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

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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 GA₃ and KNO₃ on cucumber seedlings growth, chlorophyll, photosynthesis and nutrients uptake. The cucumber seeds were treated as; CK; control, T₁; GA₃ 100 ppm, T₂; GA₃ 200 ppm, T₃; KNO₃ 1%, T₄; KNO₃ 5%, before seed sowing. The results showed that seed priming with GA₃ and KNO₃ 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 CO₂ concentration in seed priming seedlings. In addition, seed priming significantly enhanced leaf macro and micro nutrient contents. Additionally, among various treatments GA₃ 200 ppm and KNO₃ 5% are found best. These results suggested that seed priming with GA₃ and KNO₃ synergistically promoted the chlorophyll contents, photosynthesis and nutrients uptake in cucumber seedlings, thus leading to improve plant growth.

Keywords: Cucumis sativus L; gibberellic acid; KNO₃; 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...
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 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 is involved in improved seed germination, root growth, stem elongation and water and nutrient uptake. GA pre sowing seed treatments are most effective for seedlings growth and nutrients uptake (Levent et al., 2008; Bai et al., 2016). Priming of GA 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 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 (KNO₃) 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). KNO₃ regulate uptake of nutrients across cell membranes and enhancing water uptake (Summart et al., 2010). KNO₃ or CaCl₂ 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 KNO₃ (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 and KNO₃ 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 and KNO₃; Control (CK) T₁ (GA; 100 ppm), T₂ (GA; 200 ppm), T₃ (KNO₃ 1%), T₄ (KNO₃ 5%). After 12 h (hours) treatment (the seeds were treated with various GA and KNO₃ 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$_2$O        | 35.4               |
|    | KNO$_3$                       | 40.4               |
| B  | NH$_4$H$_2$PO$_4$             | 40.4               |
|    | MgSO$_4$·7H$_2$O              | 24.6               |
| C  | Na$_2$Fe-EDTA                 | 25.0               |
|    | H$_2$BO$_3$                   | 2.13               |
|    | MnSO$_4$·4H$_2$O              | 2.86               |
|    | ZnSO$_4$·7H$_2$O              | 0.22               |
|    | CaSO$_4$·5H$_2$O              | 0.08               |
|    | (NH$_4$)$_6$MO$_7$O$_2$·4H$_2$O| 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\textsubscript{3} and KNO\textsubscript{3} seed priming as compared to control (CK) (Table 2). The results indicated that maximum plant height (13.33 cm) was noted T\textsubscript{4} treatments, followed significantly by T\textsubscript{2} and T\textsubscript{3} treatments, having plant height 12.33 cm. Minimum plant height (10.5 cm) was reported in control (CK). Moreover, T\textsubscript{2} had positively increase hypocotyl diameter as compared to control (CK), but the difference between T\textsubscript{1} and T\textsubscript{3} were reported non-significant. Fresh weight was also significantly increased in GA\textsubscript{3} and KNO\textsubscript{3} seed priming cucumber seedlings, as compared to CK. In this study T\textsubscript{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\textsubscript{2} and T\textsubscript{4} respectively, as compared to CK.

| No | Plant height (cm) | Hypocotyl diameter (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\textsubscript{3} 100 ppm, T2: GA\textsubscript{3} 200 ppm, T3: KNO\textsubscript{3} 1%, T4: KNO\textsubscript{3} 5%

Effect of seed priming on cucumber seedling dry weight

Seed priming with GA\textsubscript{3} and KNO\textsubscript{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\textsubscript{4} treatment, whereas 1.55 g total dry weight was recorded in T\textsubscript{3}. Dry weight was found lowest (1.23 g) in control (CK) treatment. Strong seedling index (SSI) was reported significantly higher in T\textsubscript{4} treatments (0.60), while lowest was noted in CK (0.43), but the difference between T\textsubscript{2} and T\textsubscript{3} were found non-significant. These findings are suggested that GA\textsubscript{3} and KNO\textsubscript{3} seed priming play important role in cucumber seedlings growth.

| 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   |
| T1 | 1.20±0.07 b          | 0.18±0.02 b         | 1.39±0.07 bc         | 0.47±0.01 c   |
| T2 | 1.27±0.01 b          | 0.19±0.03 b         | 1.45±0.01 c          | 0.53±0.02 b   |
| T3 | 1.32±0.07 b          | 0.23±0.04 a         | 1.55±0.09 b          | 0.51±0.01 b   |
| T4 | 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\textsubscript{3} 100 ppm, T2: GA\textsubscript{3} 200 ppm, T3: KNO\textsubscript{3} 1%, T4: KNO\textsubscript{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](image)

**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_{3}, 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 T₂ and T₄ treatment respectively, as compare to CK treatment (Table 4). Moreover, T₁ and T₂ 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 T₂ seedling leaves had increase by 6.97% and 13.95% increase were noted in T₄ 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 T₂ and T₄ treatments respectively as compared CK. Mg and Ca contents were noted higher 49.7% and 40.7% in T₂ and 21.55% and 42.91% in T₁ 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          | T₁         | T₂         | T₃         | T₄         |
|-----|-------------|------------|------------|------------|------------|
| N   | 49.65±0.18  | 52.34±0.42 | 51.08±1.78 | 52.39±1.59 | 53.76±1.13 |
| K   | 6.16±1.04   | 6.16±1.07  | 8.50±0.55  | 8.94±0.01  | 8.33±1.14  |
| P   | 0.86±0.02   | 0.92±0.00  | 0.92±0.06  | 0.84±0.11  | 0.98±0.17  |
| Fe  | 0.12±0.02   | 0.13±0.01  | 0.17±0.02  | 0.21±0.00  | 0.18±0.01  |
| Cu  | 0.005±0.00  | 0.005±0.00 | 0.007±0.00 | 0.007±0.00 | 0.007±0.00 |
| Ca  | 5.15±0.65   | 5.64±1.28  | 7.25±2.33  | 7.36±0.67  | 5.35±0.33  |
| Mg  | 1.67±0.20   | 1.70±0.21  | 2.50±0.41  | 2.65±0.11  | 2.03±0.18  |
| Ba  | 0.035±0.00  | 0.035±0.00 | 0.039±0.00 | 0.022±0.00 | 0.032±0.01 |
| Na  | 0.65±0.09   | 0.69±0.10  | 1.06±0.04  | 0.97±0.02  | 1.35±0.99  |

Data represent the mean values ± standard deviations. Different letters indicate significant differences at P<0.05. CK: Control, T₁: GA; 100ppm, T₂: GA; 200ppm, T₃: KNO₃ 1%, T₄: KNO₃ 5%

Micronutrient contents

Seed priming also enhanced micronutrient contents in leaves of cucumber seedlings, as shown in Table 4. The results indicated that seed priming increased in Fe and Cu contents by 41.6% and 40% respectively in T₂ treatment, while 50%, and 40% respectively, were reported in T₄ 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 65% and 107% in T₂ and T₄ respectively compared to CK. The B contents were increased in T₂, while noted lower in T₃ 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 T₂ and T₄ 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](image)

**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.*, 2009).
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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_{5}N_{4}Mg and Chlorophyll b; C_{55}H_{70}O_{6}N_{4}Mg), 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

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 CO₂ 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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