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Fertilizer Concentration after Flowering Affects Growth and Fruit Setting of Ornamental Pepper

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개화 후 비료의 농도가 Ornamental Pepper의 생장과 착과에 미치는 영향

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Abstract. To evaluate the effect of the fertilizer concentration after flowering on growth and fruit setting of ornamental pepper (*Capsicum annuum* L.), plants were fertilized with 100 $mg \cdot L^{-1}$ of N (EC=0.8 $dS \cdot m^{-1}$) until flowering, and then with 0 (no fertilizer), 100, 200 or 300 $mg \cdot L^{-1}$ of N (fertilizer solution EC of 0.15, 0.8, 1.45 or 2.10 $dS \cdot m^{-1}$, respectively) until harvest. Maximum leaf area and shoot dry mass at the end of the growing period were obtained when plants were fertilized with 200 $mg \cdot L^{-1}$ of N. Total fruit number per plant at the end of the growing period was not different when plants were fertilized with 100, 200 or 300 $mg \cdot L^{-1}$ of N concentrations. When plants were fertilized with 0 $mg \cdot L^{-1}$ of N, the number of fruits per plant was decreased significantly as compared to 100, 200 or 300 $mg \cdot L^{-1}$ of N, whereas the percentage of red fruits at the end of the growing period was maximized. Total fruit fresh weight per plant at the end of the growing period was highest with the concentration of 200 $mg \cdot L^{-1}$ of N. The EC of the growing medium remained within 0.8 to 1.2 $dS \cdot m^{-1}$, 2.0 to 3.0 $dS \cdot m^{-1}$, or 3.0 to 4.5 $dS \cdot m^{-1}$ when fertilizer concentrations were 100, 200 or 300 $mg \cdot L^{-1}$ of N, respectively. Throughout most of the experiment, the pH of the growing medium remained within 5.4 to 6.2, but dropped to 4.9 near the end of the experiment when fertilizer concentration was 200 or 300 $mg \cdot L^{-1}$ of N. Content of most of the nutrients in the leaf was not affected by the different fertilizer concentrations. Only aluminum was significantly affected and decreased linearly with increasing fertilizer concentration. The results from this study indicated that optimal fertilizer concentration after flowering for commercial production of ornamental pepper was 100 or 200 $mg \cdot L^{-1}$ of N. At these concentrations, the EC of the growing medium remained approximately within 0.8 to 1.2 and 2 to 3 $dS \cdot m^{-1}$, respectively. This appears to be the optimal range for vegetative growth or fruit setting of ornamental pepper plants, and indicates that ornamental pepper can be grown with a fairly wide range of fertilizer concentrations.

Key words : *Capsicum annuum*, EC, electrical conductivity, pH

Introduction

The fertilizer concentration or the application frequency must be varied for bedding plant species because they have very different nutrient requirements. Optimal fertilizer concentrations for many kinds of bedding plants have been reported, including those for pansies (van Iersel, 1999), foliage plants (Poole and Conover, 1992), petunias, begonias (James and van Iersel, 2001), New Guinea impatiens (Judd and Douglas, 1992; Kent and Reed, 1996), *Nephrolepis exaltata* Fluffy Ruffle (Conover and Poole, 1992), poinsettia (Yelanich and Biernbaum, 1993; Argo and Biernbaum, 1995), alyssum, celosia, dianthus, gomphrena, stock and zinnia (Kang and van Iersel, 2002). However, the exact fertilizer concentration to use depends on the stage of growth, plant species, desired rate of growth, leaching percentage (irrigation method), growing temperature, pot size, and the frequency of fertilizer application. Evans and Paul (1992) reported that nutrient uptake of roses grown in a recirculating hydroponic system was low when the plants were developing auxiliary buds following pinching, then the uptake increased as the shoot elongated and leaves expanded, but decreased again as flower buds developed. Hood et al (1993) reported that the nutrient uptake pattern of snapdragons (*Antirrhinum majus* L.) also varied by developmental stage during vegetative growth, flower initiation, and visible bud development.

Recommended nutrient rates for ornamental peppers vary. It has been reported that 200 ppm of N and K should be used at each irrigation, and this should be continued until the fruit is set. Once fruit is set, fertilizer and water can be reduced. This feeding program was used for production of ornamental pepper by Starman (1993). In Georgia, 200 ppm of N was also used at every irrigation, but unamended water was used every third irrigation to prevent soluble salt buildup (Armitage and Hamilton, 1987). In North Carolina, 50 ppm of N was used during the first 4 weeks of growth, then increased to 200 ppm, and finally reduced to 100 ppm at the beginning of fruit set (Love, 1987). These studies indicated that uptake patterns of nutrients vary in ornamental peppers during progressive stages of physiological development. On the other hand, some previous researches showed that the young seedlings of most bedding plants are sensitive to fertilizer salts and have a very low total requirement, and during the finishing stage, the highest fertilizer rates are used. The objectives of this experiment were to determine the effects of different concentrations of fertilizer solution after flowering on the growth and fruit setting of ornamental pepper and to establish the optimal range for the EC of the growing medium.

Materials and methods

Plant Material

Ornamental pepper Treasures Red was seeded in plug flats (288 cells/flat) filled with soilless growing medium (Metro Mix 220, The Scotts Company, Marysville, Ohio) on February 23, 2001, and the flats were placed under intermittent mist in the double-layer polyethylene-covered greenhouse. The seeds were germinated under mist and subsequently transferred to the greenhouse, where they were thinned to one seedling/cell. The temperature set points for the greenhouse were 25°C during the day and 20°C at night. From 18 days after seeding to transplanting, the seedlings were fertilized and watered as needed.

Treatments

The seedlings were transplanted into 15 cm, round pots on April 9, 2001. The pots were filled with a soilless growing medium (Metro-Mix 500, The Scotts Co., Marysville, Ohio). The medium composition was: sphagnum peat (12–22%), vermiculite (20–35%), bark ash (0–10%), pine bark (40–50%), lime, and a starter nutrient charge. The initial pH was 5.6 and initial EC was 1.4 $dS \cdot m^{-1}$ (as determined with the SME method). Plants were placed on regular greenhouse benches in a double-layer polyethylene-covered greenhouse covered by light shade cloth (40% shade). Plants were hand-watered daily using a watering can. One hundred $mg \cdot L^{-1}$ of N (fertilizer solution EC 0.8 $dS \cdot m^{-1}$) was used for the first 30 days of growth (from transplanting to flowering). From flowering to harvesting time, 0 (no fertilizer), 100, 200 and 300 $mg \cdot L^{-1}$ of N (fertilizer solution EC of 0.15, 0.8, 1.45, or 2.10 $dS \cdot m^{-1}$, respectively) were used. Fertilizer solutions were made using a water-soluble fertilizer, developed specifically for use with soilless media (Peters 15-5-15 Peat-Lite Special, The Scotts Co.). The pH of the fertilizer solutions was not controlled so that fertilizer effects on growing medium pH could be determined. During the experiment, the plants were monitored for pests, and pesticides were applied as needed.

Measurements

The height and the width of plants, and leaf chlorophyll content were measured in every experimental unit at weekly intervals. Plant height was determined as the distance from the medium surface to the tip of the plant. Plant width was determined diagonally at the widest part of the shoot. Chlorophyll content of the leaves was measured with a SPAD-502 chlorophyll meter (Minolta, Ramsey, NJ), which measures chlorophyll content in arbitrary units (here referred to as SPAD units). EC and pH of leachate from pots were measured weekly using the pour-through method (Wright, 1986). One hundred mL of water was poured on top of the growing medium and the first 20 mL of leachate was collected. EC and pH of the leachate were measured with a Checkmate pH/EC meter (Corning, Corning, NY). Because the leachate composition depends on the moisture level of the growing medium (Yeager et al., 1983), EC and pH were always determined at 1 to 3 hour after the last irrigation event.

Fruits of five plants were harvested at the end of the experiment (74 days after transplanting) and number of fruits, fruit weight, and ratio of red fruits to total number of fruits were determined. Leaves of five plants were harvested and leaf area was determined using a LI-COR 3100 leaf area meter (LI-COR, Lincoln, NE). Shoots of five plants were used for dry weight determination. Shoots were dried in a forced-air drying oven at 70°C for a minimum of 3 days before dry weight was measured.

N and S in the leaf tissue were determined with a CNS 2000 analyzer (LECO Corp., St. Joseph, MI) (Mills and Jones, 1996), while P, K, Ca, Mg, Al, B, Cu, Fe, Mn, Na and Zn were determined by dry ashing and inductively coupled plasma spectrometry (Jones and Case, 1990).

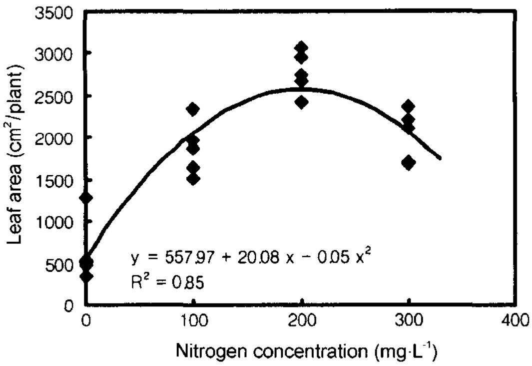

Fig. 1. The effect of fertilizer concentration on leaf area per plant at the end of the growing period. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting.

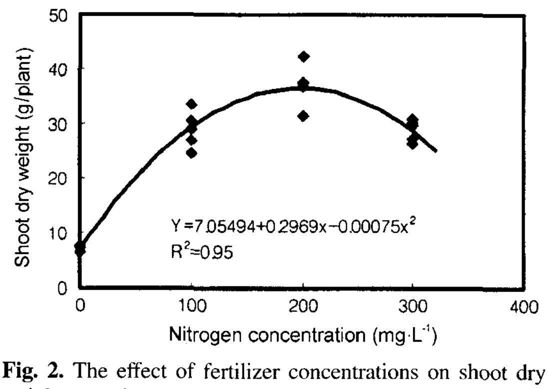

Fig. 2. The effect of fertilizer concentrations on shoot dry weight per plant at the end of the growing period. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting.

Result and discussion

Fertilizer concentration from flowering to harvesting time had a significant effect on the leaf area and dry mass of ornamental pepper. Maximum leaf area and shoot dry mass at the end of the growing period were obtained

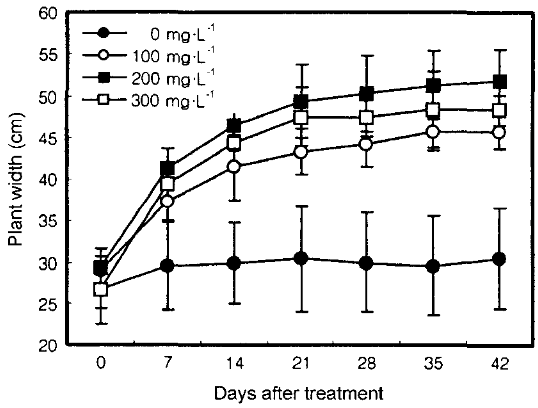

Fig. 3. The effect of fertilizer concentrations on plant width. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting. Vertical bars indicate standard errors.

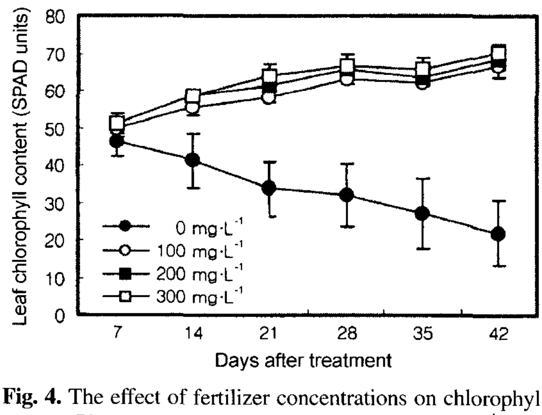

Fig. 4. The effect of fertilizer concentrations on chlorophyll content. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting. Vertical bars indicate standard errors.

when plants were fertilized with the N concentration of 200 mg · L^{-1} (Figs. 1 and 2). Throughout the experiment, 0 mg · L^{-1} of N decreased plant width and leaf chlorophyll content greatly compared to 100, 200 and 300 mg · L^{-1} of N (Figs. 3 and 4). Effects of fertilizer concentrations on plant height were similar to the effects on plant width (data not shown).

Total fruit number per plant at the end of the growing period was not different among the 100, 200, and 300 mg · L^{-1} of N treatments. When plants were fertilized with 0 mg · L^{-1} of N, the number of fruits per plant was decreased significantly compared to 100, 200 or 300 mg · L^{-1} of N, whereas red fruit percentage at the end of the growing period was maximized at 0 mg · L^{-1} of N.

Table 1. The effect of fertilizer concentrations on fruiting response of ornamental pepper.

N Conc. (mg · L^{-1})	Number of fruits			Red color fruits (%)	Total fruit weight (g/plant)
	Red	Blue	Total		
0	8.0b[z]	6.3c	14.3b	60.0a	25.5c
100	16.4a	40.8b	57.2a	28.6b	117.7ab
200	11.6b	54.2a	65.8a	22.0b	132.6a
300	11.4b	43.2ab	54.6a	17.9b	104.2b

[z]Mean separation within columns by DMRT at 5% level. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting.

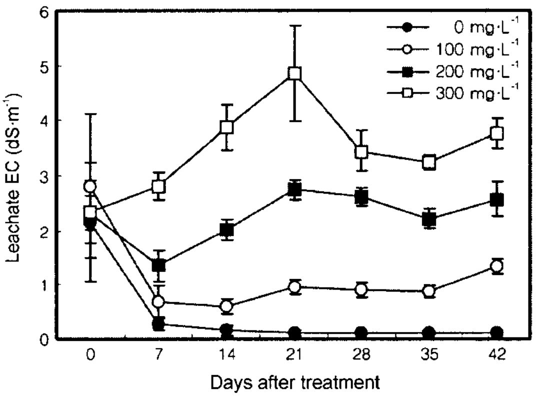

Fig. 5. The effect of fertilizer concentrations on the EC of growing medium. Plants were overhead irrigated with 100 mg · L^{-1} of N until flowering and then fertilized daily with 0, 100, 200 or 300 mg · L^{-1} of N until harvesting. Leachate from the growing medium was collected with the pour-through method and EC of the leachate was measured. Vertical bars indicate standard errors.

Total fruit fresh weight per plant at the end of the growing period was the highest with a 200 mg · L^{-1} of N concentration (Table 1).

As expected, the EC of the growing medium was affected by fertilizer concentrations (Fig. 5). The EC of the growing medium decreased significantly when plants were fertilized with 0 mg · L^{-1} of N concentration (within 0.08 to 0.1 dS · m^{-1}) throughout the experiment. The EC of the growing medium remained within 0.8 to 1.2 dS · m^{-1}, 2 to 3 dS · m^{-1} or 3 to 4.5 dS · m^{-1}, when fertilizer concentrations were 100, 200 or 300 mg · L^{-1} of N, respectively.

The results from this experiment indicate that maximum plant growth and fruit number were obtained when plants were fertilized with 200 mg · L^{-1} of N concentration (fertilizer EC 1.45 dS · m^{-1}). When plants were fertilized with 100 or 300 mg · L^{-1} of N, plant growth and fruiting were slightly lower than in the 200 mg · L^{-1} of N treatment, but even those plants were marketable. Although red fruit percentage was highest when plants were fertilized with 0 mg · L^{-1} of N, these plants were not suitable for sale. When fertilizer concentrations were 100 and 200 mg · L^{-1} of N, the EC of the growing medium remained approximately within 0.8 to 1.2 and 2 to 3 dS · m^{-1}, respectively and this appears to be the optimal range for vegetative growth (leaf area, dry mass, and plant width) and fruit setting (number of fruits and total fruit weight) of ornamental pepper plants. Armitage and Hamilton (1987) reported that the medium salt level for growth of ornamental pepper should be kept between 0.3 and 0.8 dS · m^{-1}. Warncke and Krauskopf (1983) reported that a growing medium EC of 0.75 to 2 dS · m^{-1} is acceptable, while 2 to 3.5 dS · m^{-1} is optimal for most greenhouse crops. Armitage and Hamilton (1987) and Warncke and Krauskopf (1983) determined EC with the saturated media extract method, which generally gives lower readings than does the pour-through method (Yeager et al, 1983). Taking into account the difference between the two methods, the optimal range for growing medium EC for vegetative growth of ornamental pepper in this study is similar to that reported by Warncke and Krauskopf (1983) and Armitage and Hamilton (1987). Starman (1993) argued that the standard feeding program for ornamental pepper is to apply N at 200 mg · L^{-1} until fruit set, and then to reduce the fertilizer concentration by

Table 2. Contents of some nutrients in the ornamental pepper shoots as affected by the different fertilizer concentrations.

N Conc. ($mg \cdot L^{-1}$)	Conc. ($mg \cdot g^{-1}$ dry wt.)						Conc. ($\mu g \cdot g^{-1}$ dry wt.)						
	N	P	K	Ca	Mg	S	Al	B	Cu	Fe	Mn	Zn	Na
0	24.1	3.3	68.7	18.2	8.6	2.05	52.2	97.5	7.3	69.6	123.1	71.2	250.8
100	16.4	2.9	65.1	21.3	9.4	3.99	41.1	66.7	12.9	89.9	73.0	72.1	262.7
200	29.2	3.3	71.8	21.0	8.9	3.12	39.6	63.7	7.8	77.4	101.8	87.2	268.0
300	30.8	3.1	66.4	18.9	7.7	3.11	28.9	58.5	10.3	79.6	100.4	55.9	228.3
Significance[1]	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns

[1]ns, *Nonsignificant or significant at p 0.05 by F-test. Plants were overhead irrigated with 100 $mg \cdot L^{-1}$ of N until flowering and then fertilized daily with 0, 100, 200 or 300 $mg \cdot L^{-1}$ of N until harvesting. Entire shoots were harvested at 42 days after treatment (72 days after transplanting) and used for nutrient analysis.

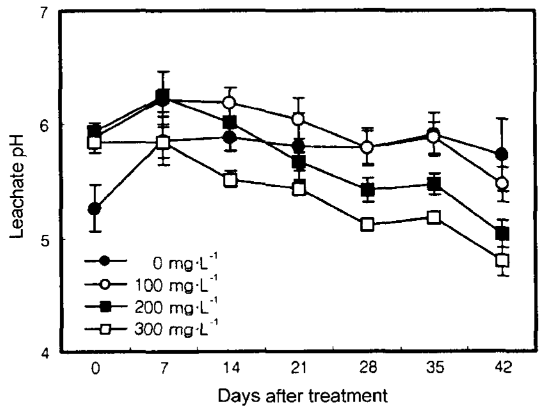

Fig. 6. The effect of fertilizer concentrations on growing medium pH. Plants were overhead irrigated with 100 $mg \cdot L^{-1}$ of N until flowering and then fertilized daily with 0, 100, 200 or 300 $mg \cdot L^{-1}$ of N until harvesting. Leachate from the growing medium was collected with the pour-through method. Vertical bars indicate standard errors.

half until market time. The optimal range for fertilizer concentration in this study is similar to that reported by Starman (1993).

Throughout the experiment, the pH of the growing medium remained within 5.4 to 6.2 when plants were fertilized with 0 or 100 $mg \cdot L^{-1}$ of N concentrations (Fig. 6). The recommended range for the pH of the growing medium for floricultural crops is 5.4 to 6.3 (Bailey and Bilderback, 1997). The leachate pH was within this range throughout most of the experiment, but dropped to 4.9 near the end of the experiment when fertilizer concentrations were 200 or 300 $mg \cdot L^{-1}$ of N. This had no obvious effect on the growth or nutrient uptake of the plants. No visual symptoms of micronutrient toxicities or deficiencies were observed.

Content of most nutrients in the leaf was not affected by the different fertilizer concentrations. Only aluminum was significantly affected and decreased linearly with increasing fertilizer concentration (Table 2).

적 요

Ornamental pepper의 생장과 착과에 미치는 개화 후 비료 농도의 영향을 구명하기 위하여 정식 후부터 개화시까지 100 $mg \cdot L^{-1}$ (EC=0.8 $dS \cdot m^{-1}$)의 N 농도로 재배하였고 그 후부터 0, 100, 200, 300 $mg \cdot L^{-1}$의 N 농도(EC=0.15, 0.8, 1.45, 2.1 $dS \cdot m^{-1}$)로 처리하여 수확시까지 재배하였다. 200 $mg \cdot L^{-1}$의 N 농도 처리에서 최대 엽면적과 건물을 수확했으며 식물체당 전체 과일 무게도 가장 무거웠다. 100, 200, 300 $mg \cdot L^{-1}$의 N 농도에서는 식물체당 과일 수에서 차이가 없었으며, 0 $mg \cdot L^{-1}$의 N 농도에서 과일수가 현저히 감소하였으나 과일의 착색비율은 높았다. 100, 200, 300 $mg \cdot L^{-1}$의 N 농도로 화분에 관비했을 때 화분내 배지의 EC는 각각 0.8에서 1.2 $dS \cdot m^{-1}$, 2.0에서 3.0 $dS \cdot m^{-1}$, 3.0에서 4.5 $dS \cdot m^{-1}$ 수준을 나타냈다. 200과 300 $mg \cdot L^{-1}$의 N 농도 처리구에서 배지의 pH가 낮았는데 특히 생육후기에는 4.9 정도까지 낮아졌다. 식물체내 무기성분 함량은 대부분 개화 후 비료의 농도에 의해 영향 받지 않았으나 오직 aluminum은 비료의 농도가 증가함에 따라 직선적으로 감소하였다. 이 실험에서 ornamental pepper의 상업적 생산을 위해서는 개화 후 질소의 농도를 100에서 200 $mg \cdot L^{-1}$ 농도로 하는 것이 좋으며, 이 때 배지의 EC는 0.8에서 3 $dS \cdot m^{-1}$로 비교적 넓은 범위를 보였다.

주제어 : 꽃고추(*Capsicum annuum*), 전기전도도, 산도

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