Impact of Solar UV-B Radiation in the Culture of Pacific White Shrimp, *Litopenaeus vannamei,* Saudi Arabia

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ABSTRACT

Middle East and North African (MENA) region are known for high levels of solar UV radiation. A study was conducted to assess the effect of UV radiation on phytoplankton chlorophyll, β-carotene and growth of pacific white shrimp, Litopenaeus vannamei in HDPE liner culture ponds for 98 days. The experiment is based on control ponds (direct sunlight) and treatment ponds (Green house) using intensive shrimp culture method. Shrimp juveniles (SPF) at the rate of 100/m2 were stocked in each pond and fed with a standard fishmeal based supplementary pellet feed having 35% protein in diet. Physico-chemical parameters of pond water, UV-B radiation, Chlorophyll-a, shrimp growth and β-carotene in meat were monitored during the study period. Significant reduction ($p<0.01$) in UV-B radiation was found in treatment ponds in comparison with control ponds at an average reduction of 23.2% for surface water due to filtration. Chlorophyll-a in phytoplankton and β- carotene in shrimp were found to be increased in treatment ponds due to low UV-B radiation. However, shrimp growth was not affected significantly ($P>0.01$) by UV-B radiation in culture ponds.

تأثير الأشعة الشمسية UV-B في تربية الروبيان الأبيض بالمحيط الهادئ، *Litopenaeus vannamei* ، المملكة العربية السعودية

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المُستلخص

تشتهر منطقة الشرق الأوسط وشمال أفريقيا (MENA) بمستويات عالية من الأشعة فوق البنفسجية الشمسية. أجريت دراسة لتقييم تأثير الأشعة فوق البنفسجية على الكلوروفيل النباتية ، β-كاروتين ونمو الجمبري الأبيض السلمي ، Litopenaeus vannamei في أحواض التربية HDPE لمدة 98 يومًا. تعتمد التجربة على برك التحكم (أشعة الشمس المباشرة) وبرك العلاج (البيت الأخضر) باستخدام طريقة الاستزراع المكثف للجمبري. تم تخزين أحواض تربية الروبيان (SPF) بمعدل 100 / m2 في كل بركة ويتم تغذيتها باستخدام حبيبات تكميلية قياسية تعتمد على الوجبة السمكية تحتوي على 35٪ بروتين في النظام الغذائي. تم رصد المعلمات الفيزيائية الكيميائية لمياه البرك والأشعة فوق البنفسجية باء ، والكلوروفيل ، ونمو الروبيان ، وبيتا كاروتين في اللحوم خلال فترة الدراسة. تم العثور على انخفاض كبير ($P <0.01$) في الأشعة فوق البنفسجية باء في برك العلاج بالمقارنة مع برك التحكم في انخفاض متوسط قدره 23.2 ٪ للمياه السطحية بسبب الترشيح. ووجد أن الكلوروفيل a في العوالق النباتية و β- كاروتين في الروبيان يزداد في أحواض المعالجة بسبب انخفاض الأشعة فوق البنفسجية - باء. ومع ذلك ، لم يتأثر نمو الجمبري بشكل كبير ($P> 0.01$) بواسطة الأشعة فوق البنفسجية - باء في أحواض التربية.

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الكلمات الدالة

الأشعة فوق البنفسجية - باء ، الكلوروفيل أ ، بيتا كاروتين ، النمو ، L.vannamei ، المملكة العربية السعودية.

Introduction

Many life processes of marine primary producers are affected by UV radiation from the level of molecules up to that of communities (Helbling et al., 2005; Halac et al., 2014). UV-B radiation causes a damage to biomolecules such as DNA and proteins, suppression of algal physiology and metabolism, and changes in marine aquatic community structure (Jokiel, 1980; Buma et al., 1995; Rai and Mallick, 1998).

Forster and Liining (1996) and Holzinger and Lutz (2006) demonstrated deleterious effects of UV radiation on the photosynthetic characteristics of phytoplankton and distribution of primary producers in aquatic system. A small increase in UV-B exposure could significantly reduce the size of plankton populations, and affect the productivity of pond ecosystem (Sinha and Hader, 2002). It has been reported that UV-B radiation causes vertical migration and mortality of zooplankton due to lack of protective pigments, (Karanas et al., 1979; Speekmann et al., 2000).

Litopenaeus vannamei is a euryhaline species that is capable of surviving over a large range of salinities and temperatures. L.vannamei is an ideal candidate species for coastal aquaculture practice due to its fast growth and disease tolerance capacity (Ponce-Palafox et al. 1997; Rosenberry, 2002). It is known that the Middle East and North African (MENA) region has the highest levels of UV radiation on globe and the radiation causes significant effects in the dynamics of aquatic systems (Bin Mahfoodh et al., 2002). However, no study has either to be reported on the effect of UV radiation on wild or cultured L.vannamei growth performance. Reports revealed that UV radiation has negative effect on aquatic organisms like amphipods, copepods, corals, sea anemones, sea urchins, fishes and amphibians (Hader et al., 2007). Recent observation on high levels of carotenoid deposition in cultured shrimp hepatopancreas and lymph suggests a degree of stress is associated with high UV radiation. Considering the consequence of solar UV radiation in aquatic organisms, a study was conducted to assess the effect of UV-B radiation on phytoplankton chlorophyll, growth performance and β-carotene of Pacific white shrimp, L.vannamei in semi intensive culture system.

Materials and Methods

1 Design of Experiment

Intensive shrimp culture method was carried out in 8 HDPE (High Density Poly Ethylene) liner ponds (300m2) at Fish Farm of King Abdul-Aziz University (KAU) in Jeddah, Saudi Arabia. The experiment duration was extended for a period of 98 days (June –September 2016). The experiment is based on control and treatment ponds, which were designed in triplicate for each of them. All culture ponds were limed and sundried for a week prior to initiate the experiment. In order to filter solar UV radiation at 50%, the treatment ponds were covered by green-house roofing material and the same was fixed 2 meters above from pond water surface. Whereas, control ponds were kept open without net cover (received direct sunlight). On 1st day of experiment, all ponds were filled (30% of pond) with seawater and manured by applying Urea (400g), Molasses (1.5liter) and Diammonium phosphate (200g). The addition of Urea, Molasses and Diammonium with similar quantity have been applied again on 4th and 8th day as well. Pond water level has been increased to 60 and 100% before applying the second and third additions. Two unit of aspirator aerator (1 hp) (Force-7, Acquaeco, Italy) were installed at 40 cm below water level with 35 cm angle downward in each pond. Based on water transparency at 60cm, healthy juveniles (1.2g) of L.vannamei at a rate of 100/m2 were stocked in each pond (hapa survival >95%). Water quality parameters such as temperature, dissolved oxygen, pH and salinity were measured on daily basis using YSI handheld multiparameter water quality meter. Ammonia (unionized), nitrates (NO3), nitrites (NO2), orthophosphates (PO4) and alkalinity (as CaCO3) were measured on weekly basis using (APHA(1998). A standard fish meal based pellet of 35% protein produced by National Aquaculture Group in Jeddah was supplemented at three times per a day (7:00am, 1:00 and 6:00pm) based on a standard feed table in the farm.

2 UV-B, Chlorophyll-a and β-Carotene Measurements

UV radiometer (NIST, Edmund Optics, USA) was used for daily recording of UV-B radiation at surface water and bottom layer (depth 1.5m in the culture ponds at five times (6:00am, 9:00am, 12:00pm, 3:00pm and 6:00pm). Water samples were collected once in every 25 days to estimate Chlorophyll-a following to Dawes (1998) and APHA (1998). Total β-carotene content in shrimp was determined using the method of Kimura and Rodriguez-Amaya (2004) with slight modifications due to standardization of carotene in shrimp meat. Shrimp samples were collected every week to assess the average of body weight (ABW), average weekly growth (AWG) and survival rate. At the end of the experiment, the survival rate and biomass of all shrimp samples in the control and treatment ponds were estimated. Specific growth rate was represented by weight difference before and after the experiment using the following formula:

Specific Growth rate = (Loge W2-LogeW1) / (T2-T1); where W1 is the weight of shrimp sample at before the experiment (T1) and W2 is the weight of shrimp sample at the end of the experiment (T2).

3 Statistical Analysis

One-way analysis of variance (ANOVA) was employed to find out the statistical difference in water quality parameters, chlorophyll content, carotene and growth between control and treatment (Snedecor and Cochran, 1989)

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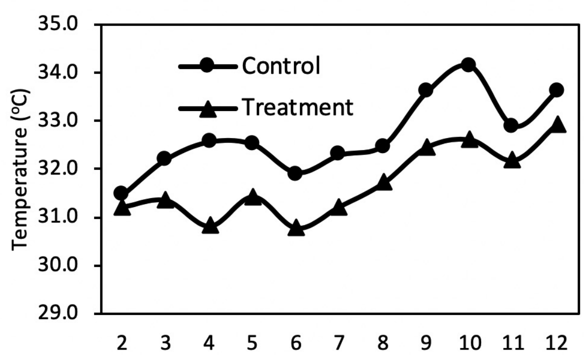
Results

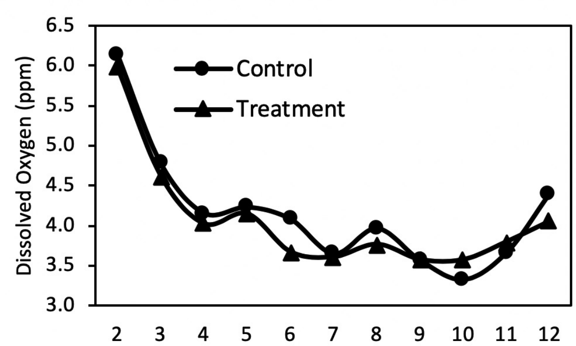
1 Physico-Chemical Parameters of Pond Water

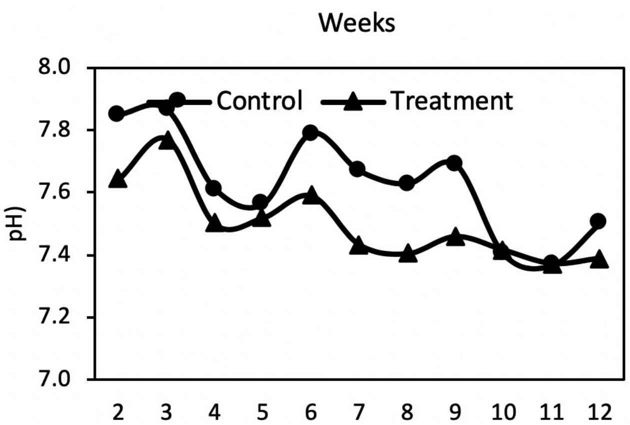
Water quality parameters measured during the study period were found to be conducive for shrimp growth (Table 1) the weekly variation of temperature, salinity, pH, dissolved oxygen and transparency are presented in Figure (1). The statistical analysis indicated that temperature, dissolved oxygen, pH, transparency, ammonia, salinity, nitrite, alkalinity and calcium showed no significant differences ($p>0.01$) between control and treatment ponds. Salinity of Red Sea water ranges between 36-38ppt and bore well (25m depth) water was used for the study The high salinity recorded in culture ponds was due to evaporation of water during culture period. However, nitrate and phosphate content showed significant differences ($p<0.01$) between control and treatment means.

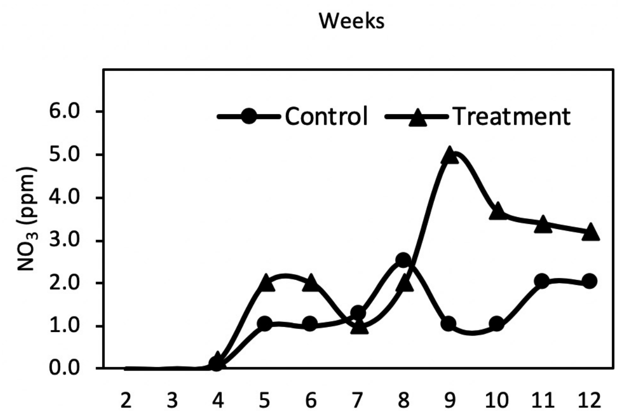
Parameters	Control	Treatment
	Mean ± SD	Mean ± SD
Water temperature (oC)	32.7±0.9	31.8±0.8
Dissolved Oxygen (ppm)	4.3±0.9	4.2±0.9
pH	7.6±0.2	7.5±0.2
Salinity (ppt)	39.6±0.3	39.6±0.3
Transparency (cm)	51.3±19.3	60.6±22.4
NH3 (ppm)	0.02±0.0	0.03±0.0
Alkalinity (ppm)	109.9±10.1	111.8±7.2
NO2 (ppm)	0.1±0.3	0.3±0.6
NO3 (ppm)*	0.9±0.8	1.8±0.5
PO4 (ppm) *	0.5±0.6	0.9±1.0
Ca (ppm)	427.3±55.2	418.2±54.0

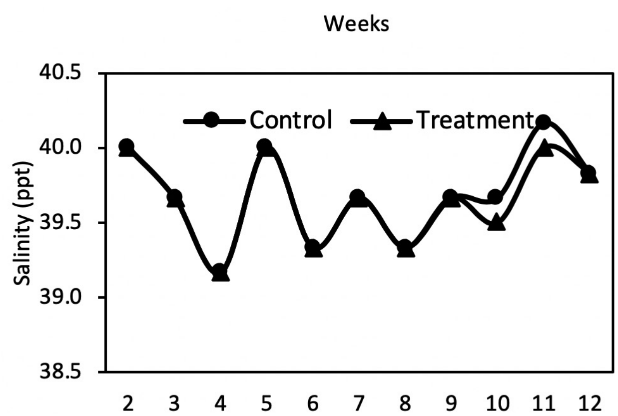
* represents significant difference at a significant level 0.01.

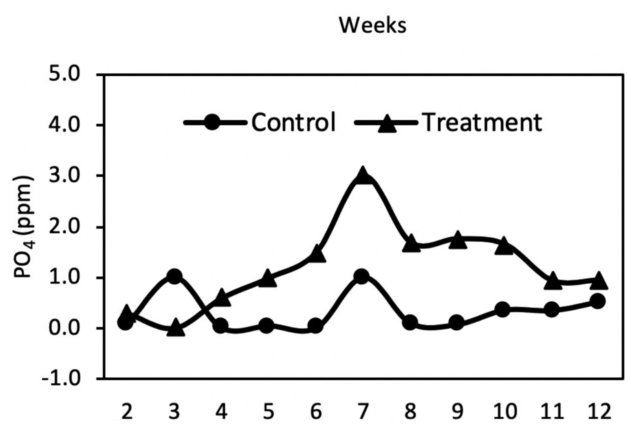


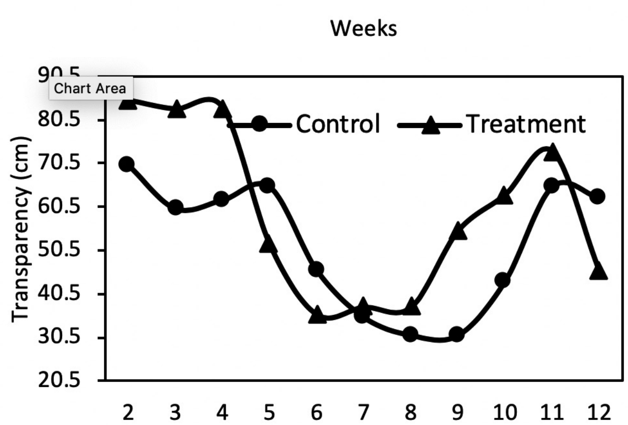












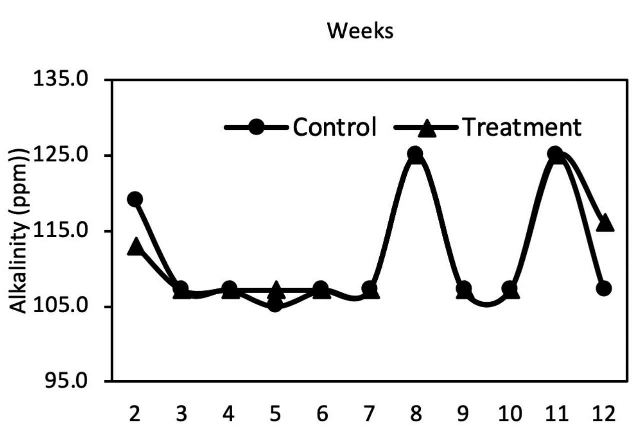


Figure1: Physical water quality parameters recorded during culture period

2 Growth Performance of Shrimp

Average weekly growth performance of shrimp in control and treatment ponds during the culture period is shown in Figure (2). The details on growth and biomass measurements are presented in Table (2). Although shrimp growth in control ponds seems to be better in comparison with treatment ponds, the statistical test indicates no significant differences ($p>0.01$). The average of weekly growth, specific growth rate and food conversion (FCR) were found to be marginally higher in control ponds, which based on direct solar radiation; whereas, biomass was slightly higher in the treatment ponds, which was covered by green-house material.

Parameters	Control	Treatment
	Mean ± SD	Mean ± SD
Initial weight (g)	1.37+0.2	1.09±0.3
Final weight (g)	24.6±1.7	23.8±0.84
Net weight gain (g)	23.2±1.1	22.9±1.02
Average weekly growth (g)	1.7±0.08	1.6±0.07
SGR (%)	1.39±0.02	1.37±0.02
Survival (%)*	78.0±6.0	84.0±9.0
FCR	2.04±0.29	1.98±0.18
Biomass/pond (kg)	578.0±65.0	581.0±53.0
Biomass (kg)/ha	19,266±2166	19,366±1766

* represents significant difference at a significant level 0.01.v

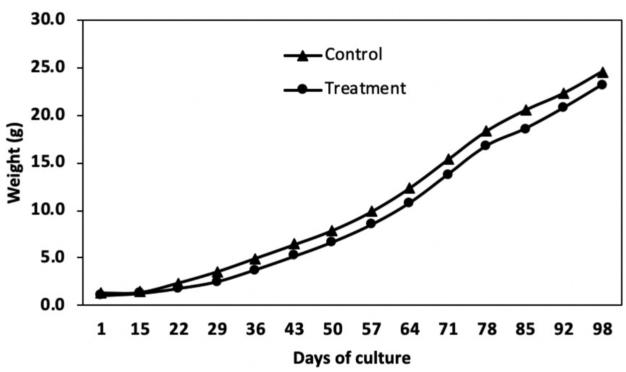


Figure2: Weekly growth of L.vannamei during culture period

3 UV-B Radiation

The measurements of solar UV-B radiation at surface water and at bottom layer (depth 1.5m) during the study period are illustrated in Figure (3). The average of UV- radiation at the surface water in the control ponds and treatment ponds were estimated to be 119.6 and 57.4 µW cm-2 respectively. Significant reduction (p<0.01) by an average of 23.2% in UV-B radiation was noticed in treatment ponds in comparison with the control ponds at surface water, which is attributed to solar filtration.

For bottom layer, the UV-B radiation in the control ponds was 58.6 µW cm-2 and in the treatment ponds was 22.4 µW cm-2 ; which indicates a reduction of 17.4% in the treatment ponds compared to control ponds. The mean of UV-B radiation/day within 3 hours interval is presented in Figure (4). The results showed that the maximum UV-B radiation at surface and bottom layer in both of control and treatment ponds, was recorded at 12 pm and the minimum was at 6am and 6pm.

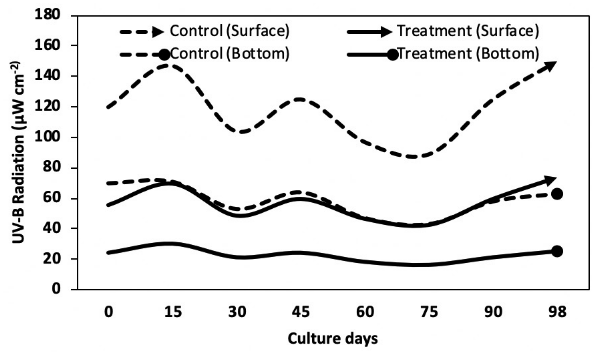


Figure 3: Mean UV-B radiation recorded during the culture period

4 Chlorophyll-a

UV- B radiation and Chlorophyll-a content in control and treatment ponds are presented in Figure (5). Chlorophyll content was found to be low in control ponds in comparison to treatment ponds. The chlorophyll content in the treatment ponds was increased due to low UV radiation. This clearly indicates that UV-B radiation plays a significant role on chlorophyll production by phytoplankton.

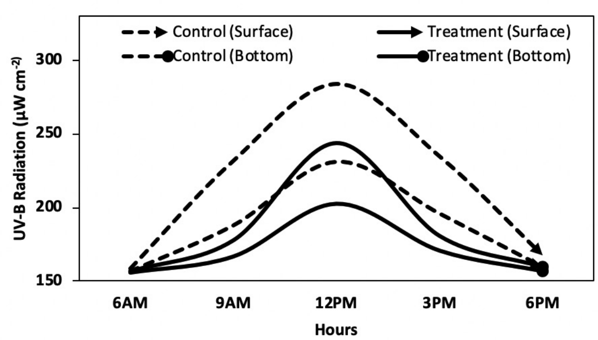


Figure 4: Mean UV-B radiation on 3 hours interval

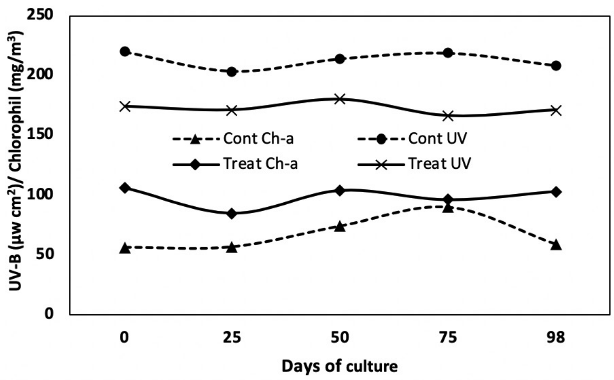


Figure5: UV-B radiation and Chlorophyll-a content in control and treatment ponds

5 β- Carotene in Shrimp

β- Carotene content of shrimp in the control and treatment ponds is presented in Figure (6). The results showed that β- Carotene in the shrimp of treatment ponds are higher than the shrimp grown in the control ponds. The increase of β- Carotene content was recorded under low UV-B radiation in treatment ponds.

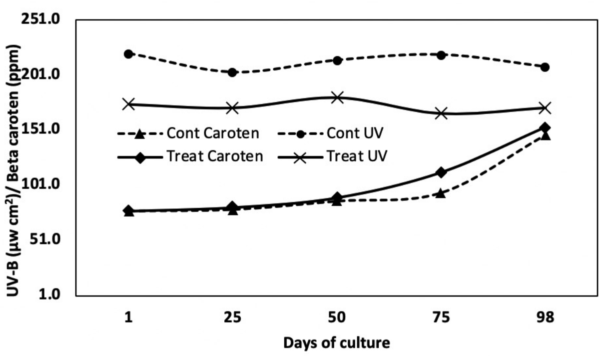


Figure 6: UV-B radiation and β- Carotene content of shrimp in control and treatment ponds

Discussion

The study was designed to examine the effect of UV-B radiation on chlorophyll content in culture ponds and also to assess the deleterious effect of UV-B radiation on growth and β-carotene in pacific white shrimp, L. vannamei. The UV-B radiation has significant effect on primary production of microalgae, bleaching of photosynthetic pigments (Chlorophylls) and carotenoids and making deleterious impacts in aquatic life as indicated by several studies (Hader, 2000; Palmisano et al., 1989; Quesada and Vincent 1993; Halac et al., 2014). According to Hader et al. (2011), with less organic matter in the upper layers of the water, UV radiation can penetrate deeper affecting the living organisms at bottom. The results of the present study showed that physico-chemical parameters in both control and treatment ponds were not influenced by UV-B radiation. Moreover, these parameters were found to be within the suitable range required for shrimp growth. The low UV-B radiation recorded at bottom of culture ponds may be due to the presence of algae and organic content formed due to shrimp culture.

The effect of UV-B radiation on phytoplankton and photosynthetic activity have extensively investigated by Hader (2000) and Hader et al., (2011). The results of these studies confirmed that increase in levels of UV-B radiation seriously causes a decrease in chlorophyll-a content and reduces the number in Phormidium uncinatum, Euglena gracilis, Peridinium gatunense, Anabaena variabilis, Ocillataria tenuis and Cryptomonas maculata. Vincent and Roy (1993) reported that reduction in UV-B radiation significantly affect chlorophyll-a content in aquatic microorganisms. The results of the present study revealed that chlorophyll-a content is increased with the decrease in UV-B radiation in treatment ponds; where sunlight was filtered by 50%, which is agreed to the findings of Vincent and Roy (1993).

Hader and Worrest (1991) found that UV-B radiation bleached the carotenoid pigments of marine Cryptomonad, Cryptomonas maculata. A reduction in Chlorophyll-a and carotenoid was also reported in marine diatoms, Ditylum brightwellii, Thalassiosira rotula and Odentella sinensis (Dohler, 1984; Sebastian et al., 1994). The present study demonstrated that β-carotene content of shrimp varies between control and treatments due to difference in UV-B radiation. High content was associated with low UV-B radiation in treatment ponds; indicating the influence of UV-B radiation on carotenoid pigment production of shrimp.

UV-B radiation induces decreased growth rate and survival of many aquatic diatoms, Dinoflagellates, Cyanobacteria and Euglena (Ekelund, 1991; Behrenfeld et al., 1994; Davidson et al., 1994; Quesada et al., 1995; Gerber and Hader, 1992; Xue, et al., 2005). However, no attempt was made to find out the effect of UV-B radiation on shrimp growth performance. Although the results of the present study showed that shrimp growth in the treatment ponds was comparatively at low rate compared to the control ponds, the differences are not considered statistically significant. The high biomass found in the treatment ponds can be attributed to the high shrimp's survival rate. Eventually, it could be concluded that UV-B radiation has no direct effect on growth rate of pacific white shrimp; however, the primary productivity of culture ponds are significantly affected by UV-B radiation and thereby plays an important role in the culture system of pacific white shrimp.

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REFERENCES

APHA (1998) American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 20th Edition. American Public Health Association, Washington, D.C. pp 1-112.

Behrenfeld MJ; LeeH; and Small LF (1994) Interactions between nutritional status and long-term responses to ultraviolet radiation stress in a marine diatom. Marine Biology, 118: 523-530.

Bin Mahfoodh M; Al-Ayed MS; and Al-Dhafiri AM (2002) Measurement and assessment of ultraviolet radiation in Riyadh, Saudi Arabia. International Journal of Sustainable Energy, 23(1): 31-38.

Buma AGJ; Van Hannen EJ; Roza L; Veldhuis MJW; and Gieskes WWC (1995) Monitoring ultraviolet-B-induced DNA damage in individual diatom cells by immuno-fluorescent thiamine dimer detection. Journal of Phycology, 31: 314-321.

Davidson AT; Bramich D; Marchant AJ; and Mcminn A (1994) Effect of UV-B radiation on growth and survival of Antarctic marine diatoms. Marine Biology, 119: 507-515.

Dawes CJ (1998) Marine Botany (2nd ed.). John Wiley & Sons, USA. pp 62-91.

Dohler G (1984) Effect of UV-B radiation upon marine diatoms, Lauderua annulata and Thalassiosira rotula grown in different salinities. Marine Biology, 83: 247, 253.

Ekelund NGA (1991) The effects of UV-B radiation on dinoflagellates. Journal of Plant Physiology, 138: 274-278.

Forster RM; and Liining K (1996) Photosynthetic response of Laminaria digitata to ultraviolet A and B radiation. Scientia Marina, 1: 65-71.

Gerber S; and Hader DP (1992) UV effects on photosynthesis, proteins and pigmentation in the flagellate, Euglena gracilis. Biochemical and spectroscopic observations. Biochemical Systematics and Ecology, 20: 485-492.

Hader DP (2000) Effects of solar UV-B radiation on aquatic ecosystems. Advances in Space Research, 26(12): 2029-2040.

Hader DP; Kumar HD; Smithc RC; and Worrest RC (2007) Effects of solar UV radiation on aquatic ecosystems and interactions with climate change. Photochemical & Photobiological Sciences, 6: 267-285

Hader DP; Helbling EW; Williamson CE; and Worrest RC (2011) Effects of UV radiation on aquatic ecosystems and interactions with climate change. Photochemical & Photobiological Sciences, 10: 242-260

Hader DP; and Worrest RC (1991) Effects of enhanced solar ultra-violet radiation on aquatic ecosystems. Photochemical & Photobiological Sciences, 53: 717-725.

Halac SR; Villafane VE; Goncalves RJ; and Helbling EW (2014) Photochemical responses of three marine phytoplankton species exposed to ultraviolet radiation and increased temperature: role of photo protective mechanisms. Journal of Photochemistry and Photobiology B, 141: 217-227.

Helbling EW; Barbieri ES; Marcoval MA; Goncalves RJ; and Villafane VE (2005) Impact of solar ultraviolet radiation on marine phytoplankton of Patagonia, Argentina. Journal of Photochemistry and Photobiology, 81(4): 807-818.

Holzinger A; and Lutz C (2006) Algae and UV irradiation: effects on ultra-structure and related metabolic functions. Micron, 37(3): 190-207.

Jokiel PL (1980) Solar radiation and coral reef epifauna. Science, 207, 1069-1073.

Karanas JJ; Van Dyke K; and Worrest RC (1979) Mid ultraviolet (UV-B) sensitivity of Acartia clausii Giesbrecht (Copepoda). Limnology and Oceanography, 24: 1104-1116.

Kimura M; and Rodriguez-Amaya DB (2004) Harvest plus handbook for carotenoids analysis; International food policy research Institute Washington DC, pp:2-11: 12-54.

Palmisano AC; Wharton RA; Cronin SE; and Des Marais DJ (1989) Lipophilic pigments from the benthos of a perennially ice-covered Antarctic lake. Hydrobiologia, 178: 73-80.

Ponce-Palafox J; Martinez-Palacios CA; and Ross LG (1997) The effects of salinity and temperature on the growth and survival rates of juvenile white shrimp, Penaeus vannamei, Boone, 1931. Aquaculture, 157: 107-115.

Quesada A; and Vincent WF (1993) Adaptation of Cyanobacteria to the light regime within Antarctic microbial mats. Verhandlungen des Internationalen Verein Limnologie, 25: 123-128.

Quesada A; Mouget JL; and Vincent WF (1995) Growth of Antartic Cyanobacteria under ultraviolet radiation. UV-A counteracts. Journal of Phycology, 31: 242-248.

Rai LC; and Mallick N (1998) Algal responses to enhanced Ultraviolet B radiation. Proceedings of the Indian National Science Academy, B64 (2):125-146.

Rosenberry B (2002) World shrimp farming 2002. Shrimp News International, 276 pp.

Sebastian C; Scheuerlein R; and Hader DP (1994) Effects of solar and artificial ultraviolet radiation on pigment composition and photosynthesis in three Prorocentrum strains. Journal of Experimental Marine Biology and Ecology, 182: 251-263.

Sinha RP; and Hader DP (2002) Life under solar UV radiation in aquatic organisms. Advances in Space Research, 30(6):1547-56.

Snedecor GW; and Cochran WG (1989) Statistical Methods. 8th Ed. Iowa State University Press, Iowa. p. 1-218.

Speekmann C; Bollens SM; Avent SR (2000) The effect of ultraviolet radiation on the vertical distribution and mortality of estuarine zooplankton. Journal of Plankton Research, 22 (12): 2325-2350.

Vincent WF; and Roy S (1993) Solar ultraviolet-B radiation and aquatic primary production: damage, protection, and recovery. Environmental Reviews, 1: 1- 12.

Xue L; Zhang Y; Zhang T; An L; and Wang X (2005) Effects of Enhanced Ultraviolet-B Radiation on Algae and Cyanobacteria. Critical Reviews in Microbiology, 31: 79-89.