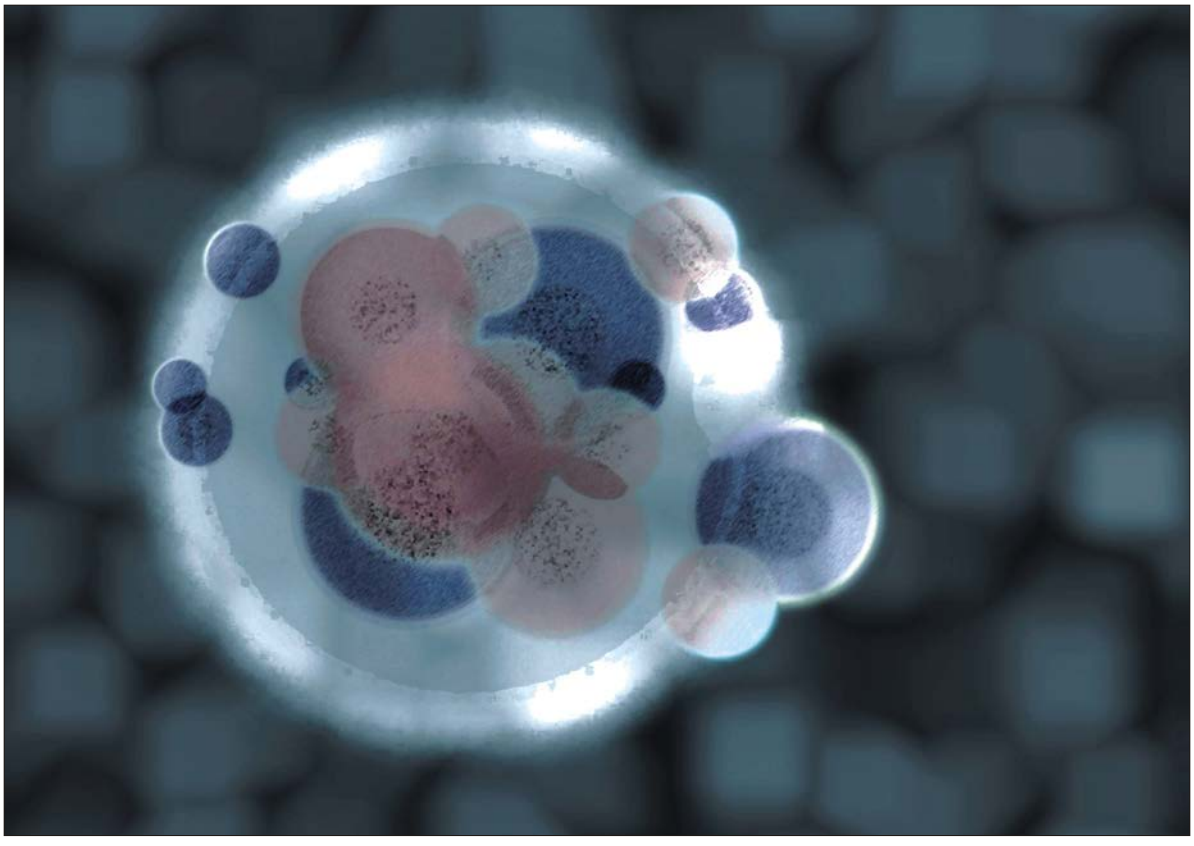

Journal of Biological Sciences

ISSN 1727-3048

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Biological Sciences 7 (7): 1270-1273, 2007
ISSN 1727-3048

Effects of Red Palm Weevil *Rynchophorus ferrugineus* (Olivier) Infestation on Gas Exchange Capacity of Two Date Palm *Phoenix dactylifera* L. Cultivars

[1]A.M. Al-Jabr, [1]A.A. Al-Khateeb, [1]S.A. Al-Khateeb and [2]H.Y. Al-Ayied
[1]College of Agriculture and Food Science, King Faisal University, Kingdom of Saudi Arabia
[2]King Abdulaziz City for Science and Technology (KACST), Riyadh, Kingdom of Saudi Arabia

Abstract: This is the first report of date palm's photosynthesis and gas exchange capacity response to Red Palm Weevil (RPW) infestation. Photosynthesis, stomatal conductance, mesophyll conductance, transpiration rate, intercellular CO_2 concentration and water use efficiency of two date palm *Phoenix dactylifera* L. cultivars (Khalas and Ruzaiz) have been studied under severe and medium RPW infestation using a portable photosynthesis system. Net photosynthetic rate was significantly reduced under infestation in Ruzaiz cv. particularly with medium infestation. Mesophyll conductance was significantly reduced under infestation in both cv. Stomatal conductance and transpiration rate were not significantly affected. However, significant reduction on Water Use Efficiency (WUE) was observed in infested Ruzaiz cv. Intercellular CO_2 concentration was higher under both severe and medium infestation in both cultivars.

Key words: Red palm weevil, date palm, photosynthesis, mesophyll conductance, infestation

INTRODUCTION

Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* is a widely growing threat to date palm plantations in Middle East region. Within 6 years of its discovery in the United Arab Emirates in 1986, it spread to all Arabian Gulf states including Bahrain, Oman, Iran and crossed the Red Sea to Egypt, Spain and Italy (Long, 2006). The larvae stages of this insect consume the tender soft tissues of trees from within. This behavior kills the palms in 6-8 months (Murphy and Briscoe, 1999). Because of the concealed nature of the larvae, infested palms do not show any obvious early symptoms.

Photosynthesis is the source of organic carbon and energy for plants which is needed for growth and fruiting in date palm. Photosynthesis begins with the absorption of light energy by leaves and is utilized in a chain of chemical reactions that lead to the reduction of CO_2 to carbohydrates (Marschner, 1997). The photosynthates are loaded and translocated via phloem to all parts of the tree. Red palm weevil attacks the stem of the tree and damages the phloem. So far no data have been seen on the effect of RPW infestation on photosynthesis and gas exchange capacity on date palm. Recently many investigators found lower photosynthesis rate of crops due to insect mining (Al-Khateeb and Al-Jabr, 2006 in cucumber; Huijie *et al*., 2006 in castor bean and kidney bean) or defoliation (Hunt *et al*., 2003 in soybean). Also Schroder *et al*. (2005) found lower photosynthesis rate in *Pinus sylvestris* due to egg deposition by the sawfly *Diprion pini* while Retuerto *et al*. (2004) found an increase in photosynthetic performance in *Ilex aquifolium* due to infestation by scale insects *Coccus* sp. A better understanding of the complex interactions between RPW and host plant can serve as a basis for manipulating the physiology of plants to reduce risk of high pest population buildup and minimize host damage. The present study was aimed to investigate the effects of RPW on date palm photosynthesis and gas exchange capacity of two date palm cultivars.

MATERIALS AND METHODS

The experiment was carried out in a date palm field at Al-Hassa Province in Kingdom of Saudi Arabia during 2002/2003. The mean air temperature during the progress of the experiment was 29/21 (day), relative humidity 39±2%. Eight years old date palm trees (*Phoenix dactylifera* L.) cultivars Khalas and Ruzaiz were selected to represent two infestation levels of RPW i.e., medium and sever caused naturally. The control trees were normal (N) without any infestation and looked healthy. The infestation level was based on the visual damage of the tree stem but leaf morphology was intact in both medium and sever infected tree. Therefore the extent of infestation was identified by the size damages caused to the stem of both date palm cultivars. Fifteen trees from each cultivar were selected for uniformity. A completely randomized block design with five replicates per treatment was used.

Corresponding Author: A.M. Al-Jabr, College of Agriculture and Food Science, King Faisal University, Kingdom of Saudi Arabia

Effect of RPW on photosynthesis (P), stomatal conductance (C), transpiration rate (E), mesophyll conductance (g), intercellular CO_2 concentration (Ci) and Water Use Efficiency (WUE) for the two date palm cultivars were determined. The photosynthetic gas exchange rates were determined on fully expanded intact leaves in a single day between 9:00 am and 12:00 noon using a portable photosynthesis system (C1-301 PS, CID, Inc., USA), with an 6.5 cm^2 window-leaf-chamber. During the measurements, the Photosynthesis Active Radiation (PAR) was 1200±00 μmol m^{-2} sec^{-1}. Leaf temperature was 26±2C. Air flow into the cuvette was 350 mL min^{-1}. The boundary layer conductance to water vapor was measured according to Parkinson (1984) and found to be 0.26 μmol m^{-2} sec^{-1}. The ambient CO_2 concentration was 320±20 μmol moL^{-1}. Calculation of P, C, E and Ci were estimated according to Caemmerer and Farguhar (1981). Mesophyll (residual) conductance (g) which is a composite measure of all liquid phase conductances to CO_2 (cell wall, plasmalemma, cytoplasm, chloroplast membrane) as well as the conductance associated with carboxylation (Bradford and Hsiao, 1982), was determined according to Fites and Teskey (1988):

$$g = Pn/Ci\ \mu mol\ m^{-2}\ sec^{-1}$$

where, the equation is effectively similar or a slightly underestimate to the initial slope of a curve plotting (Pn) as a function of (Ci). Water use efficiency (WUE) was calculated as:

$$WUE = Pn/E$$

Collected data were subjected to analysis of variance (ANOVA). SAS computer package (SAS Institute, 2001) has been used. Throughout, p = 0.05 was used to define statistical significance. Mean separations were done using standard error (SE) bars.

RESULTS AND DISCUSSION

Net photosynthesis rate in both date palm cultivars was significantly reduced under medium infestation, while no significant reduction was noticed under severe infestation (Table 1). Ruzaiz cv. was more affected. Evidence of the ability of pests to damage fruit trees and crops and to reduce metabolic activities of these crops have been reported in many studies and have been demonstrated by Hunt *et al.* (2003), Al-Khateeb and Al-Jabr (2006) and Huijie *et al.* (2006). Among fruit species, date palm trees are ranked highly tolerant to many environmental stresses (Ibrahim and Khalif, 1997). However, despite its tolerant nature, in recent years it has been subjected to severe damages by pest and diseases which affect biochemical capacities of many physiological processes. In present study, damages to photosynthetic ability of trees were significantly enhanced by moderate RPW infestation for both cultivars. This could be explained according to the assumptions of the source-sink hypothesis. In this case it is presumed that RPV infestation would induce supplementary sinks for photosynthetic which probably increase photosynthesis. Similar results were found by Retuerto *et al.* (2004) working in *Ilex aquifolium* plant affected by scale insects *Coccus* sp. The reduction in photosynthesis rate could possibly be attributed to depressions in biochemical capacity for photosynthesis or/and to reductions in stomatal conductance. Stomatal conductance of Ruzaiz was significantly lower in normal trees and medium infested ones (Table 1). In Khalas cultivar, normal trees and medium infested ones showed non significant low stomatal conductance. Furthermore, stomatal conductance under severe infestation was not substantially affected in both cultivars.

Both stomatal conductance and photosynthesis rate were not significantly affected in both cultivars under severe infestation as expected. Since the extent of infestation (medium and sever) did not cause any structure damage to the leaf morphology, it was quite likely that some of the photosynthetic related structures such as chlorophyll were still intact in configuration and content thus functioning probably. In a previous study Unab and Abuzuhira (1992) showed that the chlorophyll content of Red Palm Weevil infected date palm trees was not altered.

Table 1: Averages of net photosynthesis (P μmol m^{-2} sec^{-1}), intercellular CO_2 (Ci μmol moL^{-1}), stomatal conductance (C mmol m^{-2} sec^{-1}), mesophyll conductance (g mmol m^{-2} sec^{-1}), transpiration (E μmol m^{-2} sec^{-1}) and Water Use Efficiency (WUE) of date palm Khalas and Ruziz cultivars as affected by red palm weevil infestation (N: Normal, M: Medium and R: Sever)

Infestation	P	Ci	C	g	E	WUE
Khalas cv.						
N	8.34±0.9a	144±35.0a	90.3±6.0a	62±2a	4.76±0.4a	1.76±0.2a
M	6.22±0.7a	197±34.0a	86.0±6.1a	30±1c	4.49±0.3a	1.39±0.2a
R	7.60±1.2a	184±40.0a	107.7±17.0a	54±4b	4.60±0.6a	1.65±0.4a
Ruziz cv.						
N	8.30±1.8a	102±20.6b	71.4±4.5b	99±5a	4.23±0.22a	1.32±0.36a
M	4.74±0.5b	223±16.3a	70.4±2.9b	21±3c	4.53±0.14a	1.05±0.09a
R	6.11±0.5ab	155±24.3a	100.4±12.2a	42±2b	4.70±0.38a	1.32±0.47a

Values with the same letter(s) for each cultivar are not significantly different at p = 0.05

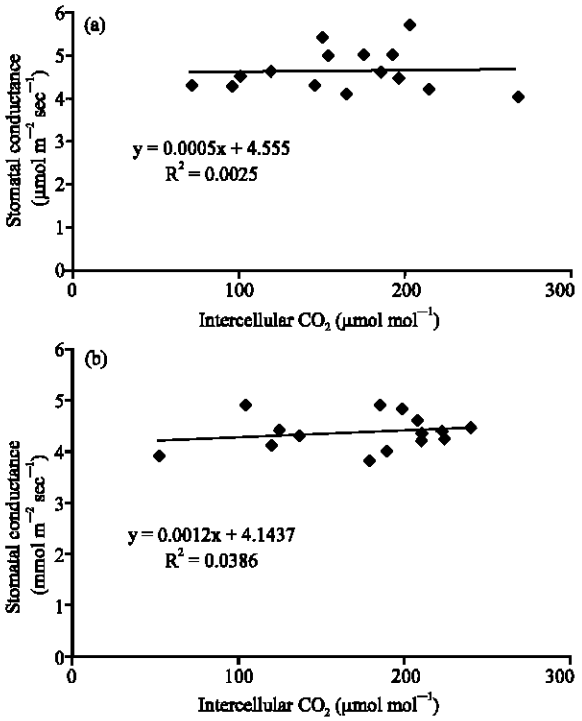

Fig. 1: The relationship between intercellular CO_2 and stomatal conductance. Khalas (a) and Ruiz (b)

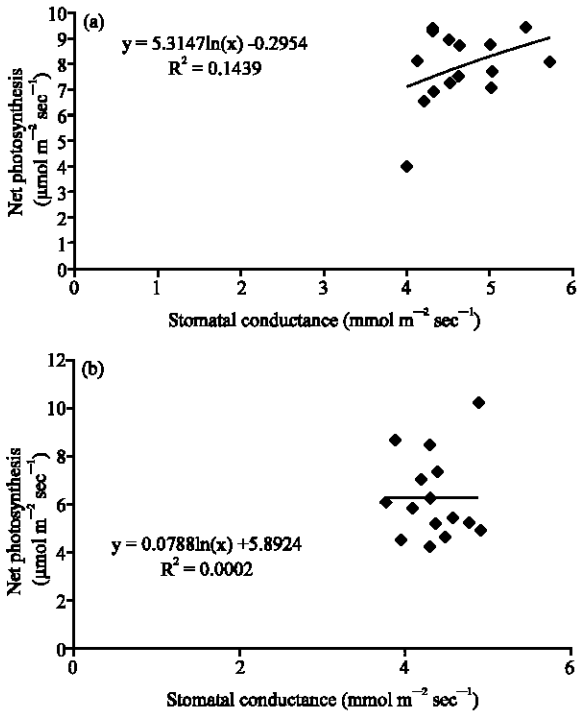

Fig. 2: The relationships between stomatal conductance and net photosynthesis. Khalas (a) and Ruiz (b)

Mesophyll conductance in both cv. was substantially reduced under medium and severe infestations compared to normal trees (Table 1). This reduction was more pronounced in Ruzaiz cv. Intercellular CO_2 concentration (Ci) was significantly lower in control plants in Ruzaiz cv. (Table 1). However, no significant changes were observed in Khalas cv. Date palm cultivars often respond differently to biodiversity stresses. The date palm cultivars Sheiba was found to be more tolerant to RPW damage and consequently most of its physiological activities were hardly affected (Siddig, 2000).

Lower rate of net photosynthesis with RPW were not associated with significant decreases in stomatal conductance (Fig. 1). Decreased stomatal conductance under infestation had also no effects on intercellular CO_2 concentrations, which were significantly increased under infestation (Fig. 2). However, if stomatal closure was the main reason for decreased rates of net photosynthesis, lower intercellular CO_2 concentrations would be expected to result from RPW infestation. The absence of such association suggests that other non-stomatal interrelated factors within the mesophyll cells also affect net photosynthesis rates. The substantial changes in mesophyll conductance were consistent with the changes in net photosynthesis. Similar results were found by Al-Khateeb and Al-Jabr (2006) and Tang *et al.* (2006) working on other crops and insects.

Transpiration rates for both date palm cultivars were not affected by RPW infestation (Table 1). The negative effect on transpiration rates is presumably due to the selective attack of RPW to phloem tissues rather than the xylem. If both plant tissues were non-selectively damaged, logistically both transpiration rate and net photosynthesis would be reduced. However, the absence of such logical trend supports our selective attack assumption. RPW mostly lay their eggs near the phloem tissue where food is abundant and accessible to the hatched eggs. The phloem normally translocates food substances other than water, which are manufactured through photosynthesis in the leaves (Tais and Teiger, 1991; Salisburry and Ross, 1994). Ninety percent of total solids in phloem consists of carbohydrates, mostly non-reducing sugars in addition to amino acids, amides, inorganic nutrients, growth hormones, nucleotides and systemic pesticides (Gardner *et al.*, 1985). The influence of plant on insect establishment and development to maturity through proper feeding and position has been demonstrated in several studies (Bernays and Chapman, 1994). High relative humidity is needed for RPW larva development. *R. cruentatus* mortality occurred much more rapidly in low relative humidity (Weissling and Gibblin-Davis, 1993). Weevils exposed to less than 60% RH exhibited over 50% mortality compared to less than 15% on 98% RH.

The selective RPW pattern of attack during its development might also indicate the instinct avoidance of hatching eggs and developing larvae to stem tissues of high water content. The high water content probably causes suffocation of developing larvae due to hypoxia. Depending on similar results Ning and Al-Hakbani (2000) investigated the potential use of systematic insecticide in controlling RPW. Water use efficiency for both cultivars under RPW infestation was not significantly affected (Table 1).

In conclusion RPW infestation seemed not to seriously affect transpiration and water use efficiency of both date palm cultivars. Further in-depth investigation that include xylem flow rate and the metabolism of carboxylation in date palm in response to RPW may be needed since photosynthesis, transpiration, water use efficiency and xylem flow rate are interdependent processes. The results of this study provisionally paved the way for the possibility of using these parameters for the early detection of RPW damage.

REFERENCES

Al-Khateeb, S.A. and A.M. Al-Jabr, 2006. Effect of leafminer *Liromyza trifolii* (Burgess) (Diptera: Agromyzidae) on exchange capacity of cucumber, *Cucumis staivus* L. grown under greenhouse conditions. Acta Hortic., 770: 423-428.

Bernays, E.A. and R.F. Chapman, 1994. Host Plat Selection by Phytophagous Insects. Chapman and Hall, London.

Bradford, K.J. and T.C. Hsiao, 1982. Physiological Responses to Moderate Water Stress. In: Physiological Plant Ecology II. Lange, O.L., P.S. Nobel, C.B. Osmond and G. Ziegler (Eds.), Springer-Verlag, Berlin, Heidelberg, NY., pp: 264-324.

Caemmerer, S.V. and G.D. Faquhar, 1981. Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. Planta, 153: 376-387.

Fites, J.A. and R.O. Teskey, 1988. CO_2 and water vapor exchange in *Pinus taeda* in relation to stomatal behavior: Test of an optimization hypothesis. Can. J. For. Res., 18: 150-157.

Gardner, F.P., R.B. Pearce and R.L. Mitchell, 1985. Physiology of Crop Plants. 1st Edn., The Iowa State Univ. Press: AMES.

Huijie, Z., D. GuoQi, Z. ZhanBei, L. ZheJun, Z. DongMei, X. Qi, W. XiaoMin, X. Ailing and L. Zhen, 2006. Effect of leaf mining by *Liromyza staivae* larvae on photosynthesis of some crops. Acta Entomol. Sinica, 49: 100-105.

Hunt, T.E., L.G. Higley and F.J. Haile, 2003. Imported longhorned weevil (Coleoptera: Curculionidae) injury to soybean: Physiological response and injury guild-level economic injury levels. J. Econ. Entomol., 96: 1168-1173.

Ibrahim, A.M. and M.N.H. Khalif, 1998. Date Palm. Its Cultivation, Management and Production in the Arab World. 2nd Edn., Almaarif Publication, Alexandria, Egypt, pp: 747.

Long, S., 2006. The Asian red palm weevil, a serous pest of Canary palm in Sicily. Informatore Fitopatologico, 56: 40-44.

Marschner, H., 1997. Mineral Nutrition of Higher Plants. 2nd Edn., Academic Press, Harcourt Brace and Company, Publishers. London, pp: 131-176.

Murphy, S.T. and B.R. Briscoe, 1999. The red palm weevil as an alien invasive: Biology and the prospects of biological control as component of IPM. Biocontrol News Inform., 20: 35N-46N.

Ning, C.K. and M. Al-Hakbani, 2000. Ethogrowth-trw on Red Palm Weevil. 1st Workshop on Control of Date Palm Weevil. 20-22 November, King Faisal Univ., Al-Hassa, KSA.

Parkinson, K.J., 1984. A simple method for determining the boundary layer resistance in leaf cuvette. Plant Cell Environ., 8: 223-226.

Retuerto, R., Fernandez-Lema, B., Rodriguez-Roiloa and J.R. Obeso, 2004. Increased photosynthetic performance in holly infested by scale insect. Funct. Ecol., 18: 664-669.

Salisburry, F.B. and C.W. Ross, 1994. Plant Physiology. Wadsworth Publishing Company. Belmont California.

SAS Institute, 2001. SAS for Windows, SAS user's guide: Statistics. Version 8.0 e. SAS Inst., Inc., Cary, North Carolina.

Schroder, R., M. Forstreuter and M. Hilker, 2005. Aplant notices insect egg deposition and changes its rate of photosynthesis. Plant Physiol., 138: 470-477.

Siddig, A.S., 2000. Studies on date Indian red weevil in Quatar and Iraq. First Workshop on Control of Date Palm Weevil. 20-22 November, King Faisal Univ., Al-Hassa, KSA.

Tais, I. and E. Teiger, 1991. Plant Physiology. The Benjamin/Commings Publishing Company, Redwood City.

Tang, J.Y., R.E. Zielinski, A.R. Zangerl, A.R. Crofts, M.R. Berenbaum and E.H. DeLucia, 2006. The differential effect of hervivory by 1st and 4th instars of *Trichoplusia ni* (Lepidoptera: Noctuidae) on photosynthesis in *Arabidopsis thaliana*. J. Exp. Bot., 57: 527-536.

Unab, G.B. and R. Abuzuhira, 1992. Diaguostic tests for Red palm Weevil (*Rhynchophorus ferrugineus*) infested date palm trees. Arab Gulf J. Sci. Res., 10: 93-104.

Weissling, T.J. and R.M. Giblin-Davis, 1993. Water loss dynamics and humidity preference of *Rhynchophorus cruentatus* (*Coleoptera: Curculionidae*) adults. Environ. Entomol., 22: 93-97.