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Effect of pH and EC of Hydroponic Solution on the Growth of Greenhouse Rose

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Abstract: High temperature and high light intensity in summer season tend to induce unbalance water uptake and mineral elements in hydroponic cultured roses. In addition, differential uptake of various elements causes unstable pH in root zone. To solve this problem the best managing range of nutrient, EC and pH, nutrient solutions were made of three levels of EC at 0.2, 0.7 and 1.2 dS m^{-1} and three pH levels, 4.0, 6.0 and 8.0, were adjusted. Stem length of rose was the greatest when a nutrient solution of pH 8.0 and EC 0.2 or 0.7 dS m^{-1} was supplied. The yield of cut-flowers was also the greatest when plants were fed with a solution of pH 8.0 regardless of EC. Maintaining of pH was possible in EC 0.7 dS m^{-1} at pinching time. The rhyzosphere pH was positively correlated with the EC in culture media even it was not changed in neutral pH range 6.0-7.0 in EC 0.2 dS m^{-1}. Dry weight was mostly positively related with pH and dry weight of cut-flower and it was greatest at pH 8.0 in EC 1.2 dS m^{-1}, however DWR, node numbers and leaf area were greater at pH 4.0 in EC 0.2. Stem Osmotic Potential (OP) was positively related with the culture media pH in EC 0.2 and 0.7 dS m^{-1}. Leaf greenness was also positively related with the pH and EC. Cut-flower length and commercial cut-flower ratio, weight and leaf length were not significantly affected by EC but pH was more effective in low EC. Higher pH induced greater root growth. T-N was mostly greater at neutral cultural media in low or mid EC level but reversed effect was shown in high EC level (EC 1.2 dS m^{-1}). The uptake pattern of Mg and Ca was same as higher at pH 6.0 in mid or low EC level and not affected by pH in low EC level. In conclusion, the best culture media of pH range is neutral with mid or low EC level which is economically valuable and practically viable.

Key words: Culture media, EC, hydroponic solution, nutrients, pH, rose

INTRODUCTION

Root zone pH is the most importantly considered in hydroponic culture. Easily changing of root zone pH will be damaged to the plant growth, so maintaining of pH in root zone is most importantly considered of all the soil factors. The adaptable pH is variable by crops, however they are mostly ranged between 5.5-6.5[1,2]. The pH of rockwool slab culture was best in 5.5[3] and it ranged between 5.0 and 6.0 for crop growth. In general, pH will be adjusted by acids or alkary[3-7]. However, it is very difficult for adjusting of pH by acids or alkary only because water and nutrient uptake easily change the media solution pH. Change of root zone pH will be easily affected by root zone temperature[8]. Additionally the increasing of temperature above 20°C improve phosphate uptake and resultantly increase pH of culture solution, however, decreasing of temperature will be decrease phosphate uptake and resultantly reduce the pH.

In Deep Flow Technique (DFT) rose culture, Dissolved Oxygen (DO) in rhyzosphere between 80-90% will be reduced low or high pH damage such as pH 4.0 and 8.0[9]. Pilbean and Kirkby[10] introduced valuable rhyzospere pH adjusting in NFT (Nutrient Film Technique) system by the refrain of accumulation of H^+ in rhyzosphere.

Acidification of culture media will be easier in high nutrient concentration in 1/4, ½ and 2 times of standard culture media of Japanese culture media in hydroponic culture of chrysanthemum[11]. Additionally, Selmer and Gislerod[12] reported that the acidification was easily found by the growth of chrysanthemum but pH was increased in low nutrient level.

FAO[13] reported that the higher of carbonic acid or bicarbonic acids in supplying water will be increasing of culture media's pH but in contrast pH was lower in low carbonic or bicarbonic acids contents. They also indicated that for maintaining of valuable pH, 30~50 ppm of carbonic or bicarbonic acids should be maintained.

Crop growth was mostly depends on water and nutrient in culture media. Of all the nutrients, N is the most effective for the growth and they are mostly uptake by the

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ratio of NH_4^+ and NO_3^- in culture media such as supplying of NO_3^- increase, however, NH_4^+ will be reducing[14]. Jones[15] additionally introduced that more than 90% of NO_3^- of total N will be increase pH and more than 20% of NH_4^+ will be reducing the pH in tomato cultivation.

Schrader *et al.*[16] introduced that N uptake ratio will be increasing by mixed supply of $NH_4^+$and NO_3^- than each single supply and additionally pH of culture media will be stable. However, it was different to cultivation crop.

Ikeda and Osawa[5] introduced that the uptake order between NH_4^+ and NO_3^- is different by crop or cultivar, growth stage, culture media pH and temperature such as the pH will be decreasing in straw berry and lettuce because they are firstly uptake of NH_4^+ and after empted or decreasing of NH_4^+ will be maintaining or increasing of the pH in culture media. However, NO_3^- will be firstly uptake in spinach, garden pea uptake of NO_3^- in pH 5.0 and increasing of pH, however there was no change in pH 7.0 because of same content of NO_3^- and NH_4^+.

Additional other reports introduced that difference of yield was not observed by N supplying source in adjusted pH[10,14,17] and they additionally introduced that toxicity or decreasing of growth was resulted from the low pH not by NH_4^+.

There was no effect of N uptake and accumulation by source in adjusted pH 6.0 in tomato and tobacco[18,19]. Plant photosynthetic activity and stomatal conductance of tomato were greatest in pH 5.5~6.0 of culture media[20] and T/R ratio and dry weight ratio were greater in pH 5.5 of culture media, especially than pH 6.0 or pH 7.0. It was different by culture media and the most valuable pH were 5.5-6.0 in vermiculite, 5.5 in perpelite.

Lettuce growth was best in pH 7 but it was not grown by the no rooting and withered of leaf in pH 3.0 which reason was no uptake of Mo, however, above than pH 8.0 will be reducing the uptake of Fe, Mn and Cu[21]. Root growth of rose in rockwool slab culture was normally grow in pH 4.5-7.0, however its growth was deteriorated in above 8.0 and lower 4.0 levels[9]. In lettuce, plant growth was better in pH 6 and 7 than pH 5 and 8[22].

Leaf number of Lettuce and water celery growth was best in pH 6.0 and 7.0, respectively and fresh weight and dry weight was the heaviest in pH 6.0[22].

Rose uptakes of NH_4^+ preference and exclude of H^+, which will be reducing culture media pH[14,23]. The uptake speed was same in the ratio 8:2 of NO_3^- and NH_4^+[24] and NH_4^+will be preference uptake in high temperature and chlorosis and defloliration will be done in 40% of NH_4^+ and rhyzosphere pH reach in 4.0.

In rockwool culture, rose grow normally in pH 4.5-7.0 of culture media but it growth will be damaged, especially root growth, in media more than 8.0 and lower than 4.0 of culture media pH[9].

In rose, inorganic nutrient uptake rate is different and easily changed of pH in culture media by growth stage[25], especially pH will be increasing from pinching to sprouting time then decreasing until flowering stage. The pH, EC and NO_3^- can easily changed by the cultivar with tree vigor from sprouting to harvesting of flower in cut-flower culture.

MATERIALS AND METHODS

Effect of supplying water pH and EC on rose growth: This experiment was done from Sept. 7 to Nov. 2 in 1999 in greenhouse in Busan Horticultural Experiment Station, National yeongnam Agricultural Experiment Station.

Materials and treatments methods: Rooting promoter (Rooton, Hannong, Korea) was treated on the bottom of cutting slips and it was selected from the healthy stem and it was cut 5 nodes then two small leaves were maintained. Cutting slips were cutting in Grodan rockwool cube (7.5x7.5x7.5 cm). Cutting slips were planted on rockwool slave (90x20x7.5 cm) in April 8, 1999 with 6 hills per slave and 3 slave per treatment with three replications.

Culture solution (Table 1) was used by the rose culture standard, Ehiji-Ken Horticultural Research Center, Japan (NO_3^- 11.0 me L^{-1}, NH_4^+ 2.0 me L^{-1}, $H_2PO_4^-$ 1.2 me L^{-1}, K^+ 4.5 me L^{-1}, Ca^{2+} 6.5 me L^{-1}, Mg^{2+} 2.0 me L^{-1}, SO_4^{-2} 2.0 me L^{-1}, Fe 2.0 ppm, Mn 0.5 ppm B 0.25 ppm, Zn 0.2 ppm, Cu 0.05 ppm, Mo 0.05 ppm, EC 1.6 dS m^{-1}). And that culture solution adjusted with EC 0.7 dS m^{-1} was used until secondary arching then EC 1.2 dS m^{-1} was maintained until just before the experiment starting. In EC treatment, 1 time for EC 1.2 dS m^{-1}, ½ time for EC 0.7 dS m^{-1} and supplying water for EC 0.2 dS m^{-1}. Treatment of pH related, 1N-H_3PO_4 and 1N-NaOH were used for the adjustment of pH 4.0, 6.0 and 8.0. Treatment duration was 15 days after 10 days pinching and maintained EC 1.2 dS m^{-1} for pH 6.0 in other cultivation duration. Other cultivation methods were same as experiment 1[26].

Growth and investigation of cut-flower quality: Pinching was done in all shoot except photosynthetic assimilation branch in September 7 then shoot growth and cut-flower quality was investigated after supplying of culture media at 10 days after pinching.

Dry weight was determined after drying 48 h at 85°C and dry weight ratio was expressed by percentage. Water potential was measured in 30 cm cut-flower stem with 3 replications on 7 am with pressure chamber (3015G2, Soil Moisture Equipment Co., USA). All of the attached leaves were included and leaf area was measured all of five flower-node with leaf area meter (Meiwa AMB). Chlorophyll content was measured on 1st leaf of 5th top

Table 1: Composition of the nutrient solution used in the experiment

Sample	EC (dS m^{-1})	pH	NH_4^+	NO_3^-	$H_2PO_4^-$	K^+	Ca^{+2}	Mg^{+2}
			me L^{-1}					
Surface water	0.2	6.9	-	0.3	-	0.1	0.5	0.2
Nutrient solution	1.2	6.3	1.3	7.9	0.77	3.3	4.6	1.3

leaf with chrophyll meter (SPAD 502, Minolta, Japan). For the measuring of inorganic nutrients and pH, solution of 60 mL in culture media within the slab was sampled with three replications after 30 min of culture media.

Other measuring methods were same as experiment 1[26].

RESULTS AND DISCUSSION

Effect of pH and EC of supplying water on rose growth change of rhyzosphere pH: The pH was very variable from Sept 16 in EC 0.2 dS m^{-1} culture media supplied plot but it was maintained with pH 7.0 before the treatment. The pH was maintained for 6.3 in pH 4.0 level, however it was rapidly decreased upto pH 5.5 from the final treatment then increased. The pH was maintained 6.7 in pH 6.0 treatment then after treatment it was increased upto 7.0 and after a little decreased and increased after flowering. The pH was slowly increased in pH 8.0 then decreased upto 6.7 then a little increased (Fig. 1).

The pH was maintained with 6.0 at pinching time at all pH treatments in EC 0.7 dS m^{-1}, however, it was rapidly decreased to pH 4.5 just after treatment and it was the same level then increased and reached the same level of other treatments after final flowering stage. Similar pH changing pattern was observed between pH 6.0 and 4.0 treatments and it increased from the after treatment and maintained 6.7, however, pH was maintained at 6.7 at 10 days after treatment and 7.3 in pH 8.0 treatment then similar inclination was found in pH 4.0 treatment.

Similar pH changing pattern was observed between pH 4.0 and 6.0 treatments in EC 1.2 dS m^{-1} and it was slowly decreased just after the treatment upto the 4.0 then increased and maintained at final harvesting stage with pH 5.5-6.0. The pH was maintained 5.6-6.0 in pH 8.0 treatment and it rapidly increased from just after treatment and reached 7.0 after 7 days of treatment then no changed. The rhyzosphere pH increased with increasing of EC, especially it was lower in all pH levels except pH 8.0 in EC 1.2 dS m^{-1}, however, rhyzosphere pH was highly maintained at 6.0-7.0 in EC 0.2 dS m^{-1}. This result was similar to the other reports; they introduced pH increased with high concentration and acidification will be promoted[11]. Additionally acidification of rhyzosphere was promoted by high concentration (high EC) in chrysanthemum culture[12], strawberry[27] and water celery[28].

Dry weight, Dry Weight Ratio (DWR), leaf number, leaf area: Dry weight was increased with increasing of pH and not related with the EC, however pH treatment effect was higher in high EC level. Dry weight ratio was greatest at pH 4.0 in EC 0.2 dS m^{-1} but it was decreased with the increasing of pH (Table 2). The DWR was greatest at pH 6.0 in EC 0.7 dS m^{-1} then pH 4.0 and 8.0 followed. DWR was increased with increasing pH in EC 1.2 dS m^{-1} and EC was decreased with increasing of supplying water EC level.

The number of cut-flower node was greatest at pH 8.0 (10.6 node/plant), in EC 0.2 dS m^{-1} then pH 4.0 and 6.0 were followed. However, node numbers were rapidly decreased at pH 4.0 in EC 0.7 and 1.2 dS m^{-1} and node numbers generally greater in high pH level.

In pH 4.0, leaf area was almost 50% lower than pH 6.0 and 8.0 in EC 0.2 dS m^{-1} treatments and leaf area was clearly increased with the increasing of pH in EC 0.7 and 1.2 dS m^{-1}. Leaf area increased with increasing of supplying water EC.

Dry weight of cut-flower was greatest at pH 8.0 in EC 1.2 dS m^{-1} and in pH 4.0 in EC 0.2 plot, DWR, node number and leaf area was highest.

Water potential and chlorophyll content: Stem Osmotic Potential (OP) was increased with increasing of culture media pH in EC 0.2 and 0.7 dS m^{-1} and it was greatest in latter (Fig. 2). However, OP was not different between pH 4.0 and 6.0 in EC 1.2 dS m^{-1}.

Quebedeaux and Ozbun[29] reported that rhyzosphere pH will be decreasing in high percentage of NH_4^+ in culture media and water uptake will be decreased by root damage from the low pH at rhyzosphere and this result dropped of leaf water potential and this report was similar to this experiment result.

The chlorophyll content (SPAD-value) was higher in pH 8.0 than pH 4.0 treatment, especially, it was lowest at pH 4.0 in EC 0.2 and 0.7 dS m^{-1} and resulted in leaf chlorosis in leaf vein (Fig. 3). Chlorophyll content was significantly different by pH treatment in low EC but the difference was lower in EC 1.2 dS m^{-1}. The results of leaf greenness was increased with increasing of pH and EC which was similar to the result that rose growth was not difference between pH 4.0 and 6.0 in rhyzosphere in short-time but chlorophyll content was lower in pH 4.0 treatment in long-term experiment[9]. Additionally, leaf was more greenness with increasing nutrient contents of culture media[27].

Table 2: Dry weight, % of dry matter, No. of leaves and leaf area of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

EC (dS m^{-1})	Solution pH	Dry weight (g)	Dry matter (%)	No. of leaves	Leaf area (cm^2)
0.2	4.0	3.7c[z]	28.2a	9.3bc	222de
	6.0	6.3ab	26.3abc	8.4ab	422ab
	8.0	5.9ab	26.1abc	10.6ab	415ab
0.7	4.0	2.9c	26.4abc	8.4cd	178e
	6.0	4.5bc	27.4ab	10.7a	368abc
	8.0	6.4ab	25.7bc	10.2ab	469ab
1.2	4.0	3.2c	24.5c	7.6d	246cde
	6.0	4.7bc	25.5bc	10.0ab	320bcd
	8.0	6.7a	26.8abc	10.8a	475a

[z]Means separation within column by Duncan's Multiple Range Test at p = 0.05

Table 3: The effect of EC and pH levels of nutrient solution on the qualities of cut flowers of rose plants grown in rockwool slabs

EC (dS m^{-1})	Solution pH	Stem weight (g)	Flower diameter (cm)	Leaf length (cm)	Length of top node (cm)	Stem diameter (mm)
0.2	4.0	18.1cd[z]	10.3ab	9.6de	8.0e	4.4bcd
	6.0	22.5b	10.8a	10.4ab	9.7bc	4.7ab
0.7	4.0	13.2d	9.7b	8.5f	7.4f	4.1d
	6.0	20.2bc	10.4a	9.5e	9.6c	4.7abc
1.2	4.0	19.2bc	10.5a	10.5bcd	9.1d	4.2cd
	6.0	20.0bc	10.6a	10.1cde	9.9bc	4.2cd
	8.0	21.8bc	10.5a	10.3cde	9.7bc	4.5bcd

[z]Means separation within column by Duncan's Multiple Range Test at p=0.05

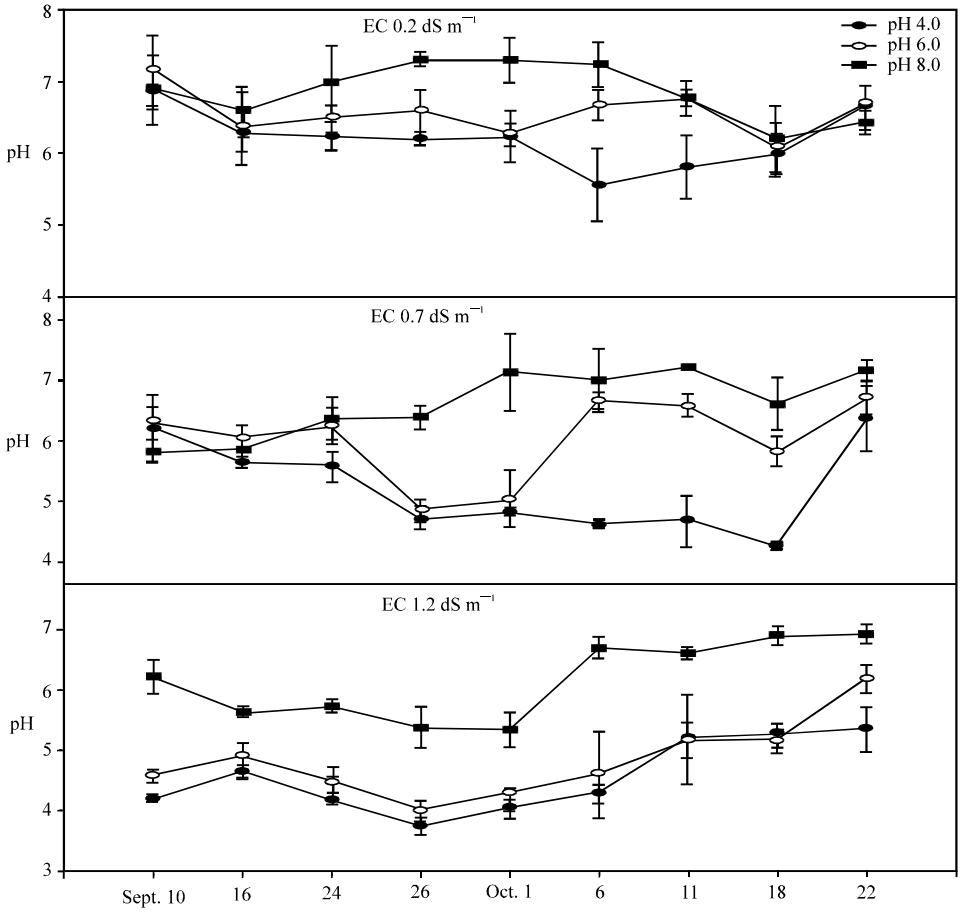

Fig. 1: Changes of pH in root zone of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

Table 4: Yield of cut stems by grade of rose plants grown in rockwool slabs a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

		Yield by grade				
EC (dS m^{-1})	Solution pH	40 cm ≥	40-49 cm	50-59 cm	60-69 cm	70 cm ≤
0.2	4.0	67.1ab[z]	18.1ab	9.1bc	5.7bc	0.0c
	6.0	45.4c	18.1ab	23.2a	8.0abc	5.3abc
	8.0	37.0c	20.6ab	19.9abc	14.1abc	8.4a
0.7	4.0	80.2a	12.4b	6.7c	0.7c	0.0c
	6.0	52.9bc	24.4a	13.6abc	5.3bc	3.8abc
	8.0	43.0c	15.3ab	21.6ab	12.6ab	7.5ab
1.2	4.0	56.1bc	22.4ab	16.4abc	4.3c	0.8bc
	6.0	53.0bc	23.9a	11.6abc	7.9abc	3.6abc
	8.0	44.1c	24.0a	22.4ab	8.3abc	1.2bc

[z]Means separation within column by Duncan's Multiple Range Test at p = 0.05

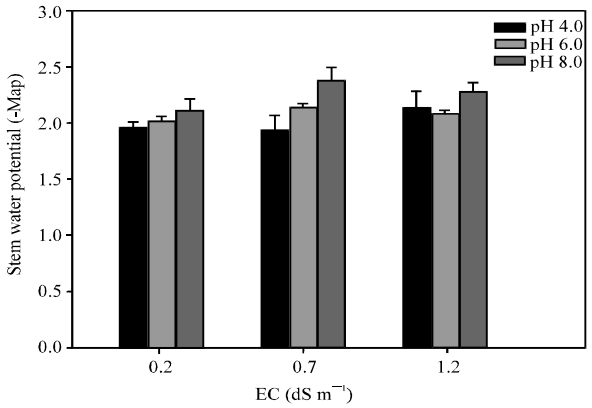

Fig. 2: Stem water potential of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

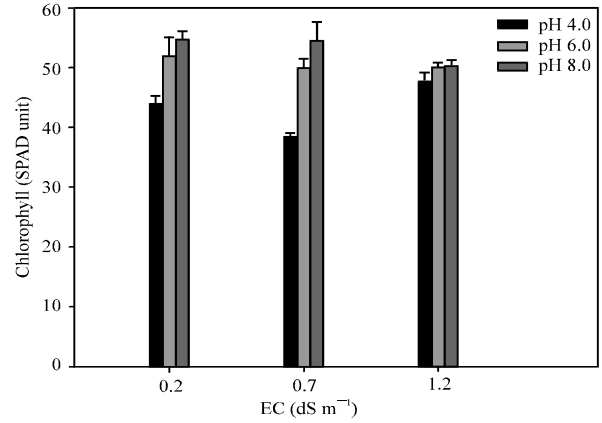

Fig. 3: Leaf chlorophyll concentration of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

Cut-flower length and quality: Cut-flower length was longest in pH 8.0, however, there was no difference with pH 6.0 but it was shortest in pH 4.0 (Fig. 4). Especially, it was longest (50 cm) at pH 8.0 in EC 0.2 and 1.2 dS m^{-1}, however it was shorter (within 40 cm) at pH 4.0 in EC 0.2 and 0.7 dS m^{-1}. Cut-flower length was not significantly difference by EC but pH effect was clear in lower EC. In this result, higher pH in rhyzosphere maintained valuable pH range 5.5-6.5 and maintained long time and it induced root growth[30].

Cut-flower weight was heavier with increasing pH and it was clearly appeared in EC 0.7 dS m^{-1} between pH 8.0 and 4.0, however, not significant by pH treatment in EC 1.2 dS m^{-1} (Fig. 5).

Flower diameter was similar between pH 8.0 and 6.0, however it was lowest at pH 4.0 and it was not significantly different by pH treatment in EC 0.2 and 0.7 dS m^{-1} (Table 3). Leaf length was increased with increasing pH and especially the longest at pH 8.0 in EC 0.7 dS m^{-1}. However, no significant effect was shown by pH treatment in EC 1.2 dS m^{-1}. Flower neck length increased with increasing of pH and it was shortest at pH 4.0 in EC 0.7 dS m^{-1}. Stem thickness was increased in EC 0.7 dS m^{-1} with increasing of pH, however, it was similar between pH 6.0 and 8.0 in EC 0.2 dS m^{-1} and it was similar between pH 4.0 and 6.0 but it was a little thicker in pH 8.0.

There were several other results with lettuce and spinach and cucumber and they were similar inclination to this experiment. In spinach, plant height and leaf numbers were longer or more at pH 6 and 7 and fresh and dry weight were heavier at pH 6.0[31]. Cucumber plant height was longer by high concentration of culture media, however, not significantly different on leaf length, leaf width and leaf number by concentration of culture media[32]. These results were similar to this experiment even different crop used for the experiment.

Grade rate and commercial yield of cut-flower: Cut-flower length and ratio were increased with increasing pH, especially, longer than 60 cm of cut-flower ratio was higher in pH 8.0 than 6.0 and 4.0. And shorter than 40 cm of cut-flower length was more in low pH treatment (Table 4). Non commercial cut-flower ratio was also more in low pH, however EC was not significantly affected on

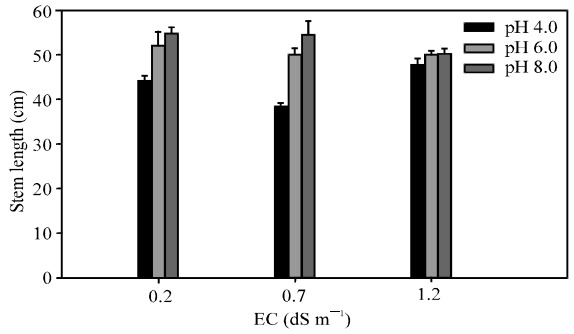

Fig. 4: Length of harvested flower stem of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

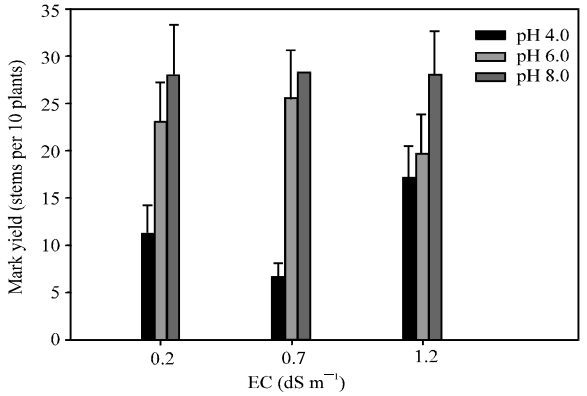

Fig. 5: Marketable cut flower yield of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4.0, 6.0 or 8.0 from 10 days after pinching

Table 5: Flower color of rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

EC (dS m^{-1})	Solution pH	Hunter color value		
		L	a	b
0.2	4.0	33.02b[z]	47.99b	15.81ab
	6.0	34.90b	52.43ab	16.50ab
	8.0	35.37b	53.10a	16.61ab
0.7	4.0	36.31a	52.81a	15.94ab
	6.0	35.99ab	52.84a	14.67b
	8.0	34.79b	52.19ab	16.39ab
1.2	4.0	34.39b	50.48ab	16.63a
	6.0	34.50b	52.67a	16.39ab
	8.0	35.85ab	53.97a	15.79ab

[z]Means separation within column by Duncan's Multiple Range Test at p = 0.05

the cut-flower ratio with increasing of long cut-flower ratio in low EC.

The main reason of lower long cut-flower ratio was decreased rhyzosphere pH with root necrosis and it reduced the inorganic nutrients uptake. High quality of cut-flower length was greatest at pH 8.0 with 28 flowers per 10 hills, however it was 15 and 10 flowers per 10 hills at pH 4.0 in 1.2 dS m^{-1} and in EC 0.2 and 0.7 dS m^{-1}, respectively. Higher EC in supplying produced higher commercial cut-flower without significant difference.

Table 6: Mineral element content within rose plants grown in rockwool slabs with a nutrient solution adjusted to EC 0.2, 0.7 or 1.2 dS m^{-1} and pH 4, 6 or 8 from 10 days after pinching

EC (dS m^{-1})	Solution pH	T-N	P	Ca	Mg	K
		(%)				
0.2	4.0	1.62d[z]	0.70e	0.47ab	0.36abc	2.17bc
	6.0	1.93abc	0.75cde	0.43bcd	0.35abc	2.22bc
	8.0	2.11a	0.83ab	0.44bc	0.36abc	2.26bc
0.7	4.0	1.80bcd	0.75de	0.39de	0.33c	2.19bc
	6.0	1.89a-d	0.79bcd	0.49a	0.38ab	2.31abc
	8.0	2.08ab	0.82abc	0.37e	0.36abc	2.11c
1.2	4.0	1.75c	0.83a	0.37e	0.34bc	2.35ab
	6.0	1.99abc	0.78bcd	0.42cd	0.39a	2.50a
	8.0	2.19a	0.87a	0.39de	0.36abc	2.52a

[z]Means separation within column by Duncan's Multiple Range Test at p = 0.05

In this experiment, commercial cut-flower yield (Fig. 5) was not significantly different by supplying EC and this result was different to the report of Roh *et al.*[31] the main reason was accumulated nutrients in rockwool slab was supplied for the rose growth and flowering, so EC should be reduced in summer than spring or autumn. Because of the shortage of rose growth in summer could not affected by pH change[32], however a little longer culture duration pH should be highly adjusted in culture media.

Flower color: Flower color is one of the genetical characteristics, however it closely related with the temperature, light source and synthesis of flavonoid for the expression of color.

The L means of clearness of flower color which was not significantly different in EC 0.2 dS m^{-1}, however it was decreased with pH increasing in EC 0.7 dS m^{-1} and increased with increasing pH in EC 1.2 dS m^{-1}.

Red color in cut-flower expressed as "a" which was increased with increasing pH in EC 0.2 and 1.2 dS m^{-1}, however not significantly different by pH in EC 0.7 dS m^{-1}.

Weinstein[33] reported that flower color will be different the pH of petal tissue such as increasing of petal tissue's pH results the changing of red color to blue, however this experiment result was different to that because flower color was blue by decreased pH of supplying water and this was affected by lower pH at rhyzosphere resulted in the decreasing of petal tissue pH (Table 5).

Currey[34] reported that high P and K increased blue color numbers than red color from the Cv. Better Times. So lowered "a" value was supplied P in the culture media for adjusting of pH 4 .0 and 6.0.

Inorganic nutrients in plant: T-N content increased with increasing pH but not affected by EC and especially the lowest in pH 4.0 of all treatment (Table 6). The P content was also increased with increasing pH in EC 0.2 and 0.7 dS m^{-1}, however it was lower at pH 6 than pH 4 in Table 6 as EC 1.2 dS m^{-1}. The Ca content in plant was lowest at pH 6.0 than pH 4.0 and 8.0 in EC 0.2 dS m^{-1}, however, it was highest at pH 6.0 than pH 4.0 and 8.0 in EC 0.7 and 1.2 dS m^{-1}.

The Mg content was not significantly different by pH in EC 0.2 dS m^{-1}, however, same as the Ca content, the highest at pH 6.0 in EC 0.7 and 1.2 dS m^{-1} then pH 8.0 and 4.0 followed. The K content was not different among the pH treatment in EC 0.2 dS m^{-1}, however it was the greatest at pH 6.0 in EC 0.7 dS m^{-1} and similar to between pH 8.0 and 6.0 in EC 1.2 dS m^{-1} but lowest at pH 4.0.

These results best at pH 6.0 in most of EC range because no root damage was found from root of lettuce will be no growing or brown rot in above pH 8.0 and lower pH 5.0[21] and the main reason was macronutrients and Mo could not uptake in more than pH 8.0 and Fe, Mn and Cu uptake was difficult in below pH 5.0.

Additionally valuable uptake pH range of NH_4^+ was pH 7.0-7.5 and pH 5.0-5.5 for NO_3^- uptake[6,35]. The main reason of higher T-N content of rose plant in high pH than low pH, was NH_4^+ uptake was higher by the preparedly NH_4^+ uptake pattern than NO_3^- and high temperature also contributed[25].

Maintaining of pH was possible in EC 0.7 dS m^{-1} at pinching time. The rhyzosphere pH was correlated with the EC in culture media even it was not changed in neutral pH range 6.0-7.0 in EC 0.2 dS m^{-1}. Rose plant dry weight was mostly positively related with pH but no related with the EC level. Dry weight of cut-flower was greatest at pH 8.0 in EC 1.2 dS m^{-1}, however DWR, node number and leaf area were greater at pH 4.0 in EC 0.2.

Stem Osmotic Potential (OP) was positively related with the culture media pH in EC 0.2 and 0.7 dS m^{-1}. Leaf greenness was also positively related with the pH and EC.

Cut-flower length and commercial cut-flower ratio, weight and leaf length were not significantly affected by EC but pH was more effective in low EC. Higher pH induced greater root growth. T-N was mostly greater at neutral cultural media in low or mid EC level but reversed effect was shown in high EC level (EC 1.2 dS m^{-1}). The uptake pattern of Mg and Ca was same as higher at pH 6.0 in mid or low EC level and not affected by pH in low EC level.

In conclusion, the best culture media pH range is neutral with mid or low EC level which is economically valuable and practically viable.

REFERENCES

1. Bae, J.H., Y.R. Cho and Y.B. Lee, 1995. Field survey for well water quality in hydroponics farms. J. Bio. Pro. Fac. Env. Con., 4: 80-88.
2. Wan, W.Y., Cao and T.W. Tibbitts, 1994. Tuber initiation in hydroponically grown potatoes by alteration of solution pH. Hortic. Sci., 29: 621-623.
3. Smith, D.L., 1987. Rockwool in Horticulture. Grower Book, London.
4. Kim, H.J. and Y.S. Kim, 1996. Automatic pH control of nutrient solution by physiological fertilizes in lettuce hydroponics. J. Bio. Fac. Env., 5: 145-151.
5. Ikeda, H. and T. Osawa, 1981. Nitrate-N and ammonium-N absorption by vegetables from nutrient solution containing ammonium nitrate and the resultant change of solution pH. Japan. Soc. Hortic. Sci., 50: 225-23012.
6. Boon, Van der, J., J.W. Steenhuizen and G.S. Eveliene, 1990. Growth and nitrate concentration of lettuce as affected by total nitrogen and chloride concentration, NH_4/NO_3 ratio and temperature of the recirculating nutrient solution. J. Hortic. Sci., 65: 309-321.
7. Moon, B.H., 1996. Reduction methods of nitrate content and quality improvement in hydroponically grown *Oenanthe stolonifera* DC. MS. Thesis, Seoul National University.
8. Bear, F.E., 1969. Chemistry of the soil. Van Nostrand Reinholt Comp 9. Zieslin, N. and P. SNIR. 1989. Responses of rose plants cultivar 'Sonia and Rosa indica major to changes in pH and aeration of the root environment in hydroponic culture. Sci. Hortic., 37: 339-349.
9. Zieslin, N. and P. Snir, 1989. Responses of rose plants cultivar 'Sonia and Rosa indica major to changes in pH and aeration of the root environment in hydroponic culture. Sci. Hortic., 37: 339-349.
10. Pilbeam, D.J. and E.A. Kirkby, 1992. Some Aspects of the Utilization of Nitrate and Ammonium by Plants. In: Mengel, K. and D.J. Pilbeam (Eds.). Nitrogen Metabolism of Plants. Oxford Publications, pp: 55-70.
11. Kang, J.G., B.S. Seo and S.J. Chung, 1996. Effect of nutrient concentration on growth and development of aeroponically grown chrysanthemum. J. Kor. Soc. Hortic. Sci., 36: 83-89.
12. Selmer-Olsen, A.R. and H.R. Gislerod, 1980. Nutrient content of chrysanthemum grown in recirculated nutrient solution. Acta Hortic., 98: 211-218.
13. FAO, 1976. Water quality for agriculture. FAO.
14. Findenegg, G.R., M.L. Van Beusichem and W.G. Keltjens, 1986. Proton balance of plants physiological, agronomical and economical implications. Neth. J. Agric. Sci., 34: 371-379.

15. Jones, J.B. Jr., 1983. A Guide for the Hydroponic and Soilless Culture Grower. Timbe Press. Portland.
16. Schrader, L.E., D. Domska, P.E. Jung, Jr. and L.A. Peterson, 1972. Uptake and assimilation of ammonium-N and nitrate-N and their influence on the growth of corn (*Zea mays* L.). Agron. J., 4: 690-695.
17. Peet, M.M., C.D. Raper, L.C. Tolley and W.P. Robage, 1985. Tomato responses to ammonium and nitrate nutrient under controlled root-zone pH. J. Plant Nutr., 8: 787-789.
18. Tolly-Henry, L.C. and C.D. Raper, 1989. Cyclic variations in nitrogen uptake rate of soybean plants. Ammonium as a nitrogen source. Plant Physiol., 91: 1345-1350.
19. Tolly-Henry, L.C. and C.D. Raper, 1989. Effects of root-zone acidity on utilization of nitrate and ammonium in tobacco plants. J. Plant Nutr., 12: 811-826.
20. Lee, Y.B., 1994. Fruit vegetable cultivation in the use of solid medium. J. Bio. Pro. Fac. Env. Con., 3: 34-54.
21. Inden, F., 1982. Management of pH in nutrient solution. J. Jap. Agric. Hortic., 57: 327-331.
22. Lee, E.H., B.Y. Lee, K.D. Lee and Y.S. Kwon, 1998. Nitrate content and activity of nitrate reductase and glutamine synthetase as affected by temperature and pH of nutrient solution in leaf lettuce and water dropwort. J. Kor. Soc. Hortic. Sci., 39: 161-165.
23. Ruth, G.N. and U. Kafkafi, 1983. The effect of root temperature and NO_3:NH_4^+ ratio on strawberry plants. Growth, flowering and root development. Agron. J., 75: 941-946.
24. Takahashi, T. and K. Takahashi, 1998. Seasonal changes of macro absorption in solution cultured roses. J. Jpn. Soc. Hortic. Sci., 67: 116-122.
25. Lycas, C., P. Giaglaras and C. Kittas, 2001. Availability of iron in hydroponic nutrient solutions for rose crops. J. Hortic. Sci. Biotechnol., pp: 350-352.
26. Kim, H.J., Y.S. Cho, O.K. Kwon, M.W. Cho, J.B. Hwang, W.T. Jeon and S.D. Bae, 2005. Effect of hydroponic solution pH on the growth of greenhouse rose. Asian J. Plant Sci., 4: 17-22.
27. Choi, K.J., G.C. Chung, S.G. Yang, H.J. Kim and G.C. Park, 1996. Effect of ionic strength of nutrient solution on the mineral concentrations of xylem sap and photosynthesis in cucumber. J. Kor. Soc. Hortic. Sci., 37: 627-632.
28. An, W.B. and Y.B. Lee, 1991. Basic studies on the development hydroponic system of water dropwort, *Oenanthe stolonifera* DC.Optimal composition of macronutrients. J. Kor. Soc. Hortic. Sci., 32: 425-433.
29. Quebedeaux, B. and J.L. Ozbun, 1973. Effects of ammonium nutrition on water stress, water uptake and root pressure in *Lycopersicon esculentum* Mill. Plant Physiol., 52: 677-679.
30. Lee, E.H., B.Y. Lee, K.D. Lee and Y.S. Kwon, 1998. Nitrate content and activity of nitrate reductase and glutamine synthetase as affected by temperature and pH of nutrient solution in leaf lettuce and water dropwort. J. Kor. Soc. Hortic. Sci., 39: 161-165.
31. Roh, M.Y., Y.B. Lee, H.S. Kim and K.B. Lee, 1997. Development of nutrient solution suitable for closed system in substrate culture of cucumber. J. Bio. Fac. Env., 6: 1-14.
32. Zieslin, N. and P. Snir, 1989. Responses of rose plants cultivar 'Sonia and Rosa indica major to changes in pH and aeration of the root environment in hydroponic culture. Sci. Hortic., 37: 339-349.
33. Weinstein, I.H., 1957. Senescence of roses. 1. Senescence or roses. 1. Chemical changes associated with senescence of cut 'Better Times' roses. Contrib. Boyce Thopson Inst., 19: 33-48.
34. Currey, G.S., 1927. The cause of blueing in red roses. Proc. Roy. Soc. N. S. Wales, 61: 307-314.
35. Mengel, K. and E.A. Kirkby, 1987. Principle of plant nutrition. International Potash Institute. Switzerland, pp: 559-572.