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Screening For Root And Yield Characteristics Under Rainfed Conditions In Sugarcane Clones (*Saccharum officinarum L.*)

Sadras Bhavana*, M. Vijay Kumar, G. S. Madhu Bindu and D.V.V. Reddy.
Agricultural Research Station, Basanthpur-Mamidigi, Medak Dist., Telangana, India.

ABSTRACT
India ranks second in terms of area and per hectare productivity of sugarcane. It being a C_4 plant is distinct and more efficient converter of solar energy, thus having potential to produce huge amounts of biomass. The root system of sugarcane deserves particular attention because it is essential for the regeneration of the cane. The root mining characteristics of different sugarcane clones assume importance in this context in tapping moisture and uptake of nutrients. The present study was conducted at Agricultural Research Station, Basanthpur, Medak District during 2016-17 to screen different varieties of Sugarcane for their rooting characteristics in relation to growth and yield. The experiment was laid in randomized block design with 3 blocks of root structures constructed especially for root studies. The root characters studied in terms of shoot to root ratio, root volume, root spread, root length and root dry weight had shown high genotypic variability. The variety, Co 86032 has maintained highest shoot-root ratio (25.31) compared to other varieties. The lowest shoot-root ratio in varieties 97 R 401 and Co C 671 was reflected in their higher root dry weights (354.9 and 323.4 g, respectively). On the other hand, root mining character evidenced in terms of root length and root volume was significantly highest for the varieties Co 95020, 97 R 129 and Co C 92061. The data on cane yield recorded after harvest indicated significant difference among the varieties. The cane yield of different varieties ranged from 96.15 to 142.66 t ha^{-1}.
Key words: *Sugarcane, root mining, shoot root ratio, root volume, root spread and yield.*

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INTRODUCTION:

Sugarcane, an industrial crop was grown in an area of 50.32 l ha with a cane production of 356.56 Mt and a productivity of 70.86 t ha^{-1} in India during 2014-15. It occupied an area of 49,000 ha with a cane production of 3.67 Mt and a productivity of 75 t ha^{-1} in the state of Telangana in 2014-15. India ranks second in terms of area and per hectare productivity. Sugarcane being a C_4 plant is distinct and more efficient converter of solar energy, thus having potential to produce huge amounts of biomass. Generally, the role of plant roots in crop production presents the state of knowledge on environmental factors in root growth and development and their effect on the improvement of the yield of annual crops. The plant root system constitutes the major part of the plant body, both in terms of function and bulk (Nand Kumar, 2012). . Understanding the development and architecture of roots holds potential for the exploitation and manipulation of root characteristics to both increase plant yield and optimize agricultural land use (Smith *et al.,* 2012). The root system of sugarcane deserves particular attention because it is essential for the regeneration of the cane. The root system of young cane consists mostly of sett roots which have a greater length per unit mass than the larger and deeper buttress and rope roots. Sugarcane root system is commonly depicted as highly branched superficial roots, downward-oriented buttress roots and deeply penetrating agglomerations of vertical roots known as rope roots. Rope roots have been observed to penetrate to depths exceeding 6 m (Evans, 1936) providing access to deep reserves of soil water. The distribution of sugarcane root length has an exponential pattern (Ball- Coelho *et al*., 1992; Van Antwerpen, 1998). Mean rates of root penetration, or the rate of descent of the cane root system of 20-30 mm d^{-1} was cited in previous records. Root penetration was down to a depth of 1.6 m for rainfed cane, but slowed in irrigated cane between 1.0 m - 1.6 m (Smith, 1998).). Highly branched superficial roots improve drought-tolerance in cultivars exhibiting low root mass (Evans, 1964). Studies on sugarcane roots lag well behind those on other crops, in part due to the large plant stature and long crop cycle.

However, the root mining characteristics of different sugarcane clones assume importance in this context in tapping moisture and uptake of nutrients. But, the information available on root traits in different sugarcane clones is meager. Hence, the present study was carried on twelve sugarcane clones for root and yield characteristics on a specially constructed root structure in randomised block design with three replications.

MATERIAL AND METHODS

The present study was conducted at Agricultural Research Station, Basanthpur-Mamidigi, Medak Dist. which comes under Central Telangana Zone, Telangana during 2016-2017. The information regarding, soil characteristics, experimental details, methods of plant analysis and statistical techniques was collected. The weather data on rainfall, number of rainy days, mean maximum and minimum temperatures and relative humidity recorded from June'16 to April'17 at the meteorological observatory of Agricultural Research Station, Basanthpur are presented in Appendix 1 and depicted in fig 1. The highest mean maximum and minimum temperature recorded was 41.9^{0}C and 11.6^{0}C in the month of February '17 and November '16 respectively. Highest mean monthly relative humidity recorded was 58.6 & 88.5% in forenoon and afternoon in the month of October and September respectively. The total of 1072.6 mm of rainfall was received during the crop during in 51 rainy days.

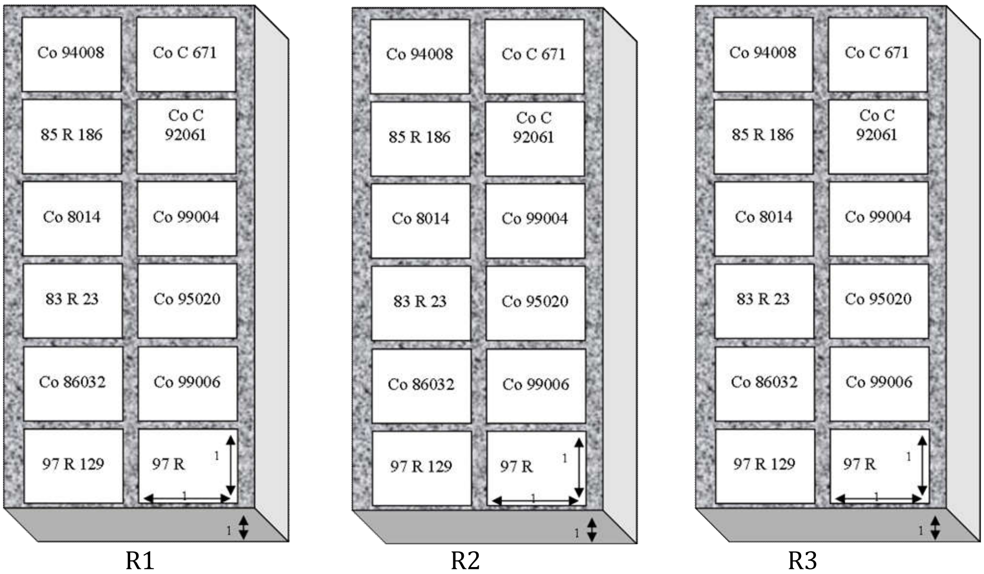
Appendix I
Monthly mean meteorological data during the crop growth period

S No.	Months	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Rainy Days No.s
		Min	Max	FN	AN		
1	June (2016)	21.1	37.6	15.6	75.4	215.2	12
2	July	21.2	33.6	31.0	74.3	233.2	12
3	August	21.3	30.2	17.9	83.0	89.8	9
4	September	21.4	27.0	40.1	88.5	461.8	15
5	October	20.9	25.4	58.6	52.5	64	1
6	November	11.6	29.4	20.0	86.6	0.0	0
7	December	11.9	27.3	25.7	86.5	1.2	0
8	January (2017)	12.2	27.7	18.6	24.2	0.0	0
9	February	13.8	41.9	13.0	65.3	0.0	0
10	March	18.0	32.9	10.8	60.8	7.4	2
11	April	16.6	30.5	12.3	58.6	6.2	2

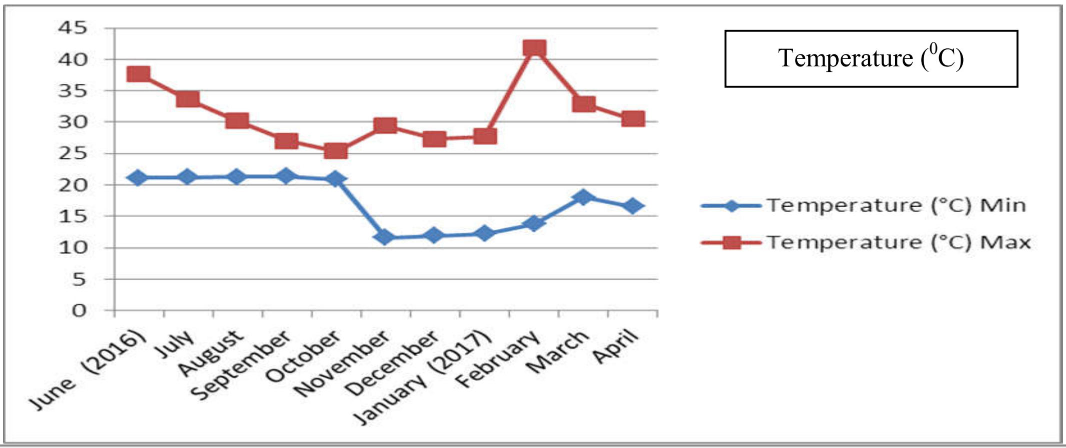
The root study was conducted on a specially constructed raised rectangular root structures each of size 1 m x 1 m x 1.2 m (L x B x Ht). A total of three blocks of katcha root structures, each block containing 12 structures were constructed specially with bricks and cement. Each structure was filled with soil up to 1.2 m level (layout and fig 1). Soil physical and chemical properties of the simulated root structure were quantified and presented in table 1.

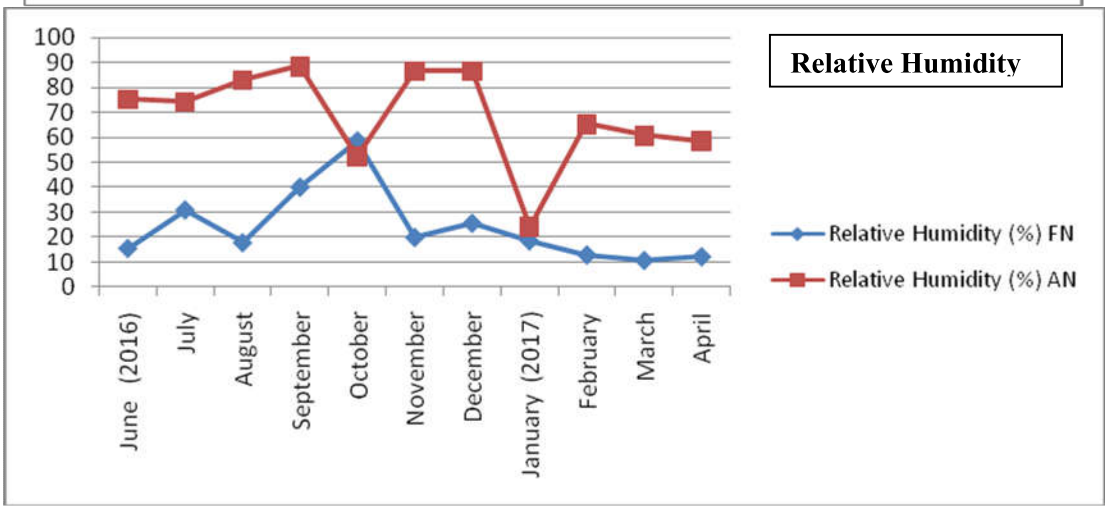
Table 1: Soil physical and chemical properties of simulated root structure.

Soil physical parameters		Values	Units
1	Soil texture	Sandy clay loam	-
2	Soil colour	Red	-
3	Bulk density	1.59	Mg m^{-3}
4	Particle density	2.82	Mg m^{-3}
5	Water holding capacity	38.7	%
6	Porosity	42.6	%
Soil chemical parameters		**Values**	**Units**
1	Soil Ph	7.09	-
2	Electrical conductivity	0.24	dSm^{-1}
3	Organic carbon	0.34	%
4	Available N	132.51	kg ha^{-1}
5	Available P_2O_5	16.58	kg ha^{-1}
6	Available K_2O	189.75	kg ha^{-1}



LAYOUT OF THE ROOT STRUCTURE





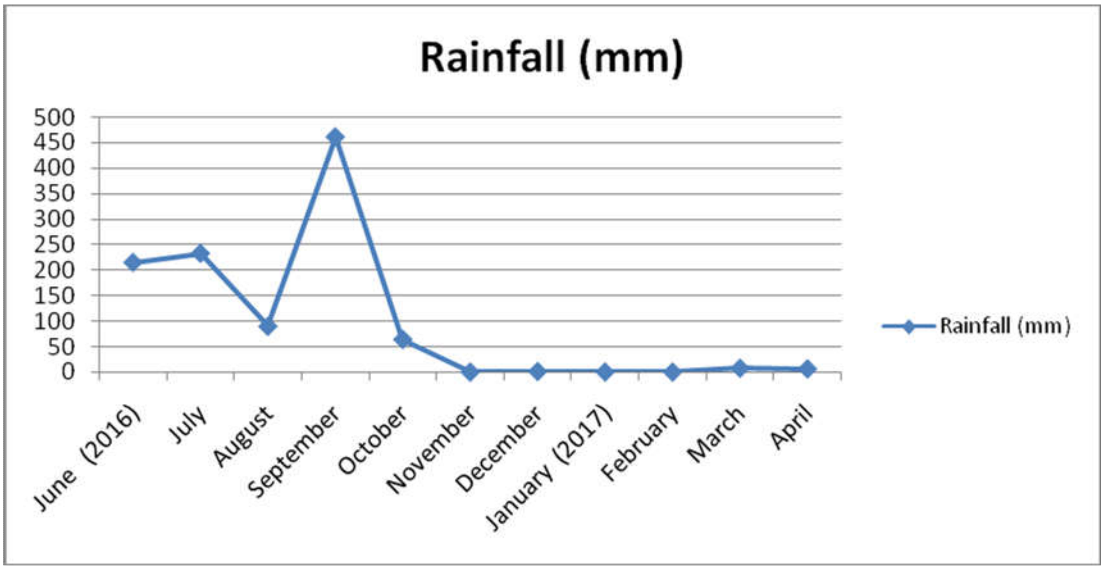


Fig.1 Meteorological data showing Temperature, Relative Humidity and Rainfall during the crop period (2016-2017).

The field experiment was conducted with 12 varieties in randomized block design replicated thrice. The detail of layout plan is given in fig 2 (Plate 1). The 12 varieties/clones studied were Co 94008, Co 99006, Co 99004, Co 86032, Co C 92061, 85 R 186, 83 R 23, Co 95020, Co 8014, Co C 671, 97 R 129 and 97 R 401. Planting, fertilization, irrigation and harvesting were done as per the recommended practices in order to quantify the growth and yield of the crop raised in root structures. Accordingly, single node seedlings @12 no.s were planted in each root structure. At harvest, the walls of root structure were dismantled systematically and plants along with intact root systems were excavated (Plate 2). Later the roots were washed with foam water and dried to record root parameters. The data from the experiment were taken randomly in each variety at harvest stage for recording the following root and yield characters.
The ratio between the weight of total shoot (all above ground parts) and root was calculated as shoot-root ratio and expressed numerically. Root volume was quantified by water displacement method using large volume measuring cylinder, expressed in c.c. Root spread was measured laterally in centimeters using graduated scale from center of the collar region to left and right ends of the root structure. Length of the root was measured in centimeters using graduated scale from collar region to the tip of the root. Harvested roots were washed and oven dried for 3 days. Weights were recorded using sensitive electronic balance. Root dry weight is expressed in g per structure. All the canes in the plot were cut close to the ground level at harvest. The tops and fresh leaves were removed and cane yield per raised bed was recorded. The cane yield was expressed in tonnes per hectare (t ha^{-1}).

Plate 1. Root structure

Plate 2. Excavation of roots after dismantling of root structure

RESULTS AND DISCUSSIONS

Root characters:

There are many below ground constraints on crop growth especially under moisture stress conditions in commercial sugarcane production. An important function of plant root system is to absorb water from the soil and transport to the shoot. Hence, the efficiency of soil water uptake by root system is key factor in determining the balance between translocation and shoot water status (Nicanor *et al*., 1992). The size and distribution of root system varies among the genotypes and cause differences in the capacity of genotypes to exploit deeper soil resources. Crop plants such as sorghum (Jordan and Miller, 1980) often depends on the growth of root in terms of root length and root dry weight (Songsri *et al*., 2009). Hence, an attempt was made to identify sugarcane clones with high root systems. Smith *et al.,* (2005) reported that roots play a critical role in controlling both shoot development and environmental growth response in sugarcane.

Shoot-root ratio

The plants have evolved to exhibit a characteristic balance between the mass contained in the shoot and root proportions in a given eco-physiological stage, and this ratio is characteristic for each species or genotype (Marschner, 1995). The shoot root ratio of different varieties has shown highly significant variation among the varieties as presented in the table and fig.

Apportioning of more biomass towards shoots than the roots was recorded in Co 86032 with higher shoot - root ratio of 25.31 indicating relatively higher shoot mass compared to root growth. Further, lowest shoot to root ratios were observed in sugarcane varieties, 97 R 401 (7.76) and 97 R 129 (9.94) indicating more partitioning of biomass to the roots at the expense of shoots.

Root Volume (cc)

Root volume varied significantly among the sugarcane varieties from 75.59 cc to 106.15 cc. Such genotypic variability was also reported in other field crops such as rice (Zumo-altoveros *et al*., 1990) and groundnut (Pranusha *et al*., 2011).

Root volume varied numerically among 12 sugarcane varieties. The sugarcane varieties Co 95020, Co 86032, Co C 92061, 97 R 129 and Co 94008 recorded relatively higher root volume compared to others. Further, lowest and at par root volumes were observed with varieties, Co 8014, 83 R 23, Co 99004, Co C 671, 97 R 401, 85 R 186 and Co 99006.

Root Spread

In sugarcane root spread is also an important factor for absorption of water and nutrients which in turn facilitate root branching (Evans, 1964). Similar to the root volume, root spread also varied significantly among the varieties. A genotypic variability of 32.24 cm to 72.96 cm was recorded.

The variety, Co 95020 recorded highest lateral root spread (72.96 cm) indicating the size and distribution of the root system is strongly affected by the distribution and availability of soil water, causing differences in the capacity of crops to exploit deeper soil resources (Baran *et al*., 1974). Further, the lowest root spread was noticed with the varieties, Co 8014 (32.24 cm), 83 R 23 (32.60 cm) and Co 99006 (35.32 cm).

Root length (cm)

Sugarcane is a deep rooted crop due to long growth cycle and longevity of the root system through multiple rotations compared to other crops. Root system reaches to a depth of 1.5 meters and even 6 meters (Ball-Coelho *et al*., 1992 and Evan, 1936). In the present study root length showed variability in Sugarcane varieties. The genotypic variability ranged from 56.09 cm to 101.44 cm.

Among the sugarcane varieties, Co 95020 (101.44 cm), 85 R 186 (96.34 cm), 97 R 129 (92.25 cm) and Co C 92061 (88.35 cm) recorded comparably highest root lengths. Higher root lengths of these varieties were reflected in their higher volumes. Further, deeper rooting reduces the vulnerability of crops to the soil water deficit by providing increased capacity for uptake from deeper zones (Wood and Wood, 1967). Evan (1964) reported that drought tolerant cultivars have a tendency to develop deep root system. The distribution of sugarcane root length has a similar exponential pattern (Ball-Coelho *et al*., 1992; Van Antwerpen, 1998). The lowest root lengths on the contrary were seen in varieties, Co 8014 (56.09 cm), Co 99004 (58.23 cm), 83 R 23 (60.77 cm), Co C 671 (66.84 cm) and Co 94008 (68.13 cm).

Root dry weight

The data recorded on root dry weight per structure. Most of the root biomass in Sugarcane is found close to the surface and then declines approximately exponentially (Smith *et al.*, 2005). Root dry weights had registered significant differences among the varieties at harvest.

The varieties, 97 R 401 and Co C 671 had recorded significantly highest root dry weights (354.90 and 323.40 g, respectively) compared to the other varieties. Further, the lowest root dry weight was noticed with the variety, Co 86032 (164.94 g). Higher root dry weight indicates that the partitioning of biomass occurs to root at the expense of shoot. This is not desirable as shoot is of economic importance in cane.

Cane Yield:

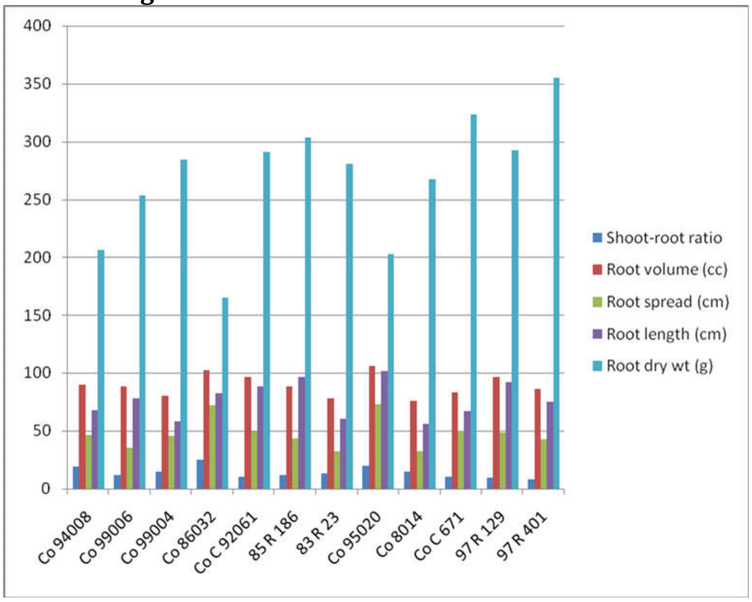
Cane yield is the ultimate manifestation of morphological, physiological, biochemical processes and growth parameters. Habib *et al*. (1991) had reported that yield attributes *viz.,* stalk height and girth improves cane yield per unit area to greater extent. The data on cane yield recorded after harvest (plate 3) indicated significant difference among the varieties and are presented in the table 3 and fig. 3.The cane yield of different varieties ranged from 96.15 to 142.66 t ha^{-1}. The varieties, Co 86032 (142.66 t ha^{-1}), Co 95020 (140.32 t ha^{-1}), Co C 671 (130.52 t ha^{-1}) and 97 R 401 (126.20 t ha^{-1}) being at par had recorded significantly highest cane yields over the remaining varieties. Better yield attributes *viz.,* number of millable canes; cane height, cane girth and single cane weight of the above varieties might have resulted in higher cane yields. The positive influence of yield attributes in increasing the cane yield of promising sugarcane cultivars was also reported by Kadam *et al*. (2007). On the other hand, lowest cane yields were observed with the varieties, 85 R 186 (96.15 t ha^{-1}), 83 R 23 (101.26 t ha^{-1}) and Co 99004 (109.20 t ha^{-1}).

Plate 3. Crop at harvest in root structures

Table 1. Mean performance of sugarcane varieties raised in root structures for root characters

S.No.	Variety	Shoot-root ratio	Root volume (cc)	Root spread (cm)	Root length (cm)	Root dry weight (g)
1	Co 94008	18.99	90.22	46.3	68.13	206.34
2	Co 99006	11.52	88.73	35.32	78.09	253.56
3	Co 99004	14.37	80.56	45.99	58.23	284.16
4	Co 86032	25.31	102.2	72.39	82.53	164.94
5	Co C 92061	10.4	96.26	49.7	88.35	290.94
6	85 R 186	11.87	88.43	43.33	96.34	303.54
7	83 R 23	13.12	78.33	32.6	60.77	280.32
8	Co 95020	19.61	106.15	72.96	101.44	202.68
9	Co 8014	14.77	75.59	32.24	56.09	267.3
10	Co C 671	10.62	83.52	50.24	66.84	323.4
11	97 R 129	9.94	96.15	48.85	92.25	292.62
12	97 R 401	7.76	86.31	42.94	74.87	354.9
Mean		**14.02**	**89.37**	**47.74**	**97.87**	**268.73**
CD (P=0.05)		**2.44**	**16.35**	**7.43**	**14.13**	**32.77**

Fig 1. Mean performance of sugarcane varieties raised in root structures for root characters



Of all the genotypes studied, Co 95020 has higher root mining capability indicating its potential in tapping the moisture and nutrients from deeper soil layers, whereas, Co 8014, 83 R 23 and Co 99006 had least root mining characters. This is shown in plate 4 & 5.

Table 3. Cane yield (t ha^{-1}) of Sugarcane varieties raised in root structures

S.No.	Variety	Yield
1	Co 94008	121.66
2	Co 99006	116.21
3	Co 99004	109.2
4	Co 86032	142.66
5	Co C 92061	119.98
6	85 R 186	96.15
7	83 R 23	101.26
8	Co 95020	140.32
9	Co 8014	121.61
10	Co C 671	130.52
11	97 R 129	120.46
12	97 R 401	126.2
Mean		**120.52**
CD (P=0.05)		**18.6**
CV (%)		**9.11**

Plate 4. Cane yield (kg ha^{-1}) of Sugarcane varieties raised in root structures

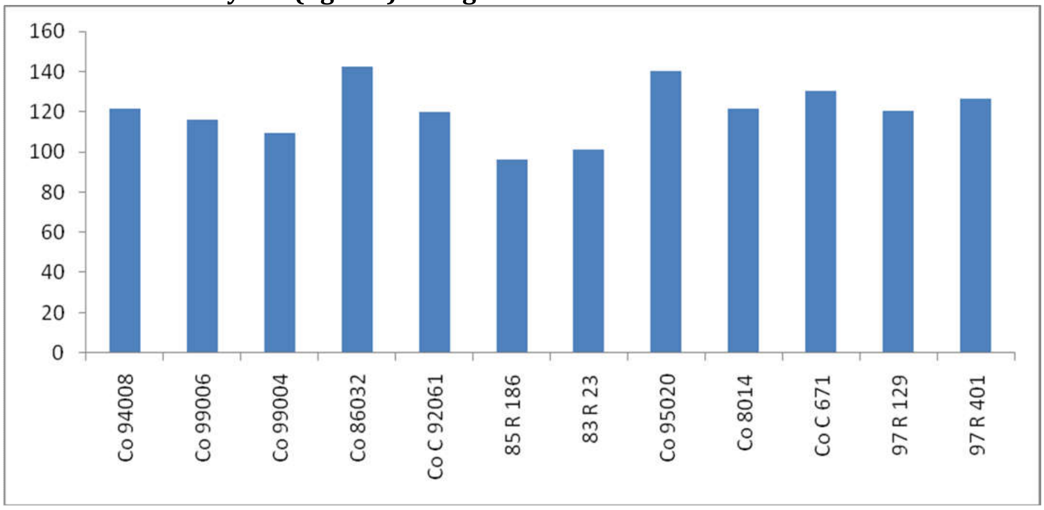


Plate 5. Root system of Co 95020

Plate 6. Root system of Co 8014

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