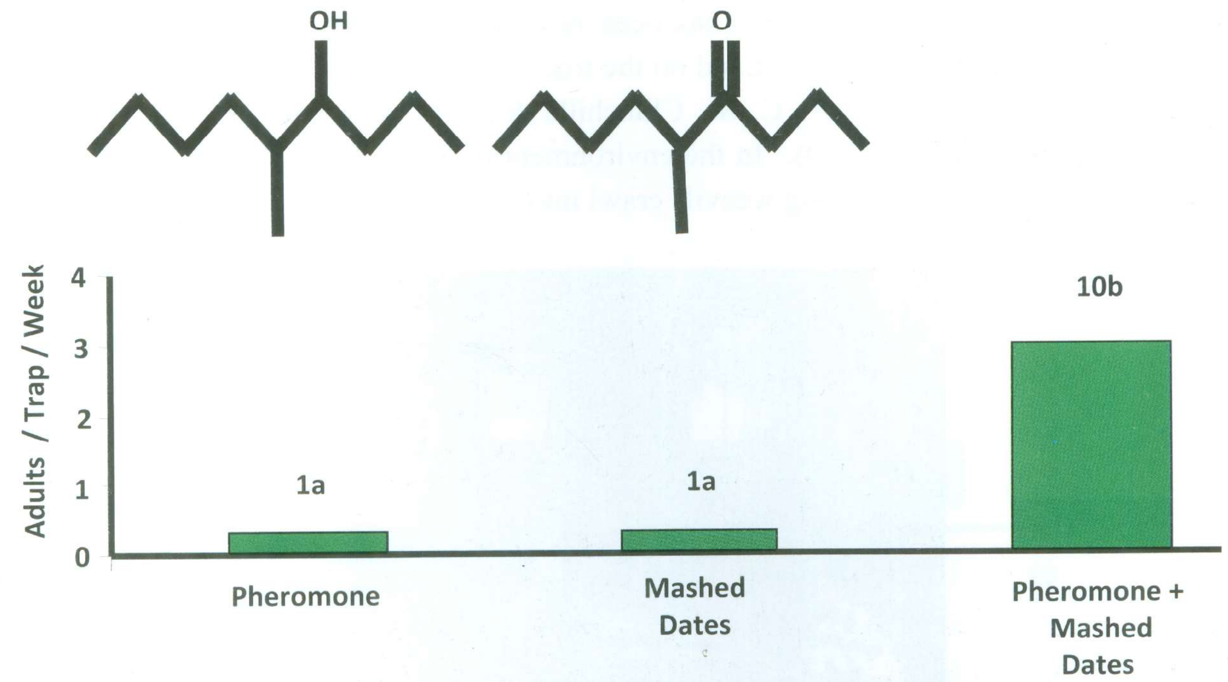


Figure 6. Captures *of R. ferrugineus* in bucket traps baited with pheromone (5-methyl-4-nonanol/5-methyl-4-nonanone, 10/1), mashed dates or pheromone + mashed dates in date palm, UAE n = 10. A. C. Oehlschlager and H. Anwar, UAE, 1992.

Interestingly in the Arabian Peninsula several different color morphs of *R. ferrugineus* were captured in the same pheromone traps. These different color morphs were analyzed to the level of mitochondrial DNA and found to be identical. Some of these color morphs are shown in Figure 7.

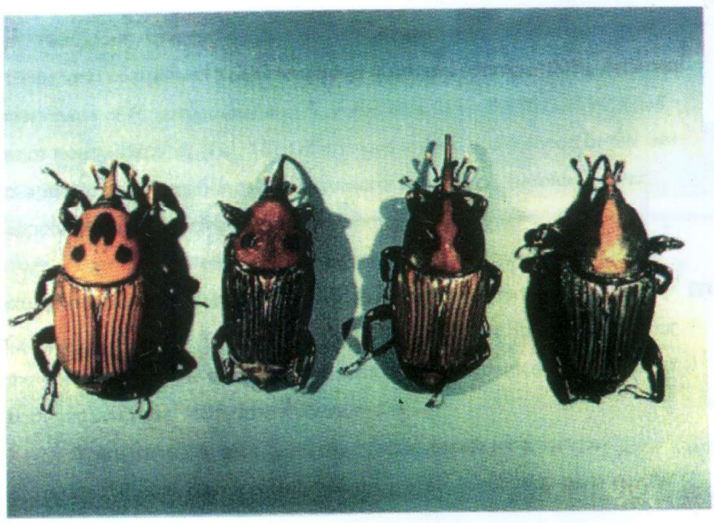


Figure 7. Color morphs of*R. ferrugineus* in UAE.

All of the above palm weevils are captured in bucket traps either tied to host or non-host trees or placed on the ground. In the case of the experiments presented for *R. cruentatus*, *R.*

palmarum, *R. phoenicus* and *R. bilineatus* above traps were tied to trees as in Figure 8. In the case of *R. palmarum* weevil behavior has been recorded as they approach traps. Weevils generally fly to the area of the trap. Land on the tree and crawl into the trap. Only side entry is observed (A. C. Oehlschlager, C. M. Chinchilla & L. M. Gonzalez, PORIM Congress Proceedings, 1993, p A645-A660). In the environment of an oil palm plantation using traps hung on trees ~85% of approaching weevils crawl into traps and are captured.

Figure 8. *R. palmarum* trap baited with pheromone released at 2-3 mg/day and 7 pieces of sugarcane ~20 cm long and soaked in 0.1% furadan to immobilize weevils upon arrival.

For *R. ferrugineus* traps placed on the ground are >6X more effective than traps placed on vertical surfaces (Figure 9). This is presumably because *R. ferrugineus* behavior is similar to that of *R. palmarum* wherein the weevil flies to the area of the trap lands and then walks into the trap.

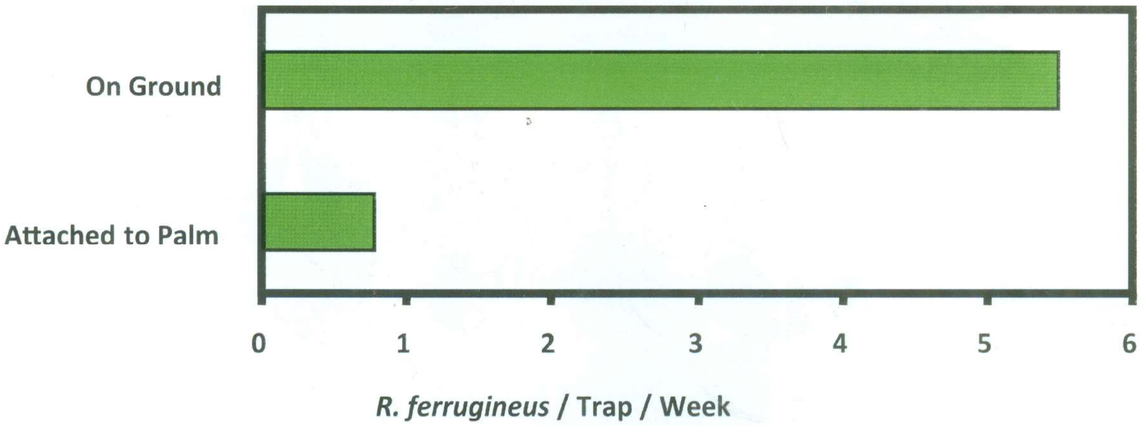


Figure 9. Ground Traps more effective for ***R. ferrugineus*** (20 Bucket Ground Traps & 20 Bucket Palm Traps July-November 1996, Egypt, Dr. G. Moawad & Y. El-Sebay, August, 1997 (Published in proceedings of FAO Workshop on Red Date Palm Weevil & its Control, Dec. 1998, Cairo).

In the case of *R. palmarum* and *R. ferrugineus* the effect of ethyl acetate on trapping efficiency has been studied. In both cases the capture rates to pheromone and food baited traps doubles or triples (Figure 10 and 11).

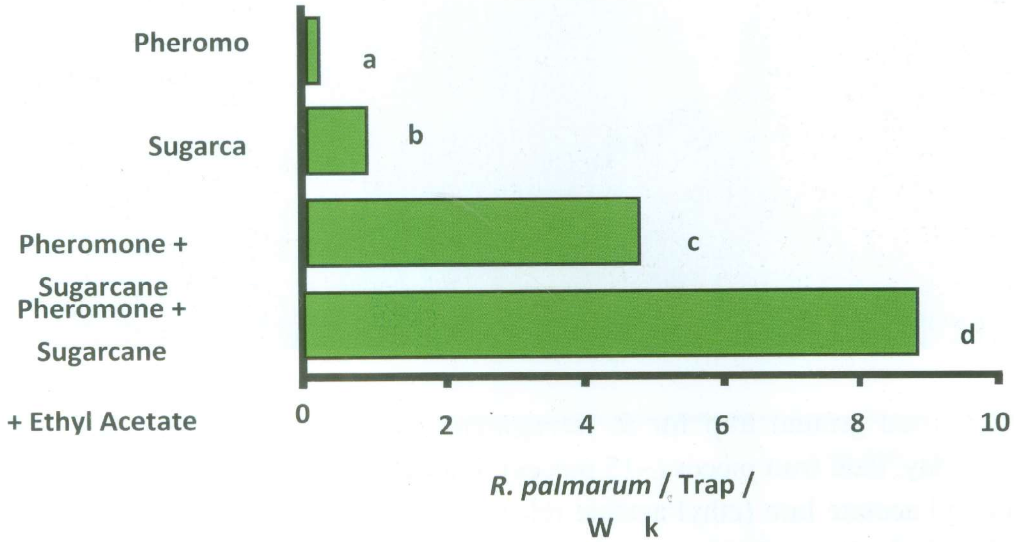


Figure 10. Capture of*R. palmarum* in Pheromone Traps hung on oil palm trees. Oehlschlager, A.C., C.M. Chinchilla, L.F. Jiron, B. Morgan and R.G. Mexon, J. Econ. Entomol. 86: 1381-1392, 1993

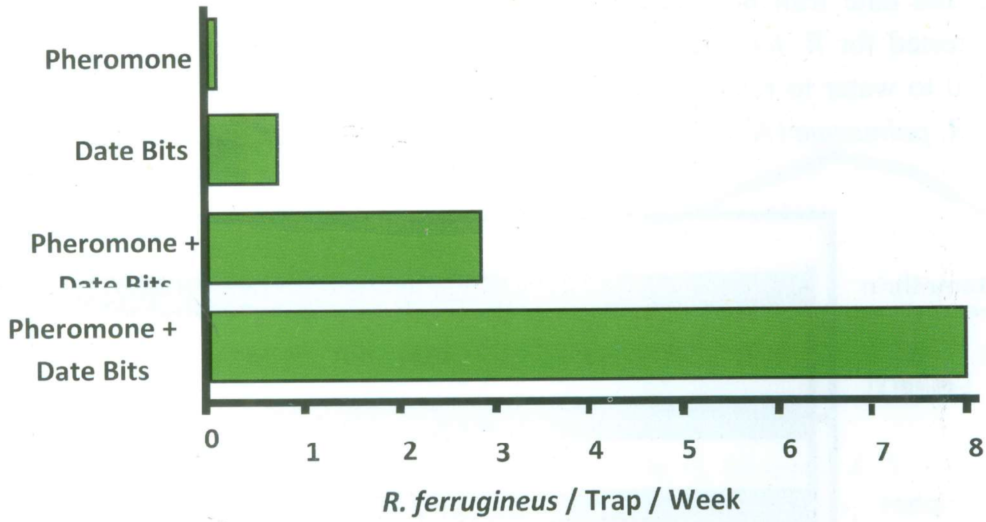


Figure 11. Capture of *R. ferrugineus* in bucket traps placed on ground. Pheromone (Ferrolure+) released at 3-10 mg/day, date fruit ~15 fruits mashed, water with 0.1% insecticide 1992 UAE Test conducted by Mr. R. K. Al-Shareqi & Dr. S. Gassouma (n = 10); 1997 UAE Experiment, (n = 7) H. Aswar & Oehlschlager, 1997 Egyptian Experiment, (n = 15) Dr. G. Moawad & Y. El-Sebay. Traps contained insecticide-treated date palm pieces. (Experiments Published in Proceedings of FAO Workshop on Red Date Palm Weevil & its Control, Dec. 1998, Cairo).

In the UAE where trapping of R. ferrugineus has been conducted for over a decade the preferred trap is currently a bucket that is buried in the ground and is rough on the outside.

Normally bucket traps are buried in the ground to the level of the side entry holes but in sand storms trap burial is disturbed so the rough sides provide a way for weevils to crawl into traps (Figure 12).

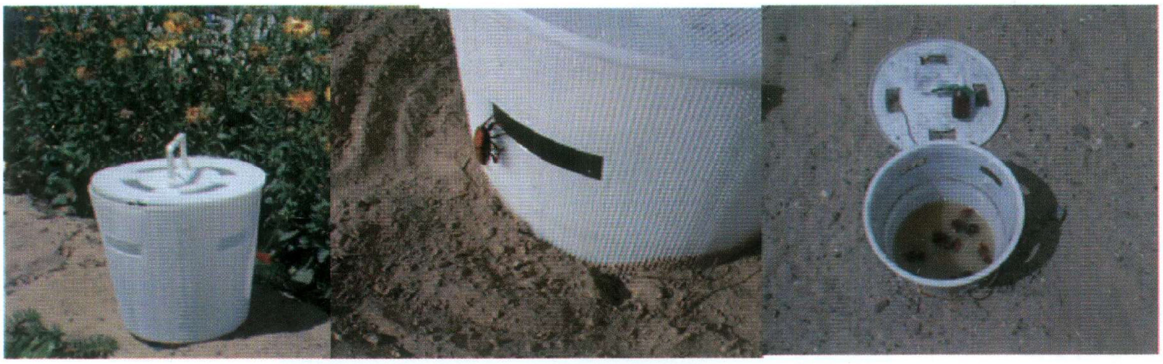
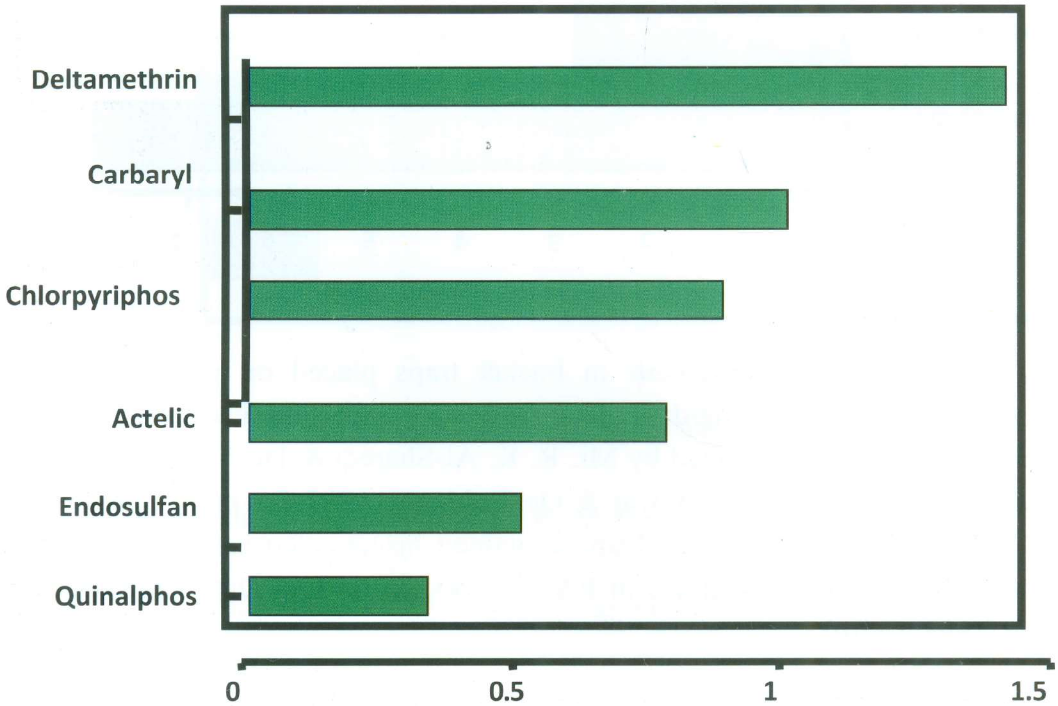


Figure 12. UAE buried ground trap for *R. ferrugineus.* Bait is pheromone (Ferrolure+) released at 3-10 mg/day, date fruit pieces (~15 pieces) floating in water (~2 liters) additionally traps contain an ethyl acetate lure (ethyl acetate released at 200-400 mg/day). In the picture the ethyl acetate lure is the brown bottle hung from the inside of the lid.

Adding insecticide to traps increases capture rates. It is important to add insecticides that do not repel *R. ferrugineus.* In Saudi Arabia the relative capture rates of traps baited with pheromone and date fruit has been determined and is shown in Figure 13. Although not thoroughly tested for *R. ferrugineus* propylene glycol, a non-poisonous high boiling liquid, can be added to water to retard evaporation. It has been found that propylene glycol is not repellent to *R. palmarum* (A. C. Oehlschlager and L. M Gonzalez, unpublished)



Relative Capture of *R. ferrugineus*

Figure 13. Repellancy of Insecticides at 0.1% in *R. ferrugineus* Traps. Test conducted by Dr. R. A. Abozuhairah, Dr. P. S. P. V. Vidyasagar & Dr. V. A. Abraham, Ministry of Agriculture & Water, Al Hassa, Kingdom of Saudi Arabia. All traps contained Ferrolure+ & insecticide-treated date palm pieces. Reported in International Congress of Entomology, Florence, Italy, 1996.

Due to seasonality *R. ferrugineus* adult population varies. More weevils emerge during the spring months and this is reflected in trap captures, which peak in March-April. There is another smaller peak in trap captures near the end of the summer season peaking in October-November (Figure 14). In this conference Faliero has presented evidence that the spring adult population causes the most palm infestation.

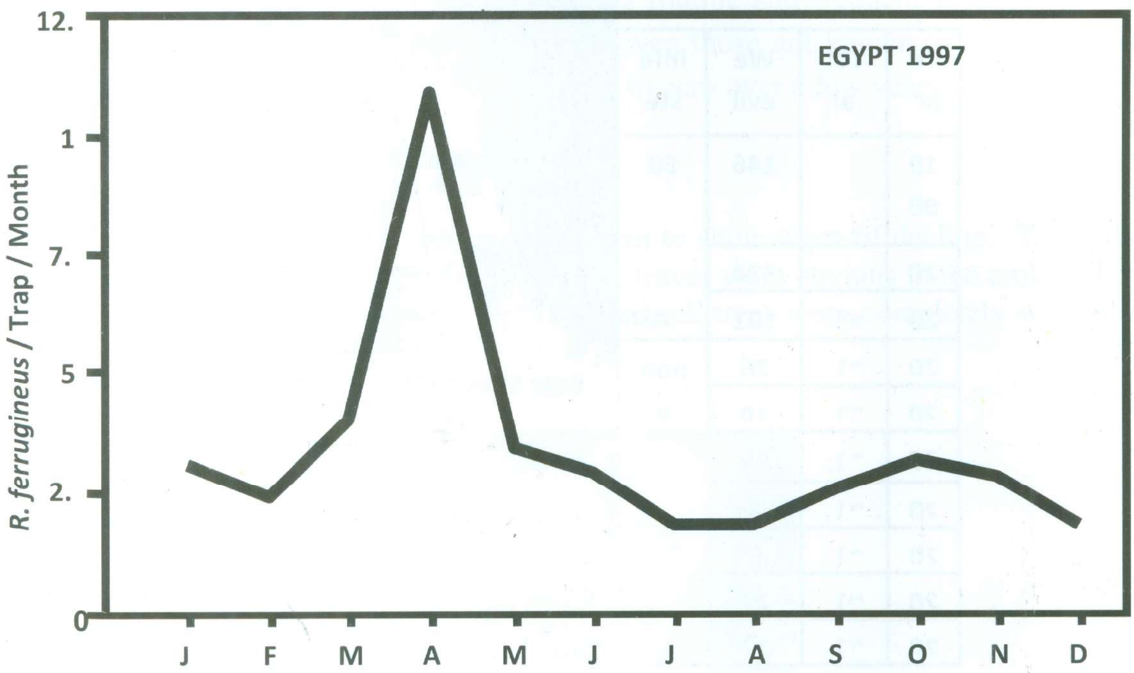


Figure 14. Mass trapping of*R. ferrugineus* in Egypt by Dr. G. Moawad & Y. El-Sebay. 200-300 bucket traps on ground containing bigas, molasses & Ferrolure+ (Data from proceedings of FAO Workshop on Red Date Palm Weevil & its Control, Dec. 1998, Cairo).

Case Studies:

In May 1999 Israel detected a single RPW infested date palm in the Jordan valley. The immediate assessment was that the weevil had entered from Jordan since it was known that Jordan was infested with RPW. For two years following the discovery of the pest in Israel, spraying and soil applications of insecticide as well as adult weevil trapping were operated in 450 ha date palm plantations. Traps loaded with commercial aggregation pheromone Ferrolure+ (4-methyl-5-nonanol and 4-methyl-5-nonanone, 9:1) supplemented with ethyl acetate and a fermenting mixture of date and sugarcane molasses were placed at 10 traps/ha in order to monitor weevil infestation and reduce the RPW population by mass trapping. In 2002 a significant decrease in population was observed which was further continued in 2003. Sex ratio of the trapped adults was skewed towards females. Israeli authorities suggested that mass trapping played a significant role in the suppression of the weevil populations in date plantation due to the exclusion of beetles from the plantation and to the preferential trapping of females over males. During the period 1999-2002 infested palms numbered 60 of which 4 were required to be removed due to heavy infestion. After 2002 no infested palms have been detected although regular inspections continue and weevils continue to be captured. (Current status of red palm weevil infestation in date palm plantations in Israel, V. Soroker, D. Blumberg, A. Haberman, M. Hamburger-Rishard, S. Reneh1, S. Talebaev1, L. Anshelevich1 and A. R. Harari, Phytoparasitica 33, 1 March, 2005, update provided to A. C. Oehlschlager by V. Soroker, 2009.) See Figure 15.

Ye ar	Tot al	We evil	Infe ste
19 99		146	60
20		324	
20	>5.	101	
20	~1.	26	non
20	~1.	10	e
20	~1,	39	
20	~1.	5	
20	~1.	6	
20	~1.	21	
20	~1.	12	

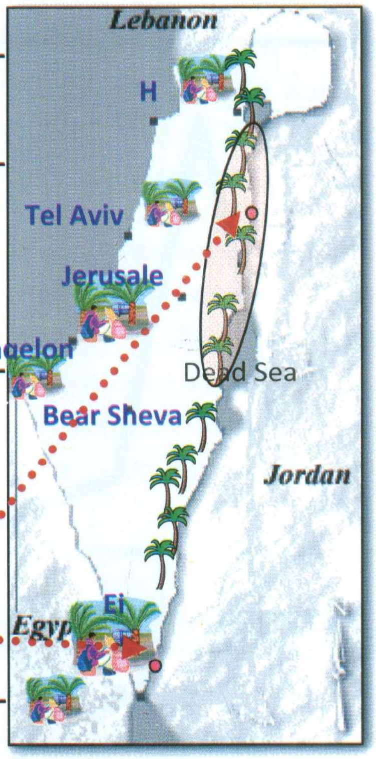


Figure 15. Country wide trapping of *R. ferrugineus* and infested palms in Israel 1999-2008. (Courtesy of Victoria Soroker, Dept. of Entomology, Agric. Res. Organization, The Volcani Center P.O.B. 6, Bet Dagan 50250, Israel)

The specifics of the Israeli trapping and tree treatment program were as follows:

- General Monitoring traps 1 trap/3 Ha over 2,200 ha
- Specific Village Monitoring along dead sea 32 km^2 using 420 traps @ 1 trap / $900m^2$
- Inspected all trees every 7-10 days
- Strict quarantine of palm transport

- Mass trapping 5,000 traps at 10 traps / ha in 450 ha of plantations, gardens, parks
- All traps inspected weekly April-Nov & 1X / 2 wks other times of the year
- All traps were set next to palm trunks on ground
- Mass trapping traps removed in Sept 2001 due to low capture & monitoring at 1 trap / 0.7 Ha in infested plantations & 1 trap / 3 ha where no weevils had been captured
- Offshoots treated with sprays every two weeks - Azinphos-methyl 0.2% or with Diazinon 0.3%. Curative methods included stem infusion with Dichlorvos 100 (10%), or soil application of Chloronicotinyl imidocloprid 5-10cc per tree.
- Heavily infested palm removed and burned (Total = 4)

This example shows that quick action instituting routine and frequent inspections of palms coupled with installation of traps in all regions even those not known to have infested trees successfully brought the number of infested trees to zero over a few years.

Emerald Ash Borer Invasion of US

Near Detroit, Michigan in 2002 ash trees in began to show signs of decline. The prominent sign of decline was that each successive year less leaves were obvious in the crown of the tree so that within five years of noticing the first die-back trees were completely without leaves during the summer period (Figure 16).

Figure 16. Ash tree in first stages of die-back. Within five years this tree will be dead.

Within a few months of the initial detection of the problem the insect responsible was shown to be a green beetle know as the emerald ash borer, *Agrilus planipennis*. The adult beetles nibble on ash foliage but cause little damage. The larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients (Figure 17).

Figure 17. Emerald ash borer (left), exit holes made by emerging adults (center) and larval damage under bark made by EAB larvae (right) (Pictures by T. Poland, USDA)

Emerald ash borer probably arrived in the United States on solid wood packing material carried in cargo ships or airplanes originating in its native Asia. Emerald ash borer is presently found in Michigan (2002), Ontario, Canada (2003), Ohio (2003), Indiana (2004), Illinois (2006), Maryland (2006), Pennsylvania (2007), West Virginia (2007), Wisconsin (2008), Missouri (2008), Virginia (2008), Minnesota (2009) and New York (2009). Since its discovery, EAB has killed over 70,000,000 ash trees in the US and Canada. The current distribution of EAB in the US and Canada is shown in Figure 18.

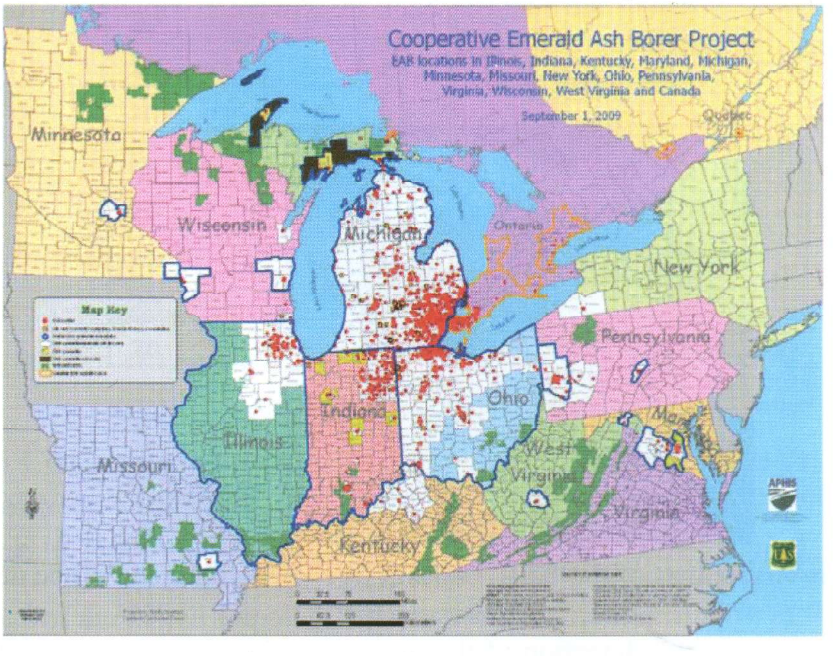


Figure18. Distribution of EAB in US and Canada in 2009 (Courtesy of D. Crook, APHIS, PPQ, USDA, Otis, ANGB, MA).

Between 2002 and 2007 the United States Department of Agriculture (USDA), in collaboration with state agriculture departments conducted research to develop monitoring and treatment systems. In late 2007 the Animal and Plant Health Protection Service (APHIS) of the USDA felt confident that it had a good monitoring system which consisted of an attractant based on stress sesquiterpenes exuded by stressed ash trees that were attractive to

EAB. These sesquiterpenes were found to be present in the tea tree native to Australia and New Zealand. Their use in large quantity in a large scale monitoring program was possible because the tea tree oil was a commercial product and available in quantity. Traps were sticky purple traps hung at head height in ash tree groves that might be susceptible. If no ash trees were available and a high risk area was identified traps were suspended to poles (Figure 19).

Figure 19. Purple EAB traps being installed (right) and installed (left) as part of the EAB national monitoring program instituted by APHIS / USDA in the US during 2008 (Picture by T. Poland, USDA).

Nation wide monitoring began in 2008 and continued in 2009. The number of traps deployed each year is ~ 60,000 and their distribution has been dictated by APHIS to be in every state even if thousands of miles separate the nearest known infested ash from the monitoring trap (Figure 20). This is because it has been determined by APHIS that the principle method of spread of EAB is via the moving of infested ash tree firewood. Although signs are posted, inspection stations manned and fines levied to prevent the movement of any cut ash from infested areas the spread continues.

Figure 20. Distribution of purple EAB traps in US 2008/2009.

Not surprisingly, the APHIS trapping program located new locations containing EAB in each of its two years of monitoring for EAB. In 2008 EAB was located in Wisconsin, Missouri and Virginia while in 2009 it was additionally found in Minnesota and New York. During the 2008 monitoring program it was found that over 90% of new reports of EAB were within 5 km of major highways and major intersections. This has promted APHIS to place traps that are in non-infested areas along major highways and at major intersections. As an example of the deployment strategy of APHIS the deployment in 2009 in Minnesota is shown along with a map of Minnesota showing major highways (Figure 21). As can be seen in Figure 21 the major metropolitan area of Minneapolis-St. Paul received a significant number of traps and this is the area in which the first EAB were located in 2008. Radiating out from that metropolitan area APHIS placed traps along the major east-west interstate highways and along the north-south interstate highways. In addition parks and recreational areas received traps as did the border with Canada.

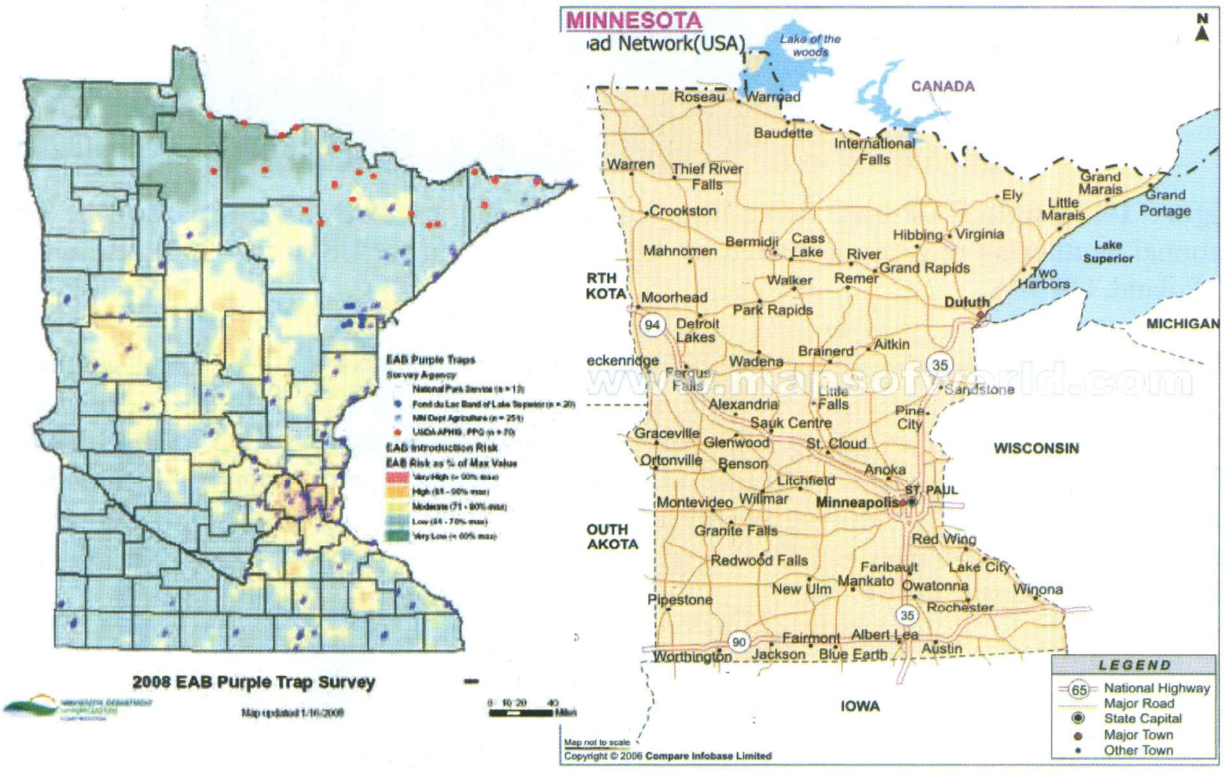


Figure 21. APHIS EAB Trap distribution in 2009 in Minnesota (left) and major highways in Minnesota (right) (Courtesy, APHIS EAB web site).

When EAB is located in a new area the subsequent year traps are deployed on at 0.5 mile grid within a 50 mile radius of the new location and on a 2 mile grid between 50 and 100 miles. The danger map created as a result of detection of EAB in the state of New York is presented in Figure 22.

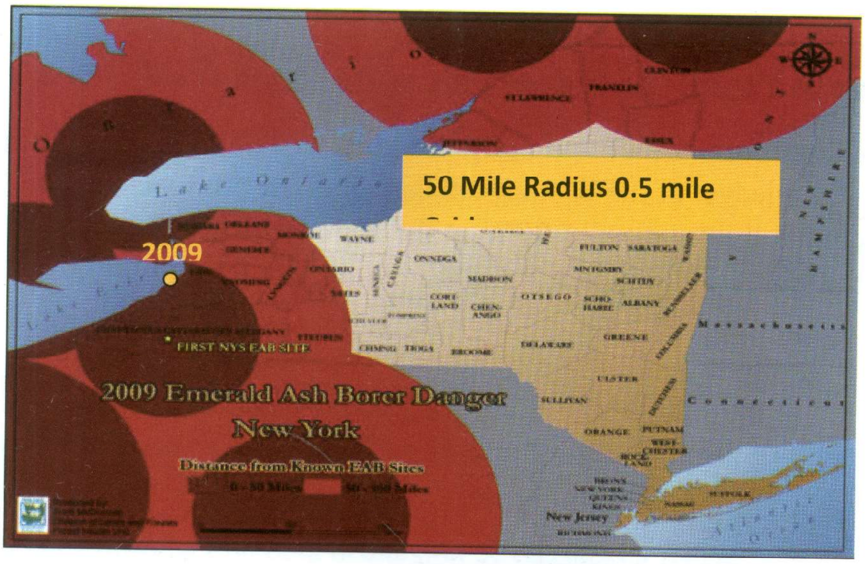


Figure 22. EAB Danger map for the state of New York after 2009 location of EAB.

EAB trap deployments that are triggered as a result of a new detection as shown for New York are modified so that within the areas to receive traps only those areas with ash trees receive monitoring traps. This is because APHIS considers it unlikely that an EAB would be found in an area that does not contain its host. To illustrate how this works I have shown the EAB danger map for Minnesota generated as a result of EAB detection in the Minneapolis-St. Paul area. You can see that the detection spot (green dot) is not in the center of the danger area. This is because the distribution of ash trees is more prominent north and west of the new EAB location area than it is south of the new EAB location (Figure 23).

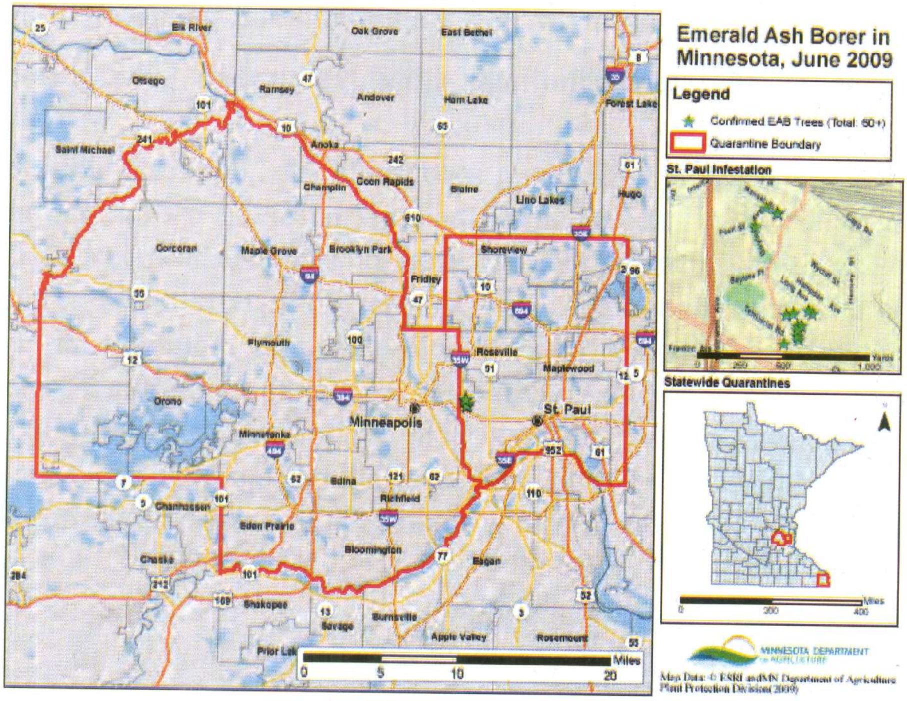


Figure 23. EAB danger map for Minnesota for 2009 following location of EAB near Minneapolis-St. Paul metropolitan area.

Summary:

Because of its biology surveillance and early detection of RPW depends on trapping. The current state of knowledge of RPW suggest that both tree inspection and trapping are necessary to determine the location of RPW at the national level. Placement of traps in un-infested areas is the most rapid way to learn of the presence of RPW.