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Influence of potassium humate and calcium phosphate on production of pepper seedlings

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ABSTRACT

Two shadow net house experiments were conducted during 2018 and 2019 in a private Nursery, Ibshawy district, Fayoum, Egypt, to study the effect of potassium humate and calcium phosphate on morphological characters, membrane permeability (RWC and MSI), leaf photosynthetic pigments and leaf elemental contents of pepper transplants. The experimental design used was a split-plot in randomized complete blocks with four replications. Potassium humate levels (0 and 0.5 g litre-medium^{-1}) were distributed in the main plots, while calcium phosphate concentrations (0, 100, 200, 400, 600, 800 and 1000 mg litre-water^{-1}) were randomly allocated to the sub-plots. Growing medium provided with 0.5 g l^{-1} potassium humate gave the highest significant values on morphological characters, membrane permeability, leaf photosynthetic pigments and leaf N, P, k and Ca contents as compared to growing medium without potassium humate treatment during both seasons. However, number of leaves transplant^{-1} was not significantly affected. Generally, foliar application of calcium phosphate at 600 and 800 mg l^{-1} was significantly recorded higher mean values of morphological characters, membrane permeability and leaf photosynthetic pigments as compared to other concentrations but number of leaves transplant^{-1} was not significantly affected. While, spraying calcium phosphate at 100 mg l^{-1} significantly recorded higher mean values of leaf N content. Application of calcium phosphate at 1000 mg l^{-1}, significantly, attained higher values of leaf P and Ca content. Whilst application of calcium phosphate 200 or 400 mg l^{-1} gave the highest significant values on leaf K content, in both seasons of 2018 and 2019. These results recommend using the growth medium supplemented with 0.5 g l^{-1} potassium humate in integration with calcium phosphate at 600 and 800 mg l^{-1} act to enhancing the plant physio-biochemical components, which reflected in high growth of pepper seedlings.

KEYWORDS

Pepper (Capsicum annuum L.), Potassium humate, Calcium phosphate, Morphological characters, Membrane permeability (RWC and MIS), Leaf photosynthetic pigments, Leaf N, P, K and Ca contents.

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1.INTRODUCTION

Seedling production in general has become a large industry in all countries of the world. The most important problems is slow growth in cold weather due to low of phosphorus absorption mainly, which affects the growth of seedlings. It is also important for the seedling producer to obtain strong and hardening seedlings to withstand the different environmental conditions when they are grown in the field. The growth media supplemented with humic acid has been shown to have beneficial influences on plant growth **(Türkmen et al., 2004)** and on the physical characteristics of growing media in Styrofoam flats in which soils or growing media tend to become compacted. Compaction is often accompanied by a decrease in water-holding capacity, drainage, aeration, the rate of water infiltration, and root penetration. The major functional groups in humic acid include carboxyl, phenolic hydroxyl, alcoholic hydroxyl, ketone, and quinoid moieties **(Russo and Berlyn, 1990).** The benefits of humic acid for plant growth may be related to its positive effects on increased fertilizer-use efficiency and/or reduced medium compaction of the growing medium **(Nardi et al., 2002).** Also, humic acid has been claimed to promote plant growth by increasing cell membrane permeability, oxygen uptake, respiration and photosynthesis, nutrient uptake, and root cell elongation **(Russo and Berlyn, 1990 and Nardi et al., 2002).** The influences of humic acid on the growth of tomato seedlings have been investigated in some growing media **(Jindo et al., 2011; Osman and Rady, 2014; Rady et al., 2018b and Colpas-Castillo et al., 2018).**

Buddhy (2014) explained that the phosphorus, one of the seventeen elements nutrients required for plant growth and reproduction, is often indicated to as the energizer since it helps store and transfer energy during photosynthesis. It is also part of the genetic material of all cells-DNA and RNA. All plants require phosphorus during periods of rapid growth. Most annual plants require large amounts of phosphorus as they begin to grow. Plants grown in cold weather which have limited roots and rapid top growth, such as pepper transplants produced, are high phosphorus users. Phosphorus absorption is reduced at low soil temperatures less than 13°C. Phosphorus is necessary to stimulate early root formation and growth, so it is necessary for the growth of seedlings roots in general, give hardiness to seedling, and promote vigorous start (cell division) to plants. Phosphorus has a role in hydrogen, oxygen, fat, and carbon metabolism, in photosynthesis, and in respiration. **Upadhyaya (2017)** mentioned that the calcium is an essential plant nutrient. It plays many important role in plant like, participate in the metabolic process of another nutrient uptake, promotes proper plant cell elongation, strengthen cell wall, and participate in an enzymatic and hormonal process. In addition, the adequate level of Ca_2^+ is required in the external medium to maintain the selectivity and integrity of cell membrane.

Accordingly, the present work was designed with the objective to evaluate the potential beneficial effects of potassium humate and/or calcium phosphate on growth, leaf photosynthetic pigments and nutrients, of pepper seedling produced. The study also aimed to establish a relationship between the positive changes in the contents of leaf photosynthetic pigments and nutrients; N, P, K and Ca and the improvement in transplant performance in growing medium.

2.MATERIALS AND METHODS

Source, physical and chemical properties of potassium humate and calcium phosphate

The physical and chemical characteristics of potassium humate according to published procedures (Humintech GmbH, Am Pösenberg 9-13 • D 41517 Grevenbroich, Germany, https://www.humintech.com/agriculture/products/powhumus-wsg-85) are presented in Table 1. Calcium phosphate $Ca(H_2PO_4)_2$ produced by Hopkin & Williams Ltd, chemical manufacturers (St Davids Court, Union Street, Wolverhampton, West Midlands, United Kingdom, WV1 3JE).

Table 1. Physical and chemical characteristics of potassium humate.

Properties	
Appearance	Water soluble granules
Potassium humates (%)	80 – 85
Humic acids (ISO 19822) (%)	65
Hydrophobic fulvic acids (ISO 19822) (%)	6
Potassium (K_2O) (%)	10 - 12
Dry substance (%)	85 - 90
Fe (%)	1.0
Other minerals (%)	2.0
Particle size of insoluble constituents (µm)	< 100
Solubility in Water (%)	100
Bulk density (kg l^{-1})	0.60
pH	9 - 10
CEC (meq $100g^{-1}$)	400 - 600

Composition of the growing medium

Coco peat, and vermiculite (1:1 v/v), were mixed with a fertilizer consisting of with 300g ammonium nitrate (33.5% N), 400g calcium superphosphate (15% P_2O_5), 150g potassium sulphate (48% K_2O), 50g micro-nutrient solution and 75g of Moncut SC [a 25% (w/w) active flutolanil-containing, wettable powder, fungicide] for each 60 l^{-1} of the mixture.

Experimental layout

Two shadow net house trials were conducted during 2018 and 2019 in a private Nursery, Ibshawy district, Fayoum, Egypt. Treatments comprised of growth medium without and with 0.5 g litre-medium^{-1} potassium humate mixed while preparing the growing medium (this level of potassium humate gave the best results among several levels that were examined in preliminary studies on pepper transplants produced - data not shown - and were therefore selected for this study), and seven concentrations of calcium phosphate; 0, 100, 200, 400, 600, 800 and 1000 mg litre-water^{-1} was applied as foliar application to run-off, three times; 25, 35 and 45 days after sowing. Few drops of salient film were added to the spraying solution as a wetting agent. The Styrofoam flats (n = 56 for all treatments) were arranged in a split-plot in randomized complete blocks with four replications (each tray was one replicate). Main plots consisted of potassium humate with two levels, while sub-plots were allocated to calcium phosphate concentrations. Individual 209-cell Styrofoam flats (2.6 cm 2.6 cm 7.0 cm; 25 cm^3 per inverted pyramid cell; Speedling, El-Amryya, Alexandria, Egypt) were sown (one seed per cell) with imported pepper seeds (*Capsicum annuum*. 'Omega' F1 Hybrid, Country of Origin: China, importer

Kanze Group For Projects Developments and Services, Egypt) on February 11, 2018 and February 12, 2019. The average temperature during this period was 19 ± 3 °C during the day and 9 ± 2 °C at night, and the relative humidity ranged from 70 - 75%, and natural day-length ranged from 11-12 h. The trays were rotated daily within each block to avoid any positional bias. All pepper seedling were grown for 55 days. Seedlings were overhead-irrigated daily and foliar application after 27 and 40 days of sowing with a fertilizer 20:20:20 NPK 4 g l^{-1} water. As well as pests control were performed whenever it was necessary and as recommended in the commercial production of pepper transplants

Data Recorded

Assessment of morphological characters: Fifty-five days old pepper seedling were removed at random from the four replicate Styrofoam flats of each medium (i.e., ten transplants from each flat) and dipped in a bucket filled with water. The pepper seedling were moved smoothly to remove any adhering particles of medium. The transplants were then separated into leaves, stems, and roots to measure stem length (cm); measured starting from the growing medium level to the apical meristem of the main stem. Stem diameter (mm); measured by using Sealy So707-Digital Electronic Vernier Caliper 0–150 mm/0–6 ″ at growing medium level. Root, leaves and stem dry weight transplant^{-1} (g); placed in an oven at 70ºC to reach a constant dry weight which was recorded in each case. Total dry weight transplant^{-1} (g); mathematically calculated by summation oven dried roots, leaves and shoots transplant^{-1}. Number of leaves transplant^{-1}. Leaf area transplant^{-1} (cm); measured using leaf area-leaf weight relationship as illustrated by **Taha and Osman (2018)**. Leaf area transplant^{-1} was calculated using the following formula: Leaf area transplant^{-1} = $\frac{(LDW)}{(DDW)} \times DA$ where LDW is the total leaf dry weight (g), DDW is the disks dry weight and DA is the discs area. Leaf area leaf^{-1} (cm); calculated using the following formula:

$$\text{leaf area leaf}^{-1} = \frac{\text{Leaf area plant}^{-1}}{\text{Number of leaves plant}^{-1}}$$

Membrane permeability: Leaf samples for membrane permeability measurements, were collected from five randomly selected transplants in each experimental unit, after 70 days from culturing date, were collected, washed with tap water, rinsed three times with distilled water to measure; relative water content (RWC %); determined using the formula of **Hayat *et al.* (2007) and** membrane stability index (MSI %); estimated as described by **Sairam (1994).**

Leaf photosynthetic pigments content: Leaf chlorophyll a, b, and carotenoid contents were determined using the dimethyl formamide (DMF) method were measured and calculated according to **Moran and Porath, 1980 and Wellburn, 1994**.

Leaf nutrient contents: Leaf samples from seven randomly selected transplants, in each experimental unit, were collected, washed with tap water, rinsed three times with distilled water and dried at 70°C in a forced-air oven till constant weight to measure: leaf N (mg g^{-1} DW); colorimetrically determined by using the technique of **Hafez and Mikkelsen (1981**). Leaf P (mg g^{-1} DW); colorimetrically estimated according to the stannous molybdate chloride method as illustrated in **A. O. A. C (1995).** Leaf K (mg g^{-1} DW); photometrically measured using Flame photometer as mentioned by **Wilde *et al.* (1985).** Leaf Ca (mg g^{-1} DW); was determined using a Perkin–Elmer Model 3300 Atomic Absorption Spectrophotometer **(Chapman and Pratt, 1961).**

Statistical analysis

All data were subjected to analysis of variance (ANOVA) for a split-plot system in a randomized complete blocks design, after testing for homogeneity of error variances according to the procedure outlined by **Gomez and Gomez (1984)** using **InfoStat software estadistico (2016).** Significant differences between treatments were compared at $P \leq 0.05$ by Duncan's multiple range test.

3.RESULTS AND DISCUSION

Morphological Characters

The growth medium supplemented with 0.5 g l^{-1} potassium humate gave the highest significant values on all vegetative growth parameters; stem length and diameter, roots, leaves, stem and total transplant dry weight $transplant^{-1}$, leaf area $transplant^{-1}$ and leaf area $leaf^{-1}$ of pepper seedlings as compared to the control treatment. Except number of leaves $transplant^{-1}$, which was not significantly affected during the two successive seasons.

Table 2. Effect of potassium humate-supplemented medium and calcium phosphate on stem length and diameter $transplant^{-1}$ of pepper seedlings.

Treatment		Stem length (cm)		Stem diameter (mm)	
Potassium humate (g l^{-1})	Calcium Phosphate (mg l^{-1})	2018	2019	2018	2019
0		13.2 B*	12.5 B	2.60 B	2.54 B
0.5		14.6 A	13.8 A	2.85 A	2.80 A
	0	11.0 D	9.7 E	2.61 B	2.43 C
	100	12.6 C	11.6 D	2.67 B	2.49 C
	200	12.8 C	12.8 C	2.67 B	2.66 B
	400	13.8 B	13.0 C	2.68 B	2.71 B
	600	16.4 A	15.6 A	2.85 A	2.81 A
	800	16.6 A	15.9 A	2.88 A	2.89 A
	1000	14.0 B	13.7 B	2.72 B	2.69 B
0	0	10.4 g	9.3 i	2.51 e	2.34 f
	100	12.0 ef	11.0 g	2.56 de	2.38 f
	200	12.2 e	12.1 f	2.52 e	2.54 e
	400	13.0 d	12.3 f	2.53 e	2.57 e
	600	15.5 b	14.7 bc	2.70 bcd	2.64 de
	800	15.7 b	15.1 b	2.74 bc	2.73 cd
	1000	13.3 d	13.2 e	2.62 cde	2.58 e
0.5	0	11.5 f	10.2 h	2.71 bcd	2.52 e
	100	13.2 d	12.2 f	2.77 bc	2.60 de
	200	13.4 d	13.4 e	2.82 b	2.77 c
	400	14.6 c	13.7 de	2.82 b	2.85 bc
	600	17.3 a	16.5 a	3.00 a	2.97 ab
	800	17.4 a	16.8 a	3.03 a	3.05 a
	1000	14.7 c	14.2 cd	2.82 b	2.81 c

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Generally, foliar application of calcium phosphate at concentrations of 600 and 800 mg l^{-1} was superior and significantly recorded higher mean values of stem length, diameter transplant^{-1}, leaves, stem and total transplant dry weight transplant^{-1}, leaf area transplant^{-1} and leaf area leaf^{-1} of pepper seedlings compared to the other concentrations of calcium phosphate in both years. While, increasing calcium phosphate concentration from 0 to 1000 mg l^{-1} increased roots dry weight transplant^{-1}, during the two successive seasons. Except number of leaves transplant^{-1}, which was not significantly affected, in both experimental seasons. Generally, the combined medium supplemented with 0.5 gl^{-1} potassium humate together with foliar application of calcium phosphate 600 and 800 mg l^{-1}, gave the highest significant values of stem length, diameter transplant^{-1}, leaves, stem and total transplant dry weight transplant^{-1}, leaf area transplant^{-1} and leaf area leaf^{-1} of pepper seedlings. While, application of calcium phosphate 1000 mg l^{-1} together with the medium supplemented with 0.5 g l^{-1} potassium humate, significantly achieved the heaviest roots dry weight transplants^{-1}. Except number of leaves transplant^{-1}, which was not significantly affected, in both experimental seasons which was not significantly affected in both years.

Table 3. Effect of potassium humate-supplemented medium and calcium phosphate on roots, leaves, stem and total transplant dry weight of pepper seedlings.

Treatment		Dry weight transplant^{-1} (g)							
		Roots		Leaves		Stem		Total transplant	
Potassium humate (g l^{-1})	Calcium phosphate (mg l^{-1})	2018	2019	2018	2019	2018	2019	2018	2019
0		0.28 ^{B*}	0.25 ^{B}	0.33 ^{B}	0.30 ^{B}	0.29 ^{B}	0.26 ^{B}	0.90 ^{B}	0.82 ^{B}
0.5		0.32 ^{A}	0.28 ^{A}	0.37 ^{A}	0.33 ^{A}	0.32 ^{A}	0.30 ^{A}	1.01 ^{A}	0.92 ^{A}
	0	0.25 ^{E}	0.23^{E}	0.30 ^{D}	0.28 ^{D}	0.24 ^{F}	0.23 ^{E}	0.79 ^{G}	0.74 ^{E}
	100	0.27 ^{D}	0.24 ^{E}	0.33 ^{C}	0.29 ^{CD}	0.27 ^{E}	0.25 ^{D}	0.87 ^{F}	0.78 ^{D}
	200	0.29 ^{C}	0.26 ^{D}	0.34 ^{B}	0.31 ^{C}	0.29 ^{D}	0.26 ^{CD}	0.93 ^{E}	0.82 ^{C}
	400	0.29 ^{C}	0.27 ^{CD}	0.36 ^{B}	0.33 ^{BC}	0.31 ^{C}	0.28 ^{BC}	0.96 ^{D}	0.88 ^{B}
	600	0.32 ^{B}	0.28 ^{BC}	0.38 ^{A}	0.34 ^{AB}	0.34 ^{B}	0.32 ^{A}	1.04 ^{B}	0.94 ^{A}
	800	0.32 ^{B}	0.29 ^{B}	0.39 ^{A}	0.35 ^{A}	0.35 ^{A}	0.32 ^{A}	1.07 ^{A}	0.96 ^{A}
	1000	0.34 ^{A}	0.31 ^{A}	0.35 ^{B}	0.33 ^{B}	0.32 ^{BC}	0.29 ^{B}	1.01 ^{C}	0.93 ^{A}
0	0	0.24 ^{g}	0.22 ^{g}	0.28 ^{g}	0.27 ^{i}	0.23 ^{i}	0.21 ^{h}	0.75 ^{k}	0.70 ^{h}
	100	0.26 ^{f}	0.23 ^{g}	0.31 ^{f}	0.28 ^{hi}	0.25 ^{h}	0.24 ^{gh}	0.82 ^{j}	0.74 ^{g}
	200	0.27 ^{f}	0.24 ^{fg}	0.33 ^{def}	0.29 ^{ghi}	0.27 ^{gh}	0.24 ^{g}	0.87 ^{hi}	0.77 ^{fg}
	400	0.27 ^{ef}	0.25 ^{ef}	0.34 ^{cd}	0.31 ^{ef}	0.29 ^{fg}	0.26 ^{efg}	0.90 ^{gh}	0.83 ^{d}
	600	0.30 ^{cd}	0.27 ^{de}	0.36 ^{bc}	0.32 ^{de}	0.32 ^{cde}	0.30 ^{bc}	0.98 ^{cde}	0.89 ^{c}
	800	0.31 ^{c}	0.27 ^{cde}	0.38 ^{b}	0.33 ^{bcd}	0.34 ^{bc}	0.30 ^{bc}	1.02 ^{c}	0.91 ^{bc}
	1000	0.32 ^{c}	0.29 ^{bcd}	0.33 ^{de}	0.31 ^{def}	0.30 ^{ef}	0.28 ^{cde}	0.95 ^{ef}	0.88 ^{c}
0.5	0	0.27 ^{f}	0.24 ^{fg}	0.31 ^{ef}	0.30 ^{fgh}	0.26 ^{h}	0.25 ^{fg}	0.84 ^{ij}	0.78 ^{ef}
	100	0.29 ^{de}	0.24 ^{fg}	0.34 ^{cd}	0.31 ^{efg}	0.29 ^{fg}	0.27 ^{def}	0.93 ^{fg}	0.82 ^{de}
	200	0.31 ^{c}	0.27 ^{de}	0.36 ^{bc}	0.32 ^{cde}	0.32 ^{de}	0.29 ^{bcd}	0.98 ^{cde}	0.88 ^{c}
	400	0.31 ^{c}	0.29 ^{bcd}	0.37 b	0.35 ^{ab}	0.34 ^{bcd}	0.30 ^{bc}	1.02 ^{c}	0.94 ^{b}
	600	0.34 ^{b}	0.30 ^{bc}	0.40 a	0.36 ^{a}	0.35 ^{ab}	0.34 a	1.09 ^{ab}	1.00 ^{a}
	800	0.34 ^{b}	0.31 ^{ab}	0.41 a	0.36 ^{a}	0.37 ^{a}	0.34 ^{a}	1.12 ^{a}	1.01 ^{a}
	1000	0.36 ^{a}	0.33 ^{a}	0.36 ^{bc}	0.34 ^{abc}	0.34 ^{b}	0.31 ^{b}	1.06 ^{b}	0.99 ^{a}

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

The enhancing effect of potassium humate-supplemented medium on morphological characters of pepper transplants compared to potassium humate-free medium (Tables 2 - 4) may be due to ability of potassium humate to form stable complexes with metal ions can be accounted for their high content of oxygen containing functional groups viz., carboxylic, phenolic aliphatic and alcoholic –OH groups **(Stevenson et al., 1993).** In addition, **Türkmen et al. (2004)** found that the application of humic acid to growing media has been shown to have enhancing effects on plant growth and on the physical characteristics of growing media in Styrofoam flats in which soils or growing media tend to become compacted. Compaction is often accompanied by reductions in water-holding capacity, aeration, drainage, the rate of water infiltration, and root penetration. In addition, **Jindo et al. (2011)** evaluated the application of humic acids stimulated the appearance of root hairs of any plant crops, promoting a significant increase in the number of lateral roots emerged from the main axis. In this case, the humic acids were the humified fraction of greater bioactivity, since it presented greater capacity of induction of lateral roots in the initial stage of development. This action may be associated with the performance of humic materials in the seedlings as a plant regulator, promoting an increase in H^+ synthesis and favoring, through the formation of an electrochemical gradient, the loosening of the cell wall and, consequently, expansion of cells, tissues and organs. Therefore, the benefits of potassium humate for transplant growth may be related to its positive effects on increased fertilizer-use efficiency and/or reduced soil compaction **(Osman and Rady, 2014).** In addition, potassium humate has been claimed to promote plant growth by increasing RWC, MSI (Table 5), chlorophyll a+b, Carotenoid (Table 6). Thus, all leading to increase in the absorption of nutrients N, P, K and Ca when an application medium supplemented with 0.5 g l^{-1} potassium humate comparing to control in Table 7.

Application of P fertilizer is necessary to ensure optimum vegetative growth plant and quality **(Zapata and Zaharah, 2002)**, as well as for the acquisition, storage, and use of energy **(Epstein and Bloom, 2004)**. Therefore, the present study demonstrated the positive relationship between P foliar application and plant vegetative growth, which is supported by previous findings that P application increases all morphological characters (Tables 2-4). It is known that leaf development depends on a high degree of P concentration in the tissue because P plays an important role in the synthesis of starch and sucrose in photosynthesis, which increases plant dry weight **(Cakmak et al., 1994).** Sufficient P makes efforts to increase dry matter accumulation by increasing the photosynthesis product of root and shoot (**Rady et al., 2018a)**. Based on the above, may be the foliar application of calcium phosphate had compensated of the decrease in phosphorous absorption through the roots (Table 7); which occurs due to low in temperature of less than 13°C, which led to the increased growth of pepper seedlings. In addition, Ca participate in the metabolic process of another nutrient uptake, promotes proper plant cell elongation, strengthen cell wall, and participate in an enzymatic and hormonal process (**Upadhyaya, 2017)**. Consequently, this was reflected positively on all the studied morphological characters (Tables 2-4). In addition to the above, spraying pepper seedlings with calcium phosphate increased RWC, MSI (Table 5), chlorophyll a+b and carotenoid (Table 6). Consequently, all this leads to an increase in the absorption of nutrients N, P, K, and Ca, which is reflected in an increase in the morphological characters of the seedlings when spraying with 800 mg l^{-1} calcium phosphate compared to the control in Table 7. Many other reports support our obtained results such as **Rady et al. (2018a) and Sajid et al. (2020).**

Table 4. Effect of potassium humate-supplemented medium and calcium phosphate on number of leaves transplant^{-1}, leaf area transplant^{-1} and leaf area leaf^{-1} of pepper seedlings.

Treatment: Potassium humate (g l^{-1})	Treatment: Calcium phosphate (mg l^{-1})	Number of leaves transplant^{-1} 2018	Number of leaves transplant^{-1} 2019	Leaf area transplant^{-1} (cm^2) 2018	Leaf area transplant^{-1} (cm^2) 2019	Leaf area leaf^{-1} (cm^2) 2018	Leaf area leaf^{-1} (cm^2) 2019
0		8.8 A*	7.3 A	16.0 B	16.0 B	1.83 B	2.19 B
0.5		9.0 A	7.6 A	18.2 A	18.4 A	2.01 A	2.42 A
	0	8.8 A	7.4 A	14.3 F	14.7 D	1.63 E	1.99 D
	100	8.9 A	7.4 A	15.8 E	16.2 C	1.78 D	2.19 C
	200	8.9 A	7.4 A	16.8 D	17.5 B	1.89 C	2.36 B
	400	8.9 A	7.4 A	17.8 BC	17.9 AB	2.01 B	2.42 AB
	600	8.9 A	7.5 A	18.4 B	18.7 A	2.07 B	2.48 A
	800	9.0 A	7.6 A	19.5 A	18.8 A	2.17 A	2.46 AB
	1000	9.0 A	7.6 A	17.1 CD	16.8 AB	1.90 C	2.23 C
0	0	8.6 a	7.3 a	13.6 i	13.8 h	1.58 h	1.89 g
	100	8.7 a	7.3 a	15.0 h	15.3 gh	1.72 fg	2.10 f
	200	8.7 a	7.3 a	15.6 gh	16.4 defg	1.79 fg	2.26 de
	400	8.7 a	7.3 a	16.9 ef	16.5 defg	1.93 de	2.27 de
	600	8.8 a	7.4 a	17.1 def	17.1 cdef	1.95 cde	2.32 cd
	800	8.9 a	7.5 a	17.8 cde	17.2 cde	2.01 cd	2.29 de
	1000	8.9 a	7.4 a	16.4 fg	16.0 efg	1.84 ef	2.17 ef
0.5	0	8.9 a	7.5 a	15.0 h	15.6 fg	1.68 gh	2.08 f
	100	9.0 a	7.5 a	16.6 f	17.2 cde	1.84 ef	2.28 de
	200	9.0 a	7.6 a	18.0 cd	18.6 bc	1.99 cd	2.46 bc
	400	9.0 a	7.5 a	18.7 bc	19.3 ab	2.08 bc	2.57 ab
	600	9.0 a	7.7 a	19.7 b	20.3 a	2.18 b	2.65 a
	800	9.1 a	7.8 a	21.2 a	20.4 a	2.33 a	2.62 a
	1000	9.1 a	7.7 a	17.9 cd	17.7 cd	1.97 cde	2.29 de

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Membrane permeability

Application of potassium humate-supplemented medium, significantly, attained higher values of RWC % and MSI % than the untreated plants, and the trend was parallel in both experimental seasons. Application of calcium phosphate at either 600 or 800 mgl^{-1}, significantly, attained higher values of RWC % and MSI % than the other concentrations calcium phosphate. Meanwhile, difference between application of calcium phosphate at 600 or 800 mg l^{-1} was not true, in the two years. The treatment combination of medium supplemented with 0.5 g l^{-1} potassium humate together with calcium phosphate at either 600 and 800 mg l^{-1} recorded the higher values of the membrane permeability, in the two growing seasons.

Table 5. Effect of potassium humate-supplemented medium and calcium phosphate on membrane permeability of pepper seedlings.

Treatment		WRC (%)		MSI (%)	
Potassium humate ($g\ l^{-1}$)	Calcium phosphate ($mg\ l^{-1}$)	2018	2019	2018	2019
0		80.7 B*	80.3 B	70.7 B	67.6 B
0.5		87.0 A	86.8 A	77.9 A	75.2 A
	0	81.3 C	81.4 C	67.0 C	61.8 E
	100	82.8 BC	83.0 BC	70.2 BC	65.2 D
	200	84.2 AB	83.7 AB	74.7 AB	68.9 C
	400	85.2 A	84.2 AB	76.8 A	73.9 B
	600	85.7 A	84.4 AB	78.3 A	78.3 A
	800	85.6 A	85.2 A	79.0 A	78.7 A
	1000	82.1 C	82.9 BC	74.4 AB	73.1 B
0	0	78.8 h	79.7 e	63.2 f	58.4 h
	100	79.8 gh	80.2 de	66.6 ef	61.2 gh
	200	81.1 fgh	80.5 de	71.3 cde	65.0 fg
	400	81.7 fgh	80.4 de	72.9 cde	69.9 de
	600	82.0 efg	80.6 de	74.3 bcd	74.0 bcde
	800	82.0 efg	80.9 de	74.9 bcd	74.5 bcd
	1000	79.5 gh	80.1 de	71.7 cde	70.4 cde
0.5	0	83.9 def	83.0 cd	70.7 df	65.1 ef
	100	85.8 bcd	85.9 bc	73.8 bcde	69.3 ef
	200	87.3 abc	87.0 ab	78.0 abc	72.9 cde
	400	88.6 ab	88.1 ab	80.6 ab	78.0 b
	600	89.3 a	88.2 ab	82.3 a	82.7 a
	800	89.2 a	89.5 a	83.1 a	82.9 a
	1000	84.7 cde	85.7 bc	77.1 abcd	75.8 bc

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Higher RWC and MSI values were observed in bean plants applied with potassium humate than control (Table 4) this indicates that the potassium humate reflected positive effect of water uptake or reduced water loss. This may be attributed to the application of humic substances, the major component of soil organic matter; it can enhance nutrient availability and improve biological, chemical, and physical soil properties **(Nardi et al., 2002; Arancon et al., 2006).** As well as may be attributed to the low molecular weight fraction of humic substances which can reach the plasma membrane where it exerts its positive effects **(Nardi et al., 2002),** improving the RWC and MSI, and promoting nutrient uptake (Table 7) by enhancing the permeability of root cell membranes **(Valdrighi et al., 1996).** Similar findings were documented by **Osman and Rady (2014); Taha and Osman (2018)** and **Rady *et al.* (2018b).** Increased of RWC and MSI indicates that foliar application of calcium phosphate (Table 5) probably reflected positive influence of water uptake or reduced water loss which consequently causes increase in leaf water potential. Hence, it could be concluded that the beneficial effect of a calcium phosphate on growth parameters of bean plants (Tables 2-4) has been related to the efficiency of their water uptake with nutrient elements (Table 7). This is due to the effect of phosphorus involved in several key plant functions, including regulation of some enzymes, transformation of sugars and starches, nutrient transport within the plant and transport of carbohydrates **(Taiz et al., 2015).** In addition, the adequate level of Ca_2^+ is required in the external medium to maintain the selectivity and integrity of cell membrane (**Upadhyaya, 2017**).

Leaf photosynthetic pigments

Application of growth medium with 0.5 g l^{-1} potassium humate gave the highest significant values in leaf chlorophyll a, b, a+b and carotenoids contents comparing to control, in both experimental seasons. Generally, calcium phosphate application with 1000 mg l^{-1} gave the highest significant values in leaf chlorophyll a, b, a+b and carotenoids contents comparing to other concentrations, whereas, no significant increases were detected between the levels 800 and 1000 mg l^{-1} on leaf chlorophyll a, b, a+b and carotenoids content, and the trend was parallel in both experimental seasons. Generally, the best combined treatment was potassium humate-supplemented medium at 0.5 g l^{-1} and calcium phosphate at 800 or 1000 mg l^{-1}, in both season.

Table 6. Effect of potassium humate-supplemented medium and calcium phosphate on leaf photosynthetic pigments of pepper seedlings.

Treatment		Chlorophyll a (mg/mm² FW)		Chlorophyll b (mg/mm² FW)		Chlorophyll a +b (mg/mm² FW)		Carotenoid (mg/mm² FW)	
Potassium humate (g l^{-1})	Calcium phosphate (mg l^{-1})	2018	2019	2018	2019	2018	2019	2018	2019
0		0.131 ^{B*}	0.128 ^{B}	0.071 ^{B}	0.067 ^{B}	0.201 ^{B}	0.195 ^{B}	0.045 ^{B}	0.038 ^{B}
0.5		0.152 ^{A}	0.141 ^{A}	0.077 ^{A}	0.072 ^{A}	0.229 ^{A}	0.212 ^{A}	0.051 ^{A}	0.043 ^{A}
	0	0.082 ^{F}	0.071 ^{F}	0.044 ^{E}	0.037 ^{F}	0.126 ^{F}	0.108 ^{F}	0.035 ^{C}	0.030 ^{D}
	100	0.122 ^{E}	0.112 ^{E}	0.064 ^{D}	0.056 ^{E}	0.186 ^{E}	0.169 ^{E}	0.044 ^{B}	0.035 ^{C}
	200	0.139 ^{D}	0.124 ^{D}	0.073 ^{C}	0.063 ^{D}	0.212 ^{D}	0.186 ^{D}	0.049 ^{AB}	0.041 ^{B}
	400	0.153 ^{C}	0.146 ^{C}	0.081 ^{B}	0.074 ^{C}	0.234 ^{C}	0.221 ^{C}	0.051 ^{A}	0.043 ^{AB}
	600	0.157 ^{BC}	0.158 ^{B}	0.083 ^{AB}	0.081 ^{B}	0.239 ^{BC}	0.239 ^{B}	0.052 ^{A}	0.045 ^{A}
	800	0.164 ^{AB}	0.162 ^{AB}	0.086 ^{AB}	0.085 ^{A}	0.250 ^{AB}	0.247 ^{B}	0.054 ^{A}	0.046 ^{A}
	1000	0.171 ^{A}	0.168 ^{A}	0.088 ^{A}	0.088 ^{A}	0.259 ^{A}	0.255 ^{A}	0.054 ^{A}	0.044 ^{AB}
0	0	0.078 ^{h}	0.065 ^{j}	0.044 ^{i}	0.035 ^{k}	0.122 ^{g}	0.100 ^{j}	0.033 ^{e}	0.028 ^{g}
	100	0.114 ^{g}	0.106 ^{h}	0.062 ^{h}	0.052 ^{i}	0.176 ^{f}	0.159 ^{h}	0.040 ^{de}	0.032 ^{g}
	200	0.129 ^{f}	0.118 ^{g}	0.070 ^{fg}	0.060 ^{h}	0.199 ^{e}	0.178 ^{g}	0.046 ^{cd}	0.039 ^{ef}
	400	0.138 ^{def}	0.141 ^{e}	0.076 ^{ef}	0.072 ^{f}	0.214 ^{de}	0.214 ^{e}	0.048 ^{cd}	0.040 ^{def}
	600	0.144 ^{df}	0.152 ^{d}	0.078 ^{de}	0.080 ^{de}	0.222 ^{d}	0.232 ^{d}	0.049 ^{bc}	0.042 ^{def}
	800	0.151 ^{cd}	0.155 ^{cd}	0.081 ^{cde}	0.082 ^{cd}	0.231 ^{cd}	0.237 ^{cd}	0.051 ^{abc}	0.042 ^{def}
	1000	0.161 ^{bc}	0.160 ^{cd}	0.084 ^{bcd}	0.085 ^{bc}	0.245 ^{bc}	0.245 ^{c}	0.052 ^{abc}	0.041 ^{cde}
0.5	0	0.086 ^{h}	0.077 ^{i}	0.044 ^{i}	0.040 ^{j}	0.130 ^{g}	0.116 ^{i}	0.036 ^{e}	0.031 ^{g}
	100	0.131 ^{ef}	0.118 ^{g}	0.066 ^{gh}	0.061 ^{h}	0.197 ^{e}	0.179 ^{g}	0.047 ^{cd}	0.037 ^{f}
	200	0.149 ^{cd}	0.129 ^{f}	0.076 ^{ef}	0.066 ^{g}	0.225 ^{cd}	0.195 ^{f}	0.052 ^{abc}	0.044 ^{bcd}
	400	0.168 ^{a}	0.152 ^{d}	0.086 ^{abcd}	0.076 ^{ef}	0.254 ^{ab}	0.228 ^{d}	0.054 ^{abc}	0.046 ^{abc}
	600	0.170 ^{a}	0.163 ^{bc}	0.087 ^{abc}	0.083 ^{cd}	0.257 ^{ab}	0.246 ^{bc}	0.056 ^{ab}	0.048 ^{abc}
	800	0.178 ^{a}	0.170 ^{ab}	0.091 ^{ab}	0.087 ^{ab}	0.269 ^{a}	0.257 ^{ab}	0.057 ^{ab}	0.049 ^{ab}
	1000	0.182 ^{a}	0.176 ^{a}	0.092 ^{a}	0.090 a	0.274 ^{a}	0.266 ^{a}	0.057 ^{a}	0.047 ^{a}

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Many authors working on humic substances on *Solanaceae* family coincides our results such as **Osman and Ewees (2008)** found that the chlorophyll a+b contents were significantly higher in leaf tomato plants irrigated with either fresh water or saline water. In pot experiments, **Rady et al. (2018b)** indicated that the application of potassium humate at 0.2 g kg^{-1} soil increased chlorophyll a+b, total carotenoids and chlorophyll fluorescence measured in terms of Fv/Fm and performance index (PI) of eggplant plants compared to the untreated control. Leaf photosynthetic pigments content (chlorophyll a+b and carotenoid synthesis) are dependent upon mineral nutrition **(Daughtry et al., 2000)**. Leaf photosynthetic pigments depend on phosphorus content, since it facilitates the plant for stability in unfavorable conditions **(Bojovic and Stojanovic, 2006).** However, the facilitation of biochemical characteristics and biosynthesis of leaf pigment molecules depends on the uptake of optimal phosphorus levels **(Waraich et al., 2015)**. Optimal phosphorus conditions, in apricot seedlings, have been shown to increase chlorophyll a+b content and plant growth **(Dutt et al., 2013)**. Previous studies have also found that phosphorus application increases the biomass and total carotenoid production of a blue-green alga *Spirulina platensis* **(Celekli et al., 2009)**, whereas phosphorus deficiency decreases protein and total chlorophyll contents **(Liang et al., 2005)**. **Kazemi (2014)** found that leaf chlorophyll content in tomato plants increased from 13.12 in the control to 22.41 and 21.14 (SPAD) with 30 ppm humic acid and 15 mM Ca foliar application. In addition, he said that the interaction between HA and Ca (30 ppm humic acid +15 mM Ca) gave the highest value (25.14) in the respect, comparing with the control plants.

Leaf N, P, K and Ca contents

Application of growth medium with 0.5 g l^{-1} potassium humate gave the highest significant values on leaf N, P, K and Ca (mg g^{-1} DW) than the growth medium without potassium humate treatment, in both seasons. Regardless of the control treatment, spraying calcium phosphate at a concentration of 100 mg l^{-1} significantly recorded higher mean values of leaf N content, with an increased in calcium phosphate concentration up to 1000 mg l^{-1} led to a gradual decrease in leaf N content. Therefore, the lowest leaf N content was at a concentration of 1000 mg l^{-1} of calcium phosphate. On the other hand, application of calcium phosphate at 1000 mg l^{-1}, significantly, attained higher values of leaf P and Ca content. While, application of calcium phosphate 200 or 400 mg l^{-1} gave the highest significant values on leaf K content, in the two growing seasons of 2018 and 2019. The treatment combination of medium supplemented with 0.5 g l^{-1} potassium humate together with foliar application of calcium phosphate 100 mg l^{-1} recorded the higher values of leaf N content, or with 1000 mg l^{-1} recorded the best values of leaf P and Ca content, or with concentrations at either 200 and 400 mg l^{-1} recorded the higher values of leaf K content, in both seasons.

The positive effect of potassium humate on N, P, K and Ca leaf content might be due to their positive effect on stability of membrane permeability; MSI and RWC (Table 5). This led to enhancing roots dry weight (Tables 2 - 4), which reflected positively on uptake of nutrients N, P, K and Ca when an application growth medium supplemented with 0.5 g l^{-1} potassium humate comparing to control. This may indicate that potassium humate improved the chemical properties of soil by increasing the number of micro-organisms which can enhance nutrient cycling and increasing the bio-availability of mineral nutrients to the transplant roots **(Sayed et al., 2007).**

Table 7. Effect of potassium humate-supplemented medium and calcium phosphate on leaf elemental of pepper seedlings.

Potassium humate (g l^{-1})	Calcium phosphate (mg l^{-1})	N (mg g^{-1} DW) 2018	N (mg g^{-1} DW) 2019	P (mg g^{-1} DW) 2018	P (mg g^{-1} DW) 2019	K (mg g^{-1} DW) 2018	K (mg g^{-1} DW) 2019	Ca (mg g^{-1} DW) 2018	Ca (mg g^{-1} DW) 2019
0		22.0 B*	23.0 B	1.67 B	1.61 B	19.9 B	19.7 B	13.4 B	13.3 B
0.5		24.5 A	25.4 A	1.86 A	1.81 A	22.0 A	21.8 A	14.8 A	14.7 A
	0	23.4 D	24.1 C	1.06 D	0.99 E	20.1 C	20.4 DE	10.3 G	10.1 G
	100	30.2 A	29.9 A	1.55 C	1.51 D	21.6 B	21.2 CD	11.3 F	11.0 F
	200	27.7 B	28.1 AB	1.83 B	1.71 C	22.5 A	22.7 A	12.6 E	13.1 E
	400	26.2 C	27.5 B	1.93 A	1.87 B	22.4 A	22.3 AB	14.2 D	14.1 D
	600	19.6 E	22.1 D	1.97 A	1.92 AB	22.0 AB	21.7 BC	15.2 C	14.9 C
	800	18.2 F	19.8 E	1.99 A	1.97 A	20.2 C	19.8 E	17.2 B	16.8 B
	1000	17.4 F	17.9 F	2.02 A	1.99 A	17.6 D	17.2 F	18.2 A	17.8 A
0	0	22.6 f	22.7 g	1.01 h	0.95 f	19.1 c	19.4 fg	9.8 h	9.6 i
	100	28.5 bc	28.3 bcd	1.43 g	1.42 e	20.5 b	20.1 ef	10.7 g	10.5 h
	200	26.1 d	26.6 cde	1.74 ef	1.61 d	21.3 b	21.5 cd	11.9 f	12.4 g
	400	24.5 e	26.1 de	1.83 de	1.72 c	21.2 b	21.1 cde	13.5 e	13.3 f
	600	18.6 h	21.2 g	1.87 de	1.80 bc	20.8 b	20.6 def	14.4 d	14.1 ef
	800	17.2 ih	18.5 i	1.88 d	1.87 b	19.2 c	18.8 gh	16.3 c	16.0 c
	1000	16.5 j	17.3 i	1.90 cd	1.89 b	17.0 d	16.6 i	17.6 b	17.2 b
0.5	0	24.2 e	25.4 ef	1.11 h	1.04 f	21.1 b	21.4 cd	10.8 g	10.6 h
	100	31.9 a	31.4 a	1.66 f	1.60 d	22.7 a	22.3 bc	11.9 f	11.6 g
	200	29.3 b	29.6 ab	1.93 bcd	1.80 bc	23.7 a	23.9 a	13.3 e	13.8 f
	400	27.9 c	29.0 abc	2.04 abc	2.01 a	23.6 a	23.5 a	15.0 d	14.8 de
	600	20.5 g	22.9 fg	2.07 ab	2.03 a	23.2 a	22.9 ab	16.1 c	15.7 cd
	800	19.2 gh	21.1 gh	2.10 a	2.08 a	21.3 b	20.8 de	18.1 ab	17.7 ab
	1000	18.2 hi	18.6 hi	2.13 a	2.09 a	18.3 c	17.9 h	18.9 a	18.5 a

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

In addition, media supplemented with humic acid (0.5 g l^{-1} media) also promoted the absorption of nutrients by preventing their precipitation in the nutrient solution **(Osman and Rady, 2014).** Also, potassium humate similarly as a good fertilizer state creating more accessibility for the nutrients (**Osman and Ewees, 2008 and Taha and Osman 2018)** by reduction soil pH value, thus increasing the availability of mineral nutrients to be absorbed by plant roots. Related to our results on *Solanaceae* family plants, **Osman and Rady (2014)** reported that the media supplemented with humic acid (0.5 g l^{-1} media) gave significant higher transfer factor (uptake) values for N, P, and K in 4-week-old tomato and eggplant transplants produced than corresponding humic acid-free media. In pot experiments, **Rady et al. (2018b)** indicated that the application of potassium humate at 0.2 g kg^{-1} soil as a single used or 0.2 g kg^{-1} soil when it was used in combination with biochar significantly increased leaf NO_3^-, NO_2^- and K^+ contents of eggplant plants compared to the untreated control. The positive effect of calcium phosphate on P and Ca leaf content (Table 7) might be due to their positive effect on stability of membrane permeability; MSI and RWC (Table 5) and increased contents of photosynthetic pigments (Table 6). Additionally, the spraying of calcium phosphate increased phosphorous and calcium content inside the leaf of pepper transplants. While the effect of calcium phosphate were less on leaf N and K content of pepper transplants for may be to the antagonism between the metabolism of elements. **Kazemi (2014)** reported that leaf N and K content of tomato was not affected by foliar application of calcium alone, but humic acid application resulted in a significant increase in the leaf N and K content. In addition, he noticed that humic acid at 30 ppm + Ca at 15 mM (2.51 and 2 %, respectively) was superior in this respect. Foliar application of humic acid alone significantly increased the nitrate reductase activity. **Ilias et al. (2007)** found that application of humic acid and Ca promoted the accumulation of K, B, Mg, Ca and Fe in leaves of okra plants. **Tejashvini and Thippeshappa (2017)** revealed that application of different Ca sources, as foliar spray will enhance the nutrient content and uptake by tomato crop. As well as, all the sources of calcium found to be effective and significantly increased nutrient content and uptake.

Within the experimental conditions studied, it has been concluded that this work provided evidence to the role of potassium humate and/or calcium phosphate application act to directly at improving the morphological characters, membrane permeability, leaf photosynthetic pigments and leaf elemental contents of pepper transplants produced (*Capsicum annuum* ‘Omega’ F1 Hybrid). Generally, the growth medium supplemented with 0.5 g l^{-1} potassium humate in integration with foliar application of calcium phosphate at 600 or 800 mg l^{-1} act to enhancing the plant physio-biochemical components, which reflected in high growth of pepper seedlings.

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الملخص العربي

تأثير هيومات البوتاسيوم وفوسفات الكالسيوم على إنتاج شتلات الفلفل

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أجريت تجربتين فى صوبة مغطاة بشباك التظليل خلال عامي ٢٠١٨ و ٢٠١٩ بمشتل خاصة بمركز ابشواي، الفيوم، مصر، لدراسة تأثير هيومات البوتاسيوم وفوسفات الكالسيوم على الصفات المورفولوجية، وثبات الأغشية، وصبغات البناء الضوئى، ومحتوى الأوراق من العناصر المعدنية لشتلات الفلفل صنف هجين اوميجا. وقد أتبع في تصميم التجربة نظام القطع المنشقة لمرة واحدة فى تصميم عشوائى كامل بأربعة مكررات. وزعت مستويي هيومات البوتاسيوم (٠ و ٠,٥ جم لكل لتر بيئة نمو) في القطع الرئيسية، بينما وزعت عشوائيًا تركيزات فوسفات الكالسيوم (٠ ، ١٠٠، ٢٠٠، ٤٠٠، ٦٠٠، ٨٠٠ و ١٠٠٠ مليجرام لكل لتر ماء) في القطع تحت الرئيسية. تمت الإضافة هيومات البوتاسيوم (٠,٥ جم لكل لتر بيئة نمو) مع نصف بيئة نمو الشتلات المجهزة للتجربة أثناء إعدادها لزراعة البذور والنصف الأخر من بيئة النمو لم يضف لها هيومات البوتاسيوم. بينما ثم الرش الورقى لتركيزات المختلفة لفوسفات الكالسيوم ثلاث مرات بعد ٢٥ ، ٣٥ و ٤٥ يوم من زراعة البذور.

أعطت بيئة النمو المحتوية هيومات البوتاسيوم بمعدل ٠,٥ جم لكل لتر بيئة نمو أعلى القيم معنويا للقياسات الخضرية، دليل ثبات الأغشية، محتوى الماء النسبى للخلايا، محتوى الأورق من صبغات البناء الضوئى ومحتوى الأوراق من N، P، k و Ca مقارنة ببيئة النمو التي لم يضاف لها هيومات بوتاسيوم، باستثناء عدد الأورق للشتلة لم تتأثر معنويًا في كلا الموسمين

بشكل عام، أعطى الرش الورقى من فوسفات الكالسيوم بتركيزات ٦٠٠ و ٨٠٠ مليجرام للتر أعلى القيم معنويا للقياسات الخضرية، دليل ثبات الأغشية، محتوى الماء النسبى للخلايا، محتوى الأورق من صبغات البناء الضوئى مقارنة بالتركيزات الأخرى باستثناء عدد الأورق للشتلة لم تتأثر معنويًا. في حين أن رش فوسفات الكالسيوم بتركيز ١٠٠ مليجرام لكل لتر أعطى أعلى القيم بشكل ملحوظ لمحتوى الأوراق من عنصر النيتروجين، وبزيادة تركيز الرش حتى ١٠٠٠ مليجرام لكل لتر حدث نقص تدريجى لمحتوى الأوراق من النيتروجين، حيث أعطى التركيز ١٠٠٠ مليجرام لكل لتر أقل محتوى للأوراق من النيتروجين. من ناحية أخرى، أعطى الرش بتركيز ١٠٠٠ مليجرام لكل لتر لأعلى القيم لمحتوى الأوراق من الفوسفور والكالسيوم. بينما، أعطى الرش بتركيز ٢٠٠ أو ٤٠٠ مليجرام لكل لتر من فوسفات الكالسيوم أعلى القيم من محتوى الأوراق من البوتاسيوم، فى موسمين النمو ٢٠١٨ و ٢٠١٩.

وبشكل عام، فإن بيئة نمو الشتلات المضاف لها ٠,٥ جم هيومات البوتاسيوم لكل لتر بيئة نمو مع الرش بتركيزات ٦٠٠ أو ٨٠٠ من فوسفات الكالسيوم لكل لتر ماء تعمل على تحسين المكونات الفيزيوكيميائية للنباتات مما ينعكس إيجابيًا على نمو وإنتاج شتلات الفلفل.