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Effect of Commercial Organic Nutrient Solutions on Growth and Chemical Composition of Lettuce under Agricultural Soilless System

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THIS STUDY was conducted during 2003/2004 and 2004/2005 seasons at the Experimental Farm of the College of Agriculture and Veterinary Medicine, King Saud University, Al-Qassim and Faculty of Agric., Ain Shams Univ., Shobra El-Khima, Cairo, Egypt, to evaluate the effect of different nutrient solutions on mineral accumulation and growth of lettuce plants grown under two soilless culture system (hydroponics and sand cultures).

The first solution was inorganic source (control), while the second solution was box solution, the third was star solution and the fourth was fruit growth solution as organic sources (commercial solutions).

The highest yield was observed with inorganic fertilizer followed by fruit growth solution. The same response was found with head fresh yield and chlorophyll content of plant leaves. This is true for either hydroponics or sand cultures treatment; the yields with hydroponics were, however, higher than with those in sand culture.

There was a high correlation between concentration of nitrate in solution of the growth medium and in leaves; the cooper solution treatment was the highest content of nitrate, while the Star solution treatment was the lowest.

This study suggested that both box and fruit growth solutions can be possibly used satisfactory for organically based hydroponic formula as safe sources, with relatively low nitrate content, for the required nutrients by plant, human, and environment.

Keywords: Lettuce, Inorganic nutrient source, Organic nutrient source.

Foods have always been considered beneficial for human health maintenance. Among those thought to have high nutritional and medicinal value is lettuce; a vegetable which contains essential dietary minerals .

Some of the leaf crops for human consumption have been found to accumulate excessive NO_3^- and are possibly responsible for methemoglobinemia, particularly in babies (Keeney, 1982). Crops known to accumulate excessive NO_3^- in the forage with overlay liberal fertilization include spinach, lettuce and dill (Olson and Kartz, 1982). The adverse effect of high NO_3^- is actually due to NO_2^-, produced through reduction in the intestine of some animals and human infants during the first few months of life. Nitrite is rapidly absorbed into blood where it oxidizes the Fe of hemoglobin to the ferric state forming methe-moglobin which cannot function in oxygen transport. Moreover, some circumstantial evidence relating exposure to either NO_3^- or NO_2^- to the incidence of cancer is available. Santanaria and Elia (1997) reported that despite the contribution of vegetables to human health, consumers are worried because some cultivation techniques, *e.g.*, the presence of pesticide residues or excessive nitrate content might reduce the quality of the product. Smith and Hadley (1989) cited that there is an increasing interest in the use of organic N sources as fertilizers for the production of vegetable crops and in particular for the production on "organic grown" advantages of organic N fertilizers over inorganic N salts. Recently, Al-Redhaiman *et al.* (2005) suggested that the application of chicken and rabbit manures to lettuce plants under soilless system can be used as relatively safe sources for the required nutrients by plant, human, and environment.

The question of hydropnic nutrition of crops by organic means, instead of employing inorganic salts of different types, has been raised many times throughout the recent years, but perhaps more frequently during the past half – decade. The demand for organic plant food materials arises for several reasons such as desire of some growers and consumers to avoid chemical fertilizers along with increasing cost of artificial salts or compounds.

Therefore, the goal of this study was to investigate the influence of different nutrient sources on mineral accumulation and growth in the leaf tissues of lettuce.

Material and Methods

This study was conducted at the Experimental Farm of the College of Agriculture and Veterinary Medicine, King Saud University, AL-Qassim Branch and Faculty of Agric., Ain Shams Univ., Shobra El-Khima, Cairo, Egypt. The experiment was conducted in the greenhouse, under hydroponics and sand cultures in two successive seasons of 2003/2004 and 2004/2005. Seeds of lettuce, cv. Calona from S & G, Holland, were germinated in a mixture of peat moss and vermiculite (1:1v/v). The seedlings were produced in mesh pots supported by the pot rims, in PVC channels after, approximately, 14 days from germination. Such seedlings were then spaced at 6.5 inch (19 cm) within the rows (PVC) giving 10 heads per 6- foot row (30 plant in plot); 30 l plastic containers each containing 25 l of aerated nutrient solution were used for supplying two channels in which the nutrient solution was recirculated. Four nutrient solutions were used as treatments. The first nutrient solution (check) contained inorganic sources (Cooper, 1979) and consisted of $Ca(NO_3)_2$, 0.575; KNO_3, 0.331; $Mg(NO_3)_2 . 7H_2O$, 0.219; KH_2PO_4, 0.0828 and K_2SO_4, 0.1466 (g/l). The micro nutrients were supplied to this solution as Fe - EDDHA 16; $MnSO_4 . 7H_2O$, 2.44; H_3BO_3, 0.68; $ZnSO_4 . 7H_2O$, 0.176; $CuSO_4 . 5H_2O$, 0.156 and $(NH_4)_6 MO_7O_{24}$, 0.148 (mg/l). The second solution represented the box solution (organic source) as following: Total organic N, 1.12; total P, 1.12; total K, 4.48; S, 0.11; Mg, 0.05; Fe, 0.6; Mn, 0.03 and Zn, 0.04%. The third solution represented the star solution (organic source) as following: Total organic N, 6.0; total P, 4.2; total K, 10.2; S, 0.24; Mg, 0.06; Fe, 0.14; Mn, 0.1 and Zn, 0.12%. The fourth treatment was growth fruit solution (organic source) as following: Total organic N, 3.75; total P, 5.0; total K, 18.75; S, 0.24; Mg, 0.06; Fe, 0.1; Mn, 0.1 and Zn, 0.12%. The characteristics of each diluted nutrient solution were mentioned in Table 1. On the other hand, the same previous nutrient solutions were used in four treatments in sand culture technique for comparison between hydroponics and sand culture technique. The sand culture experiment was carried out in plastic pots (diameter, 20 cm). The plastic pots were filled with washed sand. Each pot contained one seedling and each treatment consists of nine plants. A completely randomized design was used with three replicates of each solution. The nutrient solutions were completely renewed every 7 days. The EC of each nutrient solution was about 2.0 dS /m. The pH was adjusted at 5.5 to 6.5 using citric acid for the all organic nutrient solutions, but for the inorganic solution the pH was adjusted by using nitric and phosphoric acids (3:1 v/v). After 75 days of growth, the plants were harvested; three plants were randomly chosen from each plot and plant fresh and dry weights were determined. Total yields were also recorded. Total chlorophyll was measured at harvest in the second leaf using Minolta chlorophyll Meter SPAD –501. The samples were oven dried at 70°C then ground in a blender and stored in glass vials for elemental analysis. Dried samples were wet ashed using concentrated H_2SO_4 and 30% H_2O_2. In the digest, nitrogen was determined by steam distillation procedure using devarda alloy. Assessment for the nitrogen-NO_3 was performed using Cardy NO_3-Nitrate Meter Model HORIBA, Spectrum Technologies, Inc. reported by Al-Moshileh *et al.*(2004). Phosphorus was measured colorimetrically using ammonium molybdate procedure; sodium and potassium were determined with flame photometer and Fe, Zn Mn, Cu, Mg and Ca were measured by atomic absorption spectrophotometer (Chapman and Pratt, 1961).

TABLE 1. The characteristics of each diluted nutrient solution (1 mml nutrient solution / 250 mml water).

Parameter	Box solution	Star solution	Fruit Growth solution
pH	6.9	5.5	8.6
Ec	2.1	2.5	2.5

The data were analyzed by analysis of variance and comparison of treatment means was carried out using L.S.D range test at the p = 0.05 level of significance. Data were, finally, statistically analyzed according to Sendecor and Cochran (1980).

Results

The characteristics of each diluted nutrient solution were mentioned in Table 1. The stock solution of fruit growth solution has pH 8.6 while box and star solutions pH were 6.9 and 5.5, respectively. The pH reflects the nature of material composition in each solution. The pH of materials in fruit growth solution tends to have a basic effect while pH both of box and star solutions tend to give an acid effect. The percentages of total organic material from plant source were 39.2, 24.0 and 22.5 % for box, star and growth fruit solutions, respectively. Also, the total humus was 8.96, 14.4 and 15.0 % for box, star and growth fruit solutions, respectively. Star solution was highest in content of the nitrogen; growth fruit solution has the higher content of both phosphorous and potassium.

In fact, the differences among the solution compositions led to variations in growth of lettuce plants. Table 2 shows that yield, head fresh and dry weights generally recorded the highest values by application of cooper treatment (check) in both seasons; the lowest values were recorded with box solution. On the other hand, the yield, head fresh and dry weights in hydroponics culture was higher than sand culture. This trend was true with chlorophyll content in lettuce leaves. Response of nutritional status in lettuce plants for different nutrient solutions was shown in Tables 3 and 4. The highest concentrations of total nitrogen in lettuce leaves were found with the star solution in the two studied seasons. The phosphorous content in fruit growth solution gave the highest concentration in the first season while the inorganic treatment (cooper) was superior in the second season. The other macronutrients were, generally, highest in their content in treatments receiving the inorganic nutrient source (cooper); the highest concentrations of micronutrients were obtained with fruit growth. Finally, hydroponics culture has higher content of N, P, K, Ca, Mg, Mn and Zn than sand culture; the reverse was true with Fe and Cu.

Nitrate concentration in plant tissue was shown in Table 4; the cooper solution treatment was the highest in content of nitrate, the box solution was the lowest. Also, in hydroponics culture, nitrate content in lettuce tissues was higher than that of sand culture.

Discussion

Elevated nitrate levels in plants at harvest are uneconomical in relation to nitrogen utilization and are also undesirable nutritionally. It may be worth to mention that the actual level of nitrate must be less than 4500 mg kg^{-1} fresh weight (European Economic Community, Gent, 2003). Also, Kobryn (1996) reported that the type of growing medium, the relevant possibilities of fertilization and nutrient element uptake have significant influence on the yield and its quality; especially on the postharvest nitrate content in the lettuce head. This is clear from the high nitrate content of the cooper treatment, compared with other treatments, as a result of nitrogen form which was nitrate. This is different from the organic nitrogen form which was the main source in the other treatments. On the other hand, box solution treatment seems to be safer compared with other treatments where nitrogen concentration was the lowest in their nutrient solutions.

TABLE 2. Effect of the studied treatments on the head fresh and dry weights, yield and chlorophyll content of lettuce plants.

Treatments	First Season			
Hydroponics(H)	*Chlorophyll* (Spad)	Head fresh weight g/plant	Head dry weight g/plant	Yield Kg/plot
Control	36.2	281	10.2	9.04
Star	34.3	221	9.99	7.13
Box	33.6	168	8.83	5.42
Fruit Growth	34.2	259	10.1	8.35
L.S.D 0.05	0.10	8.80	0.10	0.009
Sand culture (S)				
Control	36.3	111	6.44	3.59
Star	33.7	97.8	5.78	3.15
Box	31.0	87.7	5.29	2.82
Fruit Growth	32.0	90.5	5.43	2.92
L.S.D 0.05	0.15	12.4	0.14	0.013
L.S.D 0.05 H*S	0.21	17.6	0.20	0.019
Second Season				
Hydroponics(H)				
Control	34.9	376	13.7	12.1
Star	33.9	250	11.2	8.05
Box	33.3	203	9.73	6.55
Fruit Growth	34.3	307	12.1	9.89
L.S.D 0.05	0.03	37.3	0.09	0.03
Sand culture (S)				
Control	37.8	100	6.03	3.25
Star	34.0	95.1	5.80	2.92
Box	32.1	88.7	5.03	2.89
Fruit Growth	34.6	91.2	5.22	3.06
L.S.D 0.05	0.03	52.8	0.13	0.05
L.S.D 0.05 H*S	0.04	74.7	0.18	0.07

TABLE 3. Effect of the different nutrient solution sources on the contents of macro and microelements in lettuce plants during the two studied growing seasons.

Treatments	First Season								
Hydroponics(H)	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Control	4.32	0.89	4.91	0.76	0.65	82.8	24.8	39.7	4.84
Star	4.34	0.79	3.32	0.75	0.51	67.6	20.3	36.5	6.35
Box	3.15	0.79	3.33	0.68	0.50	84.6	26.1	26.4	7.24
Fruit Growth	3.83	0.92	4.64	0.66	0.43	104	34.2	67.8	8.81
L.S.D 0.05	0.014	0.001	0.009	0.003	0.005	19.6	1.92	2.32	0.21
Sand culture (S)									
Control	2.79	0.59	3.54	0.67	0.45	162	10.0	21.1	12.8
Star	3.09	0.71	2.78	0.69	0.45	109	12.8	27.4	6.88
Box	2.14	0.63	3.17	0.69	0.36	106	10.3	10.8	12.6
Fruit Growth	2.66	0.71	3.23	0.66	0.44	169	26.0	57.1	12.9
L.S.D 0.05	0.028	0.002	0.13	0.004	0.007	27.2	2.71	3.29	0.30
L.S.D 0.05 H*S	0.039	0.003	0.018	0.006	0.001	38.5	3.84	4.65	0.43
Second Season									
Hydroponics(H)	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Control	3.86	0.95	5.41	0.87	0.72	86.3	25.0	40.5	7.91
Star	4.38	0.68	4.21	0.75	0.54	76.3	20.7	39.1	7.75
Box	3.29	0.78	4.20	0.73	0.47	82.9	24.4	29.0	7.77
Fruit Growth	3.71	0.75	5.24	0.81	0.58	105	35.5	69.7	8.81
L.S.D 0.05	0.223	0.0008	0.006	0.006	0.0006	12.9	2.04	0.990	0.02
Sand culture (S)									
Control	2.40	0.63	3.54	0.74	0.52	160	11.7	23.5	10.8
Star	2.68	0.34	3.19	.074	0.39	104	16.7	26.8	8.81
Box	2.33	0.50	3.51	0.65	0.37	111	11.1	19.4	9.20
Fruit Growth	2.41	0.41	3.12	0.74	0.49	165	21.6	37.7	14.7
L.S.D 0.05	NS	0.001	0.009	0.0008	0.0009	18.3	4.08	1.40	0.029
L.S.D 0.05 H*S	0.44	NS	0.013	0.001	0.0012	25.9	4.08	1.99	0.41

TABLE 4. Effect of different nutrient sources on the content of nitrate (mg/Kg DW) in lettuce plants.

Treatments	First Season	Second Season
Hydroponics (H)		
Control	3900	2950
Star	1533	1633
Box	583	733
Fruit Growth	1766	1766
L.S.D 0.05	375	315
Sand culture		
Control	1566	1600
Star	1533	1466
Box	633	666
Fruit Growth	1100	1566
L.S.D 0.05	531	361
L.S.D 0.05 H*S	751	446

It may be worth to mention that the importance of nitrate content in vegetables is underlined in the European Commission Regulation No. 563/2002, which set the maximum nitrate levels in the different seasons and cultivation methods for lettuce and spinach, and by JECFA (Joint FAO/WHO Expert Committee on Food Additives) which has fixed the acceptable daily intake (ADI) of nitrate between 0 and 3.65 mg kg^{-1} of body weight (WHO, 1995). According to this ADI, only 100 g of raw vegetables (with a NO^{-}_{3} concentration of 2500 mg kg fw^{-1}) accounts for an intake of 250 mg NO^{-}_{3}. Hence, if a 60-kg person consumes this amount alone, the ADI for NO^{-}_{3} will be exceeded by about 14%.

The hydroponics system recorded relatively the highest concentration of nitrate in plant tissue due to the fact that the lettuce roots in such system were inserted within nutrient solution; accordingly, the roots were directly contacted with nutrient solution. In fact, Massantini *et al.* (1988) mentioned that plants grown on hydroponics have more mineral salts rather than those of conventional system whose levels of heavy metals are also higher. Bohme (1995) added that in the closed type soilless culture system, nutrient management has been based on the maintenance of relatively high ion concentrations, *i.e.* high EC, sometimes with serious environmental impacts (Bohme, 1995). It can lead to luxury ion uptake and to an imbalance between vegetative and reproductive growth, which can reduce quality (*e.g.* low sugar content in fruit vegetables and high nitrate content in leaf vegetables) (Pardossi *et al.*, 1995).

Nitrogen content of plant tissues fertilized with Star treatment was the highest due to presence of relatively high concentration of organic nitrogen compared with other treatments.

Variations in chlorophyll content of leaves which was highest when plants were fertilized with inorganic source (cooper solution, check) and lowest with box solution coincide with both nitrogen form balance and nitrogen concentration in nutrient solutions. Inorganic source (cooper solution, check) treatment was followed, in the content of chlorophyll, by the fruit growth solution treatment whose nitrogen concentration was relatively high in total organic nitrogen.

In fact, mineral nutrition can affect net photosynthesis in various ways (Nàtr, 1975 and Barker, 1979); mineral nutrients are required for various processes related to the formation and function of chloroplasts. In green leaf cells, for example, up to 75% of the total organic nitrogen is located in the chloroplasts, mainly as enzyme protein. A deficiency of mineral nutrients that are directly involved in protein or chlorophyll synthesis, therefore, results in the formation of chloroplasts with low photosynthetic efficiency. The same holds true when there is a deficiency of a mineral nutrient which is directly involved in either the electron transport chain or in photophosphorylation.

Of course, increasing nitrogen concentration in the uptake media increased nitrogen uptake (Abd-Elmoniem, 1986) which, in turn, increased its concentration and enhanced chlorophyll content in plants tissues (Marschner, 1995).

K, Ca and Mg contents of plant tissues receiving inorganic source (Cooper solution, check) treatment was highest possibly due to their relatively high uptake by grown plants compared with that form other treatments (organic sources) due to variations in nutrition status of the different nutrient cultures.

Finally, it can be concluded that both fruit growth and box solutions can be possibly used satisfactory for organically based hydroponic formula to produce healthy lettuce with relatively high yield and good quality representing relatively low nitrate content in plant tissues.

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تأثير محاليل غذائية عضوية تجارية على النمو والتركيب الكيماوي للخس تحت نظام الزراعة بدون تربة

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أجريت هذه الدراسة خلال موسمي٢٠٠٣ /٢٠٠٤، ٢٠٠٤ /٢٠٠٥ وذلك بمزرعة كلية الزراعة والطب البيطري – جامعة الملك سعود فرع القصيم وجامعة عين شمس كلية الزراعة – القاهرة – مصر، وذلك لتقييم تأثير أربعة مصادر من المحاليل الغذائية على تراكم العناصر الغذائية ونمو نبات الخس النامي تحت نظامين من الزراعة بدون تربة وهما المزارع المائية والمزارع الرملية.

المحلول الأول كان من مصادر غير عضوية (كنترول) بينما الثاني هو محلول بوكس أما الثالث فكان محلول استار و الرابع هو محلول نماء الثمرة وهى مصادر عضوية تجارية.

لوحظ أن أعلى محصول نتج بواسطة معاملة المحلول الغير عضوي (كنترول) ثم تبعه معاملة محلول نماء الثمرة. نفس النتائج وجدت مع محصول الرؤوس الطازجة والمحتوى من الكلوروفيل في أوراق النبات. كان هناك ارتباط عالي بين تركيز النترات في وسط النمو وتركيزه في الأوراق بحيث كان اقل تركيز مع معاملة محلول بوكس بينما أعلى تركيز في معاملة المحلول الغذائي الغير عضوي (كنترول) .

وتقترح هذه الدراسة إمكانية استخدام كل من محلول بوكس ومحلول نماء الثمرة بأمان كمصادر للمغذيات المطلوبة بواسطة النباتات في نظم المزارع المائية على أساس عضوي بصورة آمنة (من حيث المحتوى المنخفض نسبيا من النترات) على صحة الإنسان والبيئة .