Research on Varied PH Values in Peat Substrate Greatly Affect the Nutrient Uptake in Pepper Seedling Plants

Jian Zhang[1,2], Feifei Yu[1,2], Hongmei Tian[1,2], Gang Xu[1], Zhen Tao[1] and Pengcheng Wang[1,2,a,*]

[1]Institute of Horticulture, Anhui Academy of Agricultural Sciences, Hefei, China
[2]Key Laboratory of Genetic Improvement and Ecophysiology of Horticultural Crops, Hefei, China
a. pengchengah@hotmail.com
**corresponding author:Pengcheng Wang*

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Abstract: This work evaluated the effects of pH value in substrates on the uptake of nitrogen (N), phosphorus (P), and potassium (K) in the early growth stages of pepper to grow healthy and robust seedlings. Results showed that the highest root dry weight and seedling index (SI) of pepper were obtained at pH 6.5, and the lowest values were obtained at pH 8.0. The highest N content in the roots and stems was observed at pH 5.5. The highest P content in the roots and stems was obtained at pH 5.5 and 6.0, respectively. The highest K content in the roots and stems was observed at pH 6.5 and 7.0, respectively. Pearson correlation analysis showed that the pH value was negatively correlated with N and P contents in the roots and shoots. SI was positively correlated with stem diameter, root dry weight, and shoot dry weight and also strongly linked to N in the shoots and K in the roots and shoots. Our findings suggest that regulating the pH value in substrates is a good method to improve nutrient uptake in the early growth of peppers.

1. Introduction

Since the last 60 years, container production of horticultural and vegetable crops has primarily utilized soilless substrates (Vaughn et al. 2011). These substrates are composed of organic materials such as peat, compost, or mushroom residue blended with other organic or inorganic components, for example, perlite and vermiculite (Bilderback et al. 2005, Vaughn et al. 2011). To date, soilless substrates are still primarily used in the production of containerized greenhouse and nursery crops (Burnett et al. 2016), especially for growing vegetable seedlings. However, greenhouses and nurseries have begun to use soilless substrates in the production of bedding plants, not only for fruit seedlings but also for vegetable ones (St-Martin and Brathwaite 2012). Therefore, understanding how substrates affect early plant growth is essential if we are to grow robust seedlings in modern agricultural production.

Substrates can be used as growing media to produce high-quality seedlings (Guérin et al. 2001, Marfà et al. 2002), which increase the chances of crop success after transplantation. Peat is one of the most widely used substrates because it can obtain the optimum quality and yield for horticultural cultivation (Do and Scherer 2013). However, the pH of peat-based substrates affects plant growth mainly through its effect on nutrient solubility (Ek et al. 1994, Wong 2003). By

optimizing the pH of substrates, plant growth can be enhanced. Nevertheless, few reports have focused on the effects of pH on seedling plant nutrient uptake in substrates.

Peppers (Capsicum) are a very important agricultural crop worldwide (Cankaya et al. 2017) because they are easily planted and contain several nutrients in the fruits. Five species of Capsicum are mainly cultivated worldwide, especially in China (Ou et al. 2018). Presently, a majority of pepper seedlings are cultivated in substrates by enterprises, nurseries, or plant growers (Lakhiar et al. 2018). Therefore, the physical properties of substrates will play important roles in growing peppers and greatly affect the growth of pepper seedlings. However, whether the pH in the substrate affects the nutrient uptake in pepper seedling plants still remains to be elucidated. Therefore, our study aims to better understand the effects of pH value in substrates on the uptake of nitrogen (N), phosphorus (P), and potassium (K) to facilitate the growth of pepper seedlings.

2. Materials and Methods

2.1. Preparation of Substrates

The seedling substrate made of peat, vermiculite, and perlite with volume ratio of 3:1:1 was used. The total density of the mixed substrate was 0.25–0.30 g/cm3. The total porosity was 85.8%–87.0%, and the initial pH of the peat was 5.0. Substrate pH was adjusted to 5.5, 6.0, 6.5, 7.0, and 8.0 by using quick lime. The initial properties of the substrate were as follows: available N (NH_4^+), (0.53–0.59) g/kg; available P, (0.11–0.17) g/kg; and K, (0.61–0.70) g/kg.

2.2. Plant Material and Cultivation Time

The hybrid pepper plant ‘Wan No. 10’ was used. The seeds were sown in 23 g of substrate in 6 cm-diameter plastic pots under greenhouse conditions at a temperature range of 24 °C–28 °C and a relative humidity range of 35%–45% from January 10, 2018, to August 20, 2018, at the Anhui Academy of Agricultural Sciences.

2.3. Management Under Greenhouse Conditions

The seedling plants under different treatments were cultivated in a greenhouse by following regular management. To meet the nutrient requirement of growing pepper seedling plants, 10 mL of NPK (1:3:3) solution was added to the substrates every 10 days. The plants were cultivated through surface irrigation with day and night temperatures of 24 °C–28 °C and 15 °C–20 °C, respectively.

2.4. Pepper Seedling Sampling

Ten seedling plants were sampled from each treatment and washed gently to remove the adhering substrates from the roots. The roots were snipped from the grafted plant. The shoots and roots were oven-dried for three days at 70 °C, and then their dry weights were measured. Afterward, the shoots and roots were stored for further analysis. The seedling index (SI) was calculated by the following formula: $SI = (\frac{SDI}{PHT} + \frac{RDW}{SDW}) \times TDW$, where SDI is the stem diameter, PHT is the plant height, RDW is the root dry weight, SDW is the shoot dry weight, and TDW is the total dry weight.

2.5. Measurement of N, P, and K

Dried plant samples were ground separately in a Wiley mill. Then, 0.5 g of the comminuted tissues was analyzed for N and K contents according to a previously reported method (Rashid et al. 2016).

The total K content was analyzed in the filtrate using flame atomic absorption spectrophotometry. The total P content of the plants was determined according to a previously reported method (Abbasi et al. 2011). Approximately 5 mL of sulfuric acid was added into the digestive tract. Then, 2 mL of hydrogen peroxide was added. After intense reaction, heating was continued for 5 min to remove excess hydrogen peroxide. After cooling, the digested liquid was transferred into a 100 -mL-volume bottle.

2.6. Statistical Analysis

Statistical analysis was conducted using one-way ANOVA, followed by Fisher's least significant difference and Duncan's tests at $p < 0.05$. In addition, Pearson correlation coefficient was calculated using SPSS software (version 19.0, IBM Corp., Armonk, NY, USA).

3. Results and Discussion

3.1.Dry Weights and SI

No significant difference was detected in the plant height of pepper seedlings among the five pH values in peat substrate treatments (Figure 1). However, significant differences were observed in root length with a maximum length of 18.0 cm at pH 7.0. This value was longer than that of 12.1 cm at pH 6.0 (Table 1), indicating that pH significantly affects root growth. Previous studies showed that low soil pH directly inhibits plant growth, especially the roots (Grewal and Williams 2003, Yan et al. 1992). Our observations suggested that the pepper seedling root is sensitive to varied pH in substrates. The maximum and minimum stem diameters were observed at pH 6.5 and 8.0, respectively. The highest shoot dry weight was 824 mg at pH 7.0, and the lowest value was 576 mg at pH 8.0. The highest root dry weight of pepper was 216 mg at pH 6.5, and the lowest value was only 167 mg at pH 8.0 (Table 1).

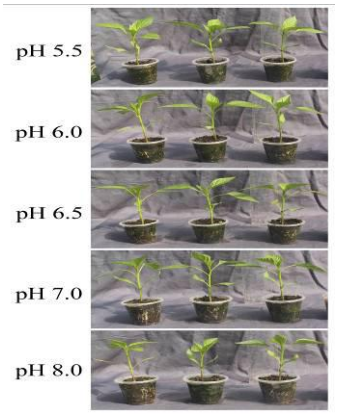

Figure 1: Photo of pepper seedling plants growing in different pH value substrates.

Analysis of seedling growth has been considered a useful tool to detect the standard viability, and seedling quality can be evaluated by the SI (Steiner 1990). In this work, the highest and lowest SI values were observed at pH 6.5 and 8.0, respectively (Table 1). The shoot dry weight and root length of pepper seedlings were the highest at pH 7.0. Although the plant height, root length, and shoot dry weight were not the largest, the root dry weight was the highest at pH 6.5, indicating that this pH value benefits pepper root growth. However, all the determined indexes were the lowest at pH 8.0, indicating that high pH value was not favorable to the growth of pepper seedlings.

Table 1: Measurement of Plant Growth Items.

Treatment	Plant height (cm)	Stem diameter (mm)	Root dry weight (g)	Shoot dry weight (g)	Total dry weight (g)	Seedling index
pH 5.5	7.93±0.15a	2.63±0.21ab	0.197±0.005ab	0.807±0.014a	1.003±0.007a	0.577ab
pH 6.0	7.88±0.16ab	2.58±0.11ab	0.179±0.007b	0.737±0.011b	0.916±0.009a	0.522b
pH 6.5	7.63±0.11ab	2.80±0.22a	0.216±0.009a	0.793±0.015ab	1.009±0.011a	0.645a
pH 7.0	8.00±0.35a	2.60±0.11ab	0.196±0.006ab	0.824±0.018a	1.020±0.015a	0.575ab
pH 8.0	7.40±0.20ab	2.13±0.13b	0.167±0.010b	0.576±0.012c	0.743±0.012b	0.429c

Different letters indicate significant differences at $p < 0.05$. Values are means ± SD.

3.2. Uptake of N, P, and K

The highest N contents in the roots and shoots of pepper were 8.92 and 32.19 mg at pH 5.5 (Table 2), respectively. The lowest N contents in the roots and shoots of pepper were observed at pH 8.0, indicating that high pH inhibits the absorption of N in pepper seedling. This finding may be attributed to N immobilization at high pH (Teutscherova et al. 2017). The N contents in the roots and shoots at pH 5.5 were 1.5 and 1.6 times higher than those at pH 8.0. The highest P contents in the roots and shoots were 0.54 mg at pH 5.5 and 3.62 mg at pH 6.0, respectively. The lowest P contents in the roots and shoots of pepper were observed at pH 8.0. Previous studies reported that P immobilization is high at high pH values not only in soils but also in solutions (Barrow 2017, Liu et al. 2008). The P contents in the roots and shoots at pH 5.5 were 2.7 and 2 times higher than those at pH 8.0. The N and P contents in pepper plant were high at pH 5.5, suggesting that seedling plants absorb more N and P under low pH value. The highest contents of K in the roots and shoots were 5.24 mg at pH 6.5 and 46.58 mg at pH 7.0, respectively. The lowest contents of K in the roots and shoots of pepper were 4.04 and 32.03 mg at pH 8.0, respectively. We found that more N, P, and K accumulated in the pepper plant grown in low pH substrate, suggesting that nutrients are more available under low pH than under high pH. Other studies also showed that soil pH substantially affects the supply of nutrients to plants, and low pH means more supply of nutrients (Khan et al. 2015, Ova et al. 2015). We obtained the same conclusion that pepper plants grown in low pH substrate can absorb more N, P, and K elements.

Table 2: Measurement of N, P and K in Pepper Seedling Plants.

Treatment		Amount (mg)		
		N	P	K
RT	pH 5.5	8.92±0.05a	0.54±0.01a	4.88±0.04ab
	pH 6.0	7.73±0.04ab	0.43±0.03b	4.49±0.06ab
	pH 6.5	8.48±0.06a	0.39±0.01bc	5.24±0.09a
	pH 7.0	6.68±0.06b	0.30±0.03c	4.82±0.04ab
	pH 8.0	6.04±0.08bc	0.20±0.02d	4.04±0.07b
SH	pH 5.5	32.19±0.07a	3.43±0.05ab	47.37±0.17a
	pH 6.0	29.33±0.08ab	3.62±0.08a	42.10±0.14ab
	pH 6.5	31.64±0.10a	2.42±0.04b	45.55±0.10ab
	pH 7.0	28.75±0.09ab	2.12±0.07b	46.58±0.11a
	pH 8.0	19.69±0.07b	1.70±0.06bc	32.03±0.09b

RT, root part; SH, shoot part.
* Total N= RT+SH.

Different letters indicate significant differences at $p < 0.05$. Values are means ± SD.

3.3. Pearson Correlation Analysis

Pearson correlation coefficient is a well-established measure of correlation (Adler and Parmryd 2010). No significant correlation was found between the pH value and plant height, stem diameter, root dry weight, and stem dry weight, indicating that the change in pH value had minimal effect on plant height at the seedling stage (Table 3). However, the pH value was negatively correlated with N (both $p < 0.05$) and P contents in the roots ($p < 0.01$) and shoots ($p < 0.05$), indicating that the change in pH value affected the absorption of nutrients by pepper seedlings.

SI was significantly and positively correlated with stem diameter ($p < 0.01$), root dry weight ($p < 0.01$), stem dry weight ($p < 0.05$), and total dry weight ($p < 0.05$), indicating that these variables were the main factors determining the seedling growth of pepper under different pH values. Here, we found that SI was also positively correlated with N content in the shoots ($p < 0.05$) and K content in the roots ($p < 0.01$) and shoots ($p < 0.05$) (Table 3). K is involved in many physiological processes, such as electrochemical homeostasis and several enzyme activities (Anschütz et al. 2014). The high content of N and K was the main factor that promoted the growth and dry matter accumulation of capsicum (Cui et al., 2019). Thus, it was significantly correlated with SI. K deficiency is also highly detrimental to plant growth and primary production by crops (Cui et al. 2019, Shin 2014). Our study indicated that K content should be properly increased in growing seedlings, but no significant correlation was detected between SI and P, indicating that P had less effects on the growth of pepper seedlings than N and K at the early stages.

Table 3: Pearson Correlations of Determined Items With pH and Seedling Index.

Determined item	PHT	SDI	RDW	SDW	TDW	
pH	-0.676	-0.723	-0.464	-0.702	-0.681	
SI	0.477	0.965**	0.980**	0.888*	0.927*	
Determined item	RTN	RTP	RTK	STN	STP	STK
pH	-0.899*	-0.989**	-0.578	-0.882*	-0.922*	-0.760
SI	0.727	0.582	0.997**	0.893*	0.274	0.889*

* Correlation is significant at $p < 0.05$ level; ** Correlation is significant at $p < 0.01$ level.

PHT, plant height; SDI, stem diameter; RDW, root dry weight; SDW, shoot dry weight; TDW, total dry weight; RTN, root total nitrogen; RTP, root total phosphorus; RTK, root total potassium ; STN, shoot total nitrogen; STP, shoot total phosphorus ; STK, shoot total potassium.

4. Conclusion

We concluded that pH value plays an important role in making substrates and can not only increase seedling index but also improve nutrient absorption. We suggest that regulating the substrate's pH value is a good alternative for improving nutrient uptake in the early growth of pepper.

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