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Research Article
Determination of Early Effective Screening Date on Phenotyping Sugarcane Roots under Hydroponics Condition

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Abstract

Background and Objective: Plant breeders are interested in rapid screening among large populations, particularly in the early stages of crop growth. However, information about applying hydroponic media on sugarcane genotype screening is still lacking. The question is arisen whether it will be feasible at an early growth stage is interested to investigate. This study was aimed to determine the most efficient screening time for phenotyping sugarcane root in hydroponics. **Materials and Methods:** Six sugarcane genotypes differing in root performance were evaluated under both hydroponics and field conditions. The genotypes were subjected to RCBD with three replications and observed at one, two and three Months After Planting (MAP) in hydroponics, whereas RCBD with four replications at three MAP in field trials. Data were recorded on growth stage, physiological and root attributes. **Results:** In one, two and three months showed positive correlation between root traits. The relationship between root length in soil and hydroponic at two MAP was existed on depth of 0-20 and 20-40 cm and at three MAP correlated with depth of 0-20, 20-40 and 40-60 cm. Both stem and root dry weight can be assigned as selection criteria to root length, root surface area and root volume of sugarcane in two and three MAP, but it was not found relative with SPAD Chlorophyll Meter Reading (SCMR) and Chlorophyll Fluorescence (CF) under hydroponic condition. **Conclusion:** This result indicated that hydroponic system can be applied in sugarcane, root screening as early as from two MAP to three MAP.

Key words: *Saccharum officinarum* spp., root length, root surface area, root dry weight, stem dry weight, indirect selection

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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

In sub-tropical zone, the vast area of rain-fed upland, farmers cultivate sugarcane in the late rainy season during October to November and are often to encounter early drought period on seedling stages[1]. The number of tests sugarcane germplasm is mostly numerous for breeders aim to collect diverse genetic stock and expect to obtain potential lines as practical as possible. In sugarcane the evaluation commonly covers morphological, agronomic and physiological traits including root attributes. Breeders interested in root screening because root systems are salient plant parts for taking up water and nutrients from the soil, maintaining integrated overall plant growth and health[2], related to yield performance[3]. Once the plant is exposed to drought, the yield will be significantly reduced as it related to the root systems[3]. Under drought conditions the root was extended[4] to exploit efficiently soil, water status[5] and distributed greatly in the deeper soil[6] to uptake the water.

Evaluation of sugarcane germplasm is rigorous and time consuming due to long life cycle; therefore, careful attention has to be paid. The evaluation is frequently carried out in soil media either pot experiments or classic field trials; however, soil media still have some weak points. For instance, soil compaction limited the root performance and root system development, resulting in poor yield[7]. Root sample in the soil condition is relatively complex, hard to estimate[8] and difficult to separate the soil from the root in washing process, it causes loss of roots. Moreover, the reliability of rooting data derived from this method is imprecise[9]. In conventional breeding in which sugarcane roots are measured based on field trial, phenotyping root systems under soil media becomes laborious, time consuming and costly[2]. Therefore, it is difficult to conduct root studies in the field. Also, the variability of the soil properties can influence the root distribution, leading to bias of root phenotype[10].

Previous studies have reported the effectivity of hydroponic media in phenotyping root studies, such as some root attributes of maize at early growth stage[11]. The close relationships on inter-root attributes, particularly root length, root surface and root volume under hydroponics were also revealed in peanut at 80 days after planting[2] and sorghum[12]. Although, significant correlation between hydroponics and soil media were existed on cowpea[13] and sugarcane[9], the feasible screening date is suspected to be crop-dependent.

Even though the earlier date of screening sugarcane genotypes under hydroponics has been noticed as three MAP[9], a further investigation on feasible screening of sugarcane genotypes emphasized on root attributes at an early growth stage is interested. To the best our knowledge, root traits are related to drought tolerance[14] and Water Use Efficiency (WUE)[15] and WUE reflects to biomass accumulation[16] that converts to yield[17]. Therefore, this current study aimed to determine the earliest effective screening date on phenotyping sugarcane roots under hydroponics validated by field trials data during the establishment phase (1 MAP) to early vegetative phase (2-3 MAP). This salient information will benefit breeders on high accuration and time-saving advantages by applying hydroponics in screening sugarcane lines, particularly under numerous breeding lines and limited area and labour.

MATERIALS AND METHODS

Study area: The research was carried out from January-March, 2018 at the Agronomy Field Crop Station, Khon Kaen University, Thailand.

Plant materials, experimental design and crop management in hydroponics: Six sugarcane genotypes were used for this study. One commercial sugarcane variety KK3 was identified as the drought-tolerance cultivar and had a good performance on rooting traits[18,1,3,9]. Further, UT13 was identified from the wild-type genotype[19] and had a long root length density both in the deep and top soils[3]. KKU99-03 also had the highest root length density in the top soil layer only and KKU99-03 was evaluated in drought area and sandy soil in northeastern Thailand[20], whereas UT12 had the high root length density in sub-soil layer only. KPS01-12 was identified to have good adaptation and high cane yield[20]. Further, this variety was common in both top-soil and sub-soil layers, whereas the long root length density of the lower soil layer was resided in KKU99-02[3].

Six sugarcane genotypes were evaluated in a hydroponic system under greenhouse conditions during January-March, 2018 at the Agronomy Field Crop Station, Khon Kaen University, Thailand. A Randomized Complete Block Design (RCBD) with three replications was assigned. Each plot consisted of three 100-liter-volume pots and each pot was planted a seedling; therefore, the population size of each plot was three individual plants.

The stems of each sugarcane genotypes was cut around 3-4 cm long. Then, those cut stems were planted in each plastic nursery bag 8.5x10 cm. Sugarcane seedlings were then transplanted into a hydroponic system at 2 weeks after planting[21]. The hydroponic system was filled with water at the

potential of hydrogen at 7.05 with an Electrical Conductivity (EC) of 0.8 ds m^{-1}. Transplanting of seedling from soil media into the hydroponic system was performed when the seedling at least had 3-4 leaves or around two weeks after planting[18]. The Dynamic Root Floating Technique (DRFT) method was applied in the hydroponic for aeration system. The nutrient solution for plant fertilizer had two formulas, namely; formula A and B. For instance, formula A composed of 50 L water, 5.5 kg $Ca(NO_3)_2$ (Calcium Nitrate) and 80 g Ferric-EDTA. While, formula B composed of 50 L water, 435 g $NH_4H_2PO_4$ (mono-ammonium phosphate), 5 kg KNO_3 (Potassium Nitrate), 2.82 kg $MgSO_4$ (Magnesium Sulphate), 875 g KPO_4^-, 9 g Mn-EDTA (Manganese), 5.5 g Zn-EDTA (Zinc) and 2 g Cu-EDTA (Copper)[9,21]. During the experimental period, the EC was checked and monitored every three days for maintaining the nutrient concentration, the nutrient solution of A and B was 4 ds m^{-1}.

Data collections: Data was collected monthly for three times in one, two and three MAP in hydroponics media and root collection at three months in the field at a soil depth of 0-20, 20-40 and 40-60 cm. The whole data collection consisted of morphological growth data, physiological traits and root traits.

Morphological growth data: On one hand, the non-destructive method was carried out in this part by collecting the upper part of plant growth, such as stem number per plant within every 3 days, cane height and leave number within every 15 days. On the other hand, the destructive method was applied every 30 days for total of dry stem weight per plant, total of leaf dry weight per plant, total leaf area per plant and total of leave number per plant. The stem number per plant was observed since the first cane stem has appeared and observed until collected monthly for three times at 1, 2 and 3 months. The cane height was measured at the main stem from the water surface until dewlap point and observed within every 15 days until collected monthly for three times at one, two and three months. After collecting stem number, cane height and physiological traits monthly. Also, with the weight of stem and leaf, total weight of both stem and leaf was measured by analytical balance every one, two and three months and collected the leave of each pot, total leaf area per plant was calculated using the ratio between the leaf surface area of each genotype with LI-3100C area meter every one, two and three months. To obtain a dried sample, all of the samples were heated in the oven at 80°C around 72 h. Then, those dried samples were recorded in total of dry stem weight per plant and total of the dry leaf weight per plant.

Physiological traits: The non-destructive method was carried out to record the chlorophyll fluorescence and SPAD Chlorophyll Meter Reading (SCMR). Chlorophyll fluorescence was observed between 10.00 and 12.00 am at the bottom, middle and tip of the fully extended leaf number three or four in each pot at 30 day intervals after plant weight. Chlorophyll fluorescence was measured with PAM-2000 Heinz Walz GmbH, Germany. SPAD Chlorophyll Meter Reading (SCMR) was observed with SPAD-501, Minolta, Tokyo, Japan between 9.00 and 12.00 am on the same sample as chlorophyll fluorescence.

Root traits: The attributes of root included root dry weight, root number, root length, root volume and root surface area. The root samples were scanned with Epson perfection V800 photo scanner and these sample scans were analyzed with a WinRhizo program (WinRhizo Pro (s) V. 2004a, Regent Instruments, Inc.) to determine root length, root volume and root surface area. The root samples were oven-dried at 80°C for 72 h or constant weight and root dry weight was then determined.

Plant materials, experimental design and crop management in field: The same six sugarcane genotypes were also tested in field trials. These genotypes were subjected to a Randomized Complete Block Design (RCBD) with three replications during April-October, 2014 at the Agronomy Crop Station, Faculty of Agriculture, Khon Kaen University, Thailand. The soil type of the experimental site was sandy loam.

The stem of each sugarcane genotypes was cut around 3-4 cm long. Then, these cut stems were planted in each plastic nursery bag 8.5×10 cm for 3-4 weeks. Then surface drip irrigation was performed to supply enough water and fertilizer (15-15-15) and carbofuran ($C_{12}H_{15}NO_3$) were applied before transplanting. Each plot was arranged in 60 m^2 with 0.5 m wide and 1.5 m long.

Root data collection in field: Data was collected at three MAP in the field and the root sample was collected using monolith method. The root sample of each plot was separated into three soil depth levels as 0-20, 20-40 and 40-60 cm. The root traits included root dry weight, root number, root length, root volume and root surface area. The root samples were scanned with Epson perfection V800 photo scanner and these sample scans were analyzed with a WinRhizo program (WinRhizo Pro (s) V. 2004a, Regent Instruments, Inc.) to determine root length, root volume and root surface area.

Statistical analysis: Analysis of variance in a RCBD was computed for both field and hydroponics trials for all observed traits by following Gomez and Gomez[22]. The genotype mean was compared with Least Significant Difference (LSD) test at 5% of root attributes derived from both trials. The simple linear correlation coefficient was calculated to investigate the associations between above-ground and root parts. Statistix 10.0 software[23] was computed to facilitate data analysis.

RESULTS AND DISCUSSION

Root performance of six sugarcane genotypes under hydroponics media: Genotype was significant for root length, root surface area and root volume at 1 MAP (Table 1). KK3, UT13 and KPS01-12 showed the best order of root length, root surface area and root volume, indicated by a large root system. UT12 and KKU99-02 showed the moderate group of root length, root surface area and root volume. KKU99-03 showed the lowest group of root length, root surface area and root volume as indicated by a small root system at 1 MAP.

Genotype was significant for root length, root surface area and root volume at 2 MAP (Table 2). KK3, KPS01-12 and UT13 showed the highest root length, root surface area and root volume indicated by a large root system. Whereas, KKU99-03 showed the moderate root length, root surface area and root volume, UT12 and KKU99-02 showed the lowest root length, root surface area and root volume, indicated by a small root system at 2 MAP. KK3, KPS01-12, UT13 and KKU99-03 showed the highest root length, root surface area and root volume. KKU99-02 showed moderate root length, root surface area and root volume. UT12 showed the lowest root length, root surface area and root volume.

Genotype was significant for root length, root surface area and root volume at 3 MAP (Table 3). Root length under field condition showed a similar pattern to that under hydroponics at 3 MAP. Both KK3 and KKU99-03 showed the highest root length indicated by a large root system.

At 1 MAP, the shaping root system architecture among six sugarcane genotypes in hydroponics showed obviously different. KK3 showed the largest root system, whereas, UT13

Table 1: Root length, root surface area and root volume observed at 1 month after planting under hydroponic condition

Variety	Root length (cm)	Root surface area (cm^2)	Root volume (cm^3)
KK3	15.493^{a}	2.957^{a}	45.54^{ab}
KPS01-12	10.376^{abc}	2.120^{abc}	35.44^{bc}
UT12	9.007^{bc}	1.936^{bc}	33.66^{bc}
KKU99-02	7.344^{bc}	1.653^{c}	30.47^{bc}
KKU99-03	5.316^{c}	1.158^{c}	20.19^{c}
UT13	13.002^{ab}	2.899^{ab}	52.01^{a}
Mean	10.089	2.121	36.22
F-test	*	*	*

*Data is significant at $p \leq 0.05$, Means following the same letter within each column are not different from each other by LSD 5%

Table 2: Root length, root surface area and root volume observed at 2 months after planting under hydroponic condition

Variety	Root length (cm)	Root surface area (cm^2)	Root volume (cm^3)
KK3	69.236^{a}	14.417^{a}	211.53^{a}
KPS01-12	54.639^{ab}	11.448^{ab}	216.82^{a}
UT12	24.242^{c}	5.556^{c}	102.58^{bc}
KKU99-02	24.440^{c}	5.470^{c}	98.26^{c}
KKU99-03	44.072^{bc}	9.337^{bc}	137.02^{b}
UT13	49.308^{ab}	10.428^{ab}	226.42^{a}
Mean	44.322	9.442	165.44
F-test	*	*	**

*Data is significant at $p \leq 0.05$, **Data is significant at $p \leq 0.01$, Means following the same letter within each column are not different from each other by LSD 5%

Table 3: Root length, root surface area and root volume observed at 3 months after planting under hydroponic condition

Variety	Root length under hydroponic (cm)	Root surface area under hydroponic (cm^2)	Root volume under hydroponic (cm^3)	Root length in the field (cm)
KK3	178.692^{a}	34.883^{a}	527.11^{a}	35.483^{a}
KPS01-12	108.627^{abc}	21.723^{abc}	348.49^{b}	29.222^{b}
UT12	37.091^{c}	8.816^{c}	162.78^{c}	23.778^{c}
KKU99-02	68.097^{bc}	15.011^{bc}	266.35^{c}	28.184^{b}
KKU99-03	135.328^{ab}	28.342^{ab}	320.75^{b}	32.904^{a}
UT13	120.474^{ab}	23.674^{abc}	477.57^{a}	24.956^{c}
Mean	108.051	22.074	350.51	29.087
F-test	*	*	**	**

*Data is significant at $p \leq 0.05$, **Data is significant at $p \leq 0.01$, ns: Data is not significant at $p \leq 0.05$, Means following the same letter within each column are not different from each other by LSD 5%

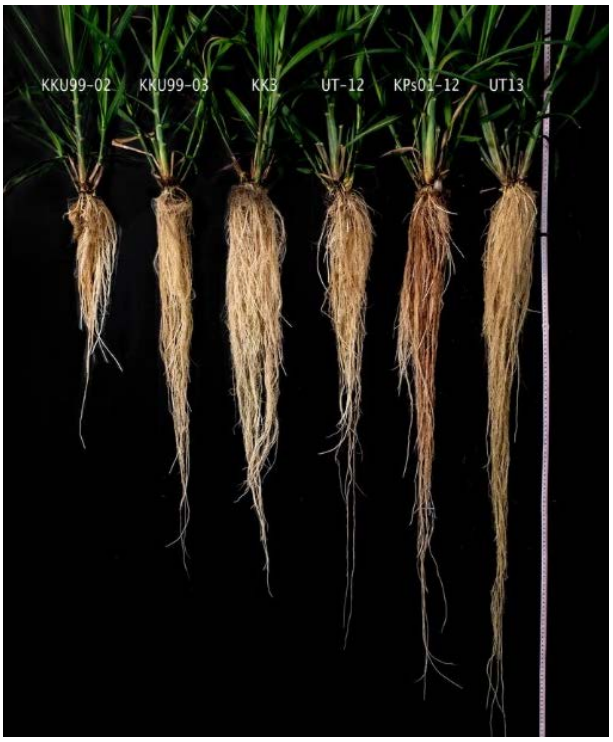

Fig. 1: Shaping root system architecture of six sugarcane genotypes in hydroponic media

followed by KPS01-12 revealed medium size with deeper root system. UT12 followed by KKU99-02 and KKU99-03 showed the smallest root system group (Fig. 1).

Sugarcane breeders interested in root screening because the root systems are salient plant parts, for taking up water and nutrients from the soil layers[24,25]. Sugarcane root system in soil condition is initiated soon after planting. In well-water condition, the root length, root surface area and root volume of sugarcane were noticed at soil upper ground[1], because the distribution of roots in the soil is affected by irrigation practices that shows a shallow root system. The effective root zone is mostly at upper soil layer due to less restriction compared to the deeper soil[26,27,3]. As irrigation is adjusted according to rooting depth, this parameter is especially important to water management[28]. Meanwhile, root distribution of sugarcane in rain-fed condition is concentrated in the deeper stored soil water. It may be an important mechanism to avoid drought[29,14,18,1,3].

Root studies in soil condition could be supported by hydroponics because the plant roots do not need to be deeply rooted and plant roots in hydroponics are suspended in nutrient-rich and water[30]. Hydroponics-based method could be an alternative way to observe effectively more information on root characteristics and growth[31]. In hydroponic media the correct supply of water and nutrients is very important in hydroponic growing systems in order to use water and fertilizers efficiently and avoid stress situations[32], consequently root plant don't have to be deep[31]. In sugarcane, Chapae *et al.*[9] noticed a relationship among root traits in hydroponics media and field condition at 3 MAP particularly on sugarcane cultivars KK3 and KPS01-12. Then, similar to the interactions between sugarcane genotypes were significant for root length, root surface area and root volume in field condition[18]. In addition, hydroponics solve some problems in soil-based trial such as; low efficiency in water use in some vegetable crops (kale, parsley and watermelon)[33], root growth disturbance causing loss production[7]. Further, root harvest and young plant of hydroponic are comfortable and less time-consuming[34].

Chumphu *et al.*,[3] classified the group of sugarcane varieties regarding root length into two groups. Group 1 composed of KK3, UT13, KKU99-03 and Kps01-12 with high root length density in the topsoil layer. Group 2 consisted of Kps01-12 and UT12 with high root length density in the sub-soil layer. While, Kps01-12 was common in both topsoil and sub-soil layers, KKU99-02 was classified in the lower-soil layer. KK3 had a good root performance in previous report[18]. However, KK3 under well-water condition showed the lowest root length, root surface area and root volume when compared to those under drought condition[1]. This result indicated that the root of KK3, UT13 and Kps01-12 under hydroponics showed the best order of root performance at 1, 2 and 3 MAP, whereas order of UT12, KKU99-02 and KKU99-03 was unstable across months (1, 2 and 3 MAP). Environment effect might explain the phenotypic of sugarcane varieties[35]. Various soil moisture conditions could trigger the different growth of roots. Later it well known as phenotypic plasticity, defined as a plant's ability to alter its phenotype in response to environment changing[36]. However, root length at 3 MAP in field condition showed non-significant among six sugarcane genotypes. It might be due to a lack of nutrients[37] leading to a lower sugarcane, root system in field condition.

Feasibility of hydroponic in rapid screening among sugarcane genotypes: Comparing to field trial: The correlation coefficients between root length and root volume and root surface area in hydroponic media were positive and strong. Root length and root volume in 1 (Fig. 2a), 2(Fig. 2b) and 3 (Fig. 2c) MAP had positive and strong correlation ($r = 0.98^{**}$, 0.99^{**}, 0.99^{**}, respectively). Root length and root surface area in 1 MAP were positively correlated ($r = 0.91^{**}$) (Fig. 2d) and there were strongly correlated in 2MAP $r = 0.99^{**}$) (Fig. 2e). Moreover, in 3 MAP, Root length and

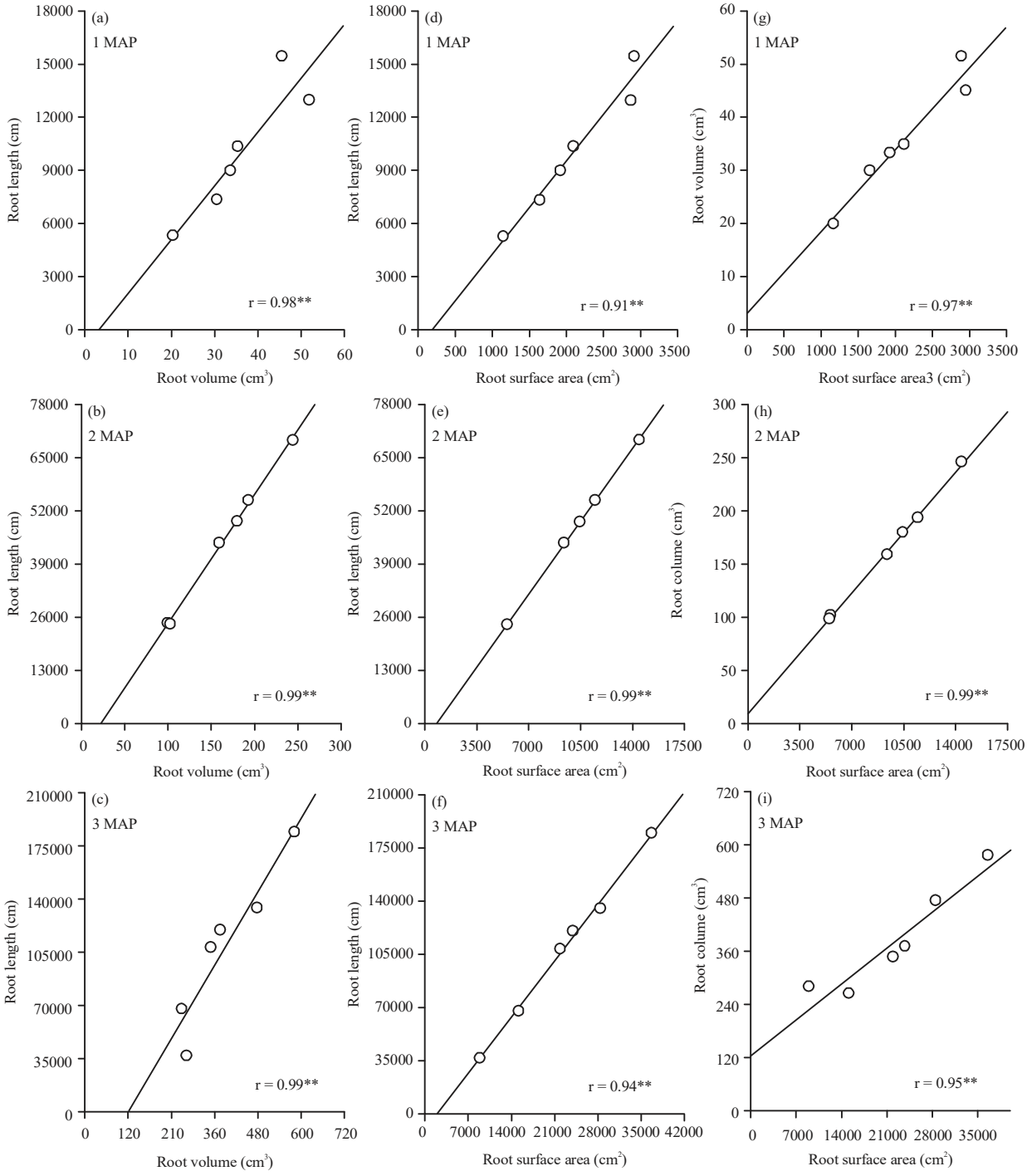

Fig. 2 (a-l): Linear correlation study between sugarcane root length, root volume and root surface area among six sugarcane genotypes under hydroponics media observed at 1, 2, and 3 Months After Planting (MAP)

root surface area were positively correlated (r = 0.94**) (Fig. 2f). Root volume and root surface area had strongly positive correlation in 1 MAP r = 0.97**) (Fig. 2g), 2 MAP (r = 0.99**) (Fig. 2h) and 3 MAP r = 0.95**) (Fig. 2i). These results suggested that root length could be used as representative parameter among observed root attributes in data validation between field-based and hydroponics-based trials. Also, this trait could be applied in breeding programs as criteria for drought-tolerance line selection due to easier in observation than other root traits[38]. The comparison between the

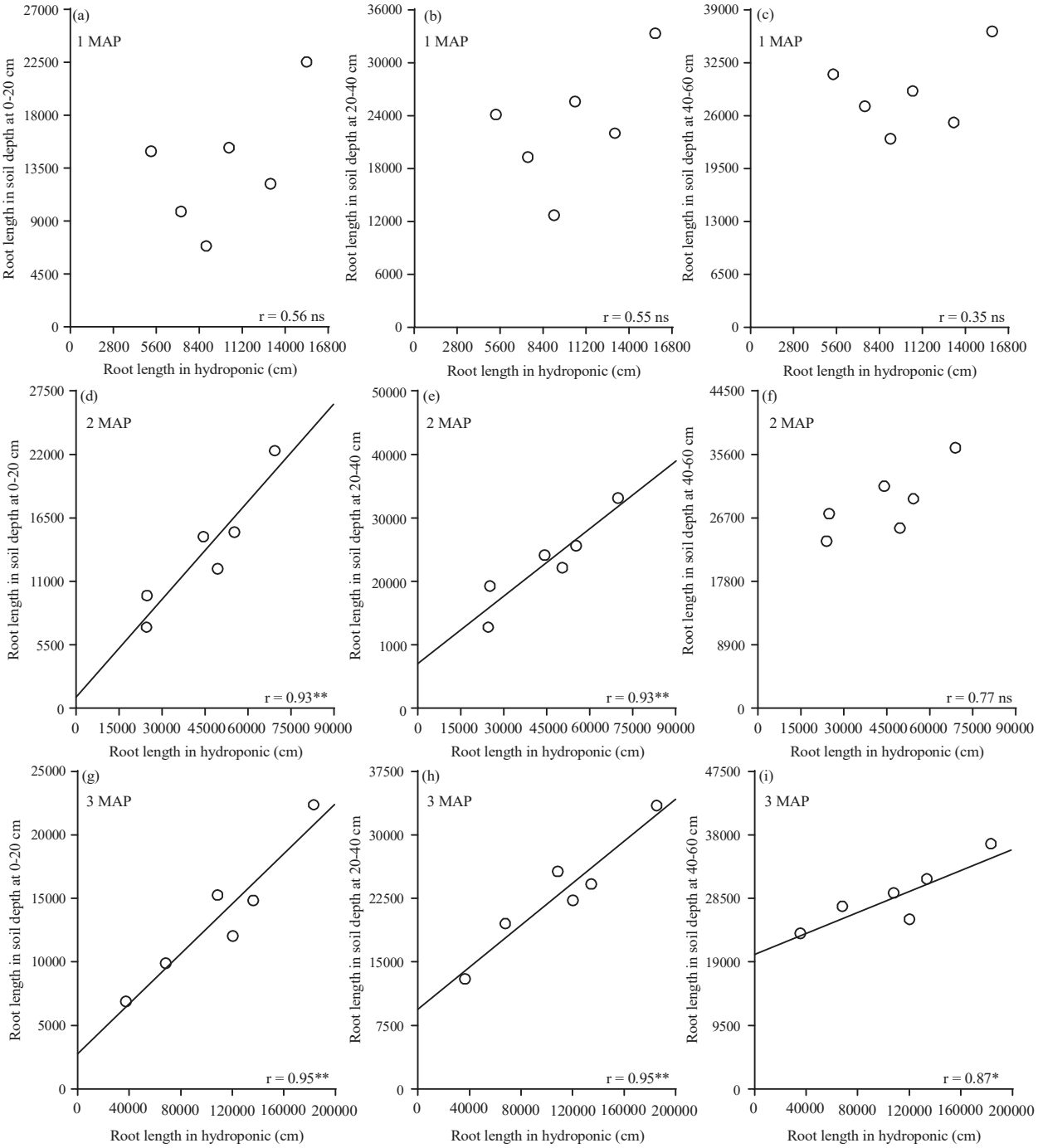

Fig. 3(a-l): Relationship of sugarcane root length between soil and hydroponic media observed in 1, 2 and 3 Months After Planting (MAP), respectively

sugarcane root length grown under soil condition and hydroponics media was not significant at soil depth of 0-20 cm (Fig. 3a), 20-40 cm (Fig. 3b) and 40-60 cm (Fig. 3c) at 1 MAP. Correlation between root length grown under soil condition and hydroponics was highly significant at 2 MAP at soil depth of 0-20 cm (r = 0.93**) (Fig. 3d), 20-40 cm (r = 0.93**) (Fig. 3e), whereas it was not significant at soil depth of 40-60 cm (r = 0.77 ns) (Fig. 3f). Correlation between root length grown under soil condition and hydroponics was highly significant at 3 MAP at soil depth of 0-20 cm (r = 0.95**) (Fig. 3g), 20-40 cm (r = 0.95**) (Fig. 3h) and high significant at soil depth of 40-60 cm r = 0.87*) (Fig. 3i). This result indicated that

Table 4: Correlation coefficients (r) between root traits and Stem Dry Weight (SDW), Root Dry Weight (RDW), SCMR, CF observed at 1, 2 and 3 months after planting (MAP)

Month after planting	Root traits	RDW	SDW	SCMR	CF
1 MAP	RL	0.91*	0.65^{ns}	0.22^{ns}	0.59^{ns}
	RSA	0.87*	0.60^{ns}	0.22^{ns}	0.59^{ns}
	RV	0.78^{ns}	0.50^{ns}	0.21^{ns}	0.58^{ns}
2 MAP	RL	0.89**	0.91**	0.85*	-0.35^{ns}
	RSA	0.88**	0.91**	0.83*	-0.34^{ns}
	RV	0.89**	0.92**	0.78^{ns}	-0.36^{ns}
3 MAP	RL	0.80**	0.85**	0.36^{ns}	0.23^{ns}
	RSA	0.79**	0.88**	0.32^{ns}	0.24^{ns}
	RV	0.76**	0.85**	0.27^{ns}	0.26^{ns}

**,*: Significant at $p \leq 0.05$, ns: Not significant at $p \leq 0.05$, RL: Root length, RSA: Root surface area, RV: Root volume, SCMR: SPAD chlorophyll meter reading, CF: Chlorophyll fluorescence

hydroponics system could substitute field trial as early as from 2-3 MAP. This earlier screening date corroborated and updated the previous report in sugarcane[9].

Root phenotyping derived from field trial mostly uses abundant tools. These are complicated, laborious, time consuming and costly. The use of pot, rhizoboxes and rhizotron can reduce the rooting labors; however, it still causes some drawbacks such as growth reduction due to limited space[38]. Also, the growth of the upper part of the plant seemed to be incomplete[39]. Consequently, the methods in planting container are suitable for shortage crops only[40,39]. Furthermore, taking root samples from soil has to pass the process of root washing[2]. Seeking the other methods for reducing various restrictions to measure sugarcane, root system is needed. Hydroponics is one of the methods in root phenotyping studies[2,31,9].

Conventional sugarcane breeding is typically time consuming and laborious as breeders commonly evaluate numerous genotypes under vast field trials. This work is difficult being applied in sugarcane, root phenotyping[8,41,10]. This present study showed the feasible method of hydroponics system to substitute field trial on assessing sugarcane genotypes as high correlation was revealed both interrelationship between attributes within hydroponics and between respective traits under hydroponics and soil media. Hydroponics become a rapid assessment of root system and other physiological traits[42]. Plant roots played important role in nutrient and root architecture became important for supporting yield performance of certain crop species[43]. In addition, it was also included in the drought tolerance function when the water supply to roots was limited or when the transpiration rate becomes very high[44]. Hence, the plant's ability to survive from severe water deficit depends on the root[45,18] by extending the root length on certain water-limit period[1] in sugarcane.

Correlation analysis, among root attributes, biomass and physiological traits under hydroponics was explored in this study (Table 4). The relationships between root length, root surface area and root volume vs. stem dry weight, root dry weight, SCMR and CF observed at 1 MAP were significant with wide range (r = 0.21-0.91). Two pairs of root attributes, namely root length vs. root dry weight and root surface area vs. root dry weight had medium and positive correlation coefficients (r = 0.91 and 0.87, respectively). The correlations between root length, root surface area and root volume vs. stem dry weight, root dry weight, SCMR and CF observed at 2 MAP were significant with varied magnitudes (r = -0.34-0.92). Most pairs of traits had positive and strong correlation coefficients (r = 0.83-0.92) excluding root volume vs. SCMR, root length vs. CF, root surface area vs. CF and root volume vs. CF. The correlations between root length, root surface area and root volume vs. stem dry weight, root dry weight, SCMR and CF observed at 3 MAP were significant with wide range (r = 0.23-0.88). However, only six pairs of traits significantly related each other, namely root length, root surface area, root volume vs. root dry weight (r = 0.80, 0.79, 0.76, respectively) and root length, root surface area, root volume vs. stem dry weight (r = 0.85, 0.88, 0.85, respectively).

Total root biomass and root length represent a root system per plant[46]. Thus, the larger root system, the more photosynthetic assimilates is required to deal with crop growth and yield[25]. Also, the photosynthetic product is invested in root dry matter[47]. Large biomass, high root length and more prolific root systems could improve water uptake[47]. Comparative studies in wheat reported that root length positively correlated with root biomass under hydroponic and soil condition[25]. Previous studies reported that physiological traits was not significantly different in crop species[1,48]. In conventional plant breeding used physiological traits wherewith plant has a long cropping system[49]. However, water stress did not affect chlorophyll content[50]. In rice positive correlation coefficients were noticed between shoot dry weight, root shoot and dry weight with root length[51]. In sugarcane under water deficit, it found a correlation between

root dry mass and root length[52]. Therefore, hydroponics with Dynamic Root Floating Technique (DRFT) is an alternative way to facilitate germplasm screening emphasized on sugarcane root attributes as early as at 2 MAP to 3 MAP. This study will benefit breeders on high accuration and time-saving advantages by applying hydroponics in screening sugarcane lines, particularly under numerous breeding lines and limited area and labour. Further studies are encouraged to ensure the feasibility of hydropnics as screening media of sugarcane lines with different aeration techniques and repeated over seasons or years.

CONCLUSION

The earliest effective screening date among sugarcane genotypes under hydroponics at 2 MAP was effective to substitute soil media at depth of 0-20 and 20-40 cm; however, it was still not effective at soil depths of 40-60 cm. The screening date at 3 MAP was effective to substitute soil media at depth of 0-20, 20-40 and 40-60 cm. Therefore, this result indicated that hydroponic system can be applied in sugarcane root screening at least from 2 MAP to 3 MAP. Moreover, stems and root dry weight can be assigned as selection criteria to identify sugarcane genotypes with large root systems under hydroponics media.

SIGNIFICANCE STATEMENT

This study discovers the most efficient screening time for phenotyping sugarcane root in hydroponics that can be beneficial for sugarcane plant breeders are interested in early stages root screening. This study will help the researcher to uncover the critical area of root screening of sugarcane investigated under hydroponic condition that many researchers were not able to explore. Thus, a new theory of these screening time for sugarcane root, may be arrived at.

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