Influence of the N/K ratio on the production and quality of cucumber in hydroponic system[1]

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ABSTRACT

The objective of this work was to evaluate the quality of fruits and the nutritional status of cucumber CV. Aodai cultivated in nutrient solutions with different N:K ratios. The hydroponic cultivation was initially performed, during the vegetative growth, in nutrient solution with 1:2.0 mmol L^{-1} N:K, and, later, during fruit setting, in four different nutrient solutions with N:K (w/w) at the ratios 1:1.4, 1:1.7, 1:2.0 and 1:2.5. An additional treatment with a nutrient solution containing the ratio 1:2.2 (w/w) N:K during the vegetative growth and N:K 1:1.4 (w/w) during fruit setting, both with 10% ammonium (NH_4^+) was included. The treatments were arranged in a randomized design with six replicates. Irrigation was carried out with deionized water until seed germination, and then with nutrient solution until 30 days after germination, when plants were transplanted. Plants in the hydroponic growing beds were irrigated with the solutions for vegetative growth, and, after 21 days, the solutions were replaced by solutions for fruit setting. At 45 and 60 days after transplanting, the fresh weight, length, diameter, volume and firmness of the fruit were evaluated, and, at 45 days after transplanting, the macronutrient concentrations in the leaves were determined. The use of different N:K ratios during fruit setting influenced the cucumber production. The ratio of 1.0:1.7 N: K (w/w), with 10% of N in the form of ammonia, is recommended for the whole cycle.

Key words: *Cucumis sativus* L., nutrient solution, ammonium, biometric evaluation of fruits

RESUMO

Influência da relação N:K na produção e qualidade de frutos de pepino em sistema hidropônico

Objetivou-se, com este trabalho, avaliar a produção, a qualidade dos frutos e o estado nutricional das plantas de pepino, cv. Aodai, cultivadas em solução nutritiva, com diferentes relações N:K. O cultivo hidropônico foi inicialmente realizado em solução nutritiva com 1:2,0 (p/p) de N:K durante o crescimento vegetativo, e, posteriormente, na frutificação, em soluções nutritivas com quatro relações N:K (p/p) 1:1,4; 1:1,7; 1:2,0 e 1:2,5; mais um tratamento adicional, no qual a solução nutritiva de crescimento vegetativo continha a relação N:K de 1:2,2 (p/p) e a de frutificação relação N:K de 1:1,4 (p/p), ambas com 10% de amônio (NH_4^+). Os cinco tratamentos foram dispostos em delineamento inteiramente casualizado, com seis repetições. A irrigação foi feita com água deionizada até a germinação das sementes, e com solução nutritiva diluída, até 30 dias após a germinação, quando se realizou o transplantio. Nos leitos de cultivo hidropônico, as plantas foram irrigadas com as soluções de crescimento vegetativo, e, após 21 dias, as soluções de

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crescimento vegetativo foram substituídas pelas soluções de frutificação. Aos 45 e 60 dias após o transplantio, avaliaram-se a massa fresca, comprimento, diâmetro, volume e resistência dos frutos e, aos 45 dias, os teores foliares de macronutrientes. A utilização de diferentes relações de N:K, na fase de frutificação, influenciou a produção de pepino. Recomenda-se uma relação N:K (p/p) de 1,0:1,7, com 10% do N na forma amoniacal, durante todo o ciclo.

Palavras-chave: *Cucumis sativus* L., solução nutritiva, amônio, avaliação biométrica dos frutos.

INTRODUCTION

The cucumber (*Cucumis sativus* L.) is an annual plant with rapid indeterminate growth that produces fruit continually for several months (Solis, 1982). It is a crop very sensitive to climate. Therefore, the use of protected cultivation associated with hydroponics significantly minimizes the effects of adverse weather. Fruits of the cultivar Aodai (group salad) have smooth skin with few spines and glossy dark green color; they are cylindrical, approximately 20 to 22 cm long and 4.5 to 5.0 cm in diameter, with average weight of 350-400 g (Gomes, 1995). The cucumber is the second most produced curcubit worldwide after the watermelon (Almeida, 2006). In Brazil, the cucumber is the fourth most widely cultivated vegetable, with mean sales volume around 45,000 t/yr from 2006 to 2009 in CEAGESP, São Paulo State (FNP Consultoria & Comércio, 2011).

The hydroponic cultivation of fruit vegetables has achieved higher yields than traditional systems and ground-bed greenhouses (Moraes & Furlani, 1999). In three successive crops, the average cucumber yield was 250 t ha^{-1}: a total of 750 t ha^{-1} yr^{-1} in hydroponic cultivation and 30 t ha^{-1} yr^{-1} in soil cultivation in the field (Castellane & Araújo, 1994).

Seeking to optimize the management of mineral nutrition, vegetables are increasingly being cultivated on substrates using fertigation. This system makes it possible to protect plants both from nutritional imbalances and soil-borne diseases and pests (CTIFL, 1995), while increasing the efficiency of water use because surface evaporation losses are reduced (Papadoupoulos, 1994). In hydroponic cultures, the substrate must be free of pathogens, weed and toxic elements; in addition to low salt concentrations, pH between 5.5 and 7.0, oxygenation between 25 to 40% after drainage; and also it should be easy to handle, disinfect and reuse (Martinez, 2005).

The cucumber is a crop that exports large amounts of nutrients. In ground-bed greenhouses, it can export 400-500 kg ha^{-1} of N, 200-250 kg ha^{-1} of P and 800-1,000 kg ha^{-1} of K for a yield of 300 t ha^{-1}, with the balance between nutrients varying at different stages of crop development (Almeida, 2006). Phosphorus and nitrogen applications are responsible for increasing yield, and potassium for fruit quality. The recommended nutrient application rates for cucumber is 50 kg ha^{-1} of N, 250-400 kg ha^{-1} of P and 100-180 kg ha^{-1} of K (Filgueira, 2007).

For fruit production in most crops, the relationship between N:K and K:P of the nutrient solution during fruit setting should be different from that used for vegetative growth (Furlani *et al*. 1999b; Adams, 1999) . According to Furlani *et al*. (1999b), the N:K ratio should be reduced and P:K increased. However, Adams (1994) discussed that the proportions of N:K absorbed by the cucumber crop do not change with the beginning of fruit setting, remaining at 1:1.3 throughout the cycle.

Fernandes *et al*. (2002) reported a good performance for the cucumber crop by changing the N:K ratio from 1:1.4 in the vegetative stage to 1:2.0 in the reproductive stage, with the nutrient solutions used for the growth and fruit setting stages based on the recommendations for tomato (Adams, 1994).

It is common to use only one formulation of nutrient solution in the hydroponic cultivation of vegetables. However, it is essential to adapt the nutrient solution to the different stages of the crop. Hence, one needs to associate the solution concentration and the ratio between nutrients with the growth and development of the crop (Fernandes *et al*., 2002). This is important because species have different nutrient extraction ratios over the cycle and nutritional imbalance may occur with accumulation or lack of nutrients throughout the crop cycle, affecting the production (Furlani *et al*., 1999b). This imbalance is most common in fruit vegetables, as they have, besides the vegetative stage, the stages of flowering and fruit setting.

Studies on nutritional requirements for the cucumber crop, in the vegetative and reproductive stages, are necessary because the plants have great capacity for survival in various nutrient solutions. But, a formulation that provides better growth and development of the plant, without excesses or shortages, is essential because the nutritional requirements depend not only on concentrations, but also other factors related to cultivation, including the type of the hydroponics system, environmental factors, the season of the year, the phenological stage, the plant species and the cultivar in production (Furlani *et al*., 1999a).

The key point in hydroponics is to adapt the nutrient formulation to meet the requirements of the crop of interest, and to associate the solution concentration and the ratio between nutrients with the growth and development of the cultivar chosen. Therefore, the objective of this study was to evaluate five nutrient solutions prepared with different N:K ratios, with part of the N supplied as NH_4^+, on the production, fruit quality and nutritional status of cucumber grown hydroponically.

MATERIAL AND METHODS

A hydroponic experiment was conducted in a greenhouse in the Federal University of Viçosa (UFV), from September to December 2007. Nutrient solutions with different N:K ratios were tested at the stages of vegetative growth and fruit setting, using expanded clay as substrate.

Hybrid seeds of cucumber, cv. Aodai, were sown in polyethylene trays, using phenolic foam as substrate, subsurface irrigated with deionized water until germination and with nutrient solution until day 30 of cultivation. At 30 days after sowing, the seedlings (10-15 cm of height) were selected and transplanted to hydroponic growing beds (2.6 m long and 0.9 m wide) containing expanded clay and nutrient solution supplied by subirrigation. The plant spacing was 0.30 x 0.30 m, and the two central plants in the plot were considered as usable. Plants were trained by tying them to horizontal wires fixed above the plant rows to a height of 60 cm, and side shoots were removed, leaving a single stem. Minimum and maximum temperatures inside the greenhouse were monitored daily, using a thermometer. During cultivation, plants were sprayed with the fungicide Saprol (1 mL L^{-1}) to control mites.

The experiment was arranged in a complete randomized design with five treatments and six repetitions. A nutrient solution with N:K ratio (w/w) of 1.0:1.4 was used in the vegetative stage, and four nutrient solutions with different N:K ratios (1.0:1.4; 1.0:1.7; 1.0:2.0; and 1.0:2.5) during the fruit setting. An additional treatment with a nutrient solution containing the ratio 1:2.2 (w/w) N:K during the vegetative growth and N:K 1:1.4 (w/w) during fruit setting, both with 10% ammonium (NH_4^+) was included (Table 1).

The nutrient solutions were calculated according to Adams (1994) and prepared in 1,000 L tanks for each treatment. The pH was maintained in the range of 5.5 to 6.5 by daily adjustment using HCl, or NaOH, according to Martinez (1999). For nutrient replenishment, a depletion of 30% was allowed, on the basis of the reduction of the initial electrical conductivity (2-2.5 mS cm^{-1}). The volume of water in the reservoir was completed when the reduction reached 40% of the initial volume.

At 21 days after transplanting, when the flowering started, the nutrient solutions for vegetative growth were replaced by the solutions for fruit setting with different N:K ratios (Table 1), each one with their respective salts (Table 2).

At 45 days after transplanting, the fresh weight, length, diameter and firmness of fruit were assessed. Also, the third fully developed leaf, from the apex to base, was collected to determine the concentrations of N, K, P, Ca, Mg and S. The second evaluation of fruits was carried out at 60 days after transplanting. In both evaluations, two usable plants were sampled per growing bed (repetition).

The fresh mass was determined by weighing (g) two fruits in a digital scale. The fruit length (cm) was determined using a tape measure. The diameter (cm) was measured in the middle portion of the fruit, using the caliper, and the firmness by using a FT-001 hand-held penetrometer, with an 8 millimeter diameter tip. The fruit volume was measured by the volume of water displaced after immersing the fruit in a 2 L beaker.

Leaves were washed with deionized water, dried at 70 °C in a forced air oven for 72 hours to constant weight and then ground in a Wiley mill with a 20 mesh sieve. The total N was determined by the Kjeldahl method described by Bremner (1965); K was measured by nitric-perchloric

Table 1. Nutrient solutions for vegetative and reproductive hydroponics growth of cucumber

N:K ratio (w/w)	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$	$H_2PO_4^-$	K^+	Ca^{+2}	Mg^{+2}	$S\text{-}SO_4^{-2}$	B	Cu	Mn	Zn	Mo	Fe
	mmol L^{-1}							µmol L^{-1}					
Solutions for the vegetative growth phase													
1.0:1.4	8.0	—	2.0	4.0	2.0	1.0	1.0	21	0.9	19	4.0	0.7	35
1.0:1.4(1)	7.2	0.8	2.0	4.0	2.0	1.0	1.0	21	0.9	19	4.0	0.7	35
Solutions for the reproductive growth phase													
1.0:1.4	12.0	—	3.0	6.03	3.0	1.5	1.5	31	1.3	28	4.0	0.7	59
1.0:1.7	12.0	—	3.0	7.32	3.0	1.5	1.5	31	1.3	28	4.0	0.7	59
1.0:2.0	12.0	—	3.0	8.61	3.0	1.5	1.5	31	1.3	28	4.0	0.7	59
1.0:2.5	12.0	—	3.0	10.77	3.0	1.5	1.5	31	1.3	28	4.0	0.7	59
1.0:2.2(1)	10.8	1.2	3.0	8.61	3.0	1.5	1.5	31	1.3	28	4.0	0.7	59

(1) Nutrient solutions of the additional treatment with 10% $N\text{-}NH_4^+$.

digestion and flame photometry; P was measured colorimetrically after phosphomolybdate reduction with ascorbic acid, according to Braga & Defelipo (1974); and Ca and Mg by atomic absorption spectrophotometry.

Data were subjected to analysis of variance and treatment effects compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

The average minimum and maximum temperatures inside the greenhouse ranged from 16 to 28 °C, respectively. The climatic variables, such as temperature and relative humidity did not affect the vegetative growth, flowering and fruit production of cucumber. The management of the crop, such as removing excess branches or side shoots, was carried out, allowing better ventilation among plants, since the cultures were grown at a spacing of 30 x 30 cm, which is considered as dense for cucumber.

The fruit yield was good, ranging between 95.02 and 149.80 t ha^{-1}, with a cycle of 65 days after sowing, considering the spacing used (Table 3). For cv. Aodai, optimum yield in the field ranges from 28 to 30 t ha^{-1} (Adams, 2006). The production of fresh mass of fruit per plant showed significant differences at 5% probability. The lowest one was obtained in the treatment with the N:K ratio of 1.0:1.4 (w/w) and having NO_3^- as the only N source throughout the crop cycle, while the highest yields were obtained with N:K ratios above 1.0:1.7 including the N:K 1.0:2.2 additional treatment. Providing 10% of N in the ammoniacal form seems to benefit the production of fresh mass, nevertheless the difference between the additional N:K 1.0:2.2 treatment containing N-NH_4^+ and the treatments with N:K ratios of 1.0:1.7, 1.0:2.0; and 1.0:2.5 were not significant. There were no significant differences between treatments for the characteristics diameter, length, volume of fruit and penetration resistance to the hand-held penetrometer (Table 3). The volume, density and firmness of pulp are directly related to fruit quality. From an economic standpoint, firmer fruits have a higher resistance to transport, handling and to attack of micro-organisms (Mascarenhas et al., 2007).

Table 2. Salts used for composing vegetative and reproductive nutrient solutions with different N:K ratios

Salt Sources	Nutrient Solutions (g 1,000L^{-1})						
	Vegetative Stage		Reproductive Stage				
	1.0:1.4	1.0:1.4[(1)]	1.0:1.4	1.0:1.7	1.0:2.0	1.0:2.5	1.0:2.2[(1)]
$MgSO_4$	242	242	363	363	363	363	363
KH_2PO_4	272	175	407	407	407	407	289
$Ca(NO_3)_2$	400	400	600	600	600	600	600
KNO_3	241	291	323	461	597	692	561
MAP	—	102	—	—	—	—	152
$NaNO_3$	194	45	320	200	82	—	—
KCl	—	—	—	—	—	102	94
H_3BO_3	1.33	1.33	1.96	1.96	1.96	1.96	1.96
$CuSO_4$	0.24	0.24	0.34	0.34	0.34	0.34	0.34
$MnSO_4$	3.92	3.92	5.77	5.77	5.77	5.77	5.77
$ZnSO_4$	1.21	1.21	1.21	1.21	1.21	1.21	1.21
$(NH_4)_6Mo_7O_{24}$	0.17	0.17	1.21	1.21	1.21	1.21	1.21
$FeCl_3$	9.46	9.46	15.94	15.94	15.94	15.94	15.94
Na_2EDTA	13.03	13.03	21.95	21.95	21.95	21.95	21.95

(1) Nutrient solution with 10% N-NH_4^+.

Table 3. Yield, fresh mass, diameter, length, volume and firmness of fruits of cucumber cv. Aodai cultivated in nutrient solutions with different N:K ratios

N:K Ratio	Yield (t ha^{-1})	Fresh Mass (g)	Diameter (cm)	Length (cm)	Volume (cm^3)	Firmness (N)
1.0:1.4	95.02 b	855.2 b	5.32	22.94	316.0	0.67
1.0:1.7	149.80 a	1348.2 a	5.31	22.60	383.7	0.69
1.0:2.0	105.04 ab	945.4 ab	5.42	21.50	392.5	0.58
1.0:2.5	140.53 ab	1264.8 ab	5.16	22.25	328.3	0.67
1.0:2.2[(1)]	148.29 a	1334.6 a	5.22	22.30	372.0	0.63
VC. (%)	23.24	23.24	8.52	8.96	15.14	12.47

(1) Nutrient solution with 10% N-NH_4^+. (2) Means followed by the same letter in the columns are not significantly different by the Tukey's test at 5% probability level.

Table 4. Nutrient concentrations in leaves of cucumber cv. Aodai cultivated in nutrient solutions with different N:K ratios, 45 days after transplanting

N:K Ratio	NO_3^-	NH_4^+	K^+	P	Ca^{2+}	Mg^+	S
	dag kg^{-1}						
1.0:1.4	0.38	3.65	4.14	1.40	4.59	0.64	0.86
1.0:1.7	0.34	3.44	4.04	1.60	5.05	0.87	1.01
1.0:2.0	0.47	3.05	4.63	1.87	3.08	0.44	1.12
1.0:2.5	0.44	3.58	3.73	1.35	4.61	0.96	1.16
1.0:2.2(1)	0.33	2.75	3.99	1.61	5.23	0.42	0.89

(1) Nutrient solution with 10% N-NH_4^+

In relation to plant nutritional status, there was no statistical difference for leaf concentrations of macronutrients at the different N:K ratios (Table 4). Fontes (2001) established critical concentrations of N, K, P, Ca, Mg and S at 4.4, 4.0, 0.51, 2.1, 0.46 and 0.50 dag kg^{-1}, respectively, for the dry matter of cucumber leaves at the beginning of fruit setting. Therefore, in this study, the plants showed satisfactory nutritional status. Only for the treatments with N:K ratios of 1.0:2.5 and the additional 1.0:2.2, the K concentrations were slightly lower than the recommended, but without any statistical difference.

At the stage of fruit setting, the highest ratio (1.0:2.5), corresponding to a K concentration of 10.77 mmol L^{-1} in solution (Table 1), provided leaf K content of 3.73 dag kg^{-1}, while at the lowest ratio (1.0:1.4), with 6.03 mmol L^{-1} K in solution, provided leaf K content of 4.14 dag kg^{-1}, which are within the range recommended for cucumber, 3 to 5 dag kg^{-1} (Almeida, 2006), showing the plant's capacity in regulating mechanisms of absorption and/or assimilation of nutrients, even when these nutrients are at altered concentrations (Furlani *et al* ., 1999b).

Application of K enhances yield by fruit weight gain (Pinto *et al.*, 1996). This fact was confirmed in melon hybrids grown in different N:K ratios, which had higher weight gain, length and diameter of fruits when grown in solution with N:K ratio of 1:2.6 (Santos *et al*., 2003).

There was no reduction in leaf Mg or Ca contents with increasing concentrations of K in the solution, nor in the K, Ca and Mg contents with the use of 10% of N in N-NH_4^+ form (Table 4).

Fresh mass of fruits showed significant differences when the nutrient solutions of fruit setting contained N:K (w/w) ratios above 1.0:1.7, independently of the N:K ratio of the solution used in the vegetative growth phase. The short vegetative stage, since the beginning of flowering occurred at approximately 50 days after germination, can probably be reponsable for this behavior. Thus, only one nutriente solution for the overall cultivation cycle can be recommended, hence, changing the N:K ratio of the solution for the reproductive stage represents an additional task during the crop cycle.

Although nutrient extraction is changed in the reproductive stage (Furlani *et al.*, 1999b), a solution can be provided with K concentration enough to meet this varying demand over the cycle, because the plant has the ability to regulate absorption of nutrients (Adams, 1994). Thus, the N:K ratio of 1.0:1.7 can be recommended throughout the crop cycle, as it provided the highest production of fresh mass (1,348.2 g) and yield (149.8 t ha^{-1}), besides showing significant difference only in relation to the treatment 1.0:1.4 (Table 3).

When comparing the production of fresh mass and yield among the treatments, we can see that the treatment with 10% N as ammonia (1.0:2.2) was significantly different from the treatment N:K ratio of 1.0:1.4, but not from the other treatments. In contrast, fresh mass production and yield of this treatment were slightly higher than of the treatments 1.0:2.0 and 1.0:2.5, and did not impair fruit production or quality. These results allow the recommendation of mono ammonium phosphate, since this fertilizer provides nitrogen in the form of ammonia (9% N) and is a good phosphorus source (48% P_2O_5), besides its low cost compared with other sources.

CONCLUSIONS

The fruit quality of hydroponics cultivated cucumber is not influenced using different N:K ratios through the fruit setting stage.

Ten percent of ammoniacal nitrogen in the nutrient solution, regardless of the growth stage, didn't impair the yield nor the quality of hydroponics cultivated cucumber.

The nutritive solution N:K (w/w) ratio of 1.0:1.7 with 10% N in the ammoniacal form can be recommended throughout the overall cucumber cultivation cycle.

Nutrient solutions with N:K ratios (w/w) between 1:1.7 and 1:2.5 during the reproductive phase had no influence on the nutritional status of the cucumber plants.

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REFERENCES

Adams P (1994) Nutrition of greenhouse vegetables em NFT and hydroponic systems. Acta Horticulturae, 361:245-257.

Adams P (1999) Plant nutrition demystified. Acta Horticulturae, 481:341-344.

Almeida D (2006) Manual de culturas hortícolas. vol. II. Lisboa, Editorial Presença. 346p.

Braga JM & Defelipo EV (1974) Determinação espectrofotométrica de fósforo em estratos de solos e plantas. Revista Ceres, 1:73-85.

Bremner JM (1965) Total nitrogen. In: Black CA (Ed.) Methods of soil analysis. Madison, American Siciety of Agronomy. Part 2, p.1149-1178.

Castellane PD & Araújo JAC de (1994) Cultivo sem solo: hidroponia. Jaboticabal, FUNEP, 43p.

CTIFL (1995) Centre techinique interprofesionel dês fuits e dês legumes. Maîtrise de la conduite climatique. Paris, CTIFL. 127p.

Fernandes AA, Martinez HEP & Oliveira LR (2002) Produtividade, qualidade dos frutos e estado nutricional de plantas de pepino, cultivadas em hidroponia, em função das fontes de nutrientes. Horticultura Brasileira, 20:571-575.

Filgueira FAR (2007) Novo manual de olericultura – agrotecnologia moderna na produção e comercialização de hortaliças. 3ª ed. rev. e ampl., Viçosa, Ed. UFV. 421p.

FNP Consultoria & Comércio (2011). Pepino. In: Agrianual 2010 - Anuário da agricultura brasileira. São Paulo, Agra-FNP. p. 400.

Fontes PCR (2001) Diagnóstico do estado nutricional das plantas. Viçosa, Ed. UFV. 122p.

Furlani PR, Silveira LCP, Bolonhezi D & Faquin V (1999a) Cultivo hidropônico de plantas. Campinas, Instituto Agronômico. 52p. (Boletim Técnico, n.180).

Furlani PR, Bolonhezi D, Silveira LCP & Faquin V (1999b) Nutrição mineral de hortaliças, preparo e manejo de soluções nutritivas. Informe Agropecuário, 20:90-98.

Gomes SMS (1995) Influência da idade, coloração externa e armazenamento de frutos na qualidade de sementes de pepino (*Cucumis sativus* L.). Dissertação de Mestrado. Universidade Federal de Viçosa, Viçosa, 80p.

Martinez HEP (2005) Manual prático de hidroponia. Viçosa, Aprenda Fácil, 271p.

Martinez HEP (1999) Hidroponia. In: Ribeiro AC, Guimarães PTG & Alvarez VVH (Eds.) Recomendações para o uso de corretivos e fertilizantes em Mina Gerais - 5ª Aproximação, Viçosa, CFSEMG. 359p.

Mascarenhas MHT, Oliveira WR, Simões JC & Resende LM de A (2007) Pepino. In: Paula Junior TJ de & Venzon M (Eds.) 101 Culturas – Manual de tecnologias agrícolas. Belo Horizonte, EPAMIG. p.603-610.

Moraes CAG & Furlani PR (1999) Cultivo de hortaliças de frutos em hidroponia em ambiente protegido. Informe Agropecuário, 20:105-113.

Papadoupoulos AP (1994) Growing greenhouse seedles cucumbers in soil and in soiless media. Canada, Agriculture and Agri-food Canada. 126p.

Pinto JM, Soares JM, Pereira JR, Costa ND, Brito LT de L, Faria CMB de & Maciel JJ (1996) Sistema de cultivo de melão com aplicação de fertilizantes via água de irrigação. Brasília, Embrapa, 24p. (Circular Técnica, 36).

Santos RNC dos, Minami K & Piedade SM de S (2003) Relação K:N em híbrido de melão *Orange Flesh* em cultivo hidropônico. Horticultura Brasileira, 21:371.

Solis FAM (1982) Concentração e extração de nutrientes e distúrbios nutricionais na cultura de pepino (*Cucumis sativus* L.) variedade Aodai. Tese de Doutorado. Escola Superior de Agricultura “Luiz de Queiroz”, Piracicaba, 139p.