

EVALUATION OF DIFFERENT SUGARCANE CLONES UNDER LOW NITROGEN STRESS

XIANG LI*, QUYAN HUANG, HAIRONG HUANG, LUNWAGN WANG,
ZHONGFENG ZHOU, HUI ZHOU AND RONGZHONG YANG

*Sugarcane Research Institute, Guangxi Academy of Agricultural Sciences,
Nanning 530007, Guangxi, China*

Key words: Sugarcane clones, Low nitrogen stress, Nitrogen use efficiency, Cane yield

Abstract

This study examined the agronomic traits yield and sucrose content of different sugarcane clones in low nitrogen stress to determine which showed the best performance. ROC22 was the control in the comparative planting experiment. Six Guitang clones from a 2004 seeding were studied. The results indicated that the germination rate, stalk diameter, millable stalks, cane yield, and sucrose content of Guitang 04/1028, Guitang 04/1531, Guitang 04/522, Guitang 04/539, Guitang 04/2299 and Guitang 04/109 were higher than those of the control. Guitang 04/539 was resistant to low nitrogen stress and showed better sprout rate, stalk diameter, millable cane, cane yield, and sugar yield in low nitrogen doses. Its cane yield and sucrose contents were 104.81 and 15.04 t/hm², respectively; they increased 17.46 and 15.04% compared to the control. Low nitrogen stress negatively influences tillering and the amount of millable cane, which decreases cane and sugar yield. Therefore, results of this experiment could serve as a reference for further sugarcane breeding research.

Introduction

Guangxi province is the largest sugarcane production area in China, producing more than 60% of the country's yield. However, according to data from the Guangxi Sugar Association, during the 09/10 crop season, the Guangxi sugarcane growth area fell 3.3% compared to the previous year, down to 0.97 million hm². Its sugar production was 6.5 million tons, a year-on-year decline of 28.2% (Development Bureau of Guangxi Zhuang Autonomous Region 2015). The decline was mainly due to higher agricultural prices, enhanced costs for labor and sugarcane growth, and declined revenue. Nitrogen fertilizer is an important factor in sugarcane production costs. Generally, between 500 and 700 kg/hm² of urea is applied (Wang *et al.* 2005) in Guangxi sugarcane growth areas, which is far more than the average in other countries (275 kg/hm²) (Tan *et al.* 2002). Brazil, as the leading sugar producer, has invested in research to reduce sugarcane production costs. Brazil has become one of the world's leading countries in efficient sugarcane production, particularly in nitrogen use. Brazil's varieties of sugarcane produce higher yields at lower nitrogen levels (Wang *et al.* 2008, Yang *et al.* 2006, Wang *et al.* 2005). Therefore, to maintain a profitable and sustainable sugar industry in Guangxi province, save energy, and reduce pollution, it is critical to promote sugarcane strands that are high-quality, high-production, high-sugar, efficient, widely applicable, and do not require high nitrogen levels. However, currently, there are no Chinese-based studies on nitrogen-efficient sugarcane. Guangxi Sugarcane Research Institute selected a batch of high-quality sugarcane varieties to explore their agronomic traits, yields and features. This study used ROC22 as the control because it is rarely used in low nitrogen stress tests. Tests on new varieties have been carried out in the test field of Guangxi Sugarcane Research Institute, which aims to enhance sugarcane development and improve China's industrial assets.

*Author for correspondence: <13978654361@163.com >.

Materials and Methods

Plant materials included Guitang 04/1028, Guitang 04/1531, Guitang 04/522, Guitang 04/539, Guitang 04/2299 and Guitang 04/109, with ROC22 as the control group (CK).

The test was carried out on the Guangxi Sugarcane Research Institute test field. The soil was neutral sandy loam with 7.1 pH, 15.04 g/kg organic matter content, 0.109 g/kg N content, 0.059 g/kg phosphorus content, 0.998 g/kg potassium content, 88.0 mg/kg available N content, 12.0 mg/kg available P content, and 55.0 mg/kg available K content.

The test employed optional groups by setting three repetitions, each having four rows that were 7 m long and 1.2 m wide. The test field covered 33.6 m² area.

New canes were grown on March 4, 2009. Before sowing, canes were cut into double-bud sections and soaked in carbendazim solution for five minutes. 107.2 thousand buds were sown in each hectare. After sowing, imidacloprid was sprinkled to prevent pests. Then, the buds were watered and covered with soil, and pre-emergent herbicide was sprinkled as well. Finally, plastic film was used to cover the mulch film. Varieties of fertilizers and the amount: FCMP1500 kg/hm², potassium 225 kg/hm². Fertilizers were applied two more times. On 5th May 2009, 75 kg/hm² urea was used. On 5th June 2009, 75 kg/hm² urea, 1500 kg/hm² FCMP and 750 kg/hm² potassium were used across the crops. All other management specifications were identical to those found on other large fields.

Research was carried out on the sugarcane sprout and tillering rates on April 30 and May 22, 2009. Sugarcane plant height was investigated from June to October in 2009 to calculate the monthly growth speed. Stem diameter measurements were made on September 27. The amount of millable cane was measured on September 30. Sugar content analysis was completed with samples in January and February in 2010. The yield was weighed on March 8, 2009 when the sugarcane was harvested. All indexes were based on investigation in small districts, which were shown by the average value of three districts.

Results and Discussion

As shown in Table 1, withholding nitrogen fertilizer before sprouting significantly affected the sprout rate. All six clones had sprout rate higher than 50%, which was higher than the ROC22 control. Of them, Guitang 04/109 showed the highest sprout rate at 79.4%. However, when N fertilizer was used two additional times during the sugarcane tillering period, the control group tillering rate reached 60.2%, which was better than those of the tested clones. Among the clones, the Guitang 04/522 tillering rate was relatively higher at 40.7%.

From July to September, sugarcane entered into the elongation period when the growth rate of all clones had a monthly growth rate exceeding 35 cm. August and September were the sugarcane clone growth peak. During August, the control group showed the highest growth rate, followed by Guitang 04/2299 and Guitang 04/109. After the addition of Nitrogen fertilizer, the control growth rate was obviously higher than those of the clones. During September Guitang 04/522 showed the highest growth followed by control (CK). After the addition of nitrogen fertilizer, the control growth rate was higher than those of the clones. During October, the clones' growth rates began decreasing. Of them, Guitang 04/522 showed the largest decline of growth rate speed which was only 8.3 cm/month. However, the speed rate of some clones rebounded, such as Guitang 04/1028, Guitang 04/1531, Guitang 04/522, Guitang 04/539, and Guitang 04/109, staying at over 30 cm. The average monthly growth rates ranked from highest to lowest is as follows: Control > Guitang 04/109 > Guitang 04/539 > Guitang 04/522 > Guitang 04/1028 > Guitang 04/1531 ≈ Guitang 04/2299.

Except for Guitang 04/1028 and Guitang 04/1531, the height of all clones and the control group, exceeded 250 cm. As shown in Table 2, Guitang 04/522 attained the highest stem height at 260 cm, while Guitang 04/1531 had the lowest stem height at 222 cm. In the experiment, all clones and the control group failed to exceed 300 cm, which might have been caused by low nitrogen stress.

Table 1. Comparison of agronomic traits of various clones under low nitrogen stress.

Clone	Sprout Rate/ (%)	Tillering Rate/(%)	Growth speed/(cm/month)					Mean
			July	August	September	October	November	
Guitang 04/1028	55.9	23.2	102.7	37.5	37.0	9.7	38.0	30.5
Guitang 04/1531	73.9	39.6	103.1	36.2	37.2	11.8	34.1	29.8
Guitang 04/522	65.6	40.7	122.8	35.0	57.5	8.3	32.4	33.3
Guitang 04/539	66.7	38.3	115.1	39.2	52.0	10.7	34.4	34.1
Guitang 04/2299	71.9	12.6	132.6	44.0	38.1	19.8	15.5	29.3
Guitang 04/109	79.4	18.2	119.1	41.7	51.2	17.8	29.8	35.1
CK	54.9	60.2	113.6	45.5	53.7	23.1	21.9	36.0

Table 2. Comparison of yield traits of various clones under low nitrogen stress.

Clone	Height (cm)	Diameter (cm)	Millable cane /((thousand stalk/hm ²))	Per stalk weight/(kg/stalk)	Yield (t/hm ²)	CK± (%)	Rank
Guitang 04/1028	225	2.79	65.51	1.49	97.67	9.46	3
Guitang 04/1531	222	2.88	73.85	1.33	98.26	10.12	2
Guitang 04/522	260	2.40	65.51	1.45	95.29	6.79	5
Guitang 04/539	256	2.56	73.85	1.42	104.81	17.46	1
Guitang 04/2299	251	2.52	76.23	1.24	94.89	6.34	6
Guitang 04/109	250	2.53	76.23	1.27	96.48	8.12	4
CK	258	2.31	59.64	1.50	89.23	0	7

The clones and the control group did not reach 3.0 cm stem diameters. Clone stem diameters were larger than that of the control group. Guitang 04/1531 had the largest stem diameter of 2.88 cm, while the control group attained 2.31 cm (Table 2).

From Table 2, it can be seen that all tested clones had more millable stems than the control. Out of them, Guitang 04/2299 and Guitang 04/109 had the highest number of millable canes at 76.23 thousand stalks/hm², compared to the control at 59.64 thousand stems/hm².

The control had higher weight than those of the clones. Guitang 04/109 and Guitang 04/2299 weighed the least at 1.27 and 1.24 kg/stem, respectively. The control stem weight was the highest 1.50 kg/stem. The stem diameter of 04/1028 was close to that of control 1.49 kg/stem.

Table 2 shows that the cane yields of all clones were higher than CK. The relationship is as follows: Guitang 04/539 > Guitang 04/1531 > Guitang 04/1028 > Guitang 04/109 > Guitang 04/522 > Guitang 04/2299 > CK. As can be seen, 04/539 had the highest cane yield at 104.81 kg/hm², which was 17.46% higher than that of the control group. Guitang 04/2299, which had a lower cane yield, yielded 6.34% more than the control group.

According to Table 3, among the six clones, from November to February, only Guitang 04/1531 and Guitang 04/522 groups had higher monthly average sucrose content than that of CK. The sucrose content of Guitang 04/1531 was 0.34% higher than that of CK. Guitang 04/1028 had the lowest sucrose at 14.33%, which was 0.59% lower than CK.

The average clone sugar yield increased on the whole. Of them, Guitang 04/539 showed the highest average hectare sugar yield 15.15 t/hm², which was 13.71% higher than that of CK. The average hectare sugar yield ranked from highest to lowest is as follows: Guitang 04/539 > Guitang 04/1531 > Guitang 04/522 > Guitang 04/109 > Guitang 04/1028 > Guitang 04/2299 > CK.

Table 3. Comparison of sucrose content and sugar yield of various clones under low nitrogen stress

Clone	Sucrose content (Mean from Nov. to Feb./%)						Sugar Yield (t/hm ²)	CK± (%)	Rank
	11	12	1	2	Mean	CK(±)			
Guitang 04/1028	13.45	15.08	14.82	13.95	14.33	-0.59	13.99	6.67	5
Guitang 04/1531	13.81	16.01	15.32	15.63	15.19	0.28	14.93	11.76	2
Guitang 04/522	14.05	15.83	15.64	15.51	15.26	0.34	14.54	9.28	3
Guitang 04/539	12.72	14.45	15.89	14.74	14.45	-0.47	15.15	13.71	1
Guitang 04/2299	13.01	14.59	15.94	14.68	14.56	-0.36	13.81	4.09	6
Guitang 04/109	11.84	14.73	17.51	14.72	14.70	-0.22	14.18	7.15	4
CK	13.46	15.65	15.37	15.18	14.92	0.0	13.31	0.0	7

Only under the low nitrogen conditions [150 (kg urea/hm²)] equivalent to 20% of the normal nitrogen fertilization level did the 6 clones have sprout rates that exceeded 50%, which was the control's sprout rate. However, the CK tillering rate 60.2% was higher than those of the clones. When nitrogen fertilizer was introduced, CK produced higher growth rate than those of the clones. The monthly growth rate ranked from highest to lowest is as follows: CK > Guitang 04/109 > Guitang 04/539 > Guitang 04/522 > Guitang 04/1028 > Guitang 04/1531 > Guitang 04/2299. The stalk heights of the clones and control group were lower than 300 cm; Guitang 04/522 had the highest stalks at 260 cm. The stalk diameters of all clones were larger than that of CK. The stalk diameter of Guitang 04/1531 was the largest at 2.88 cm. The clones had more millable cane than CK. Among them, Guitang 04/2299 and Guitang 04/109 had the most millable cane of 76,230 stalks/hm². Clone cane yield and sugar yield were also higher than those of CK. Guitang 04/539 had the highest sugar content. Guitang 04/539 cane yield was 104.81 kg/hm², which was 17.46% higher than that of CK. Its sugar yield was 15.15 t/hm², which was 13.71% higher than that of CK.

Low nitrogen stress conditions negatively affected clone tillering rates and stem heights, which was consistent with the test results of Wang *et al.* (2010a). This is because low nitrogen stress negatively impacted sugarcane photosynthesis (Liang *et al.* 2005). Therefore, sugarcane plants had to reduce functions, e.g., reducing tillering and postponing stem elongation to maintain

the adaptive response (Xu *et al.* 1997 and Chen *et al.* 2009) of normal metabolic activity. Sugarcane agronomic traits had a direct impact on its cane yield and sugar yield (Wang *et al.* 2010b). These clones were more suitable than ROC22 in sprout rate, stem diameter, and millable stems. Therefore, the sugar productivity and sugar content were higher than the control group. During the early stage of the sprout period, the clones and ROC22 grew slowly due to a lack of nitrogen. In the later stage, with the increased use of nitrogen fertilizer, their growth rates accelerated. Therefore, in the early stage, a certain amount of nitrogen fertilizer should be used (Wang *et al.* 2007). Low nitrogen stress negatively influenced tillering and the amount of millable cane of ROC22, leading to a decrease in cane yield and sugar yield compared with the clones. The low production was similar to the results of other tests used.

Under the condition of low nitrogen (urea 150 kg/hm²) equivalent to 25% of the normal nitrogen level in Guangxi sugarcane growth area (urea 600 kg/hm²), Guitang 04/539 showed the best performance on sprout rate, stalk diameter, millable cane, cane yield, and sugar yield due to its resistance to low nitrogen stress. The clone's nitrogen fixation ability must be further tested to discover more nitrogen efficient varieties.

Acknowledgements

The authors are grateful to Guangxi Academy of Agricultural Sciences (G2014JQ01, 2015JZ93), Guangxi Key Scientific and Technological Projects (1347004-2), International Technology Cooperation Projects (2013DFA31600), National Modern Agricultural Industry System (sugarcane) Guangxi Sugarcane Innovation team (nycytxgxcxtd-02), and Modern Agricultural Industrial Technology System (CARS-20-1-3) for their financial support.

References

- Chen CJ, Sun SH, Wei HW, Huang YZ, Han SJ, Lu GY and Jiang ZJ 2009 The search of new sugarcane clone. *GX Sugar* **1**: 22-25
- Development Bureau of Guangxi Zhuang Autonomous Region 2015. The situation of 2014/2015 GX Sugar mills. *GSAR* **1**: 1-2.
- Liang J, Li YR and Liang CX 2005. The physiological characteristics of different sugarcane varieties under no nitrogen fertilizing condition. *Chin. Agric. Sci. Bull.* **21**:188-190
- Tan YM, Wang LW, Wang TS, Xian W and Pang T 2002. The test of nitrogen fixation variety RB72-454. *GX Sugar* **1**: 12-15
- Wang LW, Li X, Huang JY, Li HG, Fang FX, Yang RZ, Tang SY, Tan F and Huang HR 2010b. Comparison of Characteristics Among 16 Sugar and Energy Cane Varieties. *Chin. Agric. Sci. Bull.* **26**: 4 08-415
- Wang LW, Li YR, He ZW, Xian W, Liang J and Tan YM 2007. Comparison nitrogen fixation ability of apical stem in tissue culture sugarcane seeding. *Southwest China. J. Agric. Sci.* **20**: 99-102.
- Wang LW, Li YR, Tan YM, He H 2005. Performances and Application Prospects of Several Brazilian Sugarcane Varieties in Guangxi. *Sugarcane* **2**: 1-7.
- Wang LW, Li YR, Yang RZ, Li X, Huang JY and Fang FX 2010a. Response of low nitrogen stress in different sugarcane genotypes. *Southwest China J.Agric.Sci* **23**:508-514
- Wang LW, Tan YM, Li YR, Pang T and Xian W 2005. Characteristic Studies of Sugarcane Variety GuiYin5. *Sugar crops Chin* **4**: 11-15.
- Wang LW, Yang RZ, Wei JY, Li X, Fang FX and Li XY 2008. Analysis of Cultivation benefit and varietal characters performance of multipurpose sugarcane variety B9. *J. Anhui. Agric. Sci.* **36**: 13102-13104
- Xu J and Li JD (1997) Association nitrogen fixation. *Bio. Bull.* **32**: 16-18.
- Yang RZ, Tan YM, Wang LW, Liu LM, Tan F and Li YR 2006. Evaluation of low nitrogen stress for sugarcane. *Southwest China. J. Agric. Sci.* **19**: 1132-1138.

(Manuscript received on 14 August, 2015; revised on 29 November, 2015)