

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Crop water requirement, rainfall, and irrigation consumption

The crop water requirement, rainfall, and irrigation water in PC (PC) are shown in Table 4.1 for sandy clay loam soil (SCL soil) and Table 4.2 for loamy sand soil (LS soil), and those of the 1st ratoon crop (FRC) are shown in Table 4.3 (SCL) and Table 4.4 (LS).

In SCL soil, the crop water requirements of all crop practices were similar in PC and FRC (about 1,200 mm) (Table 4.1 and Table 4.3). The rainfall and effective rain in FRC were higher than in the PC. Therefore, low effective rain established higher irrigated water in PC (1,140 mm) than in FRC (815 mm).

In LS soil, the crop water requirement in PC and FRC were similar to in SCL soil, the crop required about 1,200 mm of water (Table 4.2 and Table 4.4). The rainfall and effective rain were higher in PC (994 and 532 mm) than in FRC (591 and 315 mm). However, the actual amount of irrigation water was higher in PC (402 mm) than in FRC (342 mm) due to the inadequate water stock in FRC.

Table 4.1 Crop water requirement, rainfall, and irrigation water in PC in SCL soil.

Month	Crop requirement (mm)	Rainfall (mm)	Effective rain (mm)	Irrigation (mm)
January	33.0	–	–	32.9
February	74.0	3.00	2.10	74.5
March	117	5.00	3.50	117
April	157	15.0	10.5	157
May	176	83.0	58.1	175
June	185	28.0	19.6	184
July	156	30.0	21.0	148
August	141	121	42.0	99.0
September	94	152	76.1	24.8
October	70.0	24.0	16.8	70.3
November	55.0	5.00	3.50	54.8
Total (mm)	1,258	466	253	1,140

Table 4.2 Crop water requirement, rainfall, and irrigation water in PC in LS soil.

Month	Crop requirement (mm)	Rainfall (mm)	Effective rain (mm)	Irrigation (mm)
January	94.0	–	–	12.5
February	118.0	3.10	2.20	22.4
March	143.0	4.30	3.00	87.5
April	169.0	59.4	41.6	62.5
May	185.0	158	102	37.5
June	144.0	98.0	51.0	37.5
July	123.0	112	78.7	25.0
August	104.0	292	121	25.0
September	64.0	183	74.1	50.0
October	58.0	80.3	56.2	25.0
November	79.0	3.10	2.20	16.7
Total (mm)	1,281	994	532	402

Table 4.3 Crop water requirement, rainfall, and irrigation water in FRC in SCL soil.

Month	Crop requirement (mm)	Rainfall (mm)	Effective rain (mm)	Irrigation (mm)
February	38.5	–	–	37.0
March	88.5	4.0	2.8	83.0
April	119.7	36.0	25.2	99.0
May	147.1	70.0	49.0	99.0
June	160.0	62.0	43.4	124.0
July	188.1	123.0	69.0	124.0
August	151.6	42.0	29.4	124.0
September	121.0	240.0	122.2	25.0
October	103.8	200.0	129.3	25.0
November	66.3	7.0	4.9	50.0
December	26.3	–	–	25.0
Total (mm)	1,211	784	475	815

Table 4.4 Crop water requirement, rainfall and irrigation water in FRC in LS soil.

Month	Crop requirement (mm)	Rain fall (mm)	Effective rain (mm)	Irrigation (mm)
February	46.0	–	–	8.3
March	82.0	9.30	6.50	13.3
April	108	42.6	29.8	45.3
May	134	50.0	35.0	53.3
June	151	39.0	27.3	106.7
July	160	60.0	42.0	114.9
August	144	9.00	6.30	–
September	121	242	106	–
October	103	139	61.5	–
November	77.0	–	–	–
December	68.0	–	–	–
Total (mm)	1,236	591	315	342

4.2 First year experiment : Effects of fertilizer application and irrigation method on growth and yield of sugarcane.

4.2.1 Sugarcane growth parameters in PC

The sugarcane growth parameters including the number of shoots, plant height, leaf SPAD chlorophyll meter reading (leaf SCMR), and Leaf area index (LAI) were measured in both soil textures at 2, 4, and 6 month after planting (MAP).

1) Number of shoots

The number of shoots in each soil texture is presented in Table 4.5 for SCL soil, Table 4.6 for LS soil, and Table 4.7 for soil texture and treatment combination.

In SCL soil, the treatments significantly affected the number of shoots, the highest number of shoots was found in T3 at 2, 4 and 6 MAP, (13,907, 24,093 and 14,722 shoots/rai) compared with T2 (10,722, 21,926 and 12,315 shoots/rai) and T1 (9,796, 16,907 and 11,500 shoots/rai), respectively.

Table 4.5 Effects of irrigation and fertigation on the number of shoots in SCL soil.

Treatment	Number of shoots (shoots/rai)		
	2 MAP	4 MAP	6 MAP
T1: Rainfed condition	9,796 ^b	16,907 ^c	11,500 ^b
T2: Drip irrigation + soil fertilizer	10,722 ^b	21,926 ^b	12,315 ^b
T3: Drip fertigation	13,907 ^a	24,093 ^a	14,722 ^a
CV (%)	10.64	3.66	3.72

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, the highest number of shoots was found in T3 at 2, 4 and 6 MAP (18,574, 22,148 and 11,556 shoots/rai) compared with T2 (13,037, 18,222 and 10,963 shoots/rai) and T1 (11,648, 15,500 and 10,309 shoots/rai), respectively.

Table 4.6 Effects of irrigation and fertigation on number of shoots in LS soil.

Treatment	Number of shoots (shoots/rai)		
	2 MAP	4 MAP	6 MAP
T1: Rainfed condition	11,648 ^b	15,500 ^b	10,309 ^b
T2: Drip irrigation + soil fertilizer	13,037 ^b	18,222 ^{ab}	10,963 ^{ab}
T3: Drip fertigation	18,574 ^a	22,148 ^a	11,556 ^a
CV (%)	13.92	14.14	3.95

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The combined effects of site and treatment on number of shoots was evaluated. In general, the soil textures affected number of shoots i.e., the average number of shoot in SCL soil was higher (14,420, 20,975 and 12,846 shoot/rai) than in LS soil (11,474, 18,623 and 10,942 shoots/rai) at 2, 4 and 6 MAP, respectively. The average number of shoots was also significantly different among the treatments, T3 produced the highest number of shoots at 2, 4 and 6 MAP (16,241, 23,120 and 13,139 shoots/rai) compared with T2 (11,880, 20,074 and 11,639 shoots/rai) and T1 (10,722, 16,204 and 10,904 shoots/rai), respectively.

Table 4.7 Combined effects of site and fertigation on the number of shoots.

Variable	Number of shoots (shoots/rai)		
	2 MAP	4 MAP	6 MAP
Site (A)	**	*	**
SCL soil	14,420 ^a	20,975 ^a	12,846 ^a
LS soil	11,474 ^b	18,623 ^b	10,942 ^b
Treatment (B)	**	**	**
T1: Rainfed condition	10,722 ^b	16,204 ^b	10,904 ^c
T2: Drip irrigation + soil fertilizer	11,880 ^b	20,074 ^a	11,639 ^b
T3: Drip fertigation	16,241 ^a	23,120 ^a	13,139 ^a
Site * Treatment	ns	ns	**
CV (%)	7.50	7.17	4.12

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

2) Plant height

The plant height in each soil texture is shown in Table 4.8 for SCL soil, Table 4.9 for LS soil, and Table 4.10 for soil texture and treatment combination. In SCL soil, the treatment significantly affected sugarcane height. The highest plant height at 2, 4, and 6 MAP was found in T3 (22.1, 96.5, and 163.9 cm) compared with T2 (16.4, 73.9, and 156.0 cm) and T1 (13.7, 46.2, and 89.9 cm), respectively.

Table 4.8 Effects of irrigation and fertigation on plant height in SCL soil.

Treatment	Plant height (cm)		
	2 MAP	4 MAP	6 MAP
T1: Rainfed condition	13.7 ^c	46.2 ^c	89.9 ^b
T2: Drip irrigation + soil fertilizer	16.4 ^b	73.9 ^b	156.0 ^a
T3: Drip fertigation	22.1 ^a	96.5 ^a	163.9 ^a
CV (%)	6.71	7.45	4.83

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, the highest plant height at 2, 4, and 6 MAP was significantly different among the treatments, T3 produced the highest plant height (13.9, 37.5, and

176 cm) compared to T2 (12.0, 27.9, and 159 cm) and T1 (9.8, 19.1 and 114 cm), respectively.

Table 4.9 Effects of irrigation and fertigation on plant height in LS soil.

Treatment	Plant height (cm)		
	2 MAP	4 MAP	6 MAP
T1: Rainfed condition	9.8 ^b	19.1 ^b	114 ^b
T2: Drip irrigation + soil fertilizer	12.0 ^{ab}	27.9 ^{ab}	159 ^a
T3: Drip fertigation	13.9 ^a	37.5 ^a	176 ^a
CV (%)	7.78	10.74	6.05

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The combined effects of site (A) and treatments (B) on plant height was presented in Table 4.10. For soil texture (A), the plant height was significantly different between the soil textures. The plant height in SCL soil (17.4, 72.2, and 150 cm) was greater than in LS soil (11.9, 28.2, and 137 cm) at 2,4 and 6 MAP, respectively. For treatment (B), the treatments also significantly affected plant height, T3 produced the highest plant height at 2,4 and 6 MAP (17.9, 67.0, and 170 cm) compared with T2 (14.2, 50.9 and 157 cm) and T1 (11.7, 32.6 and 102 cm), respectively.

Table 4.10 Combined effects of site and fertigation on plant height.

Variable	Plant height (cm)		
	2 MAP	4 MAP	6 MAP
Site (A)	**	**	*
SCL soil	17.4 ^a	72.2 ^a	150 ^a
LS soil	11.9 ^b	28.2 ^b	137 ^b
Treatment (B)	**	**	**
T1: Rainfed condition	11.7 ^c	32.6 ^c	102 ^b
T2: Drip irrigation + soil fertilizer	14.2 ^b	50.9 ^b	157 ^a
T3: Drip fertigation	17.9 ^a	67.0 ^a	170 ^a
Site * Treatment	*	**	ns
CV (%)	9.75	10.16	8.41

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

4.2.2 LAI and leaf SCMR

LAI and leaf SCMR at 4 MAP in each soil texture are presented in Table 4.11 for SCL soil, Table 4.12 for LS soil, and Table 4.13 for soil texture and treatment combination.

In SCL soil, the sugarcane management significantly affected LAI and leaf SCMR. The highest LAI and leaf SCMR (6.11 and 44.7) at 4 MAP was produced in T3, compared with T2 (5.31 and 38.1) and T1 (2.62 and 34.2), respectively.

Table 4.11 Effects of irrigation and fertigation on LAI and leaf SCMR at 4 MAP in SCL soil.

Treatment	LAI	Leaf SCMR (SPAD unit)
T1: Rainfed condition	2.62 ^b	34.2 ^c
T2: Drip irrigation + soil fertilizer	5.31 ^a	38.1 ^b
T3: Drip fertigation	6.11 ^a	44.7 ^a
CV (%)	11.03	2.72

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, the highest LAI and leaf SCMR 4 MAP were recorded in T3 (4.16 and 41.6) compared to T2 (2.95 and 39.2) and T1 (1.58 and 37.7), respectively. The similar result was found in SCL soil.

Table 4.12 Effects of irrigation and fertigation on LAI and leaf SCMR at 4 MAP in LS soil.

Treatment	LAI	Leaf SCMR (SPAD unit)
T1: Rainfed condition	1.58 ^b	37.7 ^b
T2: Drip irrigation + soil fertilizer	2.95 ^a	39.2 ^{ab}
T3: Drip fertigation	4.16 ^a	41.6 ^a
F-test	**	*
CV (%)	9.52	3.42

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The combination effects of site (A) and treatments (B) on LAI and leaf chlorophyll are presented in Table 4.13. For soil texture (A), the LAI was significantly different between the soil textures. The LAI at 4 MAP of SCL soil (4.50) was greater than of the LS soil (2.79). In contrast, the leaf SCMR was not affected by the soil textures. For treatment (B), the LAI and leaf chlorophyll were significantly different among the crop managements. The highest LAI and chlorophyll at 4 MAP were found in T3 (5.06 and 43.2) compared to T2 (4.04 and 38.7) and T1 (2.04 and 35.9), respectively.

Table 4.13 Combined effects of site and fertigation on LAI and leaf SCMR.

Variable	LAI	Leaf SCMR (SPAD unit)
Site (A)	**	ns
SCL soil	4.50 ^a	39.0
LS soil	2.79 ^b	39.5
Treatment (B)	**	**
T1: Rainfed condition	2.04 ^c	35.9 ^c
T2: Drip irrigation + soil fertilizer	4.04 ^b	38.7 ^b
T3: Drip fertigation	5.06 ^a	43.2 ^a
Site * Treatment	ns	**
CV (%)	9.48	3.11

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The overall results found that, in the irrigated treatments (T2 and T3), all growth parameters including plant height, shoot numbers, LAI and leaf SCMR were significantly higher than in the rainfed practice (T1) in both soils.

The LAI are important growth parameters as they are directly related to photosynthesis. LAI value means light-receiving area in the plant which relates to the rate of photosynthesis. In this study, the result showed that the rainfed treatments in both locations (SCL and LS soil) which faced high risk of water stress had the less LAI than the drip irrigation treatments since the water stress was the cause of reduction in leaf expansion and tiller production.

The findings was in agreement with Yadav and Prasad (1988) who studied the responses of three sugarcane genotypes to water application and found that the LAI was greater in the well irrigated condition, and it decreased significantly with the water stress condition. Similarly, Begum et al. (2012) studied 6 different genotypes of sugarcane under 4 watering methods and found that the highest LAI decline was found in water stress condition. (Kawakami et al., 2006) also demonstrated that water stress caused an inhibiting leaf area of plants.

The SPAD chlorophyll meter reading (SCMR) was a tool which used for measuring leaf chlorophyll and indirectly assessing to leaf nitrogen status. Htoon et al.(2019) and Richardson et al. (2002) found that the SCMR was closely related to chlorophyll content and chlorophyll density. In this study, the results showed that rainfed conditions at high risk of drought stress had less SCMR than the drip irrigation treatments, as drought stress was a major factor in reducing chlorophyll activity, photosynthesis rate and growth. A similar study by Chumphu et al. (2019) found that the sugarcane had less SCMR than water sufficient condition in drought stress condition. Jangpromma et al. (2012) found that in 4 sugarcane cultivar, the leaf chlorophyll was reduced by drought stress condition more than water sufficient condition.

The reduction in LAI and SCMR under rainfed treatment was positively related to the reduction in shoot population and plant height in sugarcane production. A similar result was reported by Radhamani et al. (2015) who demonstrated that the leaf SCMR had significantly correlated to leaf chlorophyll content, yield, and number of millablecane (NMC) of sugarcane. Khonghintaisong et al. (2017) found that the increase of leaf SCMR was positively correlated with the daily plant height increasing, it also positively correlated to stalk production.

The overall results are in agreement of other studies such as Wonprasaid and Girdthai (2014) who reported that the irrigation treatments established higher germination and growth than no irrigation treatment. Under limited water supply (no irrigation practice) sugar cane growth was limited by reducing the length of internode, stalk germination, and biomass accumulation (Jangpromma et al., 2012 and Khonghintaisong et al., 2017).

The effect of fertilizer on sugarcane growth was related to irrigation or cultural practice. The results showed that among drip irrigation treatments, fertigation (T3) exhibited higher sugarcane growth than the soil application treatment (T2). As the soil application is a solid form of fertilizer applied, it is low efficient due to many factors such as absorbing by the soil particle, washing by the heavy rain, and vaporizing. Moreover, for the soil application, fertilizer is applied twice due to the limited labor cost, whereas for fertigation, fertilizer can be applied several times. Therefore, the fertilizer with fertigation was more uniform with less concentration at the plant root zone compared to soil application which reduced the risk of nutrient loss, especially N fertilizer (Shedeed et al., 2009).

For soil texture, the soil environment is one of major the factors affecting sugarcane growth and yield. This study founded that the SCL was better than LS soil regarding sugarcane performance. The chemical composition and physical properties of different soils affect the nutrient uptake of the plant (Begum et al., 2016). In this study, SCL was soil with higher fertility soil compared to LS soil. Moreover, SCL soil had higher water holding capacity resulting in better water and nutrient holding which consequently caused less water and nutrient loss when compared to LS (Johnston and Bruulsema, 2014).

4.2.3 Leaf tissue nutrient of sugarcane

Leaf nutrient analysis is shown in Table 4.14 for SCL soil and Table 4.15 for LS soil. In SCL soil, leaf N, K and Mg were significantly different, while P and Ca were not significantly different among the treatments. The highest N and K content in leaf tissue was found in T3 but the highest Mg content was found in T1.

In LS soil, all leaf nutrients had not significantly different among treatments.

Table 4.14 Effects of irrigation and fertigation on leaf nutrients in SCL soil at 6 MAP.

Treatments	Nutrient content (%)				
	N	P	K	Ca	Mg
T1	1.14 ^b	0.147	1.20 ^b	0.773	0.253 ^a
T2	1.20 ^{ab}	0.158	1.40 ^{ab}	0.800	0.195 ^{ab}
T3	1.27 ^a	0.141	1.68 ^a	0.648	0.113 ^b
Sufficient level (%)	2.00–2.60	0.22–0.30	1.00–1.60	0.22–0.45	0.15–0.32
CV (%)	6.24	11.48	15.20	13.58	30.17

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

Table 4.15 Effects of irrigation and fertigation on leaf nutrients in LS soil at 6 MAP.

Treatments	Nutrient (%)				
	N	P	K	Ca	Mg
T1	1.45	0.127	1.22	1.29	0.780
T2	1.43	0.111	1.09	1.09	0.708
T3	1.37	0.116	1.04	1.09	0.715
Sufficient level (%)	2.00–2.60	0.22–0.30	1.00–1.60	0.22–0.45	0.15–0.32
CV (%)	3.88	7.88	16.69	12.34	13.77

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The result of nutrient analysis established a significant difference between soil textures. In SCL soil, N and K content increased by drip irrigation treatments (T2 and T3) compared to the rainfed treatment (T1). Comparing between fertilizer application treatments, the leaf N and K tended to be higher in fertigation than in soil application treatment. In contrast, the Mg content showed the opposite trend, while P and Ca were not significantly different among the treatments. In LS soil, all of the nutrients were not different among the treatments. Even though the nutrient contents were not significantly different among the treatments, the total nutrients uptake would be higher in the irrigation treatments as they had more biomass than the rainfed treatment (predict from the yield and yield component) (Table 4.17).

In SCL soil, the higher leaf N and K contents in fertigation treatment (T3) than in soil application treatments (T1 and T2) indicated more N and K uptake under fertigation. More N and K uptake in fertigation was probably due to N and K fertilizer was readily dissolved and immediately uptake by the roots. While in the soil application treatments, N and K were in the solid form of fertilizer which was hardly dissolved in the soils with low or uneven moisture under rainfed and drip irrigation in the normal conditions. When there is too heavy rain, N and K are also easily loss by deep percolation. The results were similar to other researches such as Sinworn (2014) and (Xie, 2018) who reported that cassava leaf N and K concentration under fertigation was higher than under soil application.

Leaf tissue nutrients of sugarcane in this study were lower than the sufficient levels reported by Anderson and Bowen (1990) and McCray et al. (unpublished) who studied and recommended in Louisiana, USA.

The lower leaf nutrients in this study were probably due to the differences in sugar cane varieties and environments.

4.2.4 Yield and yield components

Yield and yield components at 12 MAP are shown in Table 4.16 for SCL soil, Table 4.17 for LS soil, and Table 4.18 for site and treatment combination.

In SCL soil, the treatments significantly affected the sugarcane yield and yield components. NMC, plant height, and cane yield of T3 were the highest (14,667 canes/rai, 299 cm, and 27.6 tons/rai) and those of T1 were the lowest (11,056 canes/rai, 191 cm, and 15.5 tons/rai), respectively. While the cane diameter showed the opposite result i.e. the cane diameter of T1 was the highest (27.8 mm) and T3 was the lowest (25.0 mm), respectively. The total soluble solid (TSS) was not significantly different among treatments

Table 4.16 Effects of irrigation and fertigation on yield and yield components at 12 MAP in SCL soil.

Treatment	NMC (canes/rai)	Plant height (cm)	Cane diameter (mm)	Yield (tons/rai)	TSS (°Brix)
T1	11,056 ^c	191 ^c	27.8 ^a	15.5 ^c	22.3
T2	12,204 ^b	265 ^b	27.0 ^a	21.5 ^b	22.5
T3	14,667 ^a	299 ^a	25.0 ^b	27.6 ^a	22.8
CV (%)	3.06	5.76	2.56	4.61	2.26

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, NMC, plant height, and cane yield were significantly different among treatments (Table 4.17). T3 showed the highest values of NMC, plant height and yield (11,037 canes/rai, 316 cm and 17.3 tons/rai) compared with T2 (10,148 canes/rai, 299 cm and 16.2 tons/rai) and T1 (9,432 canes/rai, 246 cm and 12.5 tons/rai), respectively. While the cane diameter and TSS were not affected by the irrigation and fertigation.

Table 4.17 Effects of irrigation and fertigation on yield and yield components at 12 MAP in LS soil.

Treatment	NMC (canes/rai)	Plant height (cm)	Cane diameter (mm)	Yield (tons/rai)	TSS (°Brix)
T1	9,432 ^b	246 ^b	29.9	12.5 ^b	20.3
T2	10,148 ^{ab}	299 ^a	27.8	16.2 ^a	21.5
T3	11,037 ^a	316 ^a	26.9	17.3 ^a	21.4
CV (%)	5.55	4.93	4.88	11.11	6.27

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The site and treatment combined analysis (Table 4.18) indicated that cane yield (20.4 ton/rai), NMC (12,919 stalk/rai) plant height (287 cm), and brix (22.5 %) in SCL

soil were higher than in LS soil. However, the cane diameter in LS (28.2 mm) was higher than in SCL soil. While the highest yield (22.4 tons/rai), the NMC (12,898 stalk/rai) plant height (308, 282), and brix (22.5%) were found in drip fertigation treatment (T3) and the lowest was in rainfed treatment (T1). Whereas the highest cane diameter (28.9 mm) was exhibited in the rainfed treatment (T1) and the brix was not significantly different among the treatments.

For the combination effects on yield and yield component in PC, the interaction of yield is shown in Fig. 4.1. For site, SCL had greater yield than in LS soil. For treatments, well irrigated practices (T2 and T3) had not significantly different on yield in LS soil, but 2 in SCL, T3 tended to produce more yield than T2 and T1, respectively.

The interaction effect of plant height is shown in Fig 4.2. For site, well irrigated treatments in LS (T2 and T3) had not significantly different in plant height, but in SCL T3 had higher plant height than T2 and T1, respectively. However, the result of plant height in both site (SCL and LS soil) showed that T3 tended to have the highest plant height while T1 tended to have the lowest.

The interaction effect of NMC is shown in Fig 4.3. For site, NMC was produced in SCL soil more than in LS soil. However, the treatments in both site affected the similar result, NMC was produced in T3 more than in T2 and T1, respectively.

Table 4.18 The interaction effects of site and fertigation on yield and components.

Variable	NMC (canes/rai)	Plant height (cm)	Cane diameter (mm)	Yield (tons/rai)	TSS (°Brix)
Site (A)	**	**	*	**	*
SCL soil	12,919 ^a	252 ^b	2.67 ^b	20.4 ^a	22.5 ^a
LS soil	9,897 ^b	287 ^a	2.82 ^a	15.4 ^b	21.8 ^b
Treatment (B)	**	**	*	**	ns
T1	10,243 ^c	218 ^c	2.89 ^a	13.1 ^c	22.0
T2	11,083 ^b	282 ^b	2.74 ^{ab}	18.3 ^b	22.2
T3	12,898 ^a	308 ^a	2.60 ^b	22.4 ^a	22.3
Site * Treatment	**	*	ns	**	ns
CV (%)	5.21	2.94	5.81	7.70	3.03

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$

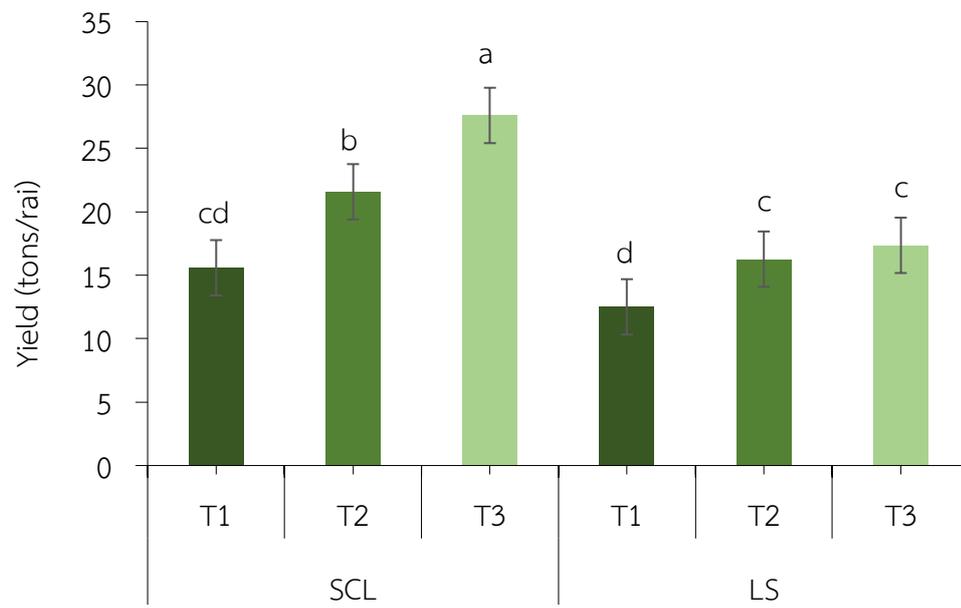


Figure 4.1 Interaction effects of site and fertigation on yield.

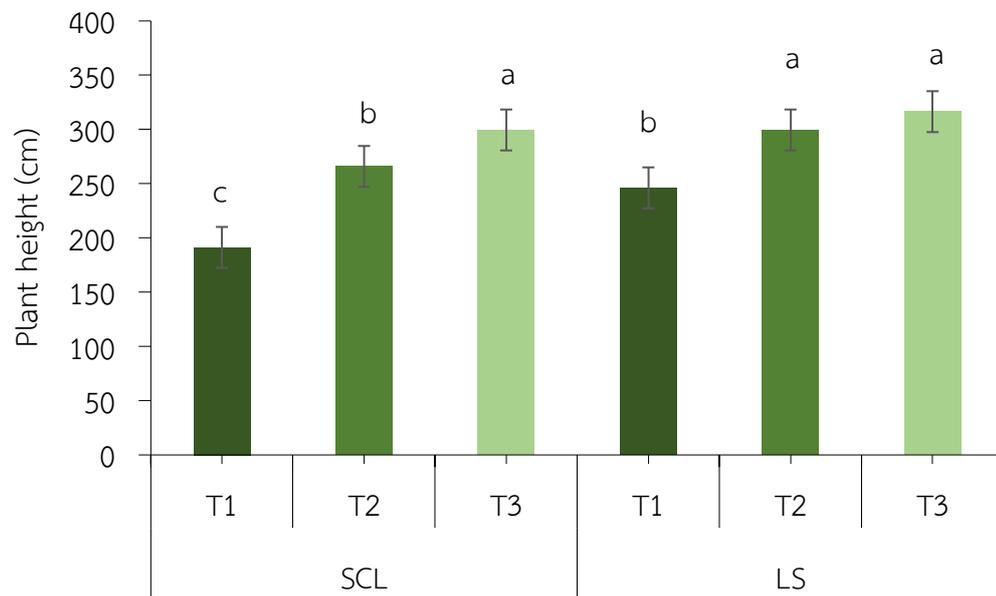


Figure 4.2 Interaction effects of site and fertigation on plant height.

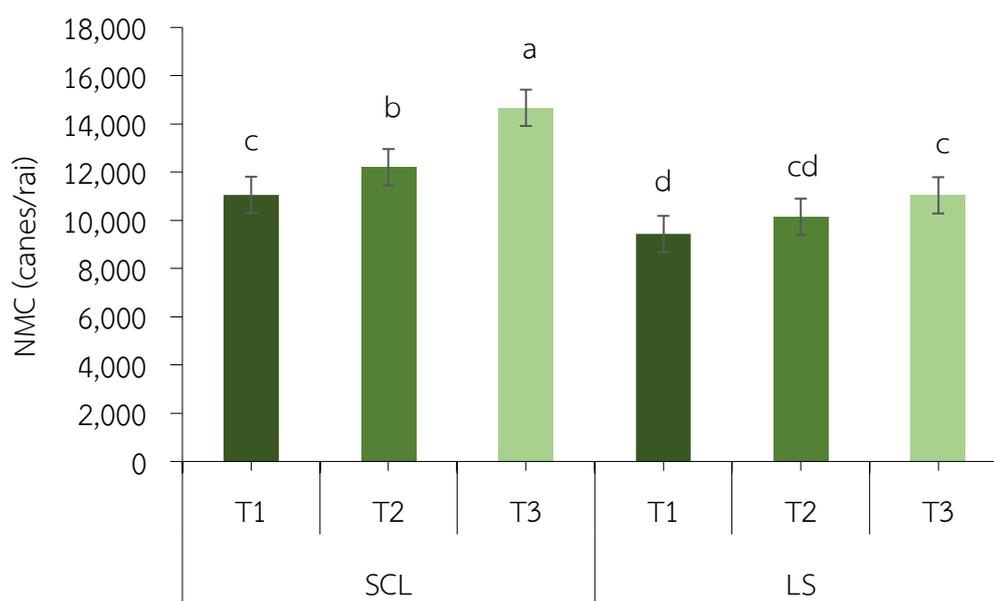


Figure 4.3 Interaction effects of site and fertigation on the NMC.

The results of yield and yield components in both soils were shown in the same direction i.e., yield and yield components in the drip irrigation treatments (T2 and T3) were higher than the rainfed practice (T1). As the drip-irrigated crop received water to meet the crop water requirement resulting to higher growth rate than the rainfed sugarcane (see the result of sugarcane growth parameter). In addition, drip irrigation also improved soil nutrient availability and increase crop nutrient uptake. The result was similar to other studies such as Wonprasaid and Girdthai (2014) who studied long term effects of irrigation on sugarcane production and found that irrigation improved the yield and yield components in sugarcane compared to the rainfed practice. Moreover, they reported that the irrigation treatment improved the ratooning periods more than 5 crops compared to 3 crops in the rainfed practice. Thong-ob (2013) who studied the effects of irrigation on cassava and found that non irrigated cassava established lower growths, yield, and yield components than irrigated treatment. In his experiment, the yield of cassava increased from 3.78 kg/plant in non-irrigated cassava to 6.40 kg/plant in irrigated cassava. The results were also supported by other studies such as Wiedenfeld and Enciso (2008) who found that the biomass of sugarcane increased when the water was sufficient and Rodrigues et al. (2009) who reported that the deficit condition

caused the reduction in the productivity of sugarcane including growth, yield, and quality. In addition, Khonghintaisong et al. (2017) reported that the water stress condition reduced the stomatal conductance and relative water content in the leaf which resulted to the reduction of biomass accumulation and yield.

Comparing between the drip irrigation treatments, it was found that the drip fertigation (T3) established higher yield and yield components than the soil application (T2 and T1). In fertigation, soluble fertilizer is normally applied several times with the low fertilizer concentration and directly to the root zone. This practice can prevent fertilizer loss due to deep percolation (under heavy rain) and fixation by soil particles and other minerals. In this study, in fertigation, fertilizer was equally applied 7 time during 1 MAP to 5 MAP, while in soil application, fertilizer was applied two times at 1 and 3 MAP. The more application frequency was the lower concentration of fertilizer which results to low chance of fertilizer loss from deep percolation and fixation. Moreover, the readily soluble nutrients under fertigation promotes the rate of nutrient uptake by sugarcane roots while the solid fertilizer application, nutrient uptake is dependent on the availability of soil water.

4.2.5 Irrigation water use efficiency (IWUE).

The IWUE was not significantly affected by the irrigation practices in LS soil, but T3 tended to have higher IWUE than T2. While in SCL soil, T3 produce higher IWUE (0.015 tons/m³) than in T2 (0.012 tons/m³) (Table 4.19).

Table 4.19 Effects of irrigation and fertigation on IWUE of sugarcane.

Source of variations	IWUE	
	(tons/m ³)	
Treatment	LS soil	SCL soil
T1: Rainfed condition	–	–
T2: Drip irrigation + soil fertilizer	0.025	0.012 ^b
T3: Drip fertigation	0.027	0.015 ^a
T-test	ns	**

Means within the same column labeled with the same letters indicate statistically significant differences with paired sample T-test.

4.2.6 Fertilizer nutrient use efficiency (FNUE).

FNUE including N, P, and K at 12 MAP of SCL, and LS soils are shown in Tables 4.20 and 4.21, respectively, and the combined effects are in Table 4.22.

In SCL soil, the treatments significantly affected FNUE. T3 produced the highest N, P, and K use efficiency (1.69, 2.26, and 1.09 tons/kg) compared with T2 (1.26, 1.69, and 0.81 tons/kg) and T1 (0.85, 1.14, and 0.55 tons/kg), respectively.

Table 4.20 Effects of irrigation and fertigation on FNUE at 12 MAP in SCL soil.

Treatment	FNUE (tons/kg)		
	N	P ₂ O ₅	K ₂ O
T1: Rainfed condition	0.85 ^c	1.14 ^c	0.55 ^c
T2: Drip irrigation + soil fertilizer	1.26 ^b	1.69 ^b	0.81 ^b
T3: Drip fertigation	1.69 ^a	2.26 ^a	1.09 ^a
CV (%)	6.45	6.45	6.45

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, the FNUE was also significantly different among the treatments, T3 produced the highest N, P and K use efficiency (0.80, 1.09 and 0.50 tons/kg) compared with T2 (0.74, 1.01 and 0.47 tons/kg) and T1 (0.57, 0.78 and 0.36 tons/kg), respectively.

Table 4.21 Effects of irrigation and fertigation on FNUE at 12 MAP in LS soil.

Treatment	FNUE (tons/kg)		
	N	P ₂ O ₅	K ₂ O
T1: Rainfed condition	0.570 ^b	0.78 ^b	0.360 ^b
T2: Drip irrigation + soil fertilizer	0.740 ^a	1.01 ^a	0.470 ^a
T3: Drip fertigation	0.800 ^a	1.09 ^a	0.500 ^a
CV (%)	11.11	11.11	11.11

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

For interaction effects, it had an interaction between site (A) and treatments (B) on FNUE including N, P and K. For site (A), SCL soil had higher FNUE (N,

P and K) in all treatment than in LS soil. However, among the fertilizer applications, the fertigation (T3) in both site which applied the same rate of fertilizer and the same irrigation practice tended to have higher FNUE than the soil fertilizer application (T2) and rainfed condition (T1), respectively (Fig 4.4).

Table 4.22 The interaction effects of site and treatments on FNUE of sugarcane.

Variable	FNUE (tons/kg)		
	N	P ₂ O ₅	K ₂ O
Site (A)	**	**	**
LS soil	0.699 ^b	0.962 ^b	0.440 ^b
SCL soil	1.270 ^a	1.690 ^a	0.814 ^a
Treatment (B)	**	**	**
T1: Rainfed condition	0.711 ^c	0.960 ^c	0.452 ^c
T2: Drip irrigation + soil fertilizer	1.000 ^b	1.354 ^b	0.639 ^b
T3: Drip fertigation	1.243 ^a	1.674 ^a	0.791 ^a
Site * Treatment	**	**	**
CV (%)	7.32	7.35	7.31

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at P < 0.05.

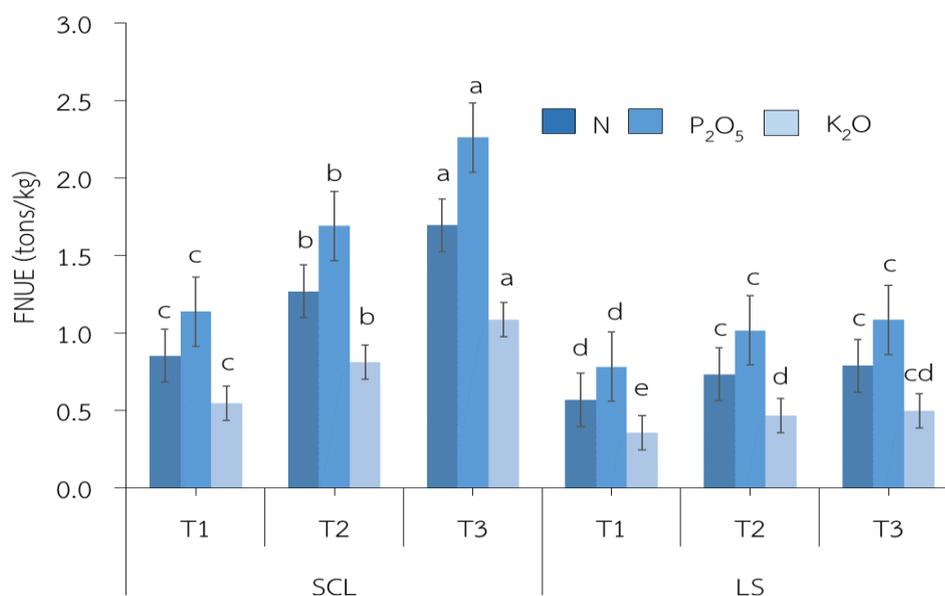


Figure 4.4 Interaction effects of site and fertigation on FNUEs.

For IWUE, it was calculated only in the drip irrigation treatments (T2 and T3). In both soils, the drip fertigation (T3) had higher IWUE than soil fertilizer application (T2). As mentioned earlier, fertigation is more efficient for crop uptake, uniform distribution, and less loss than soil application. Therefore, fertigation promoted growth and yield of sugarcane which directly improve water use efficiency. The result agreed with a previous study by Hatfield and Dold (2019) who found the increase of yield which related to increase carbon structure was the key to improve IWUE. The same study also found that drip fertigation which had the highest yields, had a greater increase in IWUE than drip irrigation and surface irrigation with soil fertilizer application. A study of Quaggio et al. (2006) found that drip fertigation could increase the water efficiency by 13% higher than the same drip irrigation with soil fertilizer application

For FNUE, in both soils textures, the drip fertigation (T3) had the highest FNUE, while the rainfed condition had the lowest FNUE. As mentioned earlier, sugarcane yield was promoted by irrigation and fertigation and all treatments were applied with the same amount of fertilizer, therefore the FNUE was improved by irrigation and fertigation as it was calculated from yield per amount of fertilizer application. The results were similar to Kolange et al. (2001) and Pawar et al. (2013) who found that the drip fertigation increased the FNUE by 40 % compared to soil fertilizer application

4.2.7 Underground stubble fresh and dry weight in SCL soil.

The underground stubble weight (Table 4.23) showed that the irrigation treatments significantly affected the stubble dry and fresh weight. The rainfed treatment (T1) had the highest stubble weight (720 and 338 kg/rai for fresh and dry weight, respectively), while the irrigation treatments (T2 and T3) produced the lowest fresh and dry stubble weight.

Table 4.23 Effects of irrigation and fertigation on Underground stubble weight in SCL soil at 12 MAP.

Treatment	Underground stubble weight (kg/rai)	
	Fresh weight	Dry weight
T1: Rainfed condition	720 ^a	351 ^a
T2: Drip irrigation + soil fertilizer	638 ^{bc}	305 ^b
T3: Drip fertigation	618 ^c	292 ^c
CV (%)	8.44	8.47

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

4.2.8 Total root length density (Total RLD) and RLD pattern in SCL soil.

The result Total RLD is shown in Table 4.24. At upper soil layers (0–20 cm depth), the drip fertigation treatments (T3) produced higher total RLD (0.243 cm/cm³) than the drip irrigation with soil fertilizer (T2) (0.222 cm/cm³) and the rainfed treatment (T1) (0.213 cm/cm³). At middle soil layers (21–40 cm depth), the TRL was not influenced by the treatments. While at deep layers (41–80 cm depth), rainfed practice (T1) produced the highest total RLD (0.0244 cm/cm³) while well irrigated treatments (T2 and T3) had the lowest.

Table 4.24 Effects of irrigation and fertigation on Total RLD in PC in SCL soil at 12 MAP.

Treatment / Depth	Total RLD (cm/cm ³)		
	0–20 cm	21–40 cm	41–80 cm
T1: Rainfed condition	0.213 ^b	0.0579	0.0244 ^a
T2: Drip irrigation + soil fertilizer	0.222 ^{ab}	0.0595	0.0182 ^b
T3: Drip fertigation	0.243 ^a	0.0485	0.0203 ^b
F-test	**	ns	*
CV (%)	8.07	13.90	14.90

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The RLD pattern is shown in Fig 4.5. At the upper soil layers (0–20 cm depth), the rainfed treatment (T1) tended to produce higher RLD close to planting row than the irrigation treatments (T2 and T3). In contrast, in the further distance

from planting row (40–80 cm), the irrigation treatments tended to produce higher RLD than the rainfed treatment. The highest total RLD value was also found in the rainfed treatment (1.247 cm/cm³). At the middle layer (21–40 cm depth), the rainfed practice also produced higher RLD close to the planting row than the irrigation treatments (T2 and T3). At the deep soil layer (41–80 cm depth), the rainfed treatment tended to produce higher RLD than the irrigation treatments (T2 and T3).

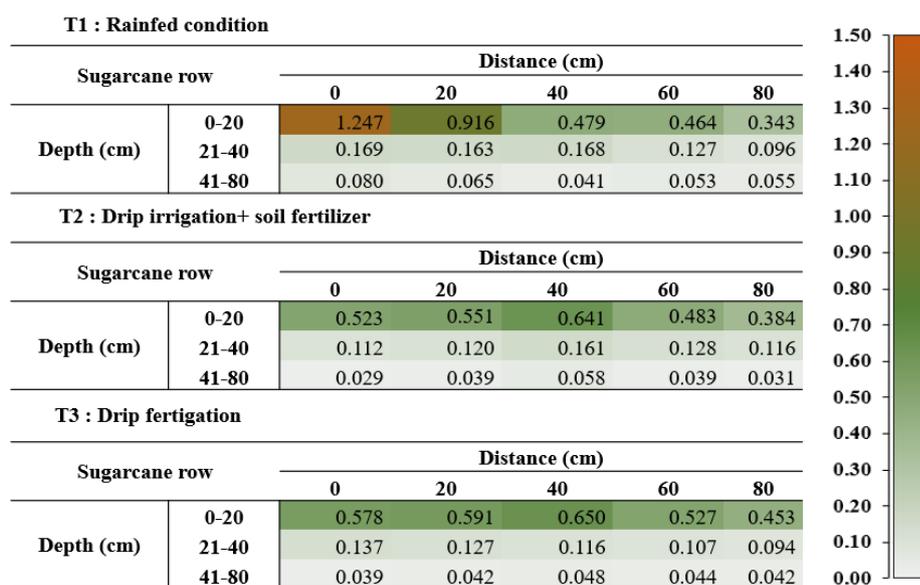


Figure 4.5 Effects of irrigation and fertigation on RLD pattern (cm/cm³) in SCL soil.

From the result, the underground structure including stubble weight, Total RLD, and RLD pattern were affected by the sugarcane practices. The underground stubble (fresh and dry weight) was the highest in the rainfed treatment. However, the underground stubble of sugarcane and its effects on ratooning have not been extensively studied. In general, the large stubble creation is related to the reserved energy for root growth and root avoidance from drought stress. Blum (2005) and Kooyers (2015) reported that one process of sugarcane adapted to drought stress was to maintain water uptake by increasing absorption root area. Basu et al. (2016) and Wasaya et al. (2018) reviewed that the character of roots can indicate drought adaptability of sugarcane and the root distribution pattern is especially important for drought tolerance. In addition, Smith et al. (2005) suggested that drought tolerance

sugarcane cultivars tended to develop deep root systems and Songsri et al. (2009) reported that large root systems related to high WUE in drought conditions. Besides the result of underground stubble, the RLD result was similarly affected by irrigation treatments i.e. large stubble creation positively correlated to RLD of sugarcane in all soil depths (upper, middle, and deep soil) with the correlation value (r) of 0.666, 0.529, and 0.662 respectively (Table 4.35). Rainfed practice tended to produce RLD close to planting row and deep soil layer more than both of drip irrigation treatments. The result was similar to Namwongsa et al. (2018) who reported that when sugarcane faced the drought stress and was rewatered, the deep root was induced more than non-stress condition. While Chumphu (2019) reported that under sufficient water conditions, the RLD was mostly distributed in upper soil layer. According to the report of Wiangnon et al. (2021) who studied the effects of drought stress and rewatering period in 13 sugarcane cultivars, they found that the root density of sugarcane related to the availability of soil water in which if the effective soil water changed, root distribution pattern would positively respond.

For Total RLD, the result showed that irrigation treatments produced higher total RLD than rainfed treatment. High root production was positively related to the biomass and yield production. The result was similar to the study of Wiangnon et al. (2021), who reported that high TRL was positively correlated with the biomass accumulation since high root production resulted to maintaining a high state of water and nutrient in leaf. Jangpromma et al. (2012) supported that the sugarcane cultivar with high WUE was positively correlated to high biomass accumulation and then high yield production as well. This result of this experiment was in agreement of these previous studies in which drip fertigation produced the highest TRL, had the highest cane yield and the highest IWUE and FNUE.

4.3 Second year experiment: Effects of Drip Fertigation on Growth, Yield, and Ratooning Ability of Sugarcane

4.3.1 The FRC germination (%)

The FRC germination at 1 Month after harvest (MAH) is shown in Table 4.25. The residual crop practices (A) significantly affected FRC germination in SCL soil but not in LS soil. In SCL soil,

Rainfed residual (M1) had the highest FRC germination (256 %) while the drip fertigation residuals (M3) had the lowest FRC germination (200 %). In LS soil, the residual practice had no significant effect on FRC germination, but it showed the similar result as in SCL soil i.e., rainfed residual (M1) tended to have the higher germination in FRC than both drip irrigation residuals (M2 and M3).

In terms of the current crop practice (B), the results were similar in both site (SCL and LS soil). the current crop practice had no significantly effect on FRC germination. However, the drip fertigation practice (S2) in FRC tended to have higher germination than rainfed condition (S1).

Table 4.25 Effects of PC residual management and FRC management on germination (%)

Source	Germination (%)	
	SCL soil	LS soil
Crop practice in PC (A)	**	ns
M1: Rainfed condition	256 ^a	140
M2: Drip irrigation + soil fertilizer	230 ^b	138
M3: Drip fertigation	200 ^b	132
Crop practice in FRC (B)	ns	ns
S1: Rainfed condition	217	135
S2: Drip fertigation	240	139
A*B	ns	ns
CV (%)	15.00	11.30

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In the FRC, the result indicated that the germination was mainly affected by PC residual effects. The current crop practice seemed to have lower effect on FRC germination than the previous crop practice. The rainfed practice of previous crop which produced the highest underground structures in PC had the highest germination of FRC. As the underground structures are the stock of carbohydrate and energy, they are important for new root and shoot creation in ratoon cane (Xu et al., 2021). The results were similar to the study of Smith et al.

(2005) who reported that the residual root and stubble after harvest were the essential structures for supporting the shoot germination in ratoon crop. Even though, this study did not clearly explain the relationship between underground structure and FRC germination, the study of Pissolato et al. (2021) indicated that high underground structures production was positively related to the carbohydrate accumulation and the carbohydrate in root of the previous crop could induce the vigor of shoot of the current ratoon crop. Moreover, this study also found that RLD in the upper soil layer of PC residual positively affected the germination of FRC. This result was similar to the study of Chumphu et al. (2019) who reported that the high RLD at the harvest stage resulted to high germination percentage in the next ratoon crop. For the current crop practice in FRC, drip fertigation tended to have higher percentage of germination than the rainfed condition which related to the higher soil moisture content in the fertigation treatment. A Similar result was found by Pierre et al. (2014) who reported that soil moisture content at -0.5 MPa which closed to FC point was suitable for cane germination.

4.3.2 Sugarcane growth parameters in FRC

1) Number of shoots

The number of shoots in FRC are shown in Table 4.26 for SCL soil and Table 4.27 for LS soil.

In SCL soil, the residual practices (A) had no significant effect on number of shoots in FRC at all MAH but the current crop practice (B) was the main factor to effect significantly on the number of shoots in FRC, drip fertigation practice (S2) had the highest number of shoot at 2, 4, and 6 MAH (38,395, 19,235, and 17,794 shoot/rai, respectively). while the rainfed condition had the lowest number of shoots at 2,4 and 6 MAH (28,041, 16,099, and 16,510 shoots/rai)

Table 4.26 Effects of PC residual management and FRC management on number of shoots at 2, 4, and 6 MAH in SCL soil.

Source	Number of shoots (shoots/rai)		
	2 MAH	4 MAH	6 MAH
Crop practice in PC (A)	ns	ns	ns
M1: Rainfed condition	34,049	17,790	17,679
M2: Drip irrigation + soil fertilizer	32,716	18,469	16,667
M3: Drip fertigation	32,889	16,741	17,111
Crop practice in FRC (B)	**	**	*
S1: Rainfed condition	28,041 ^b	16,099 ^b	16,510 ^b
S2: Drip fertigation	38,395 ^a	19,235 ^a	17,794 ^a
A*B	ns	ns	ns
CV (%)	9.82	9.46	4.66

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

In LS soil, the effect of residual practices (A) showed similar effect as in SCL soil. The number of shoots in FRC at 2,4 and 6 MAH was non significantly different among the residual effect (A). For the current crop practices (B), it had no effect on number of shoots at 2 and 4 MAH but number of shoots was affected only at 6 MAH, drip fertigation treatment (S2) had the highest number of shoots (10,296 shoots/rai), while the lowest shoots number was found in rainfed condition (8,584 shoots/rai).

Table 4.27 Effects of PC residual management and FRC management on number of shoots at 2, 4, and 6 MAH in LS soil.

Source	Number of shoots (shoots/rai)		
	2 MAH	4 MAH	6 MAH
Crop practice in PC (A)	ns	ns	ns
M1: Rainfed condition	12,593	14,716	9,629
M2: Drip irrigation + soil fertilizer	14,086	13,938	9,447
M3: Drip fertigation	14,457	12,975	9,247
Crop practice in FRC (B)	ns	ns	**
S1: Rainfed condition	14,173	13,358	8,584 ^b
S2: Drip fertigation	13,251	14,395	10,296 ^a
A*B	ns	ns	ns
CV (%)	9.82	9.46	4.66

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

2) Plant height.

The plant height of FRC in SCL and LS soil are shown in Tables 4.28 and 4.29, respectively.

In SCL soils, residual practice (A) did not affect plant height in FRC. while the plant height was affected by the current crop practice (B). In SCL soil, drip fertigation (S2) produced the highest plant height at 2, 4, and 6 MAH (32.3, 144, and 226 cm, respectively), while the lowest plant height at 2,4, and 6 MAH was found in rainfed conditions (21.8, 102, and 189 cm, respectively)

Table 4.28 Effects of PC residual management and FRC management on number of shoots at 2, 4, and 6 MAH in SCL soil.

Source	Plant height (cm)		
	2 MAH	4 MAH	6 MAH
Crop practice in PC (A)	ns	ns	ns
M1: Rainfed condition	26.7	124	212
M2: Drip irrigation + soil fertilizer	26.1	125	209
M3: Drip fertigation	25.4	120	202
Crop practice in FRC (B)	**	**	**
S1: Rainfed condition	21.8 ^b	102 ^b	189 ^b
S2: Drip fertigation	32.3 ^a	144 ^a	226 ^a
A*B	ns	ns	ns
CV (%)	8.18	7.59	4.42

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

The result of plant height in LS soil is shown in table 4.29. The previous crop practice (A) affected plant height in FRC only at 4 and 6 MAH, drip fertigation produced the highest plant height at 4 and 6 MAH (77.7 and 187 cm, respectively) while rainfed residual produced the lowest plant height at 4 and 6 MAH (49.8 and 147 cm, respectively).

The current crop practices (B) had no effect on the plant height at 2 MAH while they affected plant height at 4 and 6 MAH i.e. drip fertigation practice (S2) in current year had higher plant height than rainfed practice (S1).

There was an interaction between the residual effect of the previous crop (A) and current crop practice (B) in LS soil at 4 and 6 MAH, the result showed that the drip fertigation practice in the current year (S2) tended to produce the higher plant height than rainfed practice in all previous year residuals (Fig 4.6).

Table 4.29 Effects of PC residual management and FRC management on number of shoots at 2, 4, and 6 MAH in LS soil.

Source	Plant height (cm)		
	2 MAH	4 MAH	6 MAH
Crop practice in PC (A)	ns	**	*
M1: Rainfed condition	21.0	49.8 ^b	147 ^b
M2: Drip irrigation + soil fertilizer	22.0	76.5 ^a	170 ^{ab}
M3: Drip fertigation	27.0	77.7 ^a	187 ^a
Crop practice in FRC (B)	ns	**	**
S1: Rainfed condition	23.5	50.0 ^b	137 ^b
S2: Drip fertigation	22.7	86.0 ^a	199 ^a
A*B	ns	*	**
CV (%)	13.35	10.44	12.87

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

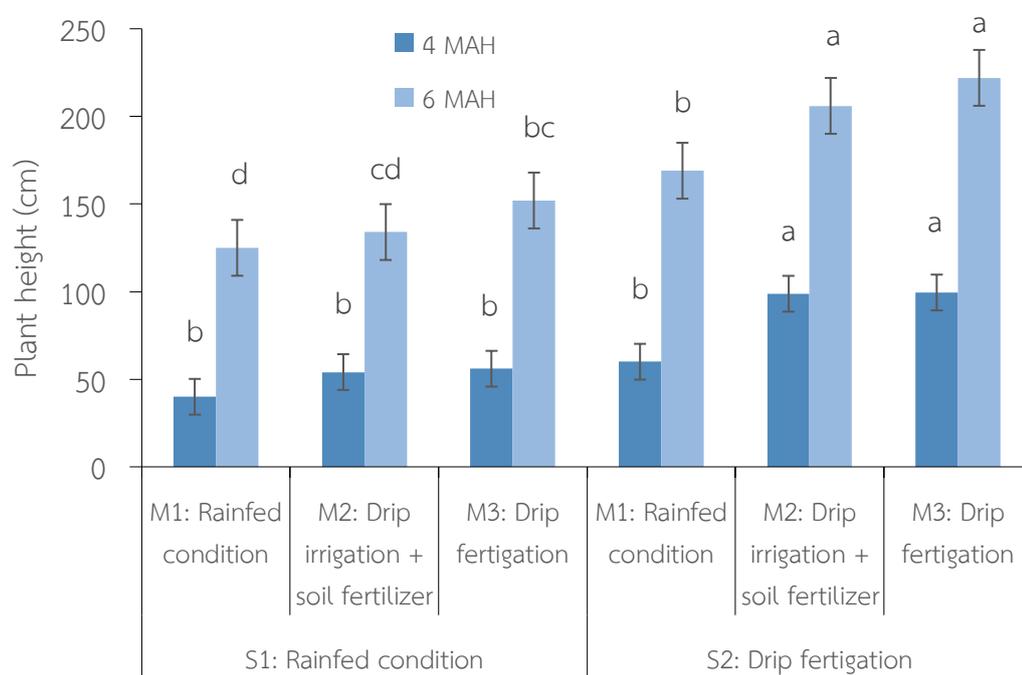


Figure 4.6 Interaction effects of PC residual management and FRC management on plant height in FRC in LS soil at 4 and 6 MAH.

4.3.3 Yield and yield components

In SCL soil, the yield and yield components were not affected by the previous crop residuals practice (A) whereas they were affected by the current year management (B) (Table 4.30).

The current practices significantly affected yield and yield components including NMC, whereas the other traits were not affected by the current crop practice i.e. plant height, cane diameter, and TSS. The highest NMC and yield were produced in drip fertigation treatment (S2) (17,636 stalk/rai and 24.6 tons/rai), while the lowest was produced in rainfed practice (S1) (14,240 stalk/rai and 19.3 tons/rai).

Table 4.30 Effects of PC residual management and FRC management on yield and yield components in SCL soil at 12 MAH.

Source	NMC (canes/rai)	Plant height (cm)	Cane diameter (mm)	Yield (tons/rai)	TSS (°Brix)
Crop practice in PC (A)	ns	ns	ns	ns	ns
M1: Rainfed condition	15,958	290	25.9	22.1	22.7
M2: Drip irrigation + soil fertilizer	15,741	293	25.9	21.6	22.9
M3: Drip fertigation	16,115	298	25.9	22.2	23.9
Crop practice in FRC (B)	**	ns	ns	**	ns
S1: Rainfed condition	14,240 ^b	292	25.4	19.3 ^b	22.7
S2: Drip fertigation	17,636 ^a	296	25.9	24.6 ^a	23.6
A*B	ns	ns	ns	ns	ns
CV (%)	10.30	4.94	5.40	11.60	4.25

Means within the same column labeled with the same letters indicate statistically significant differences to DMRT at $P < 0.05$.

In LS soil (Table 4.31), the results showed the similar effect as in SCL soil, the previous residuals (A) had no effect on yield and yield components but the current crop practices (B) were mainly factor affecting the yield and yield components in FRC. The current crop practices had significant effect on the NMC, plant height, and yield,

i.e., the highest produce was found in drip fertigation practice (S2) (17,636 cane/rai, 254 cm, and 24.6 tons/rai, respectively), while the lowest produce was found in rainfed practice (14,240 cane/rai, 206 cm, and 13.9 tons/rai, respectively).

Table 4.31 Effects of PC residual management and FRC management on yield and yield components of FRC in LS soil at 12 MAH.

Source	NMC (canes/rai)	Plant height (cm)	Cane diameter (mm)	Yield (tons/rai)	TSS (°Brix)
Crop practice in PC (A)	ns	ns	ns	ns	ns
M1: Rainfed condition	10,744	229	29.9	13.3	22.7
M2: Drip irrigation + soil fertilizer	10,264	223	27.3	13.1	22.8
M3: Drip fertigation	10,194	240	26.3	14.0	22.5
Crop practice in FRC (B)	**	**	ns	**	ns
S1: Rainfed condition	9,302 ^b	206 ^b	27.3	11.6 ^b	22.6
S2: Drip fertigation	11,500 ^a	254 ^a	27.1	15.3 ^a	22.7
A*B	ns	ns	ns	ns	ns
CV (%)	7.64	7.81	10.33	11.42	5.83

Means within the same column labeled with the same letters indicate statistically significant differences to DMRT at $P < 0.05$.

4.3.4 Total RLD and RLD pattern in FRC in SCL soil.

The Total RLD in FRC was affected by the residuals of previous crop, the rainfed condition residual (M1) had the highest influence on Total RLD production in FRC at 2 layers including upper and deep layers (0.863 and 0.065 cm/cm^3 , respectively). while drip fertigation residual (M3) had the lowest influence on Total RLD production in FRC (0.742 and 0.052 cm/cm^3 , respectively).

The current crop practice (B) significantly affected Total RLD production at 2 depths i.e., upper layer (0–20 cm) and deep layer (41–80). The highest TRL production was found in rainfed practice (S1) (0.842 and 0.062 cm/cm^3 ,

respectively) and the lowest TRL production was found in drip fertigation treatment (S2) (0.724 and 0.051 cm/cm³, respectively) (Table 4.32).

Table 4.32 Effects of PC residual management and FRC management on Total RLD in FRC in SCL soil at 6 MAH.

Source / Depth	Total RLD (cm/cm ³)		
	0–20 cm	21–40cm	41–80 cm
Crop practice in PC (A)	*	ns	*
M1: Rainfed condition	0.863 ^a	0.117	0.065 ^a
M2: Drip irrigation + soil fertilizer	0.745 ^b	0.141	0.051 ^b
M3: Drip fertigation	0.742 ^b	0.135	0.052 ^b
Crop practice in FRC (B)	**	ns	**
S1: Rainfed condition	0.842 ^a	0.127	0.062 ^a
S2: Drip fertigation	0.724 ^b	0.136	0.051 ^b
A*B	ns	ns	ns
CV (%)	12.60	9.97	16.20

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

For RLD pattern (Fig 4.7 and 4.8), In terms of the previous crop residuals (A), the rainfed residual (Fig 4.7 (M1S1) and Fig 4.8 (M1S2)) tended to produce higher RLD than the 2 irrigation residuals (M2 and M3).

In current crop practice (B), the RLD pattern of FRC was similar to the RLD pattern of PC, the rainfed practice (S1) (Fig 4.7) tended to produce the RLD in positions close to planting row and deep soil layer more than the drip fertigation treatment (S2) (Fig 4.8).

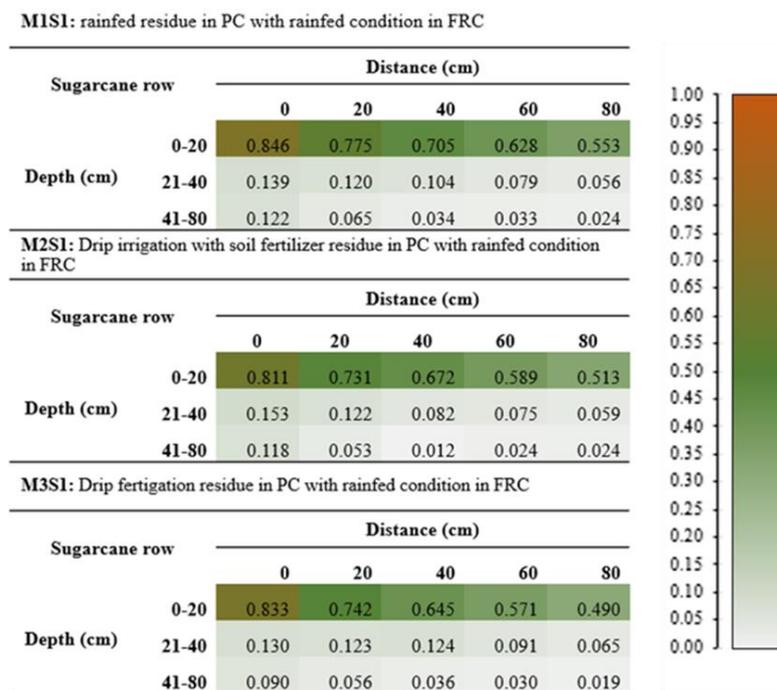


Figure 4.7 Effects of rainfed practices on RLD in FRC in SCL soil at 6 MAH (cm/cm^3).

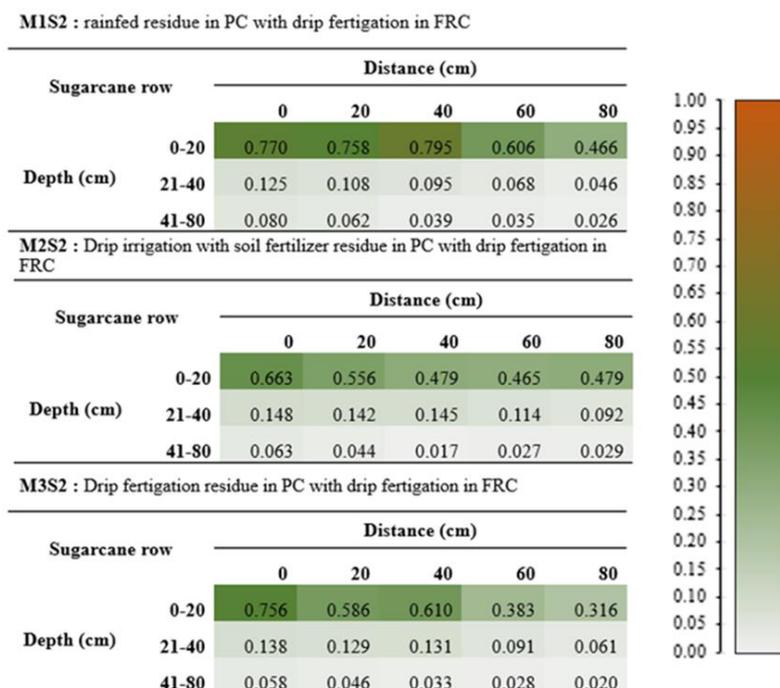


Figure 4.8 Effects of drip fertigation practices on RLD in FRC in SCL soil at 6 MAH (cm/cm^3).

In terms of root creation (Total RLD), residual effects were the key factor to indicate the root creation in FRC. In both years, the rainfed residual which produced the highest underground structures in PC had the highest root creation in FRC. The remaining structures were positively correlated with root creation as they were the source of energy that stimulated the speed of growth and improved the vigor of the ratoon crop (Pissolato et al., 2021). The study of Aguilera Esteban et al. (2019) reported that the reduction of root trait and less crop vigor had a long-term effect on decreasing of growth in ratoon cane. In addition, the influence of rapid growth and vigor resulted from residual structures can be an indicator of the ratooning ability (RA) improvement. The study of Qin et al. (2017) demonstrated that high germination, high tillering rate, and high stalk number were found in the sugarcane cultivar with strong RA.

In terms of root distribution pattern in FRC (RLD pattern), the residual practices had little effect on root distribution. While the current year practices were the main factor to determine the root pattern in FRC. The root patterns of the rainfed condition and the drip fertigation canes were different. The rainfed condition tended to have high RLD in the surface layer and deep soil layer, while the drip fertigation tended to have high RLD only in the surface layer. The result agreed with a previous study by Chumphu et al. (2019) who reported that the distribution of roots depended on available water in the soil, in water-sufficient conditions, the root was mostly distributed in the surface layer. While Namwongsa et al. (2018) found that sugarcane when faced with drought conditions, it produced the deep root more than in normal conditions.

4.3.5 Ratooning ability

The ratooning ability (RA) in SCL and LS soil are shown in Tables 4.33 and 4.34, respectively. In SCL soil, the RA estimation based on property of growth, yield and yield component were significantly different among the residual effects of previous crop (A) and current crop practices (B).

In the residual effect of previous crop (A), rainfed residual (M1) had the highest RA which based on number of shoots at 2 MAH, number of shoots at 6 MAH, NMC at 12 MAH, and yield at 12 MAH.

In current crop practice (B), drip fertigation (S2) had higher RA which based on number of shoots at 2 MAH, number of shoots 6 MAH, NMC at 12 MAH, and yield at 12 MAH than the FRC practice with the rainfed condition (M1)

The RA based on the number of shoots at 2 MAH showed an interaction between the residual effects of previous practice (A) and the current management (B) (Fig 4.9).

For residual effects of previous crop (A), even though RA based on number of shoots in the rainfed condition practice in FRC were not affected by the residual effects, the tendency of both FRC practices showed that rainfed residual (M1) tended to have higher RA based on number of shoots at 2 MAH than well-irrigated practice (M2 and M3).

For the current year practices (B), the result between rainfed condition (S1) and drip irrigation (S2) showed different effects on RA, all residual effects on drip fertigation in FRC practice had higher RA based on number of shoots at 2 MAH than rainfed condition.

Table 4.33 Effects of PC residual management and FRC management on RA (%) based on number of shoots, yield and yield component in SCL soil.

Source	RA (%)			
	2 MAH	6 MAH	12 MAH	
	Number of shoots	Number of shoots	NMC	Yield
Crop practice in PC (A)	*	**	**	**
M1: Rainfed condition	349 ^a	154 ^a	145 ^a	161 ^a
M2: Drip irrigation + soil fertilizer	306 ^{ab}	135 ^b	127 ^a	106 ^b
M3: Drip fertigation	242 ^b	116 ^c	107 ^b	80 ^b
Crop practice in FRC (B)	**	*	**	**
S1: Rainfed condition	246 ^b	131 ^b	116 ^b	104 ^b
S2: Drip fertigation	352 ^a	140 ^a	137 ^a	128 ^a
A*B	**	ns	ns	ns
CV (%)	8.46	4.92	9.39	8.97

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at P < 0.05.

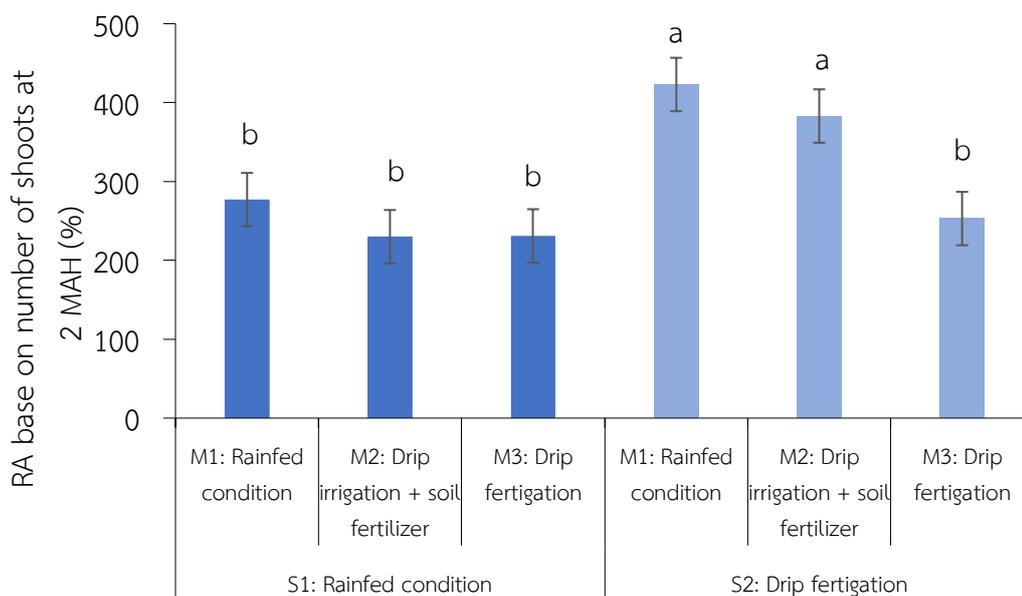


Figure 4.9 The interaction effects between PC residual management and FRC management on RA (%) based on the number of shoots at 2 MAH

In LS soil, the previous crop residual effects (A) and current crop practices (B) affected RAs based on traits of growth and yield.

The previous crop practices (A) did not affect the RA based on number of shoots at 2 MAH, but significantly affected the RA based on number of shoots at 6 MAH, NMC at 12 MAH, and yield at 12 MA. The rainfed residual (M1) had a positive effect on RAs more than the 2 irrigation residuals. (M2 and M3).

In the current crop practice (B), the RA based on the number of shoots at 6 MAH, NMC at 12 MAH, and yield at 12 MAH, were the highest in drip fertigation practice (M2) (95%, 116%, and 105%, respectively.) while the rainfed practice (M1) had the lowest RAs (79%, 94%, and 79%, respectively). (Table 4.34)

Table 4.34 Effects of PC residual management and FRC management on RA (%) based on number of shoots, yield, and yield component in LS soil.

Source	RA (%)			
	2 MAH	6 MAH	12 MAH	
	Number of shoots	Number of shoots	NMC	Yield
Crop practice in PC (A)	ns	*	*	*
M1: Rainfed condition	132	92.0 ^a	113 ^a	112 ^a
M2: Drip irrigation + soil fertilizer	138	86.7 ^b	103 ^b	84 ^b
M3: Drip fertigation	133	84.2 ^b	99 ^b	81 ^b
Crop practice in FRC (B)	ns	**	**	**
S1: Rainfed condition	139	79.6 ^b	94 ^b	79 ^b
S2: Drip fertigation	129	95.7 ^a	116 ^a	105 ^a
A*B	ns	ns	ns	ns
CV (%)	8.44	8.86	7.87	12.6

Means within the same column labeled with the same letters indicate statistically significant differences by DMRT at $P < 0.05$.

Shaw (1989) defined the RA as the performance of the ratoon crop in the percentage of growth and yield in ratoon cane compared to PC. The good RA cane has long ratoon keeping and low yield decrease in the next ratoon crop. In contrast, poor RA was defined when the performance of the ratoon was lower than PC (Qin et al., 2017).

The result of this experiment showed that previous crop practice and current crop practice influenced the RA in FRC. For previous crop practice, a rainfed condition which produced high underground structures (root and underground stubble) had the highest RA in FRC. High underground structure accumulation was positively related to high initial growth of FRC. The result agreed with other previous studies such as Kumar et al. (2017) and Xu et al. (2021) who reviewed that the residual crop practice which produced a strong root system and high underground structure influenced high RA since it was related to improving next ratoon germination and growth. The rapid growth in the initial stage of the ratoon crop was an early indicator of high RA. A similar study by Qin et al. (2014) and Milligan et al. (1990) found that sugarcane cultivars with strong RA had fast germination,

high tillering, and high shoot production. A study of Hogarth and Berding (2006) found that low germination rates had a long-term effect on reducing effective tillers and millable shoots, which was positively correlated to the reduction in RA.

In terms of RA improvement, although the residual effect was the factor that improved the speed of the initial growth of the ratoon crop, but the current year's practice was more important for improving the growth of the current crop. For current crop practices, the drip fertigation which produced the highest number of shoots, the best growth, and the highest effective shoot in the current year had higher RA than those performed in rainfed conditions. A similar result was obtained by Uribe et al. (2013) found that the ratoon cane practice with drip fertigation tended to have better growth than no irrigation. Bashir et al. (2013) also found that good growth in the ratoon crop (the high shoots population, high millable shoot, and high yield) was essential for the indication of the strong RA. This result was supported by Gomathi et al. (2013) who found that the RA positively affected the ratoon germination, thereby directly increased the shoot population and ratoon yield.

Even though drip fertigation produced the highest growth, yield, and RA, but it tended to have lower underground structures creation (root and stubble) than the rainfed condition which had a negative effect on the growth and vigor of the next ratoon crop when it was grown under non-suitable conditions (rainfed conditions). Therefore, the effective practice such as drip fertigation in the PC should be continued in the ratoon crops to keep high RA in all canes. Wonprasaid and Girdthai (2014) also found that in 3 continually years of practice between rainfed conditions and drip irrigation, drip irrigation practice was able to maintain higher RA based on the yield of first and second ratoon cane (91.0 and 101%, respectively) than the rainfed condition (89.3% and 73.3%, respectively). However, although this study showed that rainfed conditions had high RA, if the sugarcane was managed with improper methods for a long time or faced long-term drought stress, it could decline the RA since the vigor of sugarcane under rainfed conditions declined following age (Bhale 1943). Luanmanee et al. (2021) also found that the long-term practice with the rainfed conditions could reduce RA of FRC and SRC to 51.7 and 36.5%, which RA decline was not worth for further ratoon keeping.

Table 4.35 Correlations value among the treatments of PC on phenotypic traits yield and yield components in PC.

Correlations	Underground stubble (DW)			No. of shoots			Yield	NMC	
	RLDU	RLDM	RLDD	2 MAP	4 MAP	6 MAP			
Underground stubble (DW)	1	0.666**	0.529*	0.662**	-0.307	-.757*	-0.407	-0.499	-0.204
RLDU		1	.796*	.999**	-0.497	-.869**	-0.524	-.692*	-0.572
RLDM			1	.827**	-.851**	-.947**	-.911**	-.958**	-.921**
RLDD				1	-0.537	-.890**	-0.568	-.727*	-0.613
No. of shoots 2 MAP					1	.728*	.962**	.873**	.913**
No. of shoots 4 MAP						1	.813**	.872**	.758*
No. of shoots 6 MAP							1	.907**	.929**
Yield								1	.918**
NMC									1

***, Correlation is significant at the 0.01 and 0.05 level (2-tailed), respectively.

Table 4.36 Correlations value among the old residual structures of PC on phenotypic traits and RAs of FRC.

Correlations	Underground stubble (PC)	RLDU (PC)	RLDM (PC)	RLDD (PC)	Germination (%)	No. of shoots 2 MAH	NMC (FRC)	Yield (FRC)	RA(%) NMC	RA(%) yield
Underground stubble DW (PC)	1	.666**	.529*	.662**	0.320	0.159	0.146	0.191	0.435	.613**
RLDU (PC)		1	.773**	.990**	0.446	0.202	0.041	0.045	.495*	.762**
RLDM (PC)			1	.856**	.639**	0.295	0.018	0.009	.725**	.896**
RLDD (PC)				1	.508*	0.232	0.038	0.039	.567*	.824**
Germination (%)					1	.699**	0.257	0.314	.579*	.689**
No. of shoots 2 MAH						1	.665**	.698*	.598**	.539*
								*		
NMC (FRC)							1	.888*	.660**	0.362
Yield (FRC)								*		
RA(%) NMC								1	.565*	0.431
RA(%) yield									1	.854**
										1

*,** Correlation is significant at the 0.01 and 0.05 level (2-tailed), respectively.