International Journal of Botany

ISSN: 1811-9700

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS International Journal of Botany

ISSN 1811-9700
DOI: 10.3923/ijb.2020.20.33

Research Article
Suitable Planting Materials and Nutrient Concentrations for Investigating Sugarcanes under Hydroponic System

[1]Chanoknat Chapae, [1,2]Patcharin Songsri, [1,2]Wanwipa Kaewpradit, [1,2]Nuntawoot Jongrungklang and [1,2]Santimaitree Gonkhamdee

[1]Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Muang, 40002 Khon Kaen, Thailand
[2]Northeast Thailand Cane and Sugar Research Center, Khon Kaen University, Muang, 40002 Khon Kaen, Thailand

Abstract

Background and Objective: Usage of hydroponics on sugarcane has been very limited. Several aspects are considerations for sugarcane growing in hydroponics, namely plant material and nutrient concentration. Therefore, the objectives of this investigation were to (1) Determine a suitable planting material of sugarcane seedlings before transplanting into hydroponic cultivation and (2) Define an appropriate fertilizer concentration for cultivating sugarcane for optimum growth in hydroponics. **Materials and Methods:** This study was divided into 2 sub-experiments. Planting material and hydroponic tests used split plots in a randomised complete block design. For the planting material test, 3 planting materials, namely perlite, sand and filter cake, were assigned as main plots and 6 elite sugarcane lines were sub-plot treatments. In another experiment, nutrient concentrations (N 0, 1, 2, 3, 4 and 5) were the main plots and the sub-plots were 4 sugarcane genotypes. Root and shoot traits were measured in 2 trials. **Results:** Filter cake was determined a suitable planting material for sugarcane seedlings before transplanting into hydroponic cultivation, due to it having sufficient nutrients. The N2 nutrient level is able to provide a good performance on above ground growth and it seems likely to be the optimum conditions for root traits, but there were variations among genotypes. **Conclusion:** Filter cake and N2 nutrient level were an appropriate for investigating sugarcane in hydroponics.

Key words: Filter cake, perlite, electrical conductivity, shoot dry weight and hydroponic

Citation: Chanoknat Chapae, Patcharin Songsri, Wanwipa Kaewpradit, Nuntawoot Jongrungklang and Santimaitree Gonkhamdee, 2020. Suitable planting materials and nutrient concentrations for investigating sugarcanes under hydroponic system. Int. J. Bot., 16: 20-33.

Corresponding Author: Santimaitree Gonkhamdee, Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Muang, 40002 Khon Kaen, Thailand Tel: +66 43 364 637 Fax: +66 43 364 637

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sugarcane is grown by farmers as a main crop to sugar production in many subtropical countries. It not only produces sugar, but also many derivative products from sugarcane can be economically utilised, such as biofuel, molasses, ethanol, monosodium glutamate and fertilizer. Despite sugarcane being an important crop, the production, growing it in the field still has several problems; for instance, drought, appropriate tillage and pests, among others. Thus, it is necessary to conduct research for solving these obstacles. These study attributes are usually observed under soil media in either field or potted trials, which still had several constraints. These include experimental error, soil heterogeneity, imperfect sample collection and costly, time consuming and laborious methods. Moreover, this growing media is easily contaminated by soil-borne diseases[1]. An alternative method using a hydroponics system is proposed to address that problem.

Hydroponics is a plant growing method with regularly circulating water and nutrient solution[2]. In addition, it could control microenvironments and minimise disease factors[2,3]. In addition, hydroponics could be an alternative approach for root and shoot traits investigation in sugarcane[4]. Nevertheless, the usage of hydroponics on sugarcane has been very limited. Several aspects were considered in sugarcane growing in hydroponics, namely plant material and nutrient concentration. The common method of preparing the seedlings in plastic bags with soil media was time consuming in terms of cleaning the seedlings and transplanting process. Therefore, a suitable planting material to gain better germination and easier cleaning was needed. The most common intermediate materials that may be used as plant material for growing plants are sand, gravel, perlite and vermiculite[5]. The desired properties of an inert material to replace soil are that it stores moisture well and supports the root structure[6]. In addition, the most critical aspect to maintain the water quality in hydroponics system is controlling the Electrical conductivity (EC) and pH parameters appropriately. Both EC and pH values result from the nutrients that are applied. Proper EC and pH are needed to produce healthy plants instead of being harmful. Hence, suitable nutrient concentrations for the optimum growth of sugarcane in a hydroponics system are imperative for study.

To date, the information on suitable planting materials and nutrient concentrations represented via the optimum growth of sugarcane in hydroponics system have no supporting literature. Therefore, the objectives of this investigation were to (1) Determine a suitable planting material for sugarcane seedlings before transplanting into hydroponic cultivation and (2) Define an appropriate fertilizer concentration for cultivating sugarcane in order to have an optimum growth in hydroponics.

MATERIALS AND METHODS

This study was divided into two sub-experiments, namely determining (1) A suitable planting material for sugarcane seedlings before transplanting into hydroponic cultivation and (2) An appropriate fertilizer concentration for sugarcane in order to keep optimum growth during hydroponic cultivation.

1st experiment: Determining a suitable planting material for sugarcane seedlings.

Plant materials and experimental details: Seedling trials were conducted under open greenhouse conditions at the Field Crops Research Station, Agronomy Department, Khon Kaen University, Thailand in 2017 (latitude 16°28'N, longitude 102°48'E, 200 m.a.s.l.). The study started on 17 January through 5 February, 2017 by implementing a split-plot design in a randomised complete block design (RCBD) with four replications. Three materials, namely, perlite sand and filter cake, were assigned as main plots. The prices of materials were different, sand, perlite and filter cake were 0.07, 2.65 and 0.04 USD kg^{-1}, respectively. For sub plots, 6 commercial sugarcane varieties that have high potential productivity, namely KKU99-03, K88-92, UT12, UT13, LK92-11 and KK3, were chosen. A single bud set was planted in each pot of material. The cultivation of the seedlings continued until 20 days after planting (DAP). Irrigation was performed daily by giving 50 mL of water to each plant. At 20 DAP, the planting material was cleaned for separating sugarcane roots from the material using tap water at a pressure level of 1.0 bar and a washing time of 2 min.

Meteorological data: The data of daily maximum and minimum temperature, relative humidity (RH), evaporation (E_0), among others, were collected from the time of transplanting until the end of the study (around 1 month after transplanting) by a meteorological station placed 20 m from the study area. This station was operated from 17 January to 5 February, 2017. The maximum air temperature range was 21-36°C and the minimum temperature ranged from 10-25°C during the experimental period. Both air temperatures had a similar pattern, with low values during the early investigation period that then increasing during the middle and terminal periods (Fig. 1). The E_0 (range, 1.0-7.0 mm) and RH

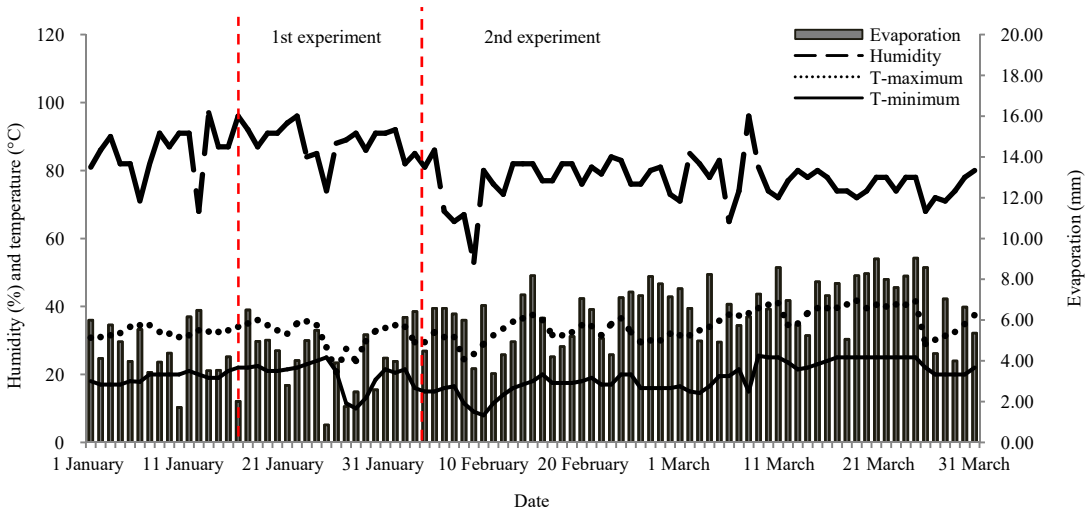

Fig. 1: Relative maximum (T-max) and minimum (T-min) temperature, humidity (RH) and evaporation (E0), during the experimental period at the weather station, Khon Kaen University, Thailand

(range, 74-96%) revealed normal conditions occurred during this experimental period (Fig. 1). Therefore, meteorological conditions should not have disturbed the normal growth of sugarcane, in this study.

Data collections: Prior to starting the experiment, the chemical properties of each material were measured. These included nutrient measurements such as pH, EC, organic matter, total N, total P, total K and organic carbon. At 20 days after planting, the plant samples were collected separately as aboveground and belowground parts. Aboveground measurements, including height, leaf area and shoot dry weight were collected. Root samples were scanned with the Epson Scan V700 model (Epson America, Inc., Long Beach, California, USA) and then root traits were analysed, including root length, root volume and root surface area with the software program Winrhizo (Winrhizo Pro (s) V. 2004a, Regent Instruments, Inc., Quebec, Canada). After that, root, leaf and stem samples were placed in an oven at 80°C for 48 h or until constant dry weight.

2nd experiment: Determining an appropriate fertilizer concentration for cultivating sugarcane.

Plant materials and experimental design: The hydroponic trial was conducted under open greenhouse conditions at the Field Crops Research Station of Agronomy Department, Khon Kaen University, Thailand (latitude 16°28'N, longitude 102°48'E, 200 m.a.s.l.). The study started on February to March 2017, with a 70×320 cm sub-experiment size (length×width) as a split plot design in a RCBD with 4 replications. The main plot was nutrient concentrations in the hydroponics system with nutrients amounts of 6 levels, including (1) No fertilizer (N0), (2) Low nutrient concentration (N1, this level was approximately recommended as optimum to Arabidopsis grown under hydroponic system[7]), (3) High fertilizer (N2, N3, N4, N5; 2, 3, 4 and 5 times from the optimum nutrients level of Arabidopsis grown under hydroponic system). In order to figure out the optimum of fertilizer rate meanwhile there have been no reported the suitable rate of fertilizer for sugarcane under hydroponics, the amounts of fertilizer levels were increased into 2, 3, 4 and 5 times because the canopy size of sugarcane bigger than Arabidopsis. The EC was checked and monitored every three days for maintaining the nutrient concentration treatments. Sub-plots were four varieties of sugarcane, namely KKU99-03, UT12, UT13 and KK3.

Experimental management: The aeration system was the dynamic root floating technique (DRFT). A single bud sett was planted in each pot in filter cake for generating seedlings. At 20 days after planting, cane seedlings were transplanted to hydroponic media treatments. At 30 days after transplanting, shoot and root data were collected. The hydroponic system was filled with water at a pH of 7.05 with an electrical conductivity (EC) of 0.8 dS m^{-1}. Liquid fertilizers namely A and B were mixed with water at the concentration of 1:300 (v/v) (concentrations of nutrients treatments were set as Table 1 and applied monthly. At 50 L, fertilizer solution of A contained $CaNO_3$-5.5 kg, Fe-EDTA 80 g while fertilizer solution B was constituted of $NH_4H_2PO_4$ 435 g, KNO_3 5 kg, $MgSO_4$-2.82 kg, KPO_4- 875 g, Cu-EDTA 2 g, Zn-EDTA-5.5 g and Mn-EDTA 9 g.

Table 1: Five concentrations of nutrients treatments

Nutrients	N0 (g)	N1 (g)	N2 (g)	N3 (g)	N4 (g)	N5 (g)
A solution						
$CaNO_3^-$	0	220.00	440.00	660.00	880.00	1.10
Fe-EDTA	0	3.20	6.40	9.60	12.80	16.00
B solution						
KNO_3	0	200.00	400.00	600.00	800.00	1.00
$MgSO_4^-$	0	112.80	225.60	338.40	451.20	564.00
KPO_4-	0	35.00	70.00	105.00	140.00	175.00
$NH_4H_2PO_4$	0	17.40	34.80	52.20	69.60	87.00
Cu-EDTA	0	0.08	0.16	0.24	0.32	0.40
Zn-EDTA	0	0.22	0.44	0.66	0.88	1.10
Mn-EDTA	0	0.36	0.72	1.08	1.44	1.80
EC levels (dS m^{-1})	0	2.00	4.00	6.00	8.00	10.00

N0: No fertilizer, N1: Low nutrient concentration, N2-N5: High fertilizer

Meteorological data: The data of daily maximum and minimum temperature, relative humidity (RH), evaporation (E_0), etc., were collected from the time of transplanting until the end of the study (around 1 month after transplanting) by a meteorological station placed 20 m from the study area. This data was collected from February to March, 2017. The maximum air temperature range was 25-42°C and the minimum temperature ranged from 8-26°C during the experimental period. Both air temperatures had a similar pattern, with low values during the early investigation period that then increases during the middle and terminal periods. The E_0 (range, 3.0-9.0 mm) and RH (range, 53-96 %) revealed normal conditions occurred during this experimental period (Fig. 1). Therefore, meteorological conditions should not have disturbed the normal growth of sugarcane, in this study.

Data collections: At 30 days after transplanting, SPAD chlorophyll meter reading (SCMR) was used as a non-destructive sampling, using a SPAD-502 chlorophyll meter (Minolta SPAD-502 m, Tokyo, Japan). The measurement was taken on the 2nd–3rd fully expanded leaf from the top of main stem between 9.00 and 12.00 am. At the same date, stem height was measured from the base up to top of primary tiller, shoot dry weights (stalk dry weight and leaf dry weight) were collected and then the leaves and stem were separated from each other. Root samples were scanned and analysed as same as with the first experiment. Three sample parts were then oven dried at 80°C for 48 h or until the dry weight was constant.

Statistical analysis: In both sub-experiments, an analysis of variance in all aspects was performed, which were measured according to split plots in a randomised complete block design (RCBD) and comparing the means by the least significant difference (LSD) method with the Statistix 8 program (copyright 1985-2003) at the significance level[8] $p<0.05$.

RESULTS AND DISCUSSION

Determining a suitable planting material for sugarcane seedlings: The three materials varied in their chemical properties, such as pH, EC, organic matter and total N. Perlite, filter cake and sand had pH values of 6.88, 6.97, 6.41, respectively and EC values were 0.732, 0.558 and 0.052 dS m^{-1} respectively. Organic matter (%) measurements were 0.783, 5.514, 0.077, respectively and the values were 0.106, 0.186 and 0.0071 for total N (%) respectively (Table 2). Total P (mg kg^{-1}), total K (mg kg^{-1}) and organic carbon of perlite, filter cake and sand also differed, total P (mg kg^{-1}) and total K (mg kg^{-1}) of perlite and filter cake were significantly higher than sand and the total P (mg kg^{-1}) values were 4,349, 4,350 and 79.75, respectively and the total K (mg kg^{-1}) values were 10,755, 1,583 and 375, respectively. The organic carbon (%) of filter cake was obviously higher at 3.195 than perlite and sand (0.427 and 0.049, respectively) (Table 2). It seems likely that sandy material had the lowest fertility when compared with the two others.

For evaluation of washing roots from materials, sand can be completely cleaned out of the pot when washed with the methodology used, while some part of the filter cake material remains in the pot. For perlite planting material, more residual material was found at the end of the set time compared with the other two materials. Due to the particles of perlite strongly attached with the root sample, the flow of water could not remove it. The same effect was found in a previous study of strawberry, where perlite was discussed as a material that was difficult to remove compared with coconut fiber[9].

Responses of above-ground traits with different planting materials: The 3 materials had significant differences in heights, leaf areas and leaf dry weights, but not stem biomass. Perlite and filter cake treatments were rather higher in heights and leaf dry weights than those with sand were, but leaf area showed good performance in filter cake treatment (Table 3). However, Stem dry weights of KKU99-03, LK92-11 and K88-92 growing from cake filters performed well; while UT12 revealed a good response when sand and perlite materials were used. In addition, perlite could be the best material for UT13 in terms of stem weight (Fig. 2a). In term of leaf area KK3, KKU99-03, LK92-11, K88-92 revealed a good response to filter cake, whereas, UT12 responded well with sand (Fig. 2b). Different genotypes were varied in their responses to material treatments. For height, UT12 revealed an outstanding response to perlite material (Fig. 2c). For leaf dry weights, almost all varieties that are used in current research

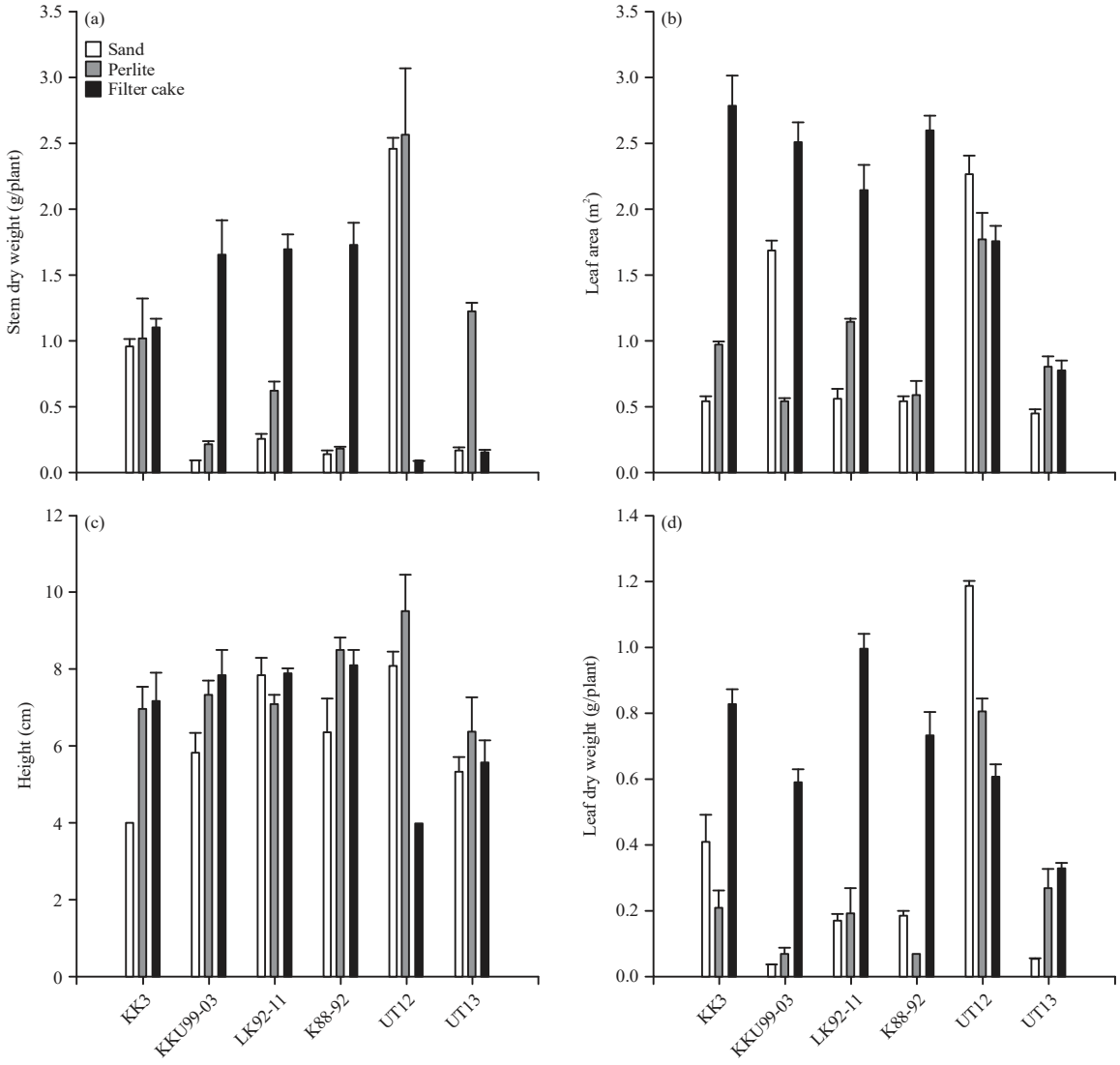

Fig. 2(a-d): A comparison of, (a) Stem dry weight, (b) Leaf area, (c) Height and (d) Leaf dry weight of 6 sugarcane seedling varieties grown in 3 planting materials

Standard error difference of means was shown via vertical bars

Table 2: Analysis of pH, EC, organic matter, total N, total P, total K and organic carbon of the 3 planting materials

Samples	pH 1:1 H_2O	EC 1:1 H_2O (dS m^{-1} at 25°C)	Organic matter (%)	Total N (%)	Total P (mg kg^{-1})	Total K (mg kg^{-1})	Organic carbon (%)
Perlite	6.88	0.732	0.783	0.106	4.349	10.755	0.427
Filter cake	6.97	0.558	5.514	0.186	4.350	1.583	3.195
Sand	6.41	0.052	0.077	0.0071	79.75	375.000	0.049

performed well when grown in filter cake, except for UT12, which showed a good leaf dry weight under sand material conditions (Fig. 2d). The same aspect of work on sugarcane has been very limited, however, there was report on other plant species, muskmelons grown in sand had a greater height and leaf surface value than those grown in perlite material[10]. This might be due to different species showing varied results.

Root traits: In term of root length, K88-92, LK92-11, UT13 and KK3 were not different among planting materials, whereas, UT12 and KKU99-03 showed a good performance when in perlite (Fig. 3a). The root surface area of LK92-11 revealed a good performance when in sand material, but the root trait of K88-92 performed well in filter cake and there were no significant differences among different materials for UT13 and KK3 (Fig. 3b). Sugarcane cultivars which use in this experiment

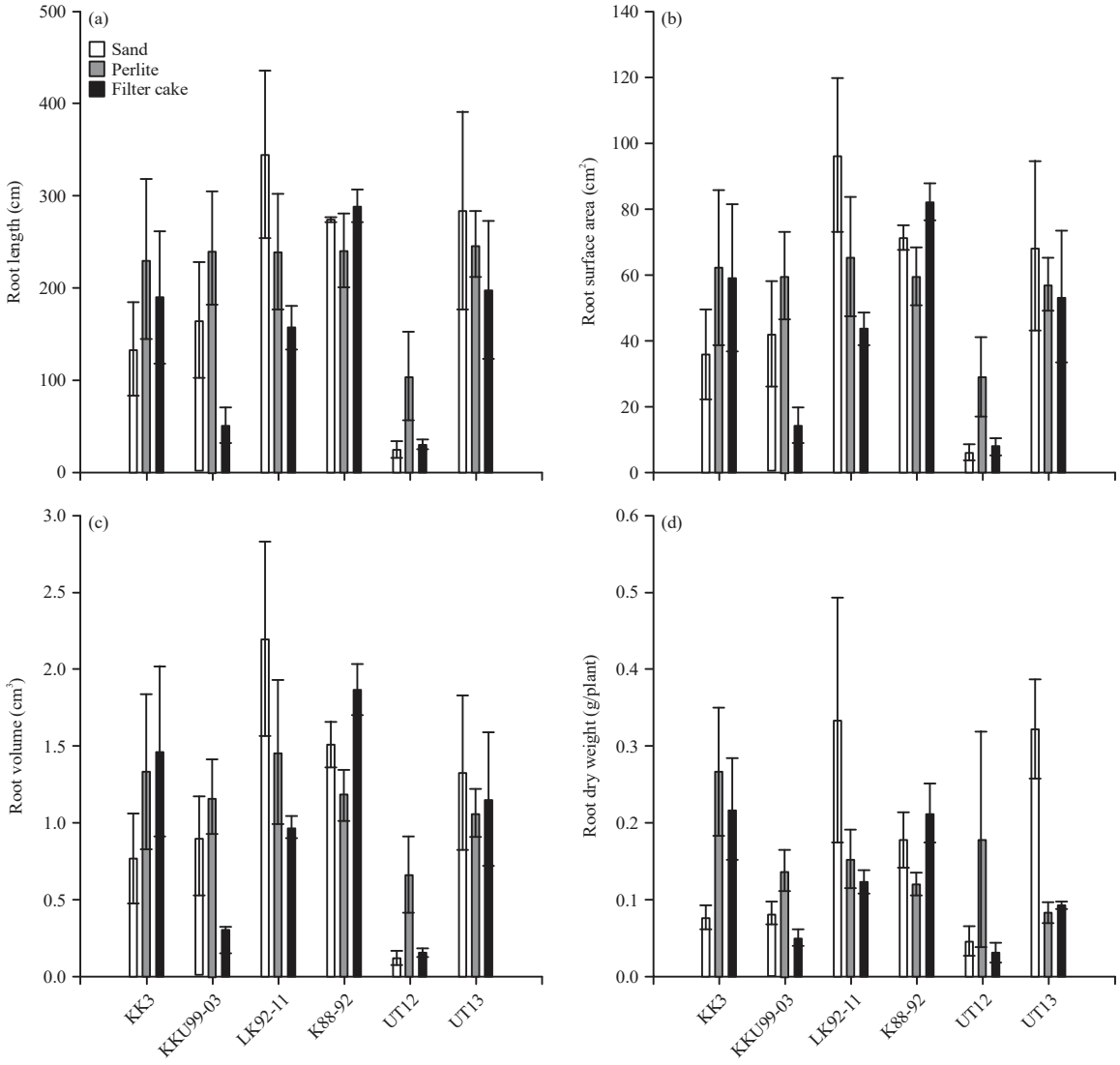

Fig. 3(a-d): A comparison of (a) Root length, (b) Root surface area, (c) Root volume and (d) Root dry weight of 6 sugarcane varieties grown in 3 planting materials for sugarcane seedling
Standard error difference of means was shown via vertical bars

Table 3: Height, leaf area, leaf dry weight and stem dry weight data of 6 sugarcane cultivars grown in 3 planting materials

Treatments	Height (cm)	Leaf area (m^2/plant)	Leaf dry weight (g/plant)	Stem dry weight (g/plant)
Materials (A)				
Sand	6.23^{b}	9.71^{b}	0.24^{b}	0.66
Perlite	7.63^{a}	10.10^{b}	0.34^{ab}	0.96
Filter cake	6.76^{ab}	20.96^{a}	0.66^{a}	1.05
F-test (A)	*	**	*	ns
Varieties (B)				
KK3	6.04^{bc}	14.33^{ab}	0.48^{ab}	1.03^{ab}
KKU99-03	7.00^{abc}	15.82^{ab}	0.23^{b}	0.65^{b}
LK92-11	7.61^{a}	12.84abc	0.45^{ab}	0.85^{ab}
K88-92	7.64^{a}	12.45bc	0.33^{ab}	0.66^{b}
UT12	7.19^{ab}	19.31^{a}	0.61^{a}	1.70^{a}
UT13	5.76^{c}	6.75^{c}	0.38^{ab}	0.45^{b}
F-test (A×B)	**	**	**	**
F-test (B)	**	ns	**	**
CV (%)	12.84	14.60	13.97	21.23

*, **Significant at 5, 1% level, respectively, mean with the same letters are not different by LSD at $p<0.05$, ns: Non-significant

had different responses on root volume, LK92-11 and KKU99-03 were no different between sand and perlite. K88-92 had high root volume when grown in filter cake, while UT13 and KK3 showed that the three materials did not affect root volumes (Fig. 3c). The root dry weights of LK92-11 and UT13 were high in sand and perlite was a suitable material in terms of root dry weights for KK3, UT12 and KKU99-03 (Fig. 3d). Root volume and root dry weight of muskmelon had significant differences between sand and perlite substrates, on the other hand, root length was not significantly different[10].

The higher total nitrogen contents of perlite and filter cake might be supporting germination and seedling growth of sugarcane. Nitrogen is a major nutrient for plants. It is a component of chlorophyll present in many major portions of the plant organs and it plays an important role in various physiological processes and protein contents. It promotes leaves, stalks and growth of other plant parts and dilation imparts dark-green colour in plants. In addition, it also promotes root growth[11]. Organic and inorganic phosphates in plants serve as buffers in the maintenance of cellular pH. This is important in plant biochemical processes and energy storage, to energy-requiring processes in the plants is known as phosphorylation. A portion of the energy derived from photosynthesis[12]. Potassium regulates the opening and closing of stomata of plants through which leaves exchange carbon dioxide (CO_2), water vapour and oxygen (O_2) with the air. Stomatal functioning is essential for plant cooling and photosynthesis, as well as the transport of water and nutrients[12].

Filter cake was determined to be a suitable planting material for preparing seedlings prior transplanting to hydroponics due to it having essential nutrients and being easier to remove from roots. In addition, in terms of the economic aspect, filter cake could reduce the investment cost for the planting materials.

Determining an appropriate fertilizer concentration for cultivating sugarcane

Physiological data: Nutrient concentrations, revealed by nutrient values, affected the SCMR values. An N4 treatment could promote the greenness of leaves, as indicated via the highest value of SCMR (Table 4). Meanwhile, SMCR were not different among N1, N2, N3 and N5. However, non-application of nutrient (N0) was significantly different from all the nutrients-applying treatments (Table 4). For genotype response, four sugarcane cultivars were similar to the overall mean of SCMR (Table 4). In rose, chlorophyll content varied significantly with different nutrient concentrations. The greenness of the leaves increased as the pH and EC increased and the optimum EC for rose[13] was 0.7 dS m^{-1} at pH 8.0.

Aboveground traits: The N2 was an outstanding treatment that showed good performance in aboveground traits, such stem height, leaf area, shoot dry weight, tiller dry weight and tiller number (Table 4). Obviously, the treatment without nutrient added (N0) did not totally generate the secondary tiller. Stem height revealed high values with N1, N2 and N3 (Table 4). For genotype response, N2 treatment were likely the optimum condition for UT12, KKU99-03 and KK3 in term of stem height, leaf area, tiller number, tiller dry weight and shoot dry weight, whereas, N1 was suitable for UT13 (Table 5).

Table 4: SPAD chlorophyll meter reading (SCMR) and above-ground traits of six nutrient levels for sugarcane in a hydroponic system

Treatments	Height (cm)	Leaf area (m^2/plant)	Shoot dry weight (g/plant)	SCMR	Tiller dry weight (g/plant)	Tiller number (No./plant)
Nutrients (A)						
0	8.61^{d}	168.7^{e}	4.7^{e}	36.0^{c}	0.0^{d}	0.0^{c}
1	12.06^{c}	390.4^{b}	8.9^{a}	48.4^{b}	2.2^{b}	2.3^{ab}
2	11.79^{a}	453.1^{a}	9.2^{a}	53.2^{b}	2.8^{a}	3.0^{a}
3	11.25^{ab}	361.8^{c}	8.2^{b}	51.0^{b}	2.3^{b}	2.7^{ab}
4	10.38^{bc}	331.6^{d}	7.0^{c}	60.0^{a}	1.5^{c}	2.3^{ab}
5	9.66^{c}	303.5^{e}	6.3^{d}	53.1^{b}	1.2^{c}	1.9^{b}
F-test (A)	**	**	**	**	**	**
Varieties (B)						
UT12	10.82^{b}	395.0^{a}	9.5^{a}	49.0^{a}	1.4^{c}	1.8^{b}
UT13	11.94^{a}	353.4^{b}	7.6^{b}	51.2^{a}	1.9^{a}	1.8^{b}
KKU99-03	10.07^{c}	336.4^{c}	7.2^{c}	52.1^{a}	1.8^{a}	2.2^{ab}
KK3	9.68^{c}	254.6^{d}	5.4^{d}	48.8^{a}	1.5^{b}	2.4^{a}
F-test (B)	**	**	**	*	**	**
F- test (A×B)	ns	**	**	ns	**	*
CV (%)	6.84	2.82	5.73	7.05	16.9	37.4

*, **: Significant at 5, 1% level, respectively, mean with the same letters are not different by LSD at $p<0.05$, 1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to arabidopsis grown under hydroponic system), 3: High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of arabidopsis grown under hydroponic system), ns: Non-significant

Table 5: SPAD chlorophyll meter reading (SCMR) and above-ground traits of 6 nutrient levels and 4 sugarcane cultivars in hydroponic conditions

Varieties	N	SCMR	Height (cm)	Tiller number (No./plant)	Leaf area (m^2/plant)	Tiller dry weight (g/plant)	Shoot dry weight (g/plant)
UT12	0	37.03	8.867	0.00	197.95	0.00	5.81
	1	43.80	12.167	2.00	497.33	1.93	9.99
	2	53.23	12.467	3.67	531.43	3.60	11.76
	3	46.70	11.367	2.00	445.80	1.00	11.79
	4	62.83	10.233	1.33	348.62	0.69	9.34
	5	50.33	9.800	1.67	348.71	0.94	8.05
SE		5.08	0.818	0.69	70.69	0.73	1.33
UT13	0	38.30	9.600	0.00	170.27	0.00	5.02
	1	50.43	13.967	2.33	426.94	2.74	9.98
	2	55.17	13.367	2.00	409.95	2.55	8.54
	3	54.60	12.400	2.33	353.56	2.86	7.93
	4	59.10	12.133	2.00	425.50	1.88	7.67
	5	49.63	10.167	2.00	334.18	1.05	6.60
SE		4.16	1.002	0.51	56.46	0.65	0.98
KKU99-03	0	36.00	8.267	0.00	198.36	0.00	5.01
	1	52.37	10.833	2.33	385.30	1.82	8.96
	2	52.83	10.700	2.67	507.87	3.04	9.79
	3	51.27	10.700	3.33	317.51	3.05	7.16
	4	62.20	9.833	3.00	299.35	1.79	6.08
	5	58.20	10.067	2.00	309.93	1.36	5.96
SE		5.17	0.559	0.69	59.67	0.66	1.08
KK3	0	32.73	7.700	0.00	108.27	0.00	2.90
	1	47.13	11.267	2.67	251.90	2.20	6.72
	2	51.73	10.633	3.67	363.25	2.02	6.80
	3	51.23	10.550	3.00	330.33	2.09	6.02
	4	55.70	9.300	3.00	252.84	1.58	4.97
	5	54.30	8.600	2.00	221.17	1.25	4.69
SE		4.86	0.793	0.75	51.75	0.48	0.86

SE: Standard error, 1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to arabidopsis grown under hydroponic system), 3: High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of arabidopsis grown under hydroponic system)

However, excess nutrient, which was over the requirement level of nutrients, did not support aboveground growth. These values decreased height, leaf area index and shoot dry weight in some plants, such as lettuce and basil [14,15]. The recommendations for nutrient solutions based on EC for different species varied, for instance, an EC 2.8 dS m^{-1} is recommended for basil plants[14], EC 2.5 dS m^{-1} is recommended for lettuce[15] and EC 1.8 dS m^{-1} is recommended for strawberry[16]. In addition, seasonality also affects the nutrient solution suitability. Suitable EC in terms of leaf area index is different between winter-summer and spring-autumn, which had the optima of EC as 3.8 and 4.1 dS m^{-1}, respectively[17].

Root characteristics: The 4 sugarcane genotypes could be divided into 3 groups based on the responses of roots to nutrient contents as shown in Fig. 4-7. The 1st group, UT12 and KKU99-03 were defined as a highly sensitive group; these showed the highest amount of root length (Fig. 4a, 5a), root volume (Fig. 4b, 5b), root surface area (Fig. 4c, 5c), root dry weight (Fig. 4d, 5d) and root diameter (Fig. 4e, 5e) when applying non-nutrient treatment. The root response of this group was to grow to obtain more nutrient, as indicated by longer and deeper root structures. The range of N1-N3 seems likely to be the suitable dose for promoting root growth when compared among nutrient application treatments (N1-N5), this nutrient concentration resulted in a higher root comparing with greater and lesser doses. UT12 cultivar showed the highest of root length (Fig. 4a), root volume (Fig. 4b), root surface area (Fig. 4c) and root diameter (Fig. 4e) under N3 treatment, whereas, N2 was the suitable dose of root dry weight in this cultivar (Fig. 4d). For KKU99-03, root length (Fig. 5a), root volume (Fig. 5b) and root surface area (Fig. 5c) were highest in N1 treatment, meanwhile the biggest root system in term of root dry weight and diameter were revealed in N3 (Fig. 5d, 5e, respectively). In contrast, all root traits of the UT13 genotype were limited when grown under the non-nutrient treatment. It seems likely that N1 was the best dose for this genotype (Fig. 5). Meanwhile, the higher nutrient concentrations gradually decreased the values of root characteristics. Root length (Fig. 6a), root volume (Fig. 6b), root surface area (Fig. 6c) and root dry weight (Fig. 6d) of UT13 revealed a good performance when in N1 treatment, but the root diameter performed well in N4 and there were no significant differences among N1-N4 (Fig. 6e). Another root response, represented in the KK3 genotype, indicated that the

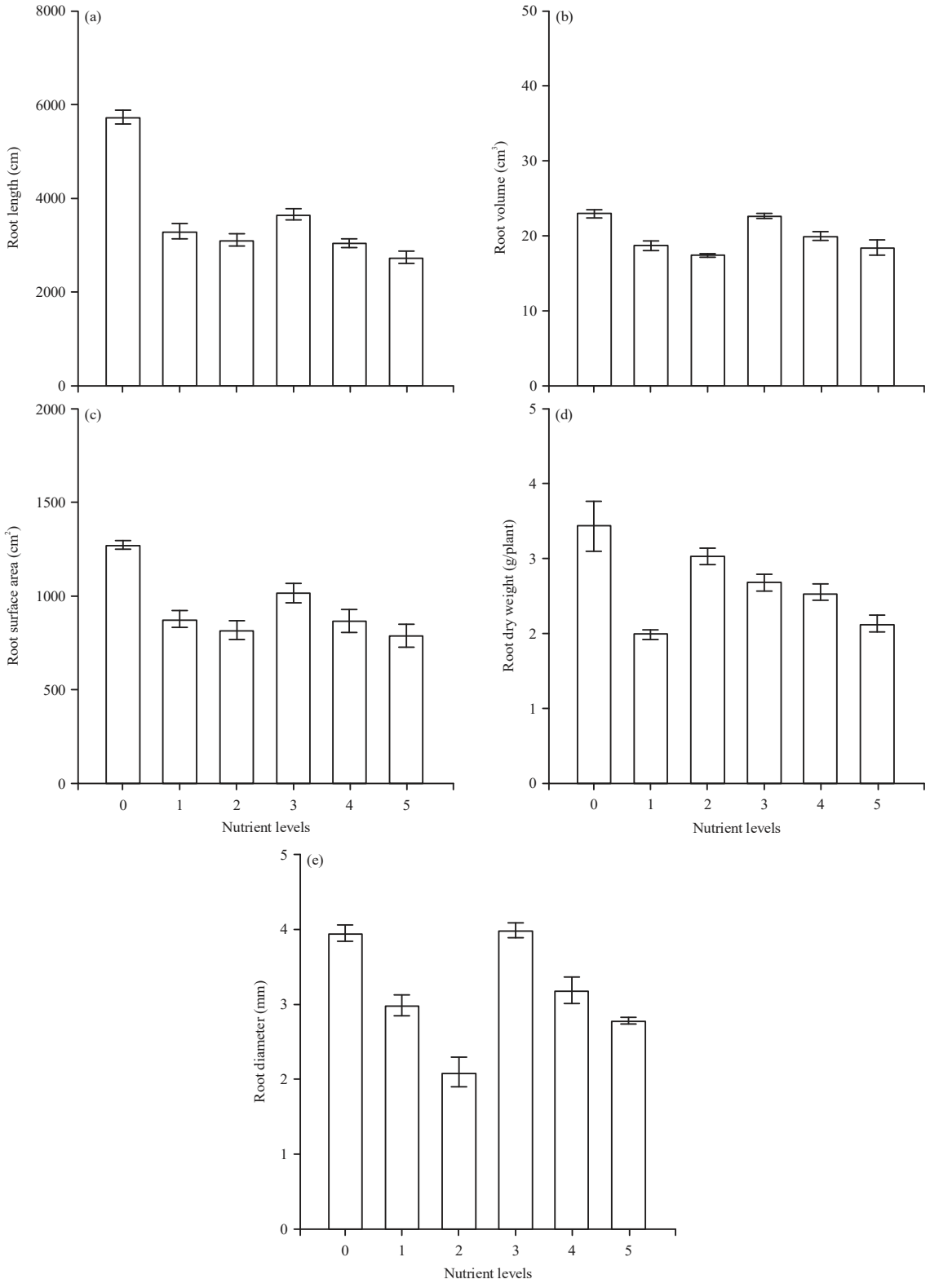

Fig. 4(a-e): A comparison of (a) Root length, (b) Root volume, (c) Root surface area, (d) Root dry weight and (e) Root diameter of UT12 cultivar in 6 nutrient levels

1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to arabidopsis grown under hydroponic system), 3: High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of arabidopsis grown under hydroponic system) for sugarcane, Standard error difference of means was shown via vertical bars

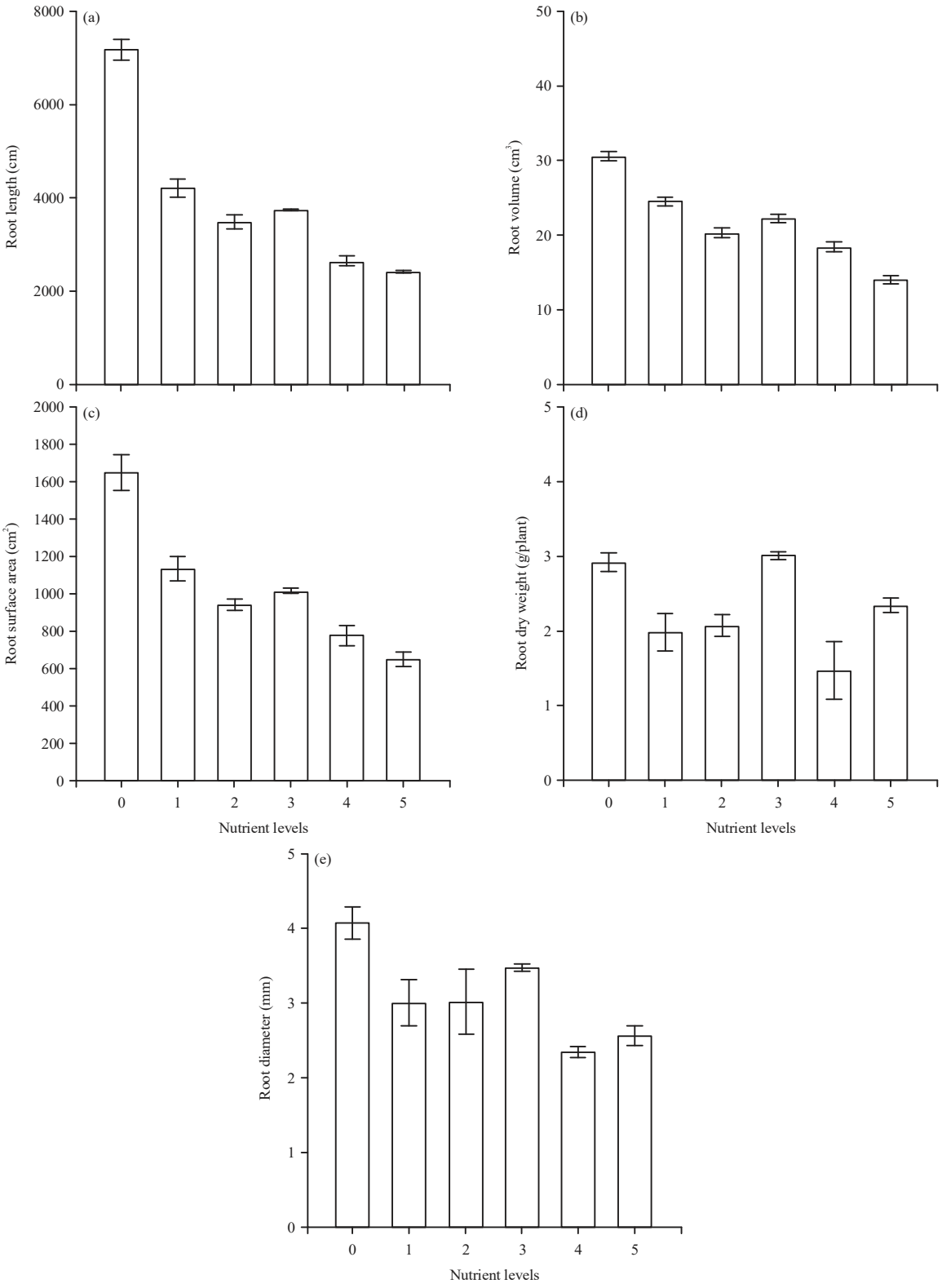

Fig. 5(a-e): A comparison of (a) Root length, (b) Root volume, (c) Root surface area, (d) Root dry weight and (e) Root diameter of KKU99-03 cultivar in 6 nutrient levels

1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to arabidopsis grown under hydroponic system), 3: High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of arabidopsis grown under hydroponic system) for sugarcane, Standard error difference of means was shown via vertical bars

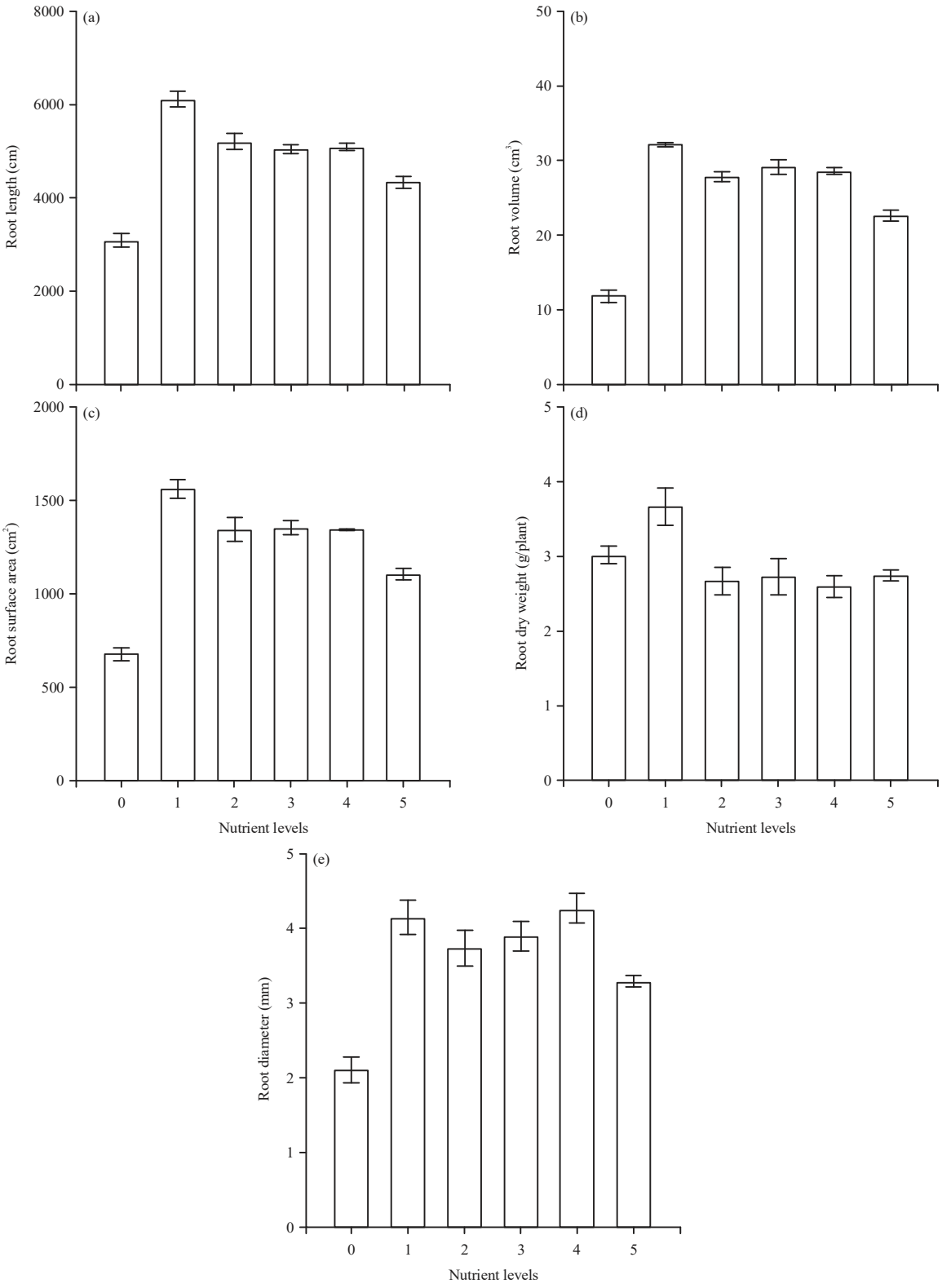

Fig. 6(a-e): A comparison of (a) Root length, (b) Root volume, (c) Root surface area, (d) Root dry weight and (e) Root diameter of UT13 cultivar at 6 nutrient levels

1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to Arabidopsis grown under hydroponic system), 3) High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of Arabidopsis grown under hydroponic system) for sugarcane, Standard error difference of means is shown via vertical bars

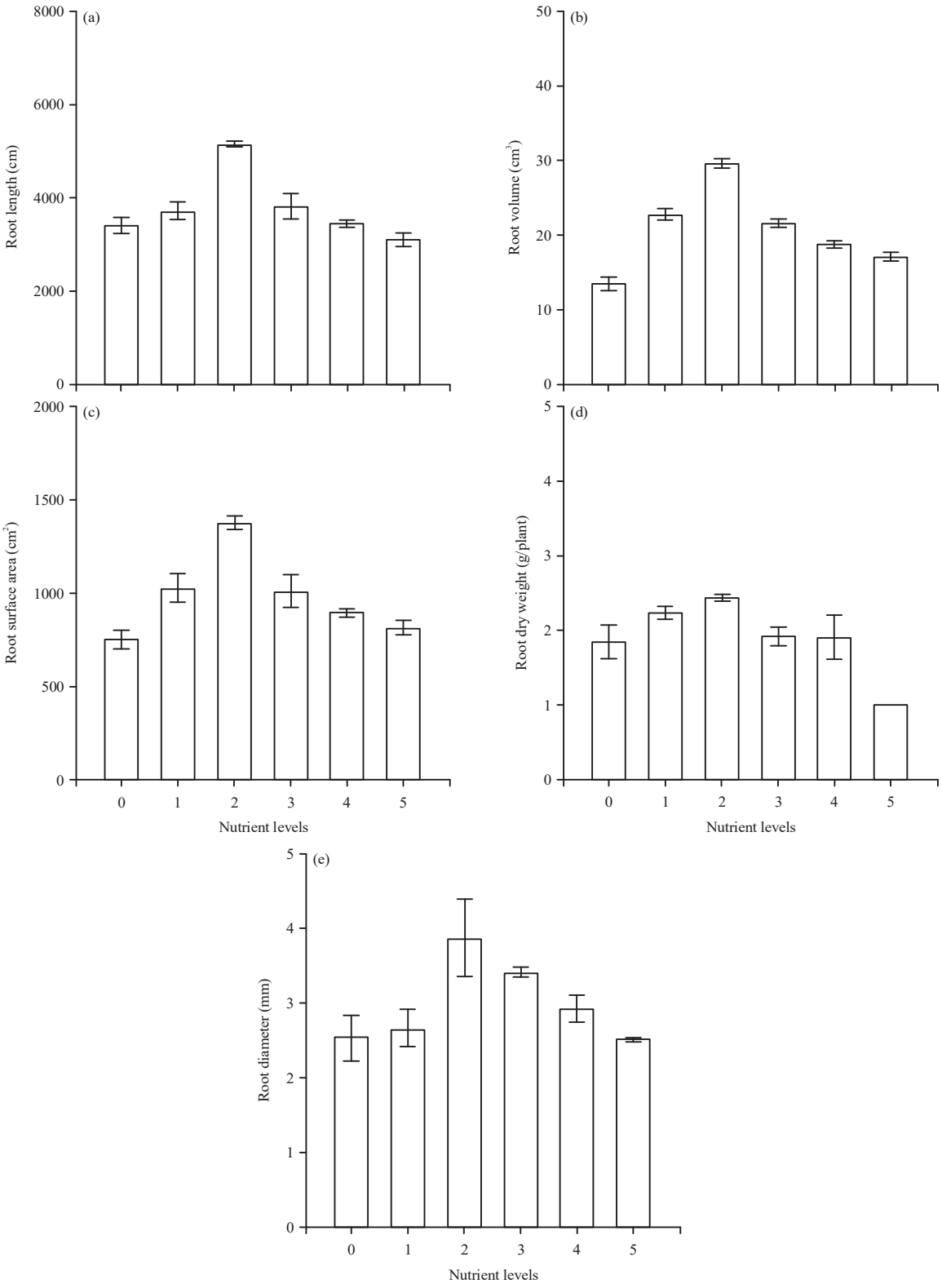

Fig. 7(a-e): A comparison of sugarcane (a) Root length, (b) Root volume, (c) Root surface area, (d) Root dry weight and (e) Root diameter of KK3 cultivars at 6 nutrient levels

1: No fertilizer (N0), 2: Low nutrient concentration (N1: This level was approximately recommended as optimum to Arabidopsis grown under hydroponic system), 3: High fertilizer (N2-N5: 2, 3, 4 and 5 times from the optimum nutrients level of Arabidopsis grown under hydroponic system) for sugarcane, Standard error difference of means was shown via vertical bars

optimum level of nutrient in term of root traits was N2, as root length, root volume, root surface area and root dry weight were significantly higher under this dose as shown in Fig. 7a-d, respectively. Root diameter performed well in N2 and there were no significant differences between N2-N3 (Fig. 7e). Previously, there was no reported optimum dose of nutrients in hydroponics for sugarcane. In strawberry, in terms of root growth, the optimum[16] EC was 1.8-2.5 dS m^{-1}. The 4 sugarcane genotypes used in this study differed in optimum nutrient concentrations necessary to promote root growth.

CONCLUSION

A suitable planting material and nutrient concentration of sugarcane seedling in hydroponics were first examined in this study. Filter cake was determined to be a suitable planting material for sugarcane seedlings before transplanting into hydroponic cultivation. This is due to it having sufficient nutrients to support the good performance of seedlings and being easier to remove from the roots. The nutrient concentration of N2 was an appropriate dose for cultivating sugarcane in hydroponics. This nutrient level was able to provide a good performance on aboveground growth. The range of N1-3 is likely the optimum condition for root traits, but there was variation of genotypes. This information could be useful for conducting research of sugarcane under hydroponic systems and consequently lead to novel research aspects.

SIGNIFICANCE STATEMENT

This study discovers suitable planting materials and nutrient concentrations of sugarcane seedling in hydroponics that can be beneficial for conducting research of sugarcane under hydroponic systems. This study will help the researcher to uncover the critical area of sugarcane investigated under hydroponic condition that many researchers were not able to explore. Thus, a new theory on these suitable planting materials and suitable nutrient concentrations, may be arrived at.

ACKNOWLEDGMENTS

We thank the Northeast Thailand Cane and Sugar Research Center, Faculty of Agriculture, Khon Kaen University, Thailand Research Fund (TRG5880086). The research was funded in part by the Government of Thailand"s Grants to Khon Kaen University (KKU) (FY2018 and FY2019) and the Thailand Research Fund for providing financial support through the Senior Research Scholar Project of Prof. Dr. Sanun Jogloy (Project no. RTA6180002).

REFERENCES

1. Kuack, D., 2015. Evaluating Field-Bred Lettuce Varieties for Hydroponic Greenhouse Production. In: University of Arkansas Researchers Trials 65 Lettuce Varieties to Determine their Potential for Production in Greenhouse Hydroponic Systems, Beytes, C., J. Zurko, A. White and J.D. White (Eds.)., Inside Grower Controlled Environment Agriculture, USA., pp: 16-19.
2. Nguyen, N.T., S.A. McInturf and D.G. Mendoza-Cózatl, 2016. Hydroponics: A versatile system to study nutrient allocation and plant responses to nutrient availability and exposure to toxic elements. J. Vis. Exp., Vol. 113. 10.3791/54317
3. Wahome, P.K., T.O. Oseni, M.T. Masarirambi and V.D. Shongwe, 2011. Effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower Quqlity of Gypsophila (*Gypsophila paniculata* L.). World J. Agric. Sci., 7: 692-698.
4. Chapae, C., P. Songsri and N. Jongrungklang, 2019. Hydroponics: An alternative method for root and shoot classification on sugarcane genotypes. Agrivita, 41: 351-363.
5. Niederwieser, J.G., 2001. Guide to Hydroponic Vegetable Production. Agricultural Research Council, Roodeplaat Vegetable and Ornamental Plant Institute, South Africa, ISBN: 9781868491964.
6. Berndsen, C. and M. Gardener, 2014. Backyard hydroponics. University of California Cooperative Extension, San Diego County.
7. Arteca, R.N. and J.M. Arteca, 2000. A novel method for growing *Arabidopsis thaliana* plants hydroponically. Physiol. Planta., 108: 188-193.
8. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley Sons, New York, USA., ISBN: 978-0-471-87092-0, Pages: 704.
9. Lopez-Medina, J., A. Peralbo and F. Flores, 2004. Closed soilless growing system: A sustainable solution for strawberry crop in huelva (Spain). Acta Hortic., 649: 213-216.
10. Radhouani, A., M. El Bekkay and A. Ferchichi, 2011. Effect of substrate on vegetative growth, quantitative and qualitative production of muskmelon (*Cucumis melo*) conducted in soilless culture. Afr. J. Agric. Res., 6: 578-585.
11. Leghari, S.J., N.A. Wahocho, G.M. Laghari, H.A. Laghari and G.M. Bhabhan *et al*., 2016. Role of nitrogen for plant growth and development: A review. Adv. Environ. Biol., 10: 209-219.
12. Barker, A.V. and D.J. Pilbeam, 2015. Handbook of Plant Nutrition. 2nd Edn., CRC Press, Boca Raton, FL., USA., ISBN-13: 9781439881972, Pages: 773.

13. Kim, H.J., Y.S. Cho, O.K. Kwon, M.W. Cho, J.B. Hwang, S.D. Bae and W.T. Jeon, 2005. Effect of pH and EC of hydroponic solution on the growth of greenhouse rose. Asian J. Plant Sci., 4: 348-355.
14. Morano, G., C. Amalfitano, M. Sellitto, A. Cuciniello, R. Maiello and G. Caruso, 2017. Effects of nutritive solution electrical conductivity and plant density on growth, yield and quality of sweet basil grown in gullies by subirrigation. Adv. Hortic. Sci., 31: 25-30.
15. Van Quy, N., W. Sinsiri, S. Chitchamnong, K. Boontiang and W. Kaewduangta, 2018. Effects of electrical conductivity (EC) of the nutrient solution on growth, yield and quality of lettuce under vertical hydroponic systems. Khon Kaen Agric. J., 46: 613-622.
16. Bagale, K.V., 2018. The effect of electrical conductivity on growth and development of strawberries grown in deep tank hydroponic systems, a physiological study. J. Pharmacogn. Phytochem., SP1: 1939-1944.
17. Amalfitano, C.A., L.D.V. Del Vacchio, S. Somma, A.C. Cuciniello and G. Caruso, 2017. Effects of cultural cycle and nutrient solution electrical conductivity on plant growth, yield and fruit quality of 'Friariello' pepper grown in hydroponics. Hortic. Sci., 44: 91-98.