Effects of Slow-release Fertilizers and Sugarcane-specific Fertilizers on Yield and Quality of Sugarcane

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Abstract The effects of slow-release fertilizers and sugarcane-specific fertilizers on the growth and quality of sugarcane were studied to provide a theoretical basis for cultivation of sugarcane with lower costs but higher efficiency. Field experiments were carried out in two major sugarcane areas in Guangxi and three fertilization treatments were studied: single application of compound fertilizers (treatment I), compound fertilizers + slow-release fertilizers (treatment II) and sugarcane-specific base fertilizers + sugarcane-specific topdressing (treatment III). Effects of equal fertilization conditions of treatment I, II and III on growth, yield and sugar of sugarcane were studied. The three fertilization treatments had little effects on emergence, tillering, and effective stems of sugarcane, but compared with the treatment of compound fertilizer (treatment I) with a ratio of N, P, and K of 1:1:1, treatment II using slow-release fertilizers as topdressing had better growth, higher plant height and stem diameter, so the yield was higher. Treatment III designed sugarcane-specific fertilizers with proper ratio according to fertilizer demands of sugarcane. Besides, the treatment III sugarcane-specific base fertilizers, containing certain amount of organic matters, could promote the sugar accumulation of sugarcane. Therefore, the sugarcane yield of treatment III was higher than that of treatment II. In conclusion, slow-release fertilizers and sugarcane-specific fertilizers can significantly increase sugarcane yield, especially sugarcane-specific fertilizers. Sugarcane-specific fertilizers have reasonable ratio and contain certain amount of organic matters, and can increase sugar content, obtain significant economic benefits, so it is worth popularization in large areas.

Key words Slow-release fertilizer, Sugarcane-specific fertilizer, Sugarcane, Growth, Yield

1 Introduction

Sugarcane is a main sugar crop in China and is also a pillar cash crop in Guangxi Autonomous Region. In recent years, the sugarcane planting area and sugar yield of Guangxi have accounted for more than 60% of China[1]. Fertilizer, as a key factor in crop growth, plays an important role in sugarcane yield and sugar accumulation. Fertilization technology is closely related to the sugarcane yield. Fertilizer type, amount, fertilizer ratio, and fertilization method directly affect the level of sugarcane yield[2]. However, for a long time, improper fertilization, especially excessive application of chemical fertilizers, leads to increase in sugarcane planting costs and drop of sugarcane quality, seriously influencing economic benefits of sugarcane planters and sugar refineries[3]. At present, various fertilizer products are available on market, such as three-element compound fertilizers, slow-release fertilizers, and sugarcane-specific fertilizers, *etc.* It is an urgent for Guangxi sugarcane production to solve the problem of how to properly use different fertilizer combinations to increase fertilizer utilization, promote sugarcane growth and yield, increase sucrose content, and increase economic benefits. Nanning City and Laibin City in Guangxi are two of the main sugarcane production areas, and their sugarcane planting area and sucrose yield accounted for about 30% of Guangxi. Through setting the experimental sites in Nanning City and Laibin City, we studied the application of different fertilizers, and comprehensively analyzed the effects of fertilization methods on sugarcane growth and yield, so as to explore an optimal fertilization method for sugarcane production in Guangxi.

2 Materials and methods

2.1 Experimental fertilizers (i) Guangxi New Orientation compound fertilizer, $N:P_2O_5:K_2O$ = 15:15:15; (ii) Guangxi New Orientation long-acting slow-release fertilizer, $N:P_2O_5:K_2O$ = 24:8:16; (iii) Guangxi New Orientation sugarcane-specific fertilizer (base fertilizer), organic matter ≥11%, $N:P_2O_5:K_2O$ = 18:7:15; (iv) sugarcane-specific fertilizer (topdressing), $N:P_2O_5:K_2O$ = 22:8:18.

2.2 Sugarcane varieties The experimental sugarcane varieties were Guitang 32 in Long'an and Guitang 42 in Laibin respectively.

2.3 Experimental site Experimental site 1: Lian'an Village sugarcane experimental base in Nanxu Town, Long'an County, Nanning City of Guangxi, the soil was lateritic red soil, and the preceding crop was sugarcane. The physical and chemical properties of the experimental soil were: total nitrogen (TN) 0.014%, total phosphorus (TP) 0.102%, total potassium (TK) 0.749%, alkali-hydrolyzable nitrogen 125 mg/kg, available phosphorus 46 mg/kg, available potassium 222 mg/kg, organic matter 31.2 g/kg, and pH 5.17.

Experimental site 2: sugarcane comprehensive experiment

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station base in Laibin City of Guangxi, the soil was sandy loam soil, and preceding crop was sugarcane. The physical and chemical properties of the experimental soil were: total nitrogen (TN) 0.012%, total phosphorus (TP) 0.062%, total potassium (TK) 0.221%, alkali-hydrolyzable nitrogen 83 mg/kg, available phosphorus 56 mg/kg, available potassium 77 mg/kg, organic matter 14.0 g/kg, and pH 4.70.

2.4 Experiment treatment Three treatments were designed: ordinary compound fertilizer (treatment I), compound fertilizer + slow-release fertilizer (24∶8∶16) (treatment II), and sugarcane-specific base fertilizer + sugarcane-specific topdressing (treatment III). According to the design principle of the equal amount of fertilizer input, that is, the total input price of fertilizer was 6 300 yuan/ha, and the specific design schemes for the three treatments were shown in Table 1 and Table 2. The fertilization adopted the two times of fertilization method, namely, one time of base fertilizer and one time of topdressing.

Table 1 Amount and price of fertilizers in three treatments

Treatment	Type of fertilizer	Application amount kg/ha	Unit price yuan/t	Converted price yuan/ha	Converted nutrient content//kg/ha			
					N	P	K	Total
I	Compound fertilizer	1 750.0	3 600	6 300	262.5	262.5	262.5	787.5
II	Compound fertilizer	583.3	3 600	6 300	87.5	87.5	87.5	806.9
	Slow-release fertilizer	1 135.1	3 700		272.4	90.8	181.6	–
III	Sugarcane-specific base fertilizer	657.0	3 000	6 300	118.3	46.0	98.6	892.5
	Sugarcane-specific topdressing	1 311.8	3 300		288.6	104.9	236.1	–

Table 2 Application amount of fertilizers in experiment sites (kg/site)

Treatment	Compound fertilizer	Slow-release fertilizer	Sugarcane-specific base fertilizer	Sugarcane-specific topdressing
I	(2.86 + 5.72)	–	–	–
II	(2.86 + 0.00)	(0.00 + 5.56)	–	–
III	–	–	(3.22 + 0.00)	(0.00 + 6.43)

Note: parenthetic data were application amount of base fertilizer and topdressing (base fertilizer + topdressing).

2.5 Field design and planting management Three fertilization treatments were set, arranged in a random block, 3 repetitions, 9 plots, 5 rows per plot, 7.0 m row length, 1.4 m row spacing, and 21 m^2 plot area. Sugarcanes were cut into double buds, sowed after soaking and sterilization, at 112 500 buds per ha, and other management was the same as conventional method for field management. Sugarcane planting time in Long'an area: April 10 – 11, 2014, topdressing time: June 18, 2014, and harvest time: December 25 – 26, 2014; sugarcane planting time in Laibin area: April 16, 2014, topdressing time: June 15, 2014, and harvest time: December 11, 2014.

2.6 Survey and analysis items The germination rate and tillering rate of sugarcane were surveyed in the early stage of sugarcane growth; the plant height, stem diameter, effective stem number, field brix and actual yield of sugarcane were surveyed during harvesting. Conventional methods were applied.

2.7 Statistical analysis Excel 2003 was used for data processing, and DPS v7.05 software was used for significant difference analysis.

3 Results and analysis

3.1 Effects of different fertilization treatments on germination rate and tillering rate In different sugarcane planting areas, the soil types and climatic conditions were different, sugarcane varieties under experiment were different, so there was significant difference in the germination rate and tillering rate between two experimental sites, but there was no significant difference between different treatments within the same experimental site (Table 3). These indicated that the single application of compound fertilizer or application of compound fertilizer plus slow-release fertilizer or sugarcane-specific fertilizer had little effects on the germination rate and tillering rate of sugarcane, because all three treatments were made by one time of base fertilizer and two times of topdressing, the amount of base fertilizer was basically the same, while the fertilizer demand of sugarcane at the early stage of growth was little.

Table 3 Effects of different fertilization treatments on germination rate and tillering rate

Experimental site	Sugarcane variety	Treatment	Germination rate//%	Tillering rate//%
Long'an	Guitang 32	I	34.0 ± 5.3 a	120.2 ± 10.7 a
		II	32.5 ± 4.1 a	120.7 ± 11.9 a
		III	33.2 ± 6.5 a	122.3 ± 13.2 a
Laibin	Guitang 42	I	65.0 ± 7.2 a	67.96 ± 6.1 a
		II	64.3 ± 5.9 a	63.14 ± 7.9 a
		III	66.1 ± 8.3 a	66.16 ± 5.2 a

3.2 Effects of different fertilization treatments on agronomic traits of sugarcane Although there was a significant difference in the germination rate and tillering rate of sugarcane between the two experimental sites, the difference in effective stem numbers of the two sugarcane varieties was not significant and basically the same (Table 4). Fertilizers of different treatments contained different ratio of nutrients. Treatment I applied compound fertilizer with ratio of N, P, and K of 1∶1∶1, treatment II applied slow-release fertilizer, fertilizer efficiency was long-lasting and the ratio of nutrients was more reasonable, and treatment III applied sugarcane-specific fertilizer with reasonable ratio of nutrients. The total nutrients of treatment I, II, and III were increasing, so the sugarcane plant height and stem diameter of treatment I, II, and III were increasing (Table 4).

Table 4 Effects of different fertilization treatments on agronomic traits of sugarcane

Experimental site	Sugarcane variety	Treatment	Plant height//cm	Stem diameter//cm	Effective stem//pcs/ha
Long'an	Guitang 32	I	222.5 ± 11.1 aA	2.71	54 451 ± 312 a
		II	243.0 ± 5.4 bAB	2.74	53 853 ± 297 a
		III	273.5 ± 14.4 Bc	2.78	54 295 ± 341 a
Laibin	Guitang 42	I	219.8 ± 14.7 aA	2.72	54 280 ± 289 a
		II	246.1 ± 5.3 bAB	2.75	54 990 ± 302 a
		III	273.3 ± 11.2 Bc	2.79	54 720 ± 327 a

3.3 Effects of different fertilization treatments on sugar content of sugarcane Due to different maturity periods, the sugar content differed greatly between the two sugarcane varieties. There was no significant difference in sugar content between treatment I and treatment II in the same sugarcane variety. The treatment III sugar content was significantly higher than that of treatment I and II, probably because the nutrient ratio of treatment III was more suitable for fertilizer demand characteristics of sugarcane, and sugarcane-specific base fertilizer of treatment III contained certain amount of organic matters and could promote the accumulation of sugar content[4].

Table 5 Effects of different fertilization treatments on sugar content of sugarcane

Experimental site	Sugarcane variety	Field brix//%		
		I	II	III
Long'an	Guitang 32	17.15 ± 0.07 a	17.30 ± 0.07 ab	17.50 ± 0.14 b
Laibin	Guitang 42	22.39 ± 0.17 a	22.95 ± 0.48 ab	23.32 ± 0.07 bB

3.4 Analysis of economic benefits of different fertilization treatments The plant height and stem diameter of treatments I, II and III were increasing, the sugarcane yield also showed an increasing trend. Specifically, the yield of sugarcane applied with sugarcane-specific fertilizer was higher than the mixed application of compound fertilizer and slow-release fertilizer, and the mixed application of compound fertilizer and slow-release fertilizer was higher than that of compound fertilizer with ratio of N, P, and K of 1∶1∶1. Calculated at 480 yuan/t sugarcane, the treatment II increased by 1 648.0 yuan/ha compared with treatment I, and treatment III was 3 341.7 yuan/ha higher than that of treatment I (Table 6). In addition, the increase in sugar content could create significant economic benefits for enterprises.

Table 6 Analysis of economic benefits of different fertilization treatments

Treatment	Experimental site	Yield kg/ha	Total income yuan/ha	Increase compared with treatment I yuan/ha	Experimental site	Yield kg/ha	Total income yuan/ha	Increase compared with treatment I yuan/ha	Average income increase yuan/ha
I	Long'an	70 926.9	34 044.9	–	Laibin	69 176.9	33 204.9	–	–
II	Long'an	74 195.0	35 613.6	1 568.7	Laibin	72 775.5	34 932.2	1 727.3	1 648.0
III	Long'an	77 599.1	37 247.6	3 202.7	Laibin	76 428.6	36 685.7	3 480.8	3 341.7

Note: calculated at 480 yuan/t sugarcane.

4 Conclusions and discussions

4.1 Effects of slow-release fertilizer on the growth of sugarcane The three fertilization treatments had little effects on emergence, tillering, and effective stems of sugarcane, but compared with the treatment of compound fertilizer (treatment I) with a ratio of N, P, and K of 1∶1∶1, treatment II using slow-release fertilizers as topdressing had long-lasting efficiency and nutrient ratio was more reasonable, and could provide certain nutrients at the late stage of sugarcane growth[5], thus the sugarcane growth was better, the plant height and stem diameter were higher, so that the yield was higher.

4.2 Effects of sugarcane-specific fertilizer on the growth of sugarcane The sugarcane-specific fertilizer optimized the ratio of N, P and K according to nutrient demand of sugarcane, the fertilizer efficiency was higher, and it promoted the absorption of nutrients and accumulation of dry matters at the key stage of sugarcane growth, so the sugarcane yield was higher[6]. Besides, sugarcane-

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specific base fertilizer contained certain amount of organic matters, so the sugar content was higher.

4.3 Analysis of economic benefits of different fertilization treatments and recommendations Under the precondition of the same fertilizer cost, the treatment II with slow-release fertilizer as topdressing increased 1 648.0 yuan/ha compared with the treatment I with single application of compound fertilizer, while the treatment III with application of sugarcane-specific fertilizer increased 3 341.7 yuan/ha compared with single application of compound fertilizer, showing significant economic benefits. In this study, we only designed three treatments with the same fertilizer cost and obtained excellent research results. On this basis, it is worth studying about the design of sugarcane-specific fertilizer rate, so as to further reduce fertilizer application costs and obtain maximum economic benefits.

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