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Evaluation of *Steinernema* sp. SA a Native Isolate from Saudi Arabia for Controlling Adults of the Red Palm Weevil. *Rhynchophorus ferrugineus* (Oliver)

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ABSTRACT

Steinernema sp. SA a native isolate of entomopathogenic nematodes (EPNs) was extracted for the first time from naturally infected adult of the red palm weevil (RPW) in Eastern Province in Saudi Arabia. The role of the native isolate in the biological control of RPW adults was evaluated. Laboratory bioassay studies showed high virulence of the nematode to adults of the RPW. Half lethal concentration (LC_{50}) after 3 days was 2077 infective juveniles (IJs)/ml and the half lethal time (LT_{50}) - using the concentration 500 IJ/ml - was 1.95 days. In the Semi-field evaluation *Steinernema* sp SA caused over 97% mortality in adults of the RPW in date palm trees under screen cages. The nematode propagated successfully in all infected insects. In the field, the nematode was sprayed on the basal parts of palm trunks and soil around them. A single spray of $2x10^6$ infective juveniles (IJs)/tree caused 37.16% reduction in RPW population in date palm farms after one week of application. However, the effect was reduced to 34.75% in the following week.

Key words: *Rhynchophorus ferrugineus, Steinernema* sp., red palm weevil, entomopathogenic nematodes.

INTRODUCTION

The date palm *Phoenix dactylifera* L is a strategic food crop in the Arabic region where every part of the tree is useful. According to the UN Food and Agriculture Organization (FAO 2005), Arab countries produce over 90% of world production of dates (16,696.56 million tons). The red palm weevil (RPW), *Rhynchophorus ferrugineus* (Oliver) (Coleoptera: Curculionidae) is the most destructive pest of the date palm in the region since its invasion to the United Arab Emirates (UAE) in 1985. It also attacks other palm species like coconut, oil palms and ornamental palms. It invaded Saudi Arabia 1987, Iran 1990 (Murphy and Briscoe 1999) and Egypt 1992 Saleh (1992). It went west to Spain 1995 (Barranco *et al.* 1995), and Italy 2004 (Sacchetti *et.al.*2005). Adults of the RPW attack palm trees and deposit eggs individually in wounded and soft tissues. The hatched larvae tunnel into the trunk or the terminal bud leading directly to the death of the tree (Sivapragasam *et al.* 1990). Because of the cryptic feeding habit of larvae their control is difficult. Primary infestations always escape attention and symptoms may not become evident until extensive damage has already occurred (Hanounik *et al.* 2000a). Larval stage lasts 2-3 months with 12 larval instars. The female may lay 370 eggs during its 2-3 month-life span. The insect has 4 generations annually in Saudi Arabia (Al Mohanna *et al.*, 2000). OEPP/EPPO (2008) reported that a complete life cycle of the weevil from the egg to adult emergence takes an average of 82 days. Males excrete aggregation pheromone that attract both sexes for food, shelter and egg deposition.

Management of RPW depends mainly on chemical insecticides (Girgis *et al.* 2002). Date palms are sprayed periodically with chemical insecticides for protection and infested trees are injected for cure. Chemicals go through the sandy soil to ground water and subsequently to all living organisms causing many environmental and health hazards.

Biological control, as a safe measure, is strongly recommended for management of this pest. Among promising biological control agents are EPNs. *Heterorhabditis indica* HSA was recorded for the first time in Saudi Arabia (Saleh *et al.* 2001) and was evaluated against larvae and adults of RPW (Saleh and Alheji 2003). EPNs proved high virulence against RPW stages UAE (Abbas *et al.* 2001 a&b) and in Egypt (Shamseldean and Abdelgawad 1994).

Adults of the RPW aggregate in leaf axils of palm trees for resting, mating and oviposition. They also aggregate at the basal part of the trunk of young date palm trees, below the soil level (Hanounik *et al.* 2000a). Abbas *et al* (2000) justified the presence of adults of the RPW in the soil as: up to 20 to 100% of adults collected from the fields were found to be parasitized with unidentified nematodes, EPNs could be isolated from RPW adults and young date palms (<10 years old) were found to undergo severe infestation below the soil surface. A considerable portion of 35% of *R. ferrugineus* infestation in date palm trees in eastern region in Saudi Arabia were found at or below the soil surface (Alkhazal *et al.* 2009).

The objective of this work is to evaluate the role of the native isolate of *Steinernema* sp. SA for biological control of RPW adults through semi-field and field applications in Saudi Arabia.

MATERIALS AND METHODS

Nematode isolation

A naturally nematode-infected adult of RPW was brought from Ben-Hammam farm in Qatif, Eastern Province of Saudi Arabia in October, 2006. This weevil was transferred to the laboratory and placed in a White trap (White 1927) for nematode extraction. The extracted nematodes were reared on larvae of the greater wax moth *Galleria mellonella* L. according to Woodring and Kaya (1988). Primary identification of the extracted nematodes to the genus level depended on symptoms appeared on nematode-infected host larvae and the morphology of nematode developmental stages described by Poinar (1990).

Virulence to adults of RPW

Sand barrier bioassay technique (Woodring and Kaya 1988) was used to determine the virulence of the new nematode to adults of the RPW. The weevils were individually exposed to serial concentrations (treatments) of the nematode (0,500,1000,2000 and 4000 IJs/ml) in 50cc tubes filled with 9g fine sand damped with 1ml distilled water. Ten replicates were prepared for each treatment. Mortality of the weevils was recorded daily. Data were statistically analyzed by plotting regression lines of concentration vs. mortality and time vs. mortality and values of LC_{50} and LT_{50} were calculated.

Semi-field evaluation

Date palm trees -5 years old- were transferred individually to halves of polyvinyl barrels, 80cm diameter X 80 cm high, filled with sandy soil. Each tree was covered with a 2 meter-high plastic screen cage to prevent escape of adult weevils. The cages were arranged outdoors beside the laboratory building in Qatif. The experiment consisted of 2 treatments (*Steinernema* sp. SA and control). Each treatment consisted of 4 replicates. Each plot represented by a tree in a cage. The trees were artificially infested with adults of RPW at a rate of 10 weevils/tree/cage. After 24 hours, the water suspension of the nematode was sprayed on the basal part of the trees and soil around them at a rate of 2 million IJs/5 liters /tree. Control plots received only water. The trees and the soil under cages were inspected after 5 and 8 days and numbers of dead and alive weevils were recorded. Dead weevils were transferred to White traps to detect nematode development and propagation.

Field evaluation

Pheromone-kairomone terrestrial traps described by Hanounik *et al* (2000a) were used for monitoring the adult population of the red palm weevil in treated and untreated date palm farms. Capacity of the trap is 10L with 3 holes in the cover and 6 holes near the upper edge of side walls. A bag containing the aggregation pheromone (Chemtica International S.A. Costa Rica) and a bottle containing kairomone (locally extracted from date fruits) are attached to the cover. The traps were distributed at 100 meters distance (i.e. 1 trap/ hectare).

A date palm farm of approximately 5 hectares was specified for each treatment. The nematode suspension was sprayed in the field using a 600 liter-spraying motor at a rate of 2 million IJs/5 liters/tree. The spray was directed to the trunk base and soil around the trees. Trap catches were recorded weekly in both farms before and after each treatment. The caught weevils were kept individually with food in 200cc cups in the laboratory and observed for 3 days and dead weevils were placed in White traps to detect nematode infections. After field applications dead insects found out traps or inside treated trees were collected, transferred to the laboratory and inspected for nematode infections.

Populations of RPW in tested farms were represented by mean of weevils/trap/week. Means were compared by ANOVA test and SE values were computed and given with their means. Percentages of reduction in the insect population due to different treatments were calculated according the equation of Henderson and Tilton (1955) as follows:

$$R = 100 \times \left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Where: R = Percent of population reduction, Tb = Numbers of insects in treated plots before treatment, Ta = Numbers of insects in treated plots after treatment, Cb = Numbers of insects in control plots before treatment, Ca = Numbers of insects in control plots after treatment.

RESULTS AND DISCUSSION

Primary nematode identification

Evidence certify that the nematode belongs to *Steinernema* were: (1) the pale yellow color of nematode-infected host larvae, (2) the giant amphemectic females of the first generation found inside host cadavers three days after infection, (3) the identical shape of the tail of steinernematid IJ, and (4) the identical appearance of coiled steinernematid IJs. Sample of this new isolate was sent for identification to the species level by DNA analysis to Kiel University, Germany. Until the complete identification, the nematode isolate was given the name *Steinernema* sp SA. This was the first record of steinernematid nematode from Saudi Arabia.

Nematode virulence to RPW adult stage

Data in table (1) show that mortality in RPW adults exposed to serial concentrations of *Steinernema* sp. SA started after 2 days for all used concentrations and reached its maximum (100%) after 4 days for the concentrations 1000 and 2000 IJ/ml and after 5 days for the concentration 4000 IJ/ml. After 5 days, concentrations above 500 IJs/ml caused 100% insect mortality. A high degree of correlation between the nematode concentration and the insect mortality ($R^2 = 0.82$) was found after 3 days of exposure. The LC_{50} after three days of exposure was 1373 IJs/ml. The highest degree of correlation between nematode concentration and insect mortality ($R^2= 0.82$) was recorded after 3 days of exposure (Fig1).The LT_{50} measured at the concentration 500 IJs/ml was 1.96 days. The highest degree of correlation between the exposure time and insect mortality ($R^2= 1.92$) was recorded when the nematode concentration was 500 IJs/ml (Fig 2).

Semi-field evaluation

Steinernema sp. SA was significantly effective for controlling RPW adults under semi-field conditions. Weevil mortality was 84.79 and 97.5% after 5 and 8 days of treatment, respectively while natural mortality in control cages during the experimental duration was 7.5-10%. This native nematode was not only efficient for controlling adults of the RPW, but also able to propagate in the weevil cadavers. Percentage weevils produced offspring was 66.39% after 13 days of treatment and increased to 100% after 20 days of treatment.

Field evaluation

During the first week post treatment the natural RPW population in control farm increased from 4 to 6.67 weevils/trap/week recording (+ 2.67 weevils). In the treated farm the single nematode spray suppressed

Table (1): Mortality in adults of *Rhynchophorus ferrugineus* after application of *Steinernema* sp. SA at different concentrations

Nematode concentration (IJ/ml)	% Insect mortality after:				
	1day	2days	3days	4days	5days
500	0	25	58.33	75	83.33
1000	0	25	75	100	100
2000	0	66.67	81.82	100	100
4000	0	75	91.67	91.67	100

Table (2): Population reduction in *Rhynchophorus ferrugineus* adults after application of *Steinernema* sp. SA in date palm farms in Qatif, Saudi Arabia during April 2007

Date	Weevils/trap/week ±SE		% Population reduction
	Control	Treated	
10/04/2007	4±0.94	5.67±0.27	
17/04/2007	6.67±0.72	6±0.94	37.16
24/04/2007	5.67±0.27	5.33±0.27	34.75

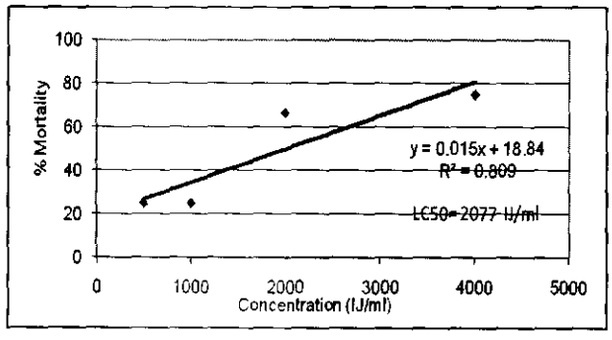

Fig. (1): Concentration-mortality line of *Steinernema* sp. SA against adults of *Rhynchophorus ferrugineus* calculated after 3 days of treatment.

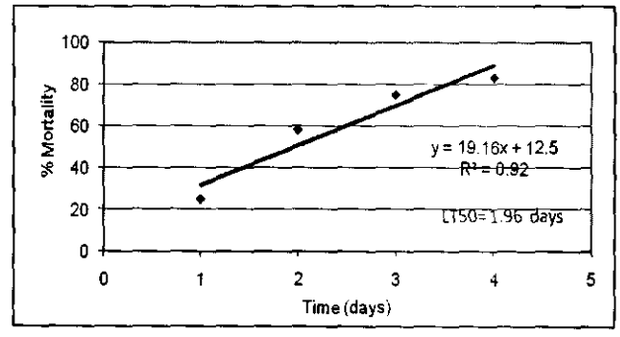

Fig. (2): Time–mortality line of *Steinernema* sp SA against adults of *Rhynchophorus ferrugineus* calculated at 500 IJs/ml

the population increase to be only + 0.33 weevils (from 5.67 to 6 weevils/trap/week) in the first week and to – 0.33 weevils (from 5. 67 to 5.33 weevils/trap week) in the second week. This effect was calculated according Henderson and Tilton (1955) equation as 37.16 and 34.75% population reduction in the first and the second weeks, respectively (Table 2).

This work comprised the first record of steinernematid nematodes (*Steinernema* sp. SA) from Saudi Arabia. The same authors previously recorded heterorhabditid nematodes (*H. indica* HSA) for the first time from Saudi Arabia (Saleh *et al.,* 2001). The steinernematid nematode was isolated from naturally infected RPW adult in Qatif region. However, Abbas *et al.* (2001a) could isolate *S. abbasi* and *H. indicus* (= *indica*) from adults of the RPW in UAE. Like most native EPN isolates obtained *Steinernema* sp. SA was virulent against RPW adults. This result agrees with the results of Abbas *et al.* (2001b) in UAE, Shamseldean and AbdelGawad (1994) in Egypt, who worked on different native EPN isolates. Shapiro *et al.* (2002) stated that choosing the right EPN species against a particular pest in a particular environment is very important for successful biological control.

Steinernema sp. SA showed high potential for *in vivo* reproduction on *G. mellonella* larvae so that a single larva produced over 600 000 IJs. A key factor in the success of EPN as bio-pesticides is their amenability for mass production (Shapiro and Gaugler 2002).

The semi-field evaluation showed that *Steinernema* sp. SA was efficient for controlling adults of the RPW under cages. The nematode spray was directed to the base of the tree and soil around it where adults of RPW usually aggregate (Hanounik *et al.* 2000a). Mortality in adults of RPW in date palm trees under cages reached 97.5% within one week after a single spray of $2x10^6$ IJ/tree. Hanounik *et al.* (2000b) were the first who targeted adults of the RPW in date palm trees and soil around them with *H. indica* HSA isolated from Qatif. *H. indica* HSA caused 86% mortality in adults of RPW under cages when used with anti-desiccants. Llacer *et al.* (2009) in Spain used *S. carpocapsae* against RPW under cages and obtained mortality around 80% in a curative assay, and up to 98% in a preventative treatment. Successful propagation of *Steinernema* sp. SA in cadavers of the RPW under the semi-field conditions gives prediction that the nematode will persist and recycle in date palm fields. Saleh *et al.* (2004) found that *S. carpocapsae* remained able to kill adults of RPW for 16 days in a date palm field in Qatif.

Field spraying of EPNs against adult stage of RPW was mentioned first by Hanounik *et al.* (2000a) in Saudi Arabia and Abbas *et al.* (2000) in UAE through a project of Biological Control of the RPW (1997-2007). This work belongs to the un-published results of the same project. The first field study showed that a single spray of *Steinernema* sp. SA of $2x10^6$ IJs/tree in Qatif region during April resulted in 37.16 and 34.75% population reduction in RPW adults in the farm. This steinernematid nematode lasted effectively at least for two weeks. Temperature in Qatif during April (around 35°C) seemed unsuitable for stronger effect or longer persistence of the steinernematid nematodes. Saleh *et al.* (2004) recorded active persistence of *S. carpocapsae* for 16 days in the same region during March.

The present results prove proved that the potential of native EPNs to control *R. ferrugineus*. The results give a ready-to-use bio-control program based on EPNs and add evidence to the recommendation of transferring biological control with EPNs to the IPM programs of RPW.

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REFERENCES

Abbas M.S.T.; M.M.E. Saleh and A.M. Akil 2001a. Laboratory and field evaluation of the pathogenicity of entomopathogenic nematodes to the red palm weevil, *Rhynchophorus ferrugineus* (Oliv.). Anz. Schadlingskunde J. Pest. Science 74, 167-168.

Abbas M.S.T; S.B. Hanounik, S.A. Mousa and M.I. Mansour 2001b. On the pathogenicity of *Steinernema abbasi* and *Heterorhabditis indicus* isolated from adult *Rhynchophorus ferrugineus* (Coleoptera). International Journal of Nematology 11(1) 69-72.

Al Mohanna O.E.; S.B. Hanounik; G. Hegazy and M. Salem 2000. Biology of the red palm weevil *Rhynchophorus ferrugineus* (Oliv.) Proceedings of first workshop on control of Date Palm Weevil, King Faisal University, Kingdom of Saudi Arabia, 85-95.

Alkhazal, M.H.; L.A. Youssef; M.S. AbdelWahed; A.S. Kassab; M.M.E. Saleh 2009. Factors affecting infestation pattern of the red palm weevil, *Rhynchophorus ferrugineus* (Oliv.) in date palm farms in Qatif, Saudi Arabia. J. Agric. Sci., Ain Shams Univ. Cairo, 17(1) 177-183.

Barranco P.; Delapena J; Cabillo T. 1995. Un Nuevo curculionido tropical para la fauna europra, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). Bol Asoc. Esp. Ent., 20:257-258.

FAO 2005. Agro-Statistics Database. Available on line at: http://en.wikipedia.org/wiki/Date_(fruit)#Production

Girgis G.N.; A.M. Batt; A.M. Okil; S.M. Haggag and M.M. Abdel Azim 2002. Evaluation of trunk injection methods for the control of red palm weevil *Rhynchophorus ferrugineus* (Oliver) in date palm trees in Egypt. 2nd International Conference, Plant Protection Institute, Cairo, Egypt, 21-24 December 2002. Vol. 1, 709-711.

Hanounik S.B.; G. Hegazy; M.S.T. Abbas; M. Salem; M.M.E. Saleh; M.I. Mansour; O. El Muhanna; S.A.I. Bgham; R. Abuzuhaira; S. Awash and A. Shambia 2000a. Biological control of *Rhynchophorus ferrugineus* (Oliv.) as a major component of IPM. Proceedings of first workshop on control of Date Palm Weevil, King Faisal University, Kingdom of Saudi Arabia, 125-150

Hanounik, S.B.; M.M.E. Saleh; R.A. Abzuhairah; M. Alheji; H. Al Dhahir and Z.H. Al Garrash 2000b. Efficacy of entomopathogenic nematodes with antidesicants in controlling the red palm weevil, *Rhynchophorus ferrugineus* on date palm trees. International Journal of Nematology 10(2) 131-134.

Henderson C.F. and Tilton E.W. 1955. Test with acarides against the brown wheat mite. J. Econ. Entomol. 48, 157-161.

Llacer E.; M.M. Martınez de Altube and J.A. Jacas 2009. Evaluation of the efficacy of *Steinernema carpocapsae* in a chitosan formulation against the red palm weevil, *Rhynchophorus ferrugineus*, in *Phoenix canariensis*. BioControl 54(4)559-565

Murphy S.T. and B.R. Briscoe 1999. The red palm weevil as an alien invasive: biology and the prospects for biological control as component of IPM. Bio control News and Information, 20 (1) 35-46.

OEPP/EPPO 2008. Data sheets on quarantine pests *Rhynchophorus ferrugineus*. Bull. OEPP/EPPO 38: 55-59.

Poinar G.O. Jr. 1990. Taxonomy and biology of Steinernematidae and Heterorhabditidae. In: Gaugler R and HK Kaya (eds.) Entomopathogenic Nematodes in Biological Control. Boca Raton, Fl., CRC Press, 23-61.

Sacchetti P.; A. Camèra; A. Granchietti; M.C. Rosi and P. Marzialetti 2005. Prima segnalazione in Italia del curculionide delle palme, *Rhynchophorus ferrugineus* Centro Sperimentale per il Vivaismo di Pistoia. www.pubblicigiardini.it/News/ NewsDet.asp?id=2035.

Saleh M.M.E.; G. Hegazy; M. Salem; S.B. Hanounik; O. Al Mohanna and M.A. Alheji 2004. Persistence of *Steinernema carpocapsae* (Nematoda: Steinernematidae) and *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) in soil around date palm trunks and their effect on adults of *Rhynchophorus ferrugineus*. *Egypt.* J. Biol. Pest Control, 14 (1) 141-145.

Saleh, M.M.E. and M. Alheji 2003. Biological control of red palm weevil with entomopathogenic nematodes in the Eastern Province of Saudi Arabia. *Egypt.* J. Biol. Pest Control, 13 (1&2) 12-25

Saleh, M.M.E.; S.B. Hanounik; O. Al-Muhanna; H. Al-Dhaher and Z. H. Al-Garrash 2001. Distribution of *Heterorhabditis indica* (Nematoda: Heterorhabditidae) in Eastern Saudi Arabia. International Journal of Nematology 11(2) 215-218.

Saleh, M.R.A. 1992. Red palm weevil Oliver is first record in Egypt and indeed in African continent. List No. 10634 Africa; Collection No. 22563. International Institute of Entomology, 56 Queen's Gate, London, UK.

Shamseldean M.M. and M.M. AbdelGawad 1994. Laboratory evaluation of heterorhabditid nematodes for control of the red palm weevil. Egypt. J. Appl. Sci. 9(3) 670-679.

Shapiro-Ilan, D.I. and R. Gaugler 2002. Production technology for entomopathogenic nematodes and their bacterial symbionts. Journal of Industerial Microbiology and Biotechnology 28: 137-146.

Shapiro-Ilan, D.I; R. Gaugler; W.L. Tedders; I. Brown and E.E. Lewis 2002. Optimization of inoculation for *in vivo* production of entomopathogenic nematodes. Journal of Nematology 34, 343-350.

Sivapragasam A.; A. Arikiah and C.A. Ranjit 1990. The red strip palm weevil, *Rhynchophorus schach* Oliv. (Coleoptera: Curcurlionidae): an increasing menace to coconut palms in Hilir Perak. Planter, 66: 113-123.

White G.F. 1927. A method for obtaining infective nematode larvae from cultures. Science 66, 302-303.

Woodring J.L. and H.K. Kaya 1988. Steinernematid and Heterorhabditid nematodes: A handbook of techniques. Arkansas Agricultural Experiment Station Southern Cooperative Bulletin 331. 30 pp.

تقييم سلالة النيماتودا *Steinernema* sp. SA الممرضة للحشرات من المملكة العربية السعودية في مكافحة سوسة النخيل الحمراء

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تم استخلاص سلالة النيماتودا الممرضة للحشرات *Steinernema* sp. SA في المملكة العربية السعودية من إحدى مزارع النخيل بالمنطقة الشرقية، وقد استهدف هذا البحث تقييم أداء هذه السلالة في مكافحة سوسة النخيل الحمراء من خلال تجارب معملية ونصف حقلية وحقلية. أظهرت النتائج أن هذا هو أول تسجيل لهذا الجنس من النيماتودا الممرضة للحشرات بالمملكة العربية السعودية وجاري التعريف إلى مستوى النوع بواسطة تحليل بصمة الحمض النووي DNA. كانت النيماتودا المكتشفة *Steinernema* sp. SA فعالة في القضاء على الآفة من خلال تجارب المختبرحيث كان التركيز النصفي (LC_{50}) لها 1373 نيماتودا/ مل بعد 3 أيام من المعاملة، وزمن الموت النصفي (LT_{50}) 1.95 يوما عند التركيز 500 نيماتودا/ مل. قابلة للإنتاج الكمي على يرقات دودة الشمع الكبرى بكفاءة حيث بلغ إنتاج اليرقة الواحدة 642000 نيماتودا. أما في تجارب التقييم نصف الحقلي لكفاءة النيماتودا المستخلصة ضد الآفة تحت الأقفاص فقد وصلت نسبة موت الحشرات الكاملة للسوسة 97.5% بعد المعاملة بمعدل 2 مليون نيماتودا / نخلة. وفى تجارب الحقول المفتوحة في مزارع النخيل وتقييم النتائج باستخدام المصائد الفرمونية الكيرمونية الأرضية فقد حققت رشة واحدة من مستحضر النيماتودا *Steinernema* sp. SA خفضا مقداره 37.16 و 34.75% في تعداد السوسة بمزارع النخيل بشرق المملكة في نهاية الأسبوع الأول والثاني بعد المعاملة، على التوالي، وذلك خلال شهر أبريل. يضيف هذا البحث أيضا دليلا على جدوى المكافحة الحيوية بالنيماتودا الممرضة للحشرات بطريقة الرش على مواقع تجمع الحشرات الكاملة بأسفل جذوع النخيل حديث العمر والتربة المحيطة بالجذوع حيث تتوفر البيئة المفضلة لنشاط النيماتودا الممرضة للحشرات. توفر هذه الطريقة الكثير من الوقت والجهد وسهلة التقييم بواسطة المصائد الفرمونية الكيرمونية وجديرة بالإدخال ضمن برنامج المكافحة المتكاملة للآفة.

كلمات مفتاحية: النيماتودا الممرضة للحشرات، *Steinernema* sp. SA، مكافحة حيوية، سوسة النخيل الحمراء، تقييم، المملكة العربية السعودية.