Physiological and photosynthesis enhancement of Thai rice (*Oryza sativa* L.) cultivars by chitosan

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ABSTRACT

This research aims to study the effect of chitosan on 10 rice cultivars. Number of leaf, tiller number per plant, stem height, leaf area, photosynthesis rate and dry weight were analyzed. Seeding were immersed by chitosan concentration level at 0.01, 0.05 and 0.10 % w/v and transplanted in the tray for 2 weeks and further grew in 8 inch pot contained soil and sprayed with all those chitosan solution compared to the control group. The results showed the increasing of all studied factors. The concentration of chitosan at 0.05% w/v would obviously cause more effect than chitosan concentration at 0.01 and 0.10% w/v. Especially to the photosynthetic activity of RD41, RD49 and RD47, the activity increased up to 41.93, 37.80 and 34.05%, respectively compared to the control group. Also increasing of number of leafs, tiller number per plant, leaf area, total dry weight and stem height. Overall, the application of chitosan to the growth of rice was significantly enhanced which affected to the photochemical reaction of rice especially to RD41, RD47, RD49 and PL2. Rice cultivars treated environmentally chitosan was an effective way to enhance and improve rice production.

Keywords: chitosan, rice, photosynthesis, dry weight, physiology

INTRODUCTION

Now a day's climate limits the worldwide cultivated rice productivity, often stress condition due to the increasing of temperature, drought and air pollution, etc. Moreover, the useless of land affect to the rice production which is contrast to the demand of rice from population. Raised pesticide uptake not only used for food productive but also its harm human being. Thus chitosan is one of the effective choice to increase rice productivity due to its natural biopolymer which is elicitor which is activate plant immune at stress condition (Ganesh et al., 2002).

Chitosan is a natural amino polysaccharide extracted from chitin. These substances has significant impacts on the stimulates the growth of plants such as increasing in photosynthetic, symbiotic nitrogen fixation and induce NOD gene, enhancing nutrient uptake, increasing in crop production, reducing stress of plant and being used as antibacterial for plants (Van et al., 2013). Beneficial effect of chitosan in carbon source microbes in soil and minerised organic nutrient into inorganic nutrient forms which is easily absorbed by plant root (Boonlertnirun et al., 2006; Sun et al., 2008). With non-toxicity and biodegradable, these substances have been applied in agricultural field (Salachna and Zawaddzińska, 2014; Farouk et al., 2013; Boonlertnirun et al., 2006; Boonlertnirun et al., 2008).

Application of chitosan to okra (*Hibiscus esculentus* L.) increased activity of leaf number plant^{-1}, total dry weight, absolute and relative growth rates, photosynthesis and yield. The elevation of those results was depended on the concentration of chitosan (Mondal et al., 2012). The results showed the positive effects at early growth stages in okra. These results are consistent with Salachna and Zawaddzińska (2014), who reported that leaf and shoots number enhanced by the application of chitosan in flowers and corns of Gompey freesia cultivated (*Freesia* spp.). Bittelli et al. (2001) studied chitosan application on the reduction of transpiration by induced closure of the plant's stomata subsequently reduced water used and increased biomass-to-water ratio.

The purpose of this study was to study the effect of chitosan on physiology, yield and photosynthesis of 10 rice cultivars in order to obtain the knowledge in which chitosan affects plant biomass production under the climate change.

MATERIALS AND METHODS

Plant materials and experimental design

Ten rice cultivars namely Rice Department 7 (RD7), Rice Department 9 (RD9), Rice Department 29 (RD29), Rice Department 41 (RD41), Rice Department 47 (RD47), Rice Department 49 (RD49), Rice Department 59 (RD59), Phitsanulok 2 (PL2), Khao Gaw Diaw 35 (KGD35) and Khao Dawk Mali 105 (KDML105) were used as the test crop. Seeding were immersed by chitosan concentration level at 0.01, 0.05 and 0.10 %w/v and transplanted in the plastic tray for 2 weeks and further grew in 8 inch pot contained clay soil for 2 weeks and sprayed with all those chitosan solution compared to the control group (Fig 1).

An experiment of pot was set up in Nakhonsawan province, Thailand. The soil used was a slit loam from Phichit province, Thailand.

Preparation of chitosan solution

In brief, a series of medium molecular weight (50 kDa) chitosan solution (0.01, 0.05 and 0.10% w/v) were prepared by dissolved 0.1 g in 100 mL 0.1% w/v acetic acid solution. The first experiment was grown the rice in the small trays for 2 weeks and then transplanted to growth pot contained soil. In the beginning, all trays were laid out in a completely randomized design with 3 replications. Ten rice cultivars were sprayed with 3 different concentrations of chitosan for 3 replicates.

Measurements of photosynthesis and physiology

Photosynthesis analyzed by a portable photosynthesis system (LI- 6400, LiCor, Lincoln, NE, USA) with an open system and logged at carbon dioxide concentration at 400 μmol mol^{-1} in the leaf chamber with a constant air flow rate of 500 μmol s^{-1}. The photosynthetic photon flux density (PPFD) was maintained at 1500 μmol m^{-2} s^{-1} by an artificial light source (Shimono et al., 2004). The principle of an open system LI-6400 based on the differences in CO_2 and H_2O in an air stream which the photosynthesis and transpiration were recorded.

Leaf numbers, tiller numbers, stem height were recorded at harvesting time.

The leaf area was measured by LI-3100 (LI-COR, Lincoln, USA) in order to compare the differences in each treatment.

Shoot and root of plant samples were final harvested, washed and then subsequently dried in a hot air oven at 70 °C for 72 hours before weighing.

Statistical analysis

The data was analyzed by Analysis of variance: one way ANOVA with different between group was performed by Duncan's New Multiple Range Test (DMRT).

RESULTS AND DISCUSSIONS

Leaf number plant^{-1}

Leaf number plant^{-1} is one of the significant parameters related to physiology which affected the growth and yield of agricultural plants (Kumari et al., 2013). The leaf plant^{-1} in rice was set at a value between 42.00-57.00 leaf plant^{-1}. RD7, RD9, RD41, RD47, RD49 and PL2 had more leafs (46.33 – 57.00 leafs) than RD29, RD59, KDML105 and KGD35 (42.00 – 49.33 leafs) with statistically significant. From the results, RD9 showed larger number of leafs at 57.00 leaf plant^{-1}, whilst it was only 43.67 leaf plant^{-1} for RD29 at the chitosan concentration of 0.05 ppm. The treatment effects and results of statistical analyze for number of leafs presented in Table 1. The percentage changed of RD7, RD9, RD41, RD47, RD59 and PL2 under 3 different concentrations of chitosan were increased (Fig. 1a).

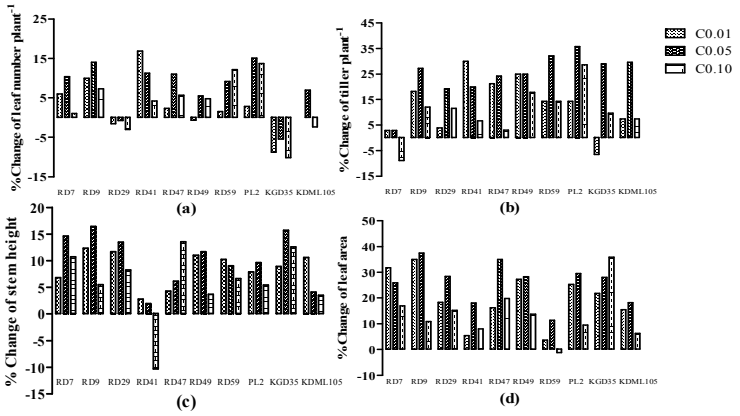

Figure 1 The percentage change of leaf number plant^{-1} (a) tiller plant^{-1} (b) stem height (c) and leaf area of rice (d) when compare control.

Under chitosan treatment at the concentration of 0.01, 0.05 and 0.10% w/v, the number of leafs in most of rice cultivars increased with no a statistical significance when compared with the control group. The number of leaf was higher in 0.05% w/v chitosan treatment since resulting from increase in plant tiller in rice (Mondal et al., 2012) and chitosan enhances a level of carbon metabolism, photosynthesis and cell redox homeostasis which are composed of main 3 processes of protein (Chamnamanoontham et al., 2015). Results revealed that number of leafs was increased in chitosan applied plants than control. Although the number of leafs under chitosan treatment was increased but this was not effect to 3 rice cultivars; RD 29, KGD35 and KDML105 which is the average number of leafs decreased due to their stimulation

The effect of the different concentration of chitosan have been studied, our results showed that the application of higher concentration of chitosan (0.05% w/v), nutrient and nitrogen uptake of rice reduced. A similar effect of chitosan on the yield of Rubusta coffee (*Coffea robusta* Pierre ex Froehner L.) was observed by Van et al., (2013). Therefore, the optimum concentration of chitosan at level 0.05% w/v results increased number of leafs which affect the photosynthesis.

Table 1 The leaf number of rice plant treated by chitosan at concentration of 0.01, 0.05, 0.10% w/v compared to the control.

Cultivar	leaf number (leaf per plant)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
RD7	49.83±2.94a	52.83±1.58a	55.00±1.15a	50.33±0.66a
RD9	50.00±2.46a	55.00±2.51a	57.00±5.68a	53.67±1.66a
RD29	44.00±1.00a	43.33±0.33a	43.67±0.33a	42.67±2.28a
RD41	47.33±0.33a	55.33±4.48a	52.67±2.66a	49.33±0.50a
RD47	49.83±3.44a	51.00±4.04a	55.33±1.33a	52.67±1.66a
RD49	48.67±0.66ab	48.33±0.66b	51.33±0.88a	51.00±1.00ab
RD59	43.67±1.45a	44.33±0.33a	47.67±1.20a	49.00±3.00a
PL2	46.33±3.17a	47.67±1.45a	53.33±2.60a	52.67±2.40a
KGD35	49.33±3.75a	45.00±2.08a	46.67±1.33a	44.33±0.33a
KDML105	43.00±0.57a	43.00±2.51a	46.00±2.00a	42.00±1.52a

The data represent the mean±SE (n = 3). Different letters indicate significant differences among treatments at $p < 0.05$.

Tiller number per plants

The average of tiller number per plant of 10 rice cultivars under week 4 showed the highest tiller at 0.05% w/v chitosan subsequently 0.01 and 0.10% w/v chitosan, respectively, whilst the lowest tiller was observed at the control group. The average value of the tiller number per plant of 10 rice cultivars at 0.01, 0.05, 0.10% w/v chitosan and control was found at 12.33, 11.23, 10.90 and 9.93 tiller plants^{-1}, respectively. Only KGD35 and RD7 showed the lower tiller when compared with the control since production of less in plant height. Under 0.05% w/v chitosan treatment, chitosan regulated the tiller of PL2, RD59 and KDML105 by 12.67, 13.33 and 11.67 tiller plants^{-1}, respectively. The tiller per plant of the control was observed at 9.33, 9.33 and 9 tiller plants^{-1}, respectively (Table 2). Moreover, the comparing between 0.05% w/v chitosan and the control, the tiller of PL2, RD59 and KDML105 increased by 35.71, 32.14 and 29.63%, respectively (Fig 1b).

Results revealed that tiller increased with increasing concentration of chitosan up to 0.05% w/v, resulting from increase in the stem height. Similarly, Boonlertnirun et al. (2006) also reported that the application of chitosan remarkably increased tiller rice cultivar Supan Buri 1.

Table 2 Tiller number of rice plant after applied different chitosan concentration at 0.01, 0.05, 0.10% w/v and control.

Cultivar	Tiller number (tiller per plant)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
RD7	11.33±0.33a	11.67±0.33a	11.67±0.66a	10.33±0.66a
RD9	11.00±1.15b	13.00±0.57ab	14.00±0.57a	12.33±0.33ab
RD29	8.67±0.33a	9.00±0.57a	10.33±0.66a	9.67±0.40a
RD41	10.00±0.57b	13.00±1.15a	12.00±0.00ab	10.67±0.50b
RD47	11.00±0.57b	13.33±1.20ab	13.67±0.66a	11.33±0.33ab
RD49	9.33±0.33b	11.67±0.33a	11.67±0.33a	11.00±0.00a
RD59	9.33±0.66b	10.67±0.33ab	12.33±0.33a	10.67±0.66ab
PL2	9.33±0.88b	10.67±0.88ab	12.67±1.20a	12.00±0.57ab
KGD35	10.33±1.20b	9.67±0.66b	13.33±0.33a	11.33±0.33ab
KDML105	9.00±0.57a	9.67±0.66a	11.67±1.20a	9.67±1.20a

The data represent the mean±SE (n = 3). Different letters indicate significant differences among treatments at $p < 0.05$.

Stem height

Statistical analysis of stem height showed a higher in all chitosan treatment with no statistically significant (Table 3). Under 0.05% w/v chitosan, the change of stem height of RD9, KDG35, RD29, RD49 and PL2 were obviously drastically increased in week 4 by 16.44, 15.70, 13.50, 11.66 and 9.67% (Fig. 1c), respectively compared with the control. These results indicate that rice cultivar application of chitosan enhanced the enzymes activities of nitrogen metabolism, which increased plant growth. A similar positive effect of chitosan on the height of okra was observed by Mondal et al. (2012). Salachna and Zawadzińsak (2014) showed that the highest soaking freesia corms (*freesia* spp.) in chitosan solutions before planting accelerated on the growth and yield of flowers and corms of freesia.

Table 3 Stem Height (cm) of rice. Plant samples were applied by chitosan concentration 0.01, 0.05, 0.10% w/v and control.

Cultivar	Stem Height (cm)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
RD7	51.17±1.74b	54.67±0.33ab	58.67±2.33a	56.67±2.18ab
RD9	48.67±1.20c	54.67±1.66ab	56.67±1.20a	51.33±1.20bc
RD29	54.33±3.48a	60.67±2.02a	61.67±1.45a	58.83±1.90a
RD41	60.00±1.00ab	61.67±2.40a	61.17±1.69a	53.83±3.75b
RD47	54.00±1.00b	56.33±2.90ab	57.33±2.33ab	61.33±0.88a
RD49	54.33±0.88b	60.33±1.45a	60.67±0.88a	56.33±2.18ab
RD59	55.33±1.20b	61.00±0.00a	60.33±1.45ab	59.00±2.64ab
PL2	55.00±1.15b	59.33±0.66a	60.33±1.33a	58.00±1.52ab
KGD35	63.67±2.18b	69.33±0.88a	73.67±0.33a	71.67±1.85a
KDML105	56.67±3.48a	62.67±3.28a	59.00±2.64a	58.67±4.33a

The data represent the mean±SE (n = 3). Different letters indicate significant differences among treatments at $p < 0.05$.

Leaf area

The research showed that soaking and spraying 10 rice cultivars in chitosan solution had stimulating effect on the leaf area. From Table 4, the chitosan treated rice had leaf area by average 14.96-24.12 cm^2 $blade^{-1}$ higher as compared with the control (11.85-20.57 cm^2 $blade^{-1}$). Moreover, RD9 and RD47 treated 0.05% w/v chitosan was by 37.55% and 34.99% higher as compared with the control, whereas 8 other rice cultivars were observed between 11.41% - 28.43% (Fig. 1d). These results revealed that the increasing of leaf area affects the photosynthetic activity due to the photochemical reaction and the exchange gases in carbon fixation occurs at the leaf. Therefore, chitosan treated rice response to photosynthesis rate. This was due to the relative of chlorophyll content as a result of application of chitosan enhance plant to uptake the nutrients in leaf (Salachna and Zawadzińsak, 2014).

Table 4 Leaf area of rice plant were applied by different chitosan concentration 0.01, 0.05, 0.10% w/v and control.

Cultivar	Leaf area (cm^2 $blade^{-1}$)			
	Control	**Chitosan 0.01%**	**Chitosan 0.05%**	**Chitosan 0.10%**
RD7	11.85±0.59c	15.62±0.24a	14.93±0.70ab	13.86±0.31b
RD9	14.46±0.86b	19.52±1.24b	19.29±1.08a	16.02±0.86b
RD29	18.33±1.28b	21.70±0.61a	23.54±0.70a	21.13±1.08ab
RD41	18.36±0.84b	19.35±0.77b	21.70±0.72a	19.84±0.60ab
RD47	15.30±0.97c	17.79±0.49b	20.65±0.88a	18.32±0.68b
RD49	16.85±0.63b	21.45±1.27a	21.61±1.02a	19.16±1.45ab
RD59	20.57±0.47a	21.32±0.87a	22.91±0.97a	20.34±0.94a
PL2	18.68±0.97b	23.40±0.52a	24.20±0.95a	20.45±0.64b
KGD35	16.07±1.31b	19.58±2.21ab	20.58±0.81ab	21.84±1.43a
KDML105	16.81±1.26b	19.42±0.57a	19.89±0.68a	17.87±0.62ab

The data represent the mean±SE (n = 6). Different letters indicate significant differences among treatments at $p < 0.05$.

Photosynthesis rate

In rice, different cultivar of rice showed their different photosynthesis level. The enhancement of photosynthetic rate was found in RD29, RD47 and RD9 which correspond to 23.32, 22.59 and 22.25 μmol $m^{-2}s^{-1}$, respectively (the average of 3 concentrations of chitosan). Moreover, the immersing and spraying chitosan also enhanced the photosynthesis rate significantly with 0.05%w/v chitosan. Under the condition of chitosan uptake, the photosynthesis involved with both concentration of chitosan and cultivar of the rice. The net photosynthesis of RD41, RD49, RD47 and RD29 were significantly improved at level 41.93, 37.80, 34.05 and 33.07%, respectively (Fig. 2a) when combining immerse and spray of 0.05% w/v chitosan. However, only chitosan treated RD59 did not increased in photosynthesis compared to control group (Table 5). The enhancement of photosynthetic pigment content suggests that chitosan treated rice led to an increase of photosynthetic activity, increase plant growth and yield. These results are in consistent with Mondal et al. (2012) who reported that the chitosan increased photosynthesis in leaves of okra. A 25 mg L^{-1} chitosan sprays on okra plants result increased photosynthesis. The similar results was reported by Van et al. (2013) that coffee plants treated with high molecular weight chitosan showed a 30-60% increase in the photosynthesis rate. Again, Khan et al. (2002) and El-Tantawy (2009) reported that the treatment of chitosan increased photosynthesis in leaves of maize and soybean as well as tomato. Therefore, it was confirmed that the photosynthetic related to the chlorophyll content in the leaves, as a results of the increasing of leaf area by chitosan application.

Chitosan might be useful for crop production due to the photosynthesis is the physiological basis for crop biomass and yield, and changes to the plant photosynthesis rate can directly reflect the influence of stress on the photosynthetic physiology of plants (Sun et al., 2013). Beneficial effects of chitosan in enhancing the photosynthesis of the plants to reduce the negative effect cause from the climate change and air pollution such as acid rain (Wang et al., 2014), High temperature (Cao et al., 2009), Ozone (Sarkar and Agrawal, 2012) could inhibit in photosynthesis.

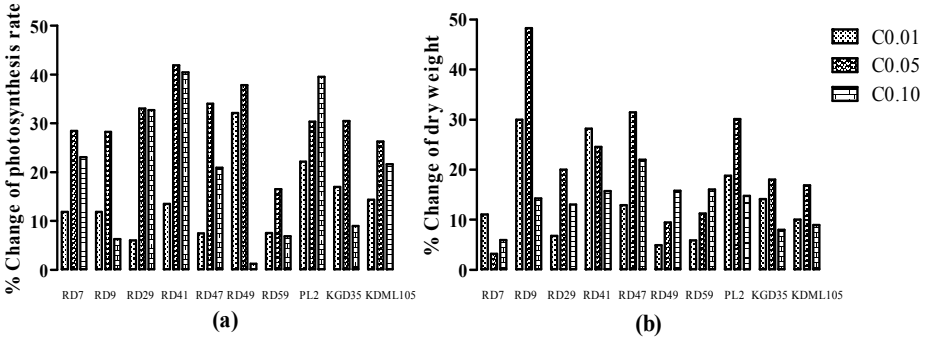

Figure 2 The percentage change of photosynthesis rate (a) and dry weight (b) of rice when compare control. Plant samples were allocated in chitosan 0.01, chitosan 0.05 and chitosan 0.10

Table 5 Photosynthesis rate of rice plant were applied by different chitosan concentration 0.01, 0.05, 0.10% w/v and control.

Cultivar	Photosynthesis Rate (µmol $m^{-2}s^{-1}$)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
RD7	16.52±0.50c	18.48±0.68b	21.22±0.75a	20.33±0.56ab
RD9	19.27±1.59b	21.55±1.02ab	24.72±0.45a	20.48±0.95b
RD29	18.80±1.62b	19.93±0.74b	25.02±1.00a	25.00±0.81a
RD41	15.90±16.1b	18.05±0.74b	22.51±1.20a	22.33±1.22a
RD47	18.70±0.80c	20.10±1.03bc	25.07±0.58a	22.61±1.11ab
RD49	13.80±0.60b	18.23±1.00a	19.02±1.17a	13.97±0.76b
RD59	18.58±1.10a	19.98±0.36a	21.65±1.27a	19.87±2.15a
PL2	14.60±0.90c	17.83±1.16b	19.03±0.40ab	20.37±0.35a
KGD35	17.03±1.02b	19.93±1.23a	22.23±1.20a	18.57±0.80b
KDML105	16.25±0.85b	18.58±0.34a	20.52±0.72a	19.77±0.57a

The data represent the mean±SE (n = 6). Different letters indicate significant differences among treatments at $p < 0.05$.

Dry weight

Soaking and spraying 10 rice cultivars in chitosan before and after planting accelerated the root and total dry weight. It was found that as a result of chitosan used with 0.05%w/v, total dry weight of RD9, PL2 and RD47 were 19.95g, 16.45g and 16.45 g (Table 6), respectively highest as compare with the control (Fig 3). Moreover, the relative photosynthesis, tiller plant^{-1} and number of leafs of RD9, RD47, PL2 and RD41 increased significantly (by 4 weeks) at 48.25, 31.46, 30.12 and 24.57%, respectively (Fig 2b). A similar positive influence of chitosan on rice cultivar features was also observed in foliar (Boonlertnirun et al., 2008). A maximum dry weight of 2,620 g Tr^{-1} was obtained compare to 2,383 g Tr^{-1} from the control by seed soaking and foliar spraying. The research by Katiyar et al. (2015) showed a positive chitosan stimutation on various crops were accelerated the plant growth and enhanced process in developing stage. Since N-acetylchitosaccharide from chitosan molecule caused higher root growth involing chemo/physiological of the cell. Again, this results were supported by the work of Mondal et al., (2012) who reported that the morphological, growth, biochemical parameter and yield attributes of okra were enhanced with the application of chitosan.

Figure 3 Rice plant were applied by chitosan concentration 0.05% w/v and control.

Table 6 Dry weight of rice plant were applied by chitosan different concentration 0.01, 0.05, 0.10% w/v and control.

Cultivar	Dry weight (g)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
Shoot dry weight				
RD7	6.33±0.56a	6.47±0.46a	6.44±0.26a	6.64±0.17a
RD9	6.70±0.58b	8.42±0.45ab	9.68±0.97a	7.19±0.59b
RD29	6.38±0.45a	7.31±0.49a	7.74±0.56a	7.38±0.39a
RD41	6.73±0.91b	10.46±0.38a	10.03±0.16a	7.98±0.38b
RD47	6.88±0.24b	7.25±0.25ab	8.64±0.71a	7.06±0.35b
RD49	6.78±0.23a	7.39±1.01a	7.08±0.68a	7.52±0.27a
RD59	6.41±0.63	7.69±0.60a	7.17±0.53a	7.33±0.64a
PL2	7.20±0.75b	8.79±0.56ab	9.27±0.23a	8.46±0.42ab
KGD35	6.80±0.49a	8.16±0.72a	8.30±0.15a	8.02±1.43a
KDML105	4.10±0.50a	5.07±0.72a	5.18±0.34a	5.03±0.32a
Root dry weight				
RD7	6.21±0.41a	7.46±1.08a	6.50±0.56a	6.64±0.53a
RD9	6.76±0.84b	9.09±0.40ab	10.27±1.07a	8.20±0.61ab
RD29	5.30±0.31a	5.63±0.65a	6.81±0.42a	6.32±0.49a
RD41	5.14±0.32b	6.28±0.73ab	6.24±0.56ab	7.13±0.33a
RD47	5.63±0.29a	6.88±0.22a	7.81±0.59a	8.21±1.61a
RD49	6.76±0.57a	6.81±0.10a	7.74±0.74a	8.16±1.19a
RD59	6.38±0.42a	5.84±0.55a	7.05±0.54a	7.51±1.43a
PL2	5.44±0.57b	6.22±0.45ab	7.18±0.35a	6.05±0.19ab
KGD35	6.58±0.33a	7.10±0.39a	7.49±0.86a	6.43±0.75a
KDML105	5.79±1.04a	5.82±0.93a	6.38±0.89a	5.74±0.66a

The data represent the mean±SE (n = 3). Different letters indicate significant differences among treatments at $p < 0.05$.

Table 6 (cont.) Dry weight of rice plant were applied by chitosan different concentration 0.01, 0.05, 0.10% w/v and control.

Cultivar	Dry weight (g)			
	Control	Chitosan 0.01%	Chitosan 0.05%	Chitosan 0.10%
Total dry weight				
RD7	12.54±0.80a	13.92±0.62a	12.94±0.29a	13.28±0.37a
RD9	13.46±0.84b	17.50±0.76ab	19.95±2.04a	15.38±0.99b
RD29	12.12±0.27b	12.94±0.54ab	14.55±0.96a	13.70±0.17ab
RD41	13.06±1.09b	16.74±1.02a	16.27±0.74a	15.12±0.35ab
RD47	12.51±0.51b	14.13±0.47ab	16.45±0.86a	15.27±1.63ab
RD49	13.54±0.80a	14.20±1.04a	14.82±0.59a	15.68±0.16a
RD59	12.78±0.91a	13.54±0.97a	14.22±0.21a	14.84±2.05a
PL2	12.64±0.87b	15.01±1.01ab	16.45±0.26a	14.51±0.50ab
KGD35	13.38±0.49a	15.27±0.65a	15.80±0.71a	14.45±2.18a
KDML105	9.89±0.73a	10.89±1.46a	11.56±1.81a	10.77±0.96a

The data represent the mean±SE (n = 3). Different letters indicate significant differences among treatments at $p < 0.05$.

CONCLUSION

Chitosan solution had significant impacts on physiology and photosynthesis rate of 10 Thai rice cultivars such as number of leaf, stem height, leaf area, dry weight and tiller. Theses impacts lead on the enhancing growth parameters of rice cultivars. The concentration of chitosan at 0.05 %w/v would obviously cause more effect than chitosan concentration at 0.01 and 0.10 %w/v. Especially to the photosynthetic activity of RD41, RD49, RD47 and RD29, the activity increased up to 41.93%, 37.80%, 34.05% and 33.07%, respectively compared to the control group. Overall, the application of chitosan to the growth of rice was significantly enhanced which affected to the photochemical reaction of rice especially to RD41, RD47, RD49 and PL2. Chitosan might be useful for rice production to stimulate growth and increase rice photosynthesis rate as well as yields.

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