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Growth and Yield of Chinese Kale Grown in Dynamic Root Floating Technique (DRFT) by Reused Nutrient Solution

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In re-circulated nutrient solution of hydroponics may lead to the accumulation of NaCl and an imbalance of essential minerals when using for long-run. This phenomenon affects on a NaCl sensitive plant such as lettuce. Commonly, the nutrient solution should be periodically changed and refilled. However, the waste or used nutrient solution (UNS) still contains essential minerals. For that reason, we focused on using of the UNS from grown lettuce in nutrient film technique (NFT) to other growing system. In this experiment, UNS was recharged by adding with the stock nutrient solution of leafy vegetable (KMITL2) and adjusted the concentration to 2.5 mS/cm and pH 5.8 for growing Chinese kale by dynamic root floating technique (DRFT). Comparison with control, that was new nutrient solution (NNS) prepared by the same stock (KMITL2) and adjusted the concentration and pH to the same level of UNS. The result from 2 crops was found that Na accumulation was increased in both NFT and DRFT. The UNS showed higher Na content than that in NNS. Other growth parameters such as; number of leaf, stem diameter, average weight per plant, fresh weight, dry weight and total yield were not significantly different. Furthermore, using UNS was shown to reduce the water, fertilizer, and acid consumption for Chinese kale production around 84-100, 65-76, and 26-55%, respectively. This experiment is the first step to improve the efficiency use of water and fertilizer by using the UNS to the second growing system, Our further research will focus on utilizing the UNS to the other growing system in continuously which leading to reduce cost and be friendly to the environment with zero waste production system.

Keywords: Hydroponics, reused nutrient solution, waste nutrient solution

Introduction

Soilless culture or hydroponics is a very popular growing system for consumption in household up to large scale industry. This cultural system can make income very well, because of the consumers prefer pesticide-free vegetables with high nutritional value. Therefore, hydropnics for vegetable production tends to increase in many area. Soilless culture is divided into two

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groups: 1) aggregate hydroponics or substrate culture (usually the nutrient solution is non-recirculated), 2) solution culture or hydroponics (mostly nutrient solution is recirculated in the system). Regarding solution culture, there are many cultural techniques such as nutrient film technique (NFT), deep flow technique (DFT) and dynamic root floating technique (DRFT). The most popular technique for leafly vagatable production is NFT because it provides the highest yield per unit area and can be produced 20 cycles year round (Nuntagij, 2014). However, management of nutrient solution has to be focused and well-organized. In circulating system, the nutrient solution passes through plant root, an exchange is taken place. As a result, as time goes by, the nutrient solution changes in concentration. Therefore, it's EC and pH has to be monitored regularly. The EC measures referred to total fertilizer that dissove as minerals in the nutrient solution, while plants uptake each essential minerals differently, therefor the high uptake mineral that plants need so much, will be inadequate and tends to decrease. Whereas low intake mineral that plants slightly need, will accumulates and causes an imbalance of nutrient solution (Grattan and Grieve, 1999). Such as, sodium chloride (NaCl) if accumulates in the nutrient solution, it may cause phytotoxic to plants (Qin *et al.*, 2013). In generally, farmers have to change nutrient solution every 2-3 weeks which is the best insurance against crop damage (Roberto, 2003). The UNS from hydroponics releases to environment can induce eutrophication, causing algal boom and the loss of oxygen in the water. Besides, UNS may be toxic to animals and people (Park *et al.*, 2008). Developed countries greatly concern about waste in agriculture. The waste from the agricultural production system was restricted to the release to environment (Kumar and Cho, 2014). There have been many researches in many countries regarding the utilization of UNS such as in growing tomato (Gent and Short, 2012), chinese cabbage (Choi *et al.*, 2011a), red pepper (Park *et al.*, 2005), musk melon (Zhang *et al.*,2006). Therefore, we intended to utilize the UNS for growing Chinese kale in DRFT in Thailand in order to increase the value of waste nutrient solution as well as to reduce it's production cost and waste from agricultural release to environment.

Materials and methods

Lettuces were grown in Nutrient film technique (NFT)

Experiments were conducted in greenhouse at farmers farm in Nakorn Ratchasima province. Lettuces were grown in the nutrient film technique (NFT) system (figure 1A). Growing lettuces were used nutrient solution of leafy vegetable, KMITL2 solution (Nuntagij, 2014) that prepared to stock A solution (80 g FeEDDHA, 3800 g $CaNO_3$) and stock B solution (1800 g KNO_3, 650 g

KH_2PO_4, 1000 g $MgSO_4$ and micro element: 4.756 g $ZnSO_4$, 1.016 g $CuSO_4$, 14.194 g $MnSO_4$, 8.894 g Boric acid and 0.343 g Ammonium molybdate). Stock A and B of KMITL2 solution were diluted with tap water to the concentration of 1.6-1.8 mS/cm and adjust pH to 5.8 by nitric acid. Six cultivars of lettuce seeds (*Lactuca sativa* var. Cos, green oak, red oak, frillice iceberg, red coral and butter head) were sow in growing cup 5×5×5.2 cm. fully with perlite as sowing media and daily watering until germination. Lettuce seedlings 7-10 day of aged were transferred to nursery 1, nursery 2 and planting gully at the age of 1, 2 and 4 weeks, respectively (Fig 1A). Harvesting was done at the age of 6 wk; therefore lettuce would be harvested in every 2 weeks. Then the nutrient solution was regularly changed to the new one and UNS from NFT was also collected to be reused for growing Chinese kale in DRFT system.

UNS management for growing the Chinese kale in DRFT

Managing the UNS before applying to DRFT grown Chinese kale was recharged by adding with stock of KMITL2 solution and adjust the concentration to 2.5 mS/cm, pH 5.8. Comparison with control, that was new nutrient solution (NNS) prepared by the same stock of KMITL2 solution and adjusted the concentration and pH to the same level of UNS. The two treatments were arranged in a randomized complete block design with three replications. Each block comprised 2 plots, of size 1×3.2 m per plot. The experiment was repeated twice with difference in growing space. Crop 1 and 2 were determinate at inter and intra-row spacing of 19×12 and 38×24 cm respectively. Seedlings were prepared in polyethylene foam size 1×1×1 inch. Then, seedlings were transplanted on the DRFT system at 1 week of age and harvested at 6 weeks after sowing (fig 1B).

Growth and yield parameters such as number of leaf (4, 5 and 6 weeks after sowing), stem diameter, fresh and dry weight of stem and leaf, average weight per plant and total yield (at the harvesting age) were determined. Meanwhile, the data regarding UNS management such as water consumption, fertilizer and nitric acid were also recorded. Besides, concentration of all elements in the nutrient solution of NNS and UNS were also analyzed either the beginning or the end of experiment. Regarding analysis of nutrient solution, all samples were analyzed for nutrient EC and pH determined using the Consort C831 (multi-parameter analyzer). NH_4^+ and NO_3^- were determined using stem-distillation method. P, K, Ca, Mg, Fe, Mn, Cu, Zn and Na were determined using ICPOES (Inductively Coupled Plasma Optical Emission Spectrometry)

Data analysis: The results were subjected to the analysis of variance and means were separated according to the Duncan's multiple range (DMRT) test at P = 0.05 probability level.

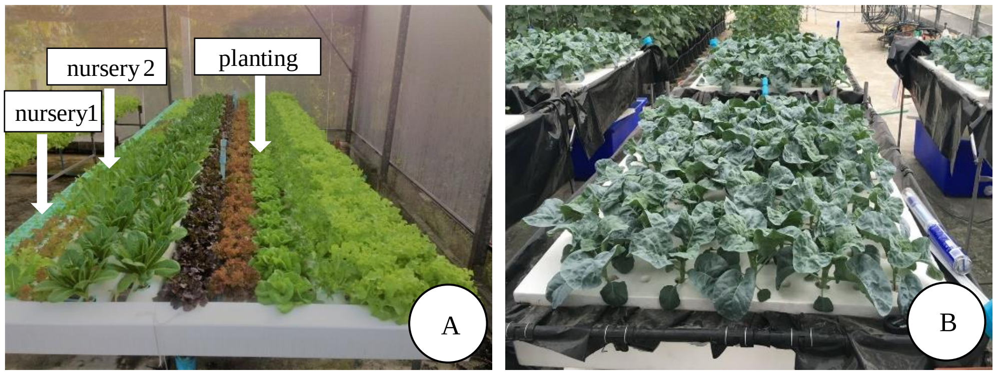

Figure 1: A= Lettuce grown in nutrient film technique (NFT) B= Chinese kale grown in Dynamic root floating technique (DRFT)

Results

Using NNS and UNS on growth and yield of Chinese kale in DRFT system

The UNS used for growing-Chinese kale in DRFT revealed that growth parameters at 4, 5 and 6 weeks of age including number of leaf and stem diameter was not significant difference compared with NNS (table 1). In addition, yield parameters of Chinese kale including, average weight per plant, edible fresh weight, dry weight and total yield grown in UNS was also not significant difference compared with that grown in NNS (table 2). Moreover, using UNS both in crop 1 and 2 could reduced water consumption, fertilizer and nitric acid for this production upto 92.84-100, 49.64-61.75 and 25.65-27.55 % respectively (table 3). Therefor using UNS, which was already recharge, for growing Chinese kale in DRFT could be possible without effect on plant growth and could be saved cost as mentioned above.

Table 1. Growth parameters of Chinese kale grown in DRFT with new and used nutrient solution over two croppings.

	Number of leaf			diameter of stem (cm)
	4 week	5 week	6 week	
Crop1				
NNS	5.3a	7.0a	8.6a	1.43a
UNS	5.6a	6.8a	8.8a	1.3a
Crop2				
NNS	7.4a	9.56a	12.1a	3.0a
UNS	7.5a	9.43a	12.16a	2.8a

NNS = new nutrient solution; UNS=used nutrient solution
*The same letter belong with each mean value is not significantly different at a 0.05 significance level

Table 2. Yield parameters of Chinese kale grown in DRFT with new and used nutrient solution over two croppings.

	Number plant	Average weight per plant(g)	Edible fresh weight (g)			Dry weight(g)			Total yield (kg)
			stem	leaf	total	stem	leaf	total	
Crop 1									
NNS	293	39.30a	20.39a	12.20a	32.59a	1.40a	1.27a	2.67a	11.510a
UNS	302	37.80a	21.48a	14.12a	35.60a	1.44a	1.24a	2.68a	11.420a
Crop 2									
NNS	138	195.40a	110.9a	86.50a	197.40a	6.56a	7.38a	13.95a	26.960a
UNS	139	178.80a	126.4a	82.10a	208.50a	8.16a	6.63a	14.80a	24.860a

NNS = new nutrient solution; UNS=used nutrient solution
*The same letter belong with each mean value is not significantly different at a 0.05 significance level

Table 3 Total water, fertilizer and nitric acid consumption for growing Chinese kale in DRFT with new and used nutrient solution over two croppings**.**

	Total water (L)	Total fertilizer (L)	Total nitric acid (L)
Crop1			
NNS	960.0	8.490	0.688
UNS	0	2.070	0.504
% save	100	61.75	25.26
Crop2			
NNS	793.2	5.070	2.750
UNS	119.6	1.800	1.230
% save	92.84	49.64	27.55

NNS = new nutrient solution; UNS=used nutrient solution

Component of the nutrient solution from new and reused nutrient solution by NFT and DRFT systems

UNS used in this experiment was obtained from the previous nutrient solution used in lettuce grown in NFT. Two weeks after growing lettuce in NFT sample of UNS was collected and analyzed the elements compared with NNS. It was showed that the concentration of all elements in UNS was decrease but many of them still remained in the nutrient solution, except for Na that trended to increase. Therefor, the UNS still useful and could be easily recharged by refilled with stock of KMITL2 solution and adjusted the concentration by EC measures equal to new one that plant needs. However, for exactly recharged the fertilizer should be add only inadequte element by calculated to modify stock of KMITL2 solution, which a further experiment of us. In this report the practically recharged revealed that the components of UNS and NNS of Chinese kale growing in DRFT was similar in concentration upto 6 weeks of cultivation. Except for Na that found high amount after used for long run. Regard to Na, it's concentration in UNS at 1 week and 6 weeks were 26.3 and 81.9 ppm respectively which were much higher than that in NNS (10.8 and 59.0 ppm respectively) **(**table 4**).**

Table 4 Component of nutrient solution from NFT system and used and new nutrient solution in DRFT system supplied to the plant.

Description	pH	EC	NH_4^+	NO_3^-	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Na
	-	mS/cm						(ppm)					
NFT-lettuce													
NNS	5.80	1.60	20.1	267	25.0	186	232	34.0	1.42	0.54	0.045	0.039	11.6
UNS	6.84	1.59	10.6	210	0.42	2.52	236	33.2	0.32	0.00	0.02	0.04	24.1
DRFT-Chinese kale													
NNS 1 wk	6.13	2.51	6.15	349	27.9	318	199	39.2	0.93	0.42	0.09	0.10	10.8
UNS 1 wk	5.90	2.70	6.15	377	29.7	208	255	46.2	0.64	0.82	0.08	0.18	26.3
NNS6 wk	6.67	8.90	13.2	150	0.00	733	708	176	1.00	0.16	0.42	0.24	59.0
UNS6 wk	5.96	7.89	17.1	50.9	0.05	1.29	882	155	1.99	0.16	0.22	0.11	81.9

NNS = new nutrient solution; UNS=used nutrient solution

Discussion

In re-circulated nutrient solution of hydroponics may lead to the accumulation of NaCl and imbalance of essential minerals when using for long run (Grattan and Grieve, 1999). From our results, Na accumulate was increased in both NFT and DRFT. This result in line with the research of Baas and Berg (2000) with reported that Na was 0.6 mM at the beginning and continued to increased to 6 and 30 mM at 16 and 30 week of rose-growing in NFT. In the same way, Carmassi *et al*. (2005) reported that NaCl was 10 and 20 mM at the beginning and continued to increased to 16 and 35 mM respectively at 9 day of tomato-growing in recirculated system. Therefore, growing-lettuce in recirculated system for long run without drain out might be reduce the growth and yield. There are many reports show that, Na concentration 50 mM (Al-Maskri *et al*., 2010) and 17 mM (Qin *et al*. 2013) were affected to growth and yield of lettuce. Farmers have to change nutrient solution every 2 weeks were the best insurance against crop damage, as frequent changes will provide your crop with all the nutrients it needs (Roberto, 2003). This experiment, the UNS from NFT was managed to be used again for growing-Chinese kale, Althought, the UNS showed higher Na content than that in NNS. That in line with the other research of Gent and Short (2012) and Choi *et al*. (2011b) with report about Na content in recycle system higher than control of growing-tomato and Chinese cabbage in hydroponics, but we can used the UNS without adverse effect on plant growth.

This study showed that number of leaf, diameter of stem, average weight per plant, fresh weight and dry weight of stem and leaf, total yield of plant using UNS and NNS was not significant difference. Because, family Craciterae can tolerance to imbalance essential minerals and high accumulation of NaCl (Qin *et al*., 2013). In addition, it's was needed nutrient higher than lettuce. Therefore, we can additional refill stock nutrient solution. Famers were applied simple in the fields. Our experiment were in line with the serveral research, report that using UNS no significant differences was observed compared with control on the growth and yield of Chinese cabbage (Choi *et al*., 2011b; Hong *et al*., 2009), tomato (Gent and Short, 2012), gerbera (Savvas *et al*., 2002). Moreover, some reported that using UNS was significantly higher growth and yield than control in red pepper (Park *et al*., 2005), musk melon (Zhang *et al*., 2006) and Chinese cabbage (Choi *et al*., 2011a).

In addition, this study found that using UNS could be reduce the water, fertilizer, and acid consumption for Chinese kale production around 84-100, 65-76, and 26-55% respectively. With the same results of Gent and Short (2012) showed that the recycle nutrient solution could be save water everaged 14-17 %. In Conclusion**,** we conducted to evaluated the possibility of used nutrient solution for alternative water resource consistent to save water shortage in agriculture, and environmental pollution by decreasing the amount of chemical fertilizers during crop cultivation. In this study, UNS was practiclly recharged by refilled with stock of KMITL2 solution. Furthermore, using UNS was shown to reduce the water, fertilizer, and acid consumption for Chinese kale production leading to cost reduction to farmmer.

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