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Research Article

Seed priming as a promising technique to improve growth, chlorophyll, photosynthesis and nutrient contents in cucumber seedlings

Ali ANWAR[1,2], Xianchang YU[1], Yansu LI[1*]

[1]*Chinese Academy of Agricultural Sciences, Institute of Vegetables and Flowers, Beijing 100081, China; liyansu@caas.cn (*corresponding author)*
[2]*Graduate School of International Agricultural Technology and Crop Biotechnology Institute/Green Bio Science & Technology, Seoul National University, Pyeongchang, 25354, Korea; dr.ali_ivf@yahoo.com*

Abstract

Seed priming is a technique to improve seed germination, seedlings growth, uniformity and yield. The present study was designed to, investigate the physiological mechanism of seed priming with GA_3 and KNO_3 on cucumber seedlings growth, chlorophyll, photosynthesis and nutrients uptake. The cucumber seeds were treated as; CK; control, T1; GA_3 100 ppm, T_2; GA_3 200 ppm, T_3; KNO_3 1%, T_4; KNO_3 5%, before seed sowing. The results showed that seed priming with GA_3 and KNO_3 significantly increased the plant height, fresh and dry weight and strong seedling index. Moreover, chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoid contents, net photosynthesis rate (Pn), stomatal conductance (Gs), transpiration rate (Tr) and intercellular CO_2 concentration in seed priming seedlings. In addition, seed priming significantly enhanced leaf macro and micro nutrient contents. Additionally, among various treatments GA_3 200 ppm and KNO_3 5% are found best. These results suggested that seed priming with GA_3 and KNO_3 synergistically promoted the chlorophyll contents, photosynthesis and nutrients uptake in cucumber seedlings, thus leading to improve plant growth.

Keywords: *Cucumis sativus* L; gibberellic acid; KNO_3; nutrients uptake; plant growth

Introduction

Seed priming is pre-sowing treatment that can improves seed germination performance and abiotic stress tolerance. The earlier studies showed that seed priming techniques are used for improvements of seed germination under normal and adverse environmental conditions (Jisha *et al*., 2013) and useful physiological approaches that could adapt glycophyte species to saline conditions (Eskandari, 2013; Gholami *et al*., 2015; Ruttanaruangboworn *et al*., 2017). The positive effects of seed priming have been reported in many vegetable crops, such as tomato and pepper (Khan *et al*., 2009; Muhammad *et al*., 2010; Nakaune *et al*., 2012). Seed priming also stimulates metabolic processes in pre-germinated seeds and makes active seed for radical protrusion and reduce physical resistance during imbibition of endosperm, repairs membranes and also improve developments of immature embryos (Khan *et al*., 2009; Gamboa-Debuen *et al*., 2010; Kubala *et al*., 2015). Seed priming regulates various molecular, biochemical and physiological activities in seedlings (Yasutaka

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et al., 2005; Nakaune *et al*., 2012), including cell division, elongation and stress response proteins activation (Sivritepe *et al*., 2003; Varier *et al*., 2010; Mahajan *et al*., 2011). Thus, it can be concluded that seed priming plays a key role in plant growth and developments.

Gibberellic acid (GA) is plant hormone that produces in root of plant and play essential role in plant growth and developments (Bai *et al*., 2016). GA_3 play a significant role in regulation of plant growth and development at different environmental conditions (Muhammad and Eui Shik, 2007; Levent *et al*., 2008). GA_3 is involved in improved seed germination, root growth, stem elongation and water and nutrient uptake. GA_3 pre sowing seed treatments are most effective for seedlings growth and nutrients uptake (Levent *et al*., 2008; Bai *et al*., 2016). Priming of GA_3 also stimulate seedlings sprouting, increase growth, activate enzymes (Muhammad and Eui Shik, 2007), that's are essential for carbohydrate metabolism, chlorophylls biosynthesis and other important enzymes, thus improve embryo developments, germination and seedlings growth, as previously reported by Varier *et al*. (2010). These findings are suggested that GA_3 is an important plant hormone that activates variety of developmental process during plan growth.

Nitrogen (N), potassium (K) and phosphorous (P) are major and essential nutrients for plant growth and development. The availability of these essential nutrients and uptakes are very important that effects growth. Plant possess a comprehensive transport system that is involved in uptake and transportation in nitrate, phosphate and potassium ion for soil though roots to shoots (Yi - Fang *et al*., 2008). Moreover, these nutrients, nitrogen (KNO_3) plays an important function in balancing membrane potential and activating enzymes, and regulating osmotic pressure in cells (Chérel, 2004; de Jong *et al*., 2014; O'Brien *et al*., 2016), cell wall structure, cell elongation and cell division (Patade *et al*., 2009). KNO_3 regulate uptake of nutrients across cell membranes and enhancing water uptake (Summart *et al*., 2010). KNO_3 or $CaC1_2$ seed priming increased proteins, free amino acids and soluble sugars during germination under salt and water stress condition (Khan *et al*., 2009). Acid phosphatase and phytase enzyme activities in the cotyledons, roots and shoots of lettuce under stress were increased by seed priming of KNO_3 (Nasri *et al*., 2011).

Cucumber (*Cucumis sativus.* L) is important economic vegetable crop, it is originated from southern Asia, and widely cultivated in greenhouse during winter and summer seasons, as reported by Anwar *et al*. (2019). Because of high nutritional value, cucumber is very commonly cultivated and consumed all around the globe and mostly in China (FAO, 2017). Induced inhibition of seedlings growth caused by many environmental factors; light, temperature, and other abiotic stress, effects many physiological and biochemical process including reduction in photosynthesis, chlorophyll biosynthesis, nutrients uptake or imbalance in nutrients accumulation (Shah *et al*., 2012; Yan *et al*., 2013) and inhibition of biological carbon and nitrogen fixation (Meena *et al*., 2016), thus leads in significant reduction in plant growth and yield of vegetable crops. Keeping in view the given facts, the current study was designed to evaluate the effect of GA_3 and KNO_3 seed priming at seedlings stage in cucumber. This study will provide deep understanding for protection and healthy vegetable nursery, and will be useful for protected vegetables production.

Materials and Methods

Plant material and experimental setup

The experiment was conducted at Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences, Beijing, China. The cucumber (Cv. 'Zhongnong 26') seeds were treated with different levels of GA_3 and KNO_3; Control (CK) T_1 (GA_3 100ppm), T_2 (GA_3 200ppm), T_3 (KNO_3 1%), T_4 (KNO_3 5%). After 12 h (hours) treatment (the seeds were treated with various GA_3 and KNO_3 concentrations for 12 h) the seeds were dried at room temperature for 2 days. The seeds were grown in pots filled with soil mixture (Peat and vermiculite with 2:1, v/v). The experiment was conducted in control chamber having 14 h photoperiod (300 μmol. $m^{-2} s^{-1}$) at 25-28 °C during day time and 18-20 °C at night time for 10 h. After 7 days of seed germination the nutrients solutions were applied at same rate according to Yamazaki nutrients formula for cucumber seedlings (Table 1) with two days' interval.

Table 1. Yamazaki nutrition solutions and their concentration (mg/L) for cucumber seedlings

No	Name of compound	Concentration mg/L
A	$Ca(NO_3)_2$-$4H_2O$	35.4
	KNO_3	40.4
B	$NH_4H_2PO_4$	40.4
	$MgSO_4$-$7H_2O$	24.6
C	Na_2Fe-EDTA	25.0
	H_3BO_3	2.13
	$MnSO_4$-$4H_2O$	2.86
	$ZnSO_4$-$7H_2O$	0.22
	$CuSO_4$-$5H_2O$	0.08
	(NH_4) $6MO_7O_2$-$4H_2O$	0.02

Measurement of plant growth parameters

The same sizes of plants were selected after 15 days after seeds germination, to determined height and hypocotyl diameter using ruler and digital venire caliper respectively as described by Anwar *et al.* (2019). To determine fresh and dry weight, roots and shoots were separated and weighted as as described by Bai *et al.* (2016).

Chlorophyll contents measurement

To determine chlorophyll contents, fully expend fresh leave form each treatment (0.2 g) were homogenized in 95% ethanol for 24 h. The absorbance was read 665 nm, 649 nm and 470 nm, using spectrophotometer (Anwar *et al.*, 2018). The chlorophyll was calculated by using following formula:

Chlorophyll a (mg/L) =12.21OD663-2.81OD646

Chlorophyll b (mg/L) = 20.13OD646-5.03OD663

Carotenoid (mg/L) = (1000OD470-3.27Ca-104Cb)/229

Chlorophyll (a, b and Carotenoid) (mg/g. FW) = C*V*n/W (V=0.02 L, n=1, W=0.2 g)

Measurement of photosynthesis

The net photosynthesis rate (Pn), stomatal conductance (Gs), transpiration rate (Tr) and intercellular CO_2 concentration of 3rd fully expanded leaf was determined by using portable photosynthesis system (LI-6400XT, LI-COR Lincoln, US) as described earlier (Anwar *et al.*, 2018).

Measurement of total nutrient contents

The total nutrient contents in plant leaves were determined by element analyser (Vario MAX CN Elemental Analyzer, Elementar, Hanau, Germany). The samples were 1st digested in HNO_3 by using microwave digestion system (Mars X press Microwave Digestion system, CEM, Matthews, NC, USA). Samples were then analysed for total nutrient concentrations with an inductively coupled plasma optical emission spectrometer (ICP-OES, Optima 5300 DV, Perkin Elmer, Waltham, USA), Jaldal Method were used for total N contents (Jiahui *et al.*, 2018).

Statistical analysis

There were four independent biological replications for each treatment, and the whole experiment was repeated four times. The data were statistically analyzed using an analysis of variance (ANOVA), and treatments were compared using the LSD test (P=0.05) using Statistix 8.1 software.

Results

Effect of seed priming on cucumber seedling growth

Plant height, root length, hypocotyl diameter, fresh weight were significantly increased by GA_3 and KNO_3 seed priming as compare to control (CK) (Table 2). The results indicated that maximum plant height (13.33 cm) was noted T_4 treatments, followed significantly by T_2 and T_3 treatments, having plant height 12.33 cm. Minimum plant height (10.5 cm) was reported in control (CK). Moreover, T_2 had positively increase hypocotyl diameter as compared to control (CK), but the difference between T_1 and T_3 were reported non-significant. Fresh weight was also significantly increased in GA_3 and KNO_3 seed priming cucumber seedlings, as compared to CK. In this study T_2 was caused of notable increment in shoot, root and total fresh weight (Table 2). In addition, fresh weight 51.80% and 44% were increased in T_2 and T_4 respectively, as compared to CK.

Table 2. Effect of GA_3 and KNO_3 seed priming on plant height, root length, hypocotyl diameter and fresh weight

No	Plant height (cm)	Hypocotyl dimeter (mm)	Shoot fresh weight (g)	Root fresh weight (g)	Total fresh weight (g)
CK	10.5±0.71 c	1.86±0.04 c	10.97±1.34 c	2.35±0.59 c	13.34±1.32 c
T1	11.67±0.57 b	2.14±0.06 b	13.25±0.44 b	2.51±0.20 bc	15.76±0.35 b
T2	12.33±0.60 ab	2.26±0.13 a	17.04±1.71 a	3.21±0.48 a	20.25±1.26 a
T3	12.33±0.60 ab	2.19±0.09 ab	15.85±0.89 a	3.06±0.27 ab	18.91±1.10 a
T4	13.33±1.15 a	2.17±0.05 ab	15.98±0.72 a	3.23±0.11 a	19.21±0.64 a

Data represent the mean values ± standard deviations. Different letters indicate significant differences at $P<0.05$. CK: Control, T1: GA_3 100 ppm, T2: GA_3 200 ppm, T3: KNO_3 1%, T4: KNO_3 5%

Effect of seed priming on cucumber seedling dry weight

Seed priming with GA_3 and KNO_3 resulted in a significant increased dry weight of cucumber seedlings, as compared to CK, as presented in Table 3. The results indicated that among various treatments, shoot, root and total dry weight, (1.49 g, 0.24 g and 1.73 g respectively) were noted in T_4 treatment, whereas 1.55 g total dry weight was recorded in T_3. Dry weight was found lowest (1.23 g) in control (CK) treatment. Strong seedling index (SSI) was reported significantly higher in T_4 treatments (0.60), while lowest was noted in CK (0.43), but the difference between T_2 and T_3 were found non-significant. These findings are suggested that GA_3 and KNO_3 seed priming play important role in cucumber seedlings growth.

Table 3. The effect of GA_3 and KNO3 seed priming on dry weight of shoot, root, total and root/shoot ratio

No.	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	SSI
CK	1.04±0.03 c	0.18±0.01 b	1.23±0.06 d	0.43±0.01 d
T_1	1.20±0.07 b	0.18±0.02 b	1.39±0.07 bc	0.47±0.01 c
T_2	1.27±0.01 b	0.19±0.03 b	1.45±0.01 c	0.53±0.02 b
T_3	1.32±0.07 b	0.23±0.04 a	1.55±0.09 b	0.51±0.0.1 b
T_4	1.49±0.012 a	0.24±0.03 a	1.73±0.01 a	0.60±0.02 a

Data represent the mean values ± standard deviations. Different letters indicate significant differences at $P<0.05$. CK: Control, T1: GA_3 100 ppm, T2: GA_3 200 ppm, T3: KNO_3 1%, T4: KNO_3 5%

Effect of seed priming on cucumber seedling chlorophyll contents

Chlorophyll is the most important parameter that play an important role in photosynthetic capacity. In present study, the chlorophylls contents were significantly enhanced by GA_3 and KNO_3 seed priming, as presented in Figure 1. The results indicated that total chlorophyll contents (Chlorophyll a, b, a+b and carotenoid) were reported significantly higher in T_4 having 2.19, 0.89, 0.49 and 3.02 mg/g FW, respectively, followed by T_2 (2.09, 0.77, 0.47 and 2.86 mg/g FW) treatment in cucumber seedlings, but there is no significant difference between T_1, T_3, but significantly higher than CK, as presented in Figure 1. These findings are suggested the seed priming with GA_3 and KNO_3 significantly enhanced chlorophylls accumulation.

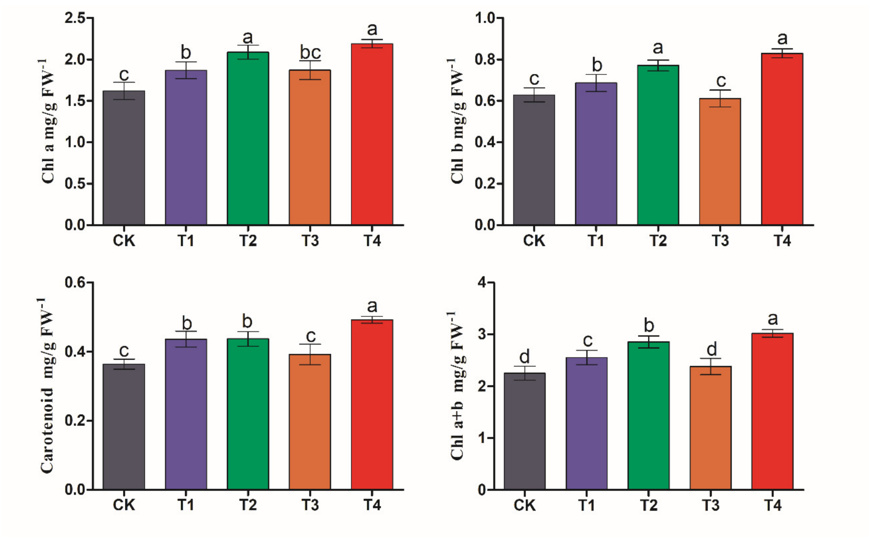

Figure 1. The effect of seed priming on chlorophyll contents in cucumber seedlings. Data represent the mean values ± standard deviations. Different letters indicate significant differences at $P<0.05$. CK: Control, T1: GA_3 100ppm, T2: GA_3 200ppm, T3: KNO_3 1%, T4: KNO_3 5%

Effect of seed priming on cucumber seedling photosynthesis

As shown in Figure 2, the GA_3 and KNO_3 seed priming significantly improved photosynthetic parameters including net photosynthetic rate (Pn), stomatal conductance (Gs), intercellular CO_2 concentration (Ci) and transpiration rate (Tr) in cucumber seedlings. The results showed that Pn, Gs, Ci and Tr were increased by 55.47%, 88.23%, 51.04% and 171.82% in T_4 treatment and 45.80%, 52.94%, 56.98% and 98.89% were increased in T_3, when compared to CK. Whereas there is no significant difference between T_1, T_3 and CK. Similarly, Gs and Tr were found higher in T_1 and slightly decreased in T_4 and T_2, but remind statically higher than CK and T_3. It can be attributed that seed priming played important role in improvements of photosynthesis by increasing chlorophyll contents (Figure 1).

Effect of seed priming on total nutrients contents in cucumber leaves

The data presented in (Table 4), shows that GA_3 and KNO_3 seed priming significantly (P=0.05) enhanced nutrients accumulation in cucumber leaves. The results showed that nutrients accumulations were significantly higher in seed priming of GA_3 and KNO_3 seedlings than control treatment (CK).

Macronutrient contents

The contents of total nitrogen (N) in the leaves of cucumber seedlings were significantly increased by 2.88% and 8.27% in T_2 and T_4 treatment respectively, as compare to CK treatment (Table 4). Moreover, T_1 and T_2 were also resulted in significant increment of N contents, when compared with CK. Seed priming had significantly enhanced P contents in leaves of cucumber seedlings. P contents in T_2 seedling leaves had increase by 6.97% and 13.95% increase were noted in T_4 treatment in comparison with untreated (CK) cucumber seedlings (Table 4). The K contents in cucumber leaves were significant improved by various seed priming treatments, as given in Table 4. The maximum increase K 37.9% and 35.2% reported contents were reported in T_2 and T_4 treatments respectively as compared CK. Mg and Ca contents were noted higher 49.7% and 40.7% in T_2 and 21.55% and 42.91% in T_1 respectively in leaves of cucumber seedlings, when compared with CK treatment. These findings are reflecting that seed priming played an important role in nutrient uptake and accumulation.

Table 4. Effect of seed priming on nutrients in leaves of cucumber seedling (mg/g DW^{-1})

No.	CK	T_1	T_2	T_3	T_4
N	49.65±0.18 c	52.34±0.42 ab	51.08±1.78 bc	52.39±1.59 ab	53.76±1.13 a
K	6.16±1.04 b	6.16±1.07 b	8.50±0.55 a	8.94±0.01 a	8.33±1.14 a
P	0.86±0.02 b	0.92±0.00 ab	0.92±0.06 ab	0.84±0.11 b	0.98±0.17 a
Fe	0.12±0.02 c	0.13±0.01 c	0.17±0.02 b	0.21±0.00 a	0.18±0.01 b
Cu	0.005±0.00 b	0.005±0.00 b	0.007±0.00 a	0.007±0.00 a	0.007±0.00 a
Ca	5.15±0.65 b	5.64±1.28 ab	7.25±2.33 ab	7.36±0.67 a	5.35±0.33 b
Mg	1.67±0.20 b	1.70±0.21 b	2.50±0.41 a	2.65±0.11 a	2.03±0.18 ab
Ba	0.035±0.00 b	0.035±0.00 b	0.039±0.00 a	0.022±0.00 c	0.032±0.01 b
Na	0.65±0.09 c	0.69±0.10 c	1.06±0.04 a	0.97±0.02 b	1.35±0.99 a

Data represent the mean values ± standard deviations. Different letters indicate significant differences at $P<0.05$. CK: Control, T1: GA_3 100ppm, T2: GA_3 200ppm, T3: KNO_3 1%, T4: KNO_3 5%

Micronutrient contents

Seed priming also enhanced micronutrient contents in leaves of cucumber seedlings, are shown in Table 4. The results indicated that seed priming increased in Fe and Cu contents by 41.6% and 40% respectively in T_2 treatment, while 50%, and 40% respectively, were reported in T_4 treatment by comparing with CK treatment (Table 4). Similarly, Na contents in leaves of cucumber seedlings were also increased significantly in seed priming treatments. The Na contents were increased 63% and 107% in T_2 and T_4 respectively compared to CK. The B contents were increased in T_2, while noted lower in T_3 treatments, as shown in Table 4. Furthermore, it can be concluded that seed priming had positively enhanced seedlings growth by enhancing nutrients uptake. Taken together, seed priming treatment T_2 and T_4 resulted a significant increment in Chlorophyll contents, photosynthetic capacity and total nutrients contents, thus enhanced cucumber seedlings growth (Table 4).

Correlation analysis

The correlation analysis indicated that chlorophylls have positive correlation with plant growth indices, while showed negative correlation with root length and root/shoot ratio dry weight (Table 5). The photosynthesis (Pn, Gs, Ci and Tr) parameters reflect a positive correlation between cucumber seedlings growth, but chlorophyll, photosynthesis showed negative correlation between root/shoot ratio. In addition, photosynthesis parameters were showed maximum positive correlation with physiological parameters, than chlorophylls, but interactive correlation between chlorophyll and photosynthesis are found positive. These results concluded that chlorophylls and photosynthesis produce changes in cucumber seedling growth, which was significantly enhanced in seed priming treatments.

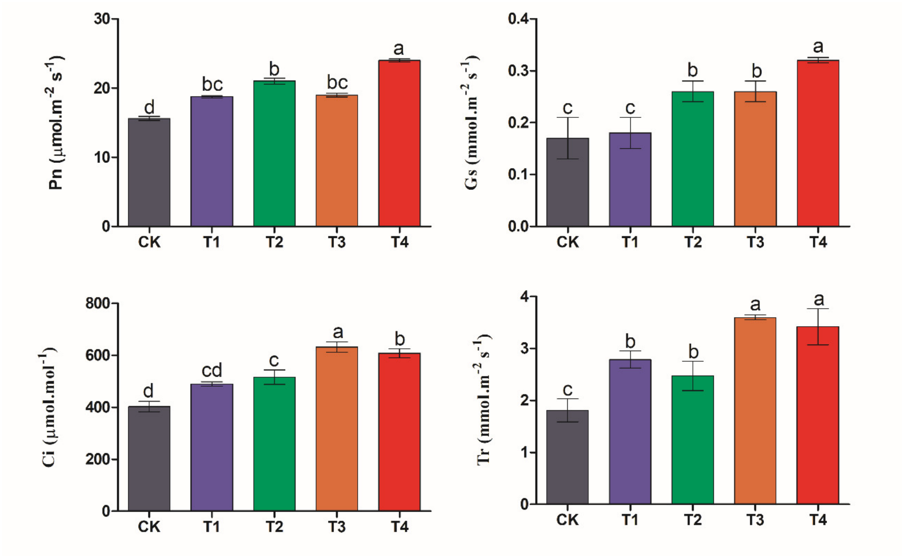

Figure 2. The effect of seed priming on photosynthesis in cucumber seedlings. Data represent the mean values ± standard deviations. Different letters indicate significant differences at $P<0.05$. CK: Control, T1: GA_3 100 ppm, T2: GA_3 200 ppm, T3: KNO_3 1%, T4: KNO_3 5%

Discussion

Seed priming techniques are recently used commercially to enhance seed vigor in term of germination and stress tolerance potential. In other words, it is also known as pre-germinative metabolism, because it activates metabolic process before seed germination, thus it showed a strong response to abiotic stress during germination. Seed priming extensively described, in term of plant ecological and physiological, cellular and molecular biology (Farooq *et al*., 2007; Shah *et al*., 2012; Sharma *et al*., 2014). Recently, the increased quality of seed has become a key priority of agriculture market. Seed priming is also used to achieve rapid and uniform seed germination and seedling emergence to enhanced crop production performance. In the present study, we found that seed priming increase cucumber seedlings growth; height, hypocotyl diameter, shoot, fresh weight and dry weight as compared to CK treatment (Table 2, 3). The results were similar to those of earlier studies, which reported that seed priming enhanced watermelon and maize seedlings fresh weight, hypocotyl, when compared with unprimed seedlings (Demir and Mavi, 2004; Farooq *et al*., 2007; Imran *et al*., 2013). These findings are suggested that seed priming incredibly enhanced cucumber seedlings growth.

Chlorophylls are vital pigments that absorb a considerable amount of light energy and perform photosynthesis reactions in plant. Chlorophyll is very sensitive to various environmental stress, thus caused a significant reduction in chlorophyll contents and biosynthesis, thus effects plant growth and yield (Demir and Mavi, 2004; Khan *et al*., 2009; Shah *et al*., 2012). In the present study seed priming significantly increased chlorophyll contents in cucumber seedlings (Figure 1). The results are in agreement with previous studies, who reported that bio priming significantly enhanced chlorophyll contents in wheat leaves (Jiajin *et al*., 2010; Rahimi, 2013; Siri *et al*., 2013; Sharma *et al*., 2014). Chlorophyll contents is an important parameter often used as an indicator for developments of chloroplast and photosynthetic capacity (Xia *et al*., 2009; Bai *et al*., 2016; Meena *et al.*, 2016), thus considered as a base for plant growth and developmental process. In present study, seed priming also enhanced N and Mg contents (Table 4), which is involved in chlorophyll biosynthesis. The Chlorophyll molecule contain Mg covalently link with four nitrogen (N) atoms (Chlorophyll a; $C_{55}H_{72}O_5N_4Mg$ and Chlorophyll b; $C_{55}H_{70}O_6N_4Mg$), so it might be the reason that seed priming enhanced nutrients uptake (Table 4) and resulted to enhanced chlorophyll contents in cucumber leaves. The correlation analysis, showed that chlorophyll have positive correlated with growth parameters and photosynthesis (Table 5). Taken together, these results suggested that seed priming enhanced chlorophyll contents thus leads to improve cucumber seedlings growth.

Table 5. Correlation analysis between plant different morphological parameters, chlorophyll and photosynthesis

Table. 5 Pearson correlation analysis between plant different morphological parameters, chlorophyll and photosynthesis

	Plant height	Root length	Hypocotyl dimeter	Shoot fresh weight	Root fresh weight	Total fresh weight	Shoot dry weight	Root dry weight	Total dry weight	Root/shoot ratio	Chlorophyll A	Chlorophyll B	Carotenoid	Chl. A+B	Pn	Gs	Ci	Tr
Plant height cm	100%																	
Root length cm	42%	100%																
Hypocotyl dimeter mm	81%	69%	100%															
Shoot fresh weight g	87%	71%	93%	100%														
Root fresh weight g	90%	62%	81%	97%	100%													
Fresh weight g	88%	70%	92%	100%	98%	100%												
Shoot dry weight g	99%	36%	72%	80%	86%	81%	100%											
Root dry weight g	80%	42%	42%	59%	72%	61%	87%	100%										
Total dry weight g	97%	36%	67%	76%	83%	77%	100%	91%	100%									
Root/shoot ratio	-40%	9%	-58%	-30%	-14%	-28%	-34%	13%	-28%	100%								
Chlorophyll A mg/g FW	77%	-5%	63%	66%	68%	67%	72%	32%	66%	-62%	100%							
Chlorophyll B mg/g FW	74%	-22%	43%	52%	61%	53%	72%	41%	69%	-48%	96%	100%						
Carotenoid mg/g FW	67%	-21%	51%	53%	55%	53%	62%	21%	56%	-64%	99%	96%	100%					
Chlorophyll A+B	76%	-9%	59%	64%	67%	64%	71%	32%	65%	-59%	100%	97%	99%	100%				
Pn	97%	55%	89%	88%	86%	88%	95%	75%	93%	-48%	67%	59%	56%	65%	100%			
Gs	95%	44%	69%	86%	95%	88%	95%	86%	95%	-13%	71%	71%	60%	70%	88%	100%		
Ci	87%	68%	72%	78%	80%	79%	89%	90%	90%	-13%	36%	33%	22%	34%	91%	85%	100%	
Tr	89%	20%	50%	57%	67%	58%	95%	91%	97%	-25%	55%	64%	48%	55%	84%	85%	85%	100%

Scale	
100%	+ correlation
50%	
25%	
0%	No correlation
-25%	
-50%	
-100%	- correlation

The mean data representing different plant growth effected by seed priming. Deep red color (100%) are representing strong positive correlation and deep blue color are representing negative correlation. The negative correlation are shows non-significant correlation with other parameters.

Photosynthesis is the base of plant growth and developmental process, while its capacity is often mainly ascribed to stomatal and non-stomatal limitations, and caused of reduction in Pn capacity, as well as Gs and Ci (Shu *et al.*, 2016). In this study, Photosynthetic activities (photosynthesis parameters including intercellular CO_2 concentration (Ci), photosynthetic rate (Pn), stomatal conductance (Gs) and transpiration rate (Tr)) were significantly improved by seed priming in cucumber seedlings, as compared to CK (Figure 2). Chlorophylls accumulation are important parameter frequently used as an indicator of photosynthetic capacity, in present study we reported that seed priming enhanced chlorophylls accumulation (Figure 1), resulted a significant increment in photosynthetic capacity (Figure 2). The previous study reported a strong correlation between leaf N and chlorophylls, and concluded that photosynthesis capacity is frequently attributed to chlorophyll and N accumulation in leaf (Castro *et al.*, 2014), which is a key molecule for photosynthesis. In the present study, we also reported that seed priming enhanced N and Mg accumulation in cucumber leaf (Table 4). The previous study reported, that N and Mg are key molecule of chlorophyll biosynthesis, thus it might be reason that seed priming enhance leaf nutrients accumulation (N and Mg) (Kutík *et al*., 1995; Lawlor, 2002), and ultimate enhanced chlorophylls accumulation (Figure 1), and photosynthetic capacity (Figure 2) to improve cucumber seedlings growth (Table 2). The results were similar to those of earlier studies, which reported that seed priming with Salicylic acid and PEG enhanced photosynthesis in rice seedlings (Li and Zhang, 2010; Shaheen *et al*., 2016), and Zhang *et al*. (2012), who reported that photosynthesis capacity in cucumber plant are increased by seed priming and also increased photochemical efficiency of PS II.

Sustaining ion homoeostasis by nutrients uptake and compartmentalization is not only fundamental for plant growth (Ghars *et al*., 2008), but also essential for almost all metabolic and cellular functions, such as energy metabolism, primary and secondary metabolism, regulation of genes, hormonal regulation, cell protection, reproduction, other signal transduction (Hansch and Mendel, 2009; Meena *et al*., 2016). In this study, GA_3 and KNO_3 seed priming resulted a significant increment in minerals nutrition concentration (N, P, K, Mg, Ca, Cu, Fe, Na and Ba) in leaves of cucumber seedlings (Table 4**).** The results were similar to those of earlier studies, which reported that seed priming enhanced leaf nutrients accumulation and significantly enhance seedlings growth in mungbean (Shah *et al*., 2012). Seed priming enhanced significantly nutrients uptake and balancing of membrane potential and regulating of osmotic pressure cells (Chérel, 2004), thus it might be reasoning that seed priming regulate nutrients uptake, chlorophylls accumulation and photosynthesis, leads significant increment in cucumber seedlings growth (Tables 1, 2).

Conclusions

Taken together, we presented physiological and biochemical evidences of seed priming regulate plant growth. As expected, cucumber seedlings growth was found significantly increased GA_3 and KNO_3 seed priming treatments, as compared to control. The KNO_3 and GA_3 seed priming had improved cucumber seedlings growth, fresh and dry weight, total chlorophyll contents, photosynthetic activity and leaves nutrients contents. Moreover, the personal correlation analysis concluded that chlorophyll and photosynthesis have positive correlation with plant height, hypocotyl dimeter, fresh and dry weight, and suggested that, seed priming regulates nutrient uptake, which involved in chlorophyll biosynthesis and photosynthesis, thus regulate cucumber growth. Among the treatments T_2 (GA_3 200ppm) and T_4 (KNO_3 5%) seed priming was found superior and recommended for improved seedlings growth of cucumber. The finding could improve our understanding of seed priming and would be useful for healthy nursery rising and protected vegetable production.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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