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Studies on Sugarcane Cultivation

II. Effects of the mixture of charcoal with pyroligneous acid on dry matter production and root growth of summer planted sugarcane (*Saccharum officinarum* L.)

S. M. Moslem UDDIN*, Seiichi MURAYAMA, Yukio ISHIMINE, Eiji TSUZUKI** and Jiro HARADA***

(*College of Agriculture University of the Ryukyus, Nishihara, Okinawa 903-01, Japan;*
** United Graduate School of Agricultural Science, Kagoshima University, Kagoshima 890, Japan;*
*** Faculty of Agriculture, Miyazaki University, Miyazaki 889-21, Japan;*
**** Faculty of Agriculture, Saga University, Honjou, Saga 840, Japan*)

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Abstract: An experiment was conduced to study the effects of a mixture of charcoal with pyroligneous acid (charcoal 4 : pyroligneous acid 1 ; Sannekka E) on dry matter production and root growth of summer planted sugarcane. Sugarcane variety NCo 310 was tested against four levels of Sannekka E (SE) ; 0 (control)、200, 400, and 800 Kg $10a^{-1}$ and the experiment was laid out in a randomized complete block design with five replications. Yield contributing characters, such as stalk number, stalk length, stalk diameter and sugar content in stalks were increased by application of SE. Values of CGR, NAR and LAI of SE treated crops were higher in comparison to those of the controls. The correlation coefficients between CGR and NAR, and CGR and LAI were significant. The yield of cane stalks, sugar and total dry matter content in SE treated plots had been increased by 13-24%, 19-31% and 14-20%, respectively, over the controls. The highest cane stalk yield (11.4 kg m^{-2}), sugar yield (1.95 kg m^{-2}) and total dry matter content (4.4 kg m^{-2}) were obtained by the application of SE of 400 kg $10a^{-1}$. Root content in unit soil cover depths was higher in SE treated plots.

key words: Dry matter, Pyroligneous acid, Root system, Sannekka E, Sugarcane.

サトウキビの栽培に関する研究　第2報 木酢液・木炭混合物が夏植サトウキビの乾物生産および根の生育に及ぼす影響：S. M. モスレム ウデイン*・村山 盛一・石嶺 行男・続 栄治**・原田 二郎***（*鹿児島大学連合大学院, 琉球大学農学部, **宮崎大学農学部, ***佐賀大学農学部）

要 旨：木酢液・木炭混合物（サンネカ E）が夏植サトウキビの乾物生産および根の生育に及ぼす影響を明らかにするために, サトウキビ品種 NCo 310 を供試し, サンネッカ E 施用量を 0（対照区）, 200, 400 および 800 kg/10 a の 4 水準設定して 5 反復で実験を実施した. その結果, サンネッカ E 施肥により茎重, 茎長, 茎径, 糖含量等のサトウキビの収量構成要素が増大した. サンネッカ E 施用区における CGR, NAR および LAI は対照区より高い値を示し, CGR と NAR および LAI の相関は有意であった. 原料茎収量, 蔗糖収量および全乾物重もサンネッカ E 区が対照区よりそれぞれ 13-24%, 19-31%および 14-20%増加した. また, 原料茎収量, 蔗糖収量および全乾物重の最高値は 400 kg/10 a サンネッカ E 区で得られた. サンネッカ E 区の根系の分布は水平方向, 垂直方向とも各分布域における根重密度はサンネッカ E 区が高かった.

キーワード：乾物生産, 根系, サトウキビ, サンネッカ E, 木酢液.

It has been demonstrated that potential shoot production of white clover grown in a particular soil environment is affected by a large root system[5]. This is also true in the case of sugarcane. Growth duration of sugarcane is long and the root system of this crop consists of a) superficial roots, absorb water and nutrients, b) buttress roots that provide stability to the plant and c) rope roots that penetrate into soil to a depth of three to six meters during severe drought[4]. Root distribution of crop is affected by tillage, irrigation, fertilizers and varietal characteristics[2,7,15]. Some sugarcane varieties differ in the width depth of root system development[8]. Recently, a mixture of charcoal and pyroligneous acid (Sannekka E) was reported to be a growth stimulant and quality improver of crops[11,16,17]. Tsuzuki et al.[16] reported that branch root formation was accelerated in Sannekka E (SE) treated rice crop. Our previous studies also indicated that SE treated spring planted sugarcane had a marked higher value in dry weight of shoots and roots, in length of primary roots and branch roots in comparison to controls[11].

Although we studied the effects of SE on cane and sugar yield of spring crops under both field and pot conditions and ratoon crops under field conditions[11,12,18,19], no studies on matter production and root distribution have yet been done on summer planted sugarcane under field conditions. Sugarcane, a long duration large crop with a profuse root system requires wide space for its normal growth and development, which needs almost 18 months to attain maturity for summer planting crops. In pot culture, spontaneous root growth is hampered to space limitation. Consequently authentic recommendation on root growth and yield of cane can not be carried out only through pot culture. Therefore, this study was conducted to determine the effects of SE on matter production and spatial distribution of roots of summer planted sugarcane in field conditions.

Materials and Methods

The experiment was conducted during the period from August 1991 to April 1993 in the experimental farm of the University of the Ryukyus using sugarcane variety NCo 310. The experiment included four levels of SE ; no application of SE (Control), SE application of 200, 400 and 800 kg $10a^{-1}$. Two-eyed seedpieces treated with Benlate T were planted at a 30 cm distance along the furrows in gray upland (Jahgaru) soil on August 25, 1991 (summer planted sugarcane) and row spacing was maintained at 1.5 m. The experiment was laid out in a randomized complete block design with five replications in 7 m × 6 m in a total of 20 plots. To avoid border effect, each plot was planted with border rows using the same variety of sugarcane. The SE (manufactured by Miyazaki Midori PHARMS ... INC) was mixed with loose soil in trenches with up to 5 cm soil depth before planting the seedpieces. Chemical fertilizers, NPK were applied at recommended levels[3]. Agronomical treatments were performed when necessary.

Germination of sugarcane bud was counted at 45 days after planting (DAP). For detailed growth analysis samplings were done at an interval of two months by taking one meter of row length. Sub-samples were divided into green leaves, tops and sheath, stalks and dead leaves (trash). Leaf area was measured by using an Area meter (LI-3100, LI. Cor. Inc. Lincoln, Nebraska, USA). A small representative sample of plant parts was dried at 85°C using an electric oven for seven days. Crop Growth Rate (CGR), Relative Growth Rate (RGR), Net Assimilation Rate (NAR) and Leaf Area Index (LAI) were determined. The crop was finally harvested on the first week of February, 1993. Number of stalks, stalk length, stalk diameter, dry weight of plant parts, sugar content in cane stalks, yields of cane stalks, sugar and dry matter weight were measured at harvest. Stalks were cut at the point of attachment to the stalk of the fifth leaf from the flag leaf. The amount of sugar in cane juice was determined by liquid chromatography (Shimadzu LC 5A).

Root samples were taken at two growth stages, at the vegetative growth stage (June 20), and the maturing stage (October 20). The Auger method was employed to determine the spatial distribution of roots[6]. Hand operated auger consisting of a cylindrical tube of 15 cm length with an inside diameter of 7 cm was used. In each treatment, soil-root samples were replicated five times at 10 cm intervals up to 50 cm distance from the hill. Soil-root samples at five different soil cover depths (0-10, 10-20, 20-30, 30-40 and 40-50 cm depth) were taken with a core sampler of 5 cm in length from each sampling point (Fig. 1). Data were calculated for 10 cm soil cover depth. Due to the hardness of soil, sampling

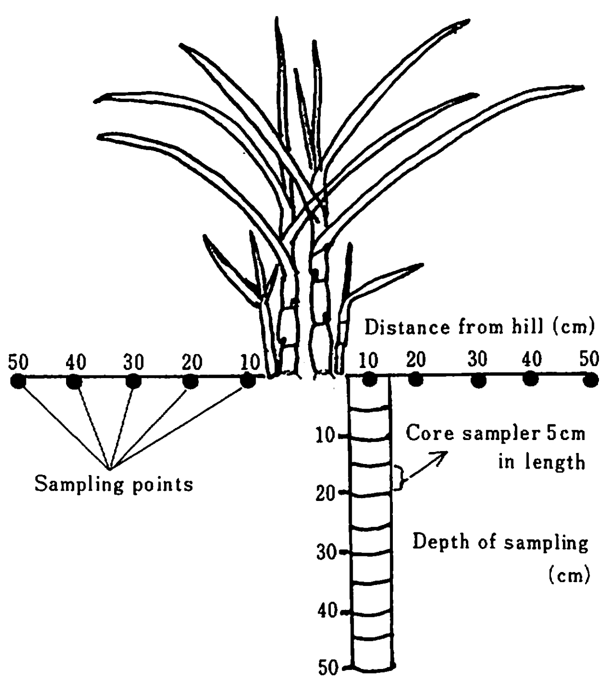

Fig. 1. Sampling scheme of root for the auger method.

was not possible below 50 cm soil cover depth. After washing with tap water, roots were separated from organic debris and their fresh weight was measured after drying with blotting-paper. Data were given as fresh root weight g 100^{-1} cc of soil.

Results

The data on germination, stalk number, stalk length, stalk diameter, stalk yield, sugar content in stalks and sugar yield are shown in Table 1. The highest germination of 72% was obtained from the SE application of 200 kg $10a^{-1}$, which exceeded the control significantly however, 400 and 800 kg $10a^{-1}$ were not found to be significant. Although insignificant, a tendency for increase in number of stalks and stalk diameter was observed in SE treated plots.

Different levels of SE increased the stalk length by 14-26%, and the largest value was obtained from the 800 kg $10a^{-1}$ SE treated plot. Significantly higher yield of stalk was obtained from the SE treated plots compared to the controls. The highest stalk yield of 11.4 kg m^{-2} was obtained from the 400 kg $10a^{-1}$ SE applied crop, which is 24% higher than that of the control.

Significantly higher sugar content in cane stalks was obtained from the SE treated plots compared to the control plots. The highest sugar content of 17.1% in stalks were obtained in 400 kg $10a^{-1}$ SE applied plots. Sugar yield in 400 kg $10a^{-1}$ SE treated plots were 31% higher than that of the control plots and it yielded about 1.95 kg m^{-2}.

Table 1. Effects of Sannekka E (SE) application on germination, yield contributing characters, stalk yield, sugar content and sugar yield of summer planted sugarcane.

SE levels (kg/10a)	Germination rate (%)	Stalk number ($\times 10^3$/10a)	Stalk length (cm)	Stalk diameter (c)	Stalk yield (kg/m²)	Sugar content (%)	Sugar yield (kg/m²)
Cont.	67b	10.0a	199c	2.2a	9.2b	16.2b	1.49d
	(100)	(100)	(100)	(100)	(100)	(100)	(100)
200	72a	11.0a	226b	2.3a	11.2a	16.8a	1.88 b
	(108)	(110)	(114)	(105)	(122)	(104)	(126)
400	70b	11.0a	242a	2.3a	11.4a	17.1a	1.95a
	(102)	(110)	(122)	(105)	(124)	(106)	(131)
800	70b	10.5a	251a	2.4a	10.4ab	17.0a	1.77c
	(102)	(105)	(126)	(109)	(113)	(105)	(119)

Means followed by a common letter are not significantly different at 5% level by Duncan's multiple range test. Figures in parentheses indicate percentage to the control.

Table 2. Dry matter production and distribution amongst plant parts at harvest of summer planted sugarcane grown under different levels of Sannekka E (SE) application.

SE levels (kg/10a)	Green leaves (g/m²)	Top and sheath (g/m²)	Trash (g/m²)	Stalk (g/m²)	Total (g/m²)
Cont.	330b	432b	618c	2600c	3980d
	(8.3)	(10.9)	(15.5)	(65.3)	(100)
200	335b	456a	649b	2850a	4290b
	(7.8)	(10.6)	(15.1)	(66.4)	(100)
400	364a	449a	707a	2880a	4400a
	(8.3)	(10.2)	(16.1)	(65.5)	(100)
800	335b	456a	629bc	2800b	4220c
	(7.9)	(10.8)	(14.9)	(66.4)	(100)

Means followed by a common letter are not significantly different at 5% level by Duncan's multiple range test. Figures in the parentheses indicate percent distribution of matter production among different plant parts.

Dry matter weight and their distribution among different plant parts are given in Table 2. Dry matter weight of each part of SE applied crops were higher than that of the controls.

The CGR, RGR, NAR and LAI at different growth stages are shown in Fig. 2. The CGR increased markedly in the SE treated crops compared with the control ones throughout the growing period. However, CGR in all the treatments continued increasing up to 330 DAP and declined afterwards. The highest CGR value of 15.85 g m^{-2} day^{-1} was obtained by SE application of 200 kg $10a^{-1}$, followed by

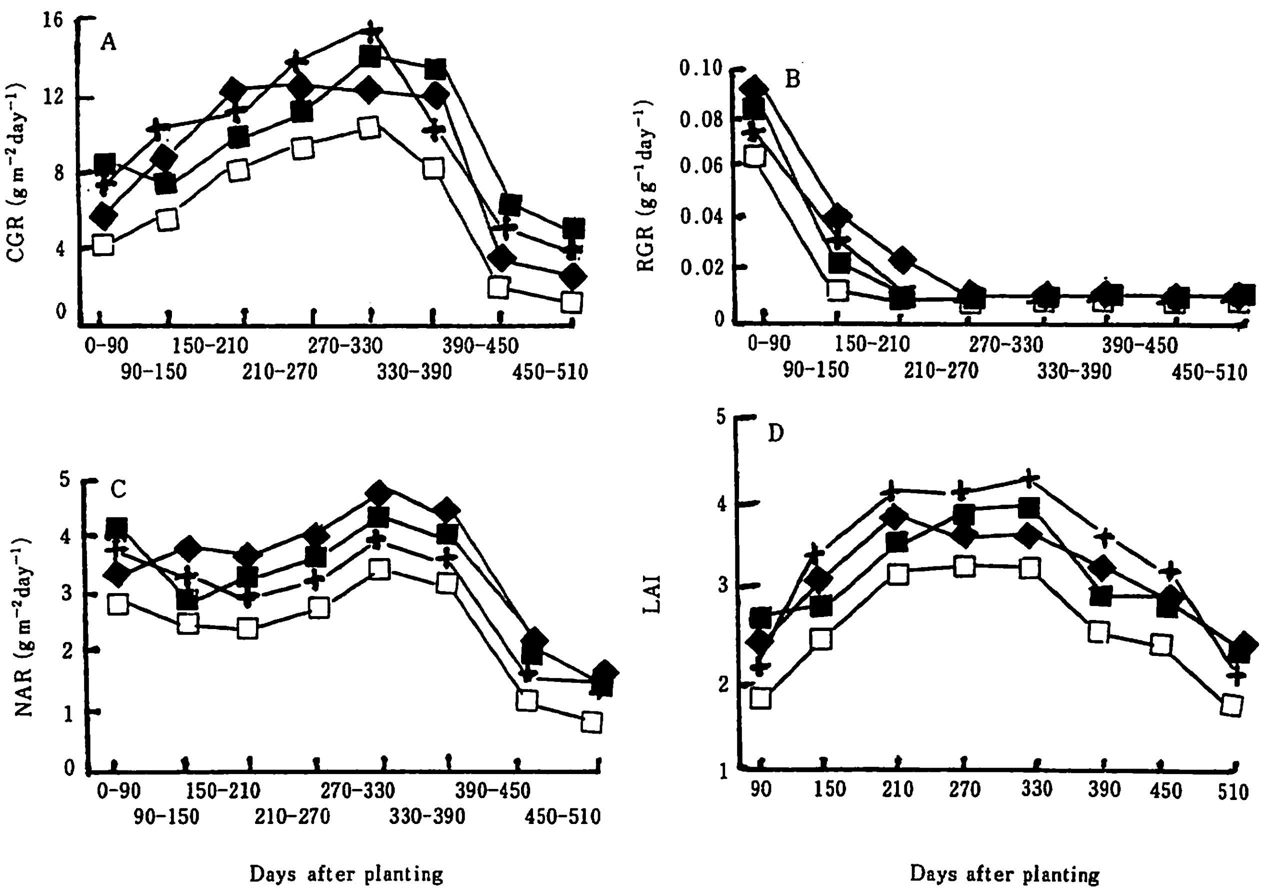

Fig. 2. Effects of Sannekka E application on CGR (A), RGR (B), NAR (C) and LAI (D) of summer planted sugarcane. □ : 0 (Control), + : 200, ■ : 400, ◆ : 800 (kg/10a Sannekka E).

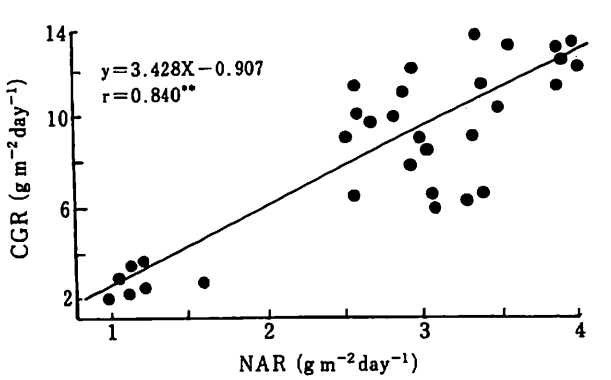

Fig. 3. Relationship between crop growth rate (CGR) and net assimilation rate (NAR) of summer planted sugarcane.
**indicates 1% level of significance.

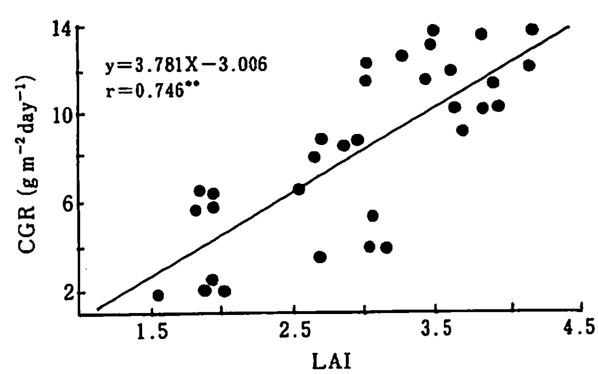

Fig. 4. Relationship between crop growth rate (CGR) and leaf area index (LAI) of summer planted sugarcane.
**indicates 1% level of significance.

the application of 400 kg $10a^{-1}$.

During the early growth stage, NAR in all treatments was almost static, at up to 210 DAP, and then increased up to 330 DAP, and thereafter gradually declined. LAI in all treatments continued increasing progressively up to 210 DAP, and then remained almost static up to 330 DAP, and thereafter gradually decreased. Higher values of LAI was obtained throughout the whole growing season in SE treated plots in comparison to the control plots. The highest LAI value of 4.4 was obtained from the 200 kg $10a^{-1}$ SE treated plots at 330 DAP.

Figure 3 shows the relationship between CGR and NAR of sugarcane. Significant correlation was observed with a coefficient of r= 0.840**. There was a significant correlation between CGR and LAI having a coefficient of r=0.746** (Fig. 4).

Root weight densities were highest at 10-20 cm depth in all the treatments throughout the growing season. Gradual decrease from the surface was noted in this respect. Vertical distribution of root volume in SE applied crop was higher than the control crop at all soil-cover depths (Fig. 5).

Horizontal distribution of roots in summer planted cane is presented in Fig. 6. Mean root weight density in June sampling showed

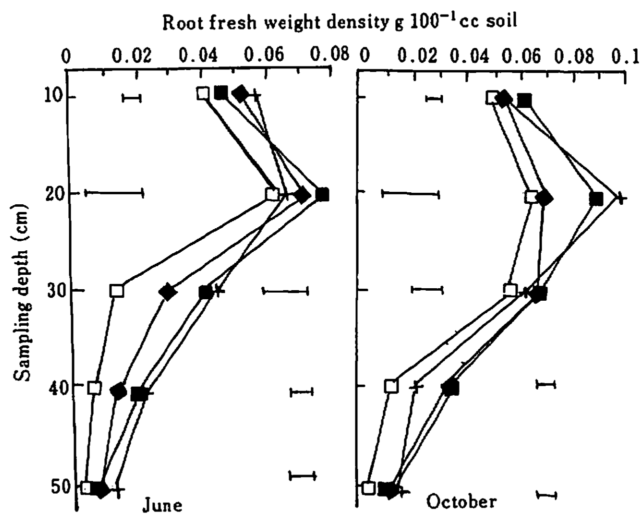

Fig. 5. Effect of Sannekka E (SE) application on vertical distribution of roots in summer planted sugarcane. □ : 0 (cont.), + : 200, ■ : 400 and ◆ : 800 (kg/10a SE). ⊢⊣: LSD ($P < 0.05$).

Table 3. Root weight density distribution in both vertical and horizontal direction expressed in percentage to the total amount of roots distributed.

Sannekka E level (kg/10 a)	Sampling time	Distribution pattern	Distance from soil surface/hill (cm) 0—10	10—20	20—30	30—40	40—50	Total
Cont.	June	Vertical	32	50	10	5	3	100
		Horizontal	41	26	18	10	5	100
	October	Vertical	25	35	31	6	3	100
		Horizontal	22	22	35	13	8	100
200	June	Vertical	27	35	22	10	6	100
		Horizontal	44	24	16	9	7	100
	October	Vertical	21	41	26	7	5	100
		Horizontal	19	32	26	13	10	100
400	June	Vertical	24	41	22	10	3	100
		Horizontal	34	34	17	10	5	100
	October	Vertical	22	36	25	15	2	100
		Horizontal	19	31	24	16	10	100
800	June	Vertical	31	40	18	7	4	100
		Horizontal	40	27	17	10	6	100
	October	Vertical	22	30	28	16	4	100
		Horizontal	19	31	30	10	10	100

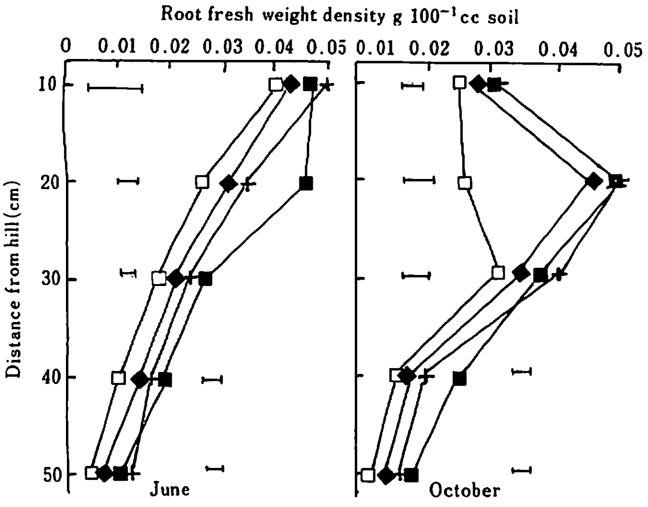

Fig. 6. Effect of Sannekka E (SE) application on horizontal distribution of roots in summer planted sugarcane. □ : 0 (cont.), + : 200, ■ : 400 and ◆ : 800 (kg/10a SE). ⊢⊣ : LSD ($P < 0.05$).

maximum value near the hill and then decreased gradually with distance from the hill in all the treatments. On the contrary, root volume in October sampling was highest between 10 and 20 cm distance from the hill in all the SE treated plots. At both the vegetative growth stage and maturing satge, the average root weight density under SE application was significantly larger than the control ($P < 0.05$). The results reveal that the root system was well developed in a vertical direction in SE treated plots (Table 3).

Discussion

Soil factors, like temperature, moisture, aeration and other physical factors have a great influence on germination of sugarcane seeds and root development, which can be enhanced by management practices, like the application of fertilizers and organic matter[8]. In the present study, higher germination of seeds and greater number of stalks were obtained from the SE treated crops than that of the control crops. The increased stalks seemed to be due to the positive effect of SE on tiller production and prevention of tiller mortality. This result confirmed our previous studies, where higher stalks were obtained by SE treated spring planted crops of sugarcane[11].

Stalk length and stalk diameter are one of the important yield contributing factors[8]. Variation in stalk length, stalk diameter, stalk yield and sugar yield of sugarcane between the SE treated and control crops were noted.

The results of this study confirmed the higher rate of dry matter production in sugarcane with the application of SE[11]. The increased weight of cane and dry matter were obtained due to the higher number of stalks with a larger stalk length and diameter. The increased sugar content in stalks in SE treated crops may be due to the beneficial effects of SE as has been stated by Tsuzuki et al.[17] and Uddin et al.[18,19].

Results of growth analysis indicated significant importance of CGR in sugar and cane yields. Furthermore, the possibility of increased CGR was due to the higher LAI especially, up to 210 DAP and NAR from 210 -330 DAP. Amano et al.[1] considered NAR and LAI to be important factors in improving CGR, consequently dry matter production is further enhances. In the present experiment, SE treated crops gave higher values of NAR and LAI, particularly from the premature growth stage to final harvest. Positive correlation between CGR and NAR; and CGR and LAI were obtained. This increased NAR and LAI contributed in enhancing CGR and this eventually resulted in higher yield.

The exact cause of SE accelerated growth and dry matter production in the shoot of sugarcane in SE treated plots is not known clearly yet. However, it is assumed that the SE applied cane had higher root weight densities than the control crops. Thus it seemed that SE influenced production of sufficient roots to provide water and nutrients for the extended shoot. This concept is supported by Tsuzuki et al.[16], who found more new crown roots and branch roots in SE treated rice plant. Murayama et al.[12] reported that acceleration of root growth resulted in higher shoot growth in SE treated sugarcane in pot culture. Moreover, when we consider the spatial distribution of roots in field culture, root could be grown more vigorously due to natural conditions. In this experiment, both vertical and horizontal distribution and average weight density of roots in the SE treated plots showed higher value than the controls. This weight could be caused by the application of SE, which promoted both the formation and elongation of roots. This is in agreement with Murayama et al.[13] and Tsuzuki et al.[16]. Moreover, root spatial distribution is important because it influences uptake of water and nutrients[9,10,14].

Results of this experiment demonstrate that higher root production and well-developed root system of sugarcane under SE application contributes towards the ability of the plant to produce more vegetative growth resulting in higher dry matter and sugar yield.

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* In Japanese with English abstract.

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