Comprehensive Evaluation of New Self-cultivated Sugarcane Lines by Grey Relational Analysis

Wenqing MA *, **Qiang GUO**, **Chizhang WEI**, **Hengrui LI**, **Chong PENG**, **Zhenhua LIANG**

South Subtropical Agricultural Scientific Research Institute of Guangxi/Land Reclamation Sugarcane Improved Variety Research & Breeding Centre of Guangxi, Longzhou 532415, China

Abstract The grey relational analysis (GRA) was used to evaluate the 10 sugarcane lines by 13 main agronomic characters. The result showed that the grey correlation degree of self-cultivated lines GNY08 – 320 (0.7502), GNY08 – 336 (0.7409), GNY08 – 186 (0.7369), and GNY08 – 225 (0.7277) were higher than ROC22 (CK), so the 4 lines can be further tested, and the others were worse than CK that should be further observed or eliminated.

Key words Sugarcane, Grey relational analysis, Lines, Comprehensive evaluation

Chongzuo City of Guangxi Zhuang Autonomous Region is the "capital of sugar", and the largest city of sugarcane production. Its sugar yield has ranked the first in China for 10 consecutive crushing seasons. In 2012, the sugarcane planting area in Chongzuo City reached 294 800 hm^2, about 18.904 9 million tons of sugarcane was delivered to sugar refineries (having a growth rate of 10.27% compared with the same period of previous year), and sugar yield up to 2.292 3 million tons (having a growth rate of 7.12% compared with the same period of previous year), and its sugar yield accounted for 1/5 and 1/3 of the whole China and Guangxi Region. Therefore, the sugarcane yield of Chongzuo City has a great influence on sugarcane yield of Guangxi Region and even the whole China, and cultivating sugarcane varieties suitable for this area is of great significance. Studies have shown[1-2] that it is feasible to make comprehensive evaluation of sugarcane varieties (lines) by grey relational analysis (GRA), and the evaluation results are consistent with actual situations. For this reason, we carried out comprehensive evaluation of 13 main agronomic characters of 9 self-cultivated sugarcane lines and 1 control variety using the grey relational analysis, to objectively and comprehensively evaluate sugarcane quality and select new sugarcane varieties suitable for sugarcane planting areas in Chongzuo City.

1 Materials and methods

1.1 General situation of experimental area We carried out experiment in sugarcane testing base of South Subtropical Agricultural Scientific Research Institute of Guangxi. The testing base is situated in 22°45′N and 106°88′E, and has a height above sea level of 200 m. With subtropical monsoon climate, it is warm and free of frost in the whole year. The annual mean temperature is 22.4℃, the annual precipitation is 1 260 mm, and annual mean sunshine hours is 1 550 hours.

1.2 Experimental materials Experimental materials include GNY09 – 353 (X_1), GNY08 – 186 (X_2), GNY08 – 212 (X_3), GNY08 – 358 (X_4), GNY08 – 516 (X_5), GNY08 – 320 (X_6), ROC22 (CK), GNY08 – 336 (X_7), GNY08 – 116 (X_8), and GNY08 – 225 (X_9), and the major variety ROC22 was taken as control group. Except the control group, other 9 new sugarcane lines are cultivated by South Subtropical Agricultural Scientific Research Institute of Guangxi.

1.3 Experimental methods We adopted field cultivation method, random complete block design, repeating three times, the field area is 23.1 m^2 (1.1 m × 7 m × 3 rows), double bud segment, 8 004 buds/667m^2, and conventional field management. According to experimental requirements, we separately measured indicators of related agronomic characters. Average values of main agronomic characters are listed in Table 1.

2 Analytical methods

2.1 Determination of reference series In accordance with the grey system theory[3-4], we took the 10 sugarcane varieties (lines) as a whole and built a grey system, each variety (line) is a factor in this system. According to sugarcane breeding objective and production realities of this area, we set the optimum values of each character as the reference series X_0 (as listed in Table 1). In the 13 agronomic characters, the fiber content was measured by central effect; for reducing saccharide, rate of withered leaves and Pokkah boeng, the lower, the better; variation was measured by lower effect, and other indicators were measured by upper characters.

2.2 Dimensionless Since dimension of original data of each character is different, it is difficult to make direct comparison, and we have to carry out dimensionless treatment of original data,

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* Corresponding author. E-mail: mwenqing2003@163.com

as listed in Table 2.

Table 1 Main agronomic characters of experimental materials

Lines	Sprouting rate//%	Seedling emergence rate//%	Tillering rate//%	Stalk diameter//cm	Effective stalks//hm^2	Single stalk weight//kg	Sugar content//%
X_0	136.92	63.80	102.85	2.750	73 170	2.162	16.18
X_1	123.96	48.47	82.93	2.523	68 400	1.650	13.89
X_2	134.58	57.56	85.78	2.980	53 250	2.162	14.64
X_3	106.23	50.00	80.06	2.650	64 935	1.820	16.18
X_4	109.22	50.39	67.87	2.693	55 845	2.039	13.31
X_5	103.02	56.80	61.37	2.832	71 865	1.726	12.22
X_6	136.92	58.48	87.11	2.630	55 410	1.787	16.04
CK	123.00	54.69	81.98	2.577	60 615	1.575	15.31
X_7	126.24	63.80	91.16	2.917	58 440	1.891	15.50
X_8	103.51	60.55	93.66	2.560	73 170	1.642	12.99
X_9	120.47	52.34	102.85	2.901	54 120	2.069	14.13

Lines	Stalk yield t/hm^2	Sugar yield t/hm^2	Fiber content//%	Reducing saccharide//%	Rate of withered leaves//%	Pokkah boeng
X_0	118.7	17.3	13.00	0.37	6.91	1
X_1	106.5	14.8	10.78	1.23	6.91	2
X_2	89.4	13.1	11.54	1.07	7.78	2
X_3	106.7	17.3	11.04	0.91	9.72	2
X_4	82.1	10.9	10.76	1.70	11.00	1
X_5	118.7	14.5	10.03	0.63	15.35	2
X_6	92.0	14.7	10.86	0.82	9.16	1
CK	83.4	12.8	10.80	0.37	10.29	1
X_7	103.8	16.1	11.92	0.99	9.65	2
X_8	100.4	13.0	12.01	0.50	10.72	2
X_9	88.7	12.5	10.78	0.72	17.93	1

Note: stalk diameter, effective stalks, single stalk weight, stalk yield, sugar content, sugar yield, fiber content, and reducing saccharide were measured in March; "1, 2" in Pokkah boeng column denotes having or having no natural occurrence of Pokkah boeng.

Table 2 Dimensionless treatment of original data

Lines	Sprouting rate//%	Seedling emergence rate//%	Tillering rate//%	Stalk diameter//cm	Effective stalks//hm^2	Single stalk weight//kg	Sugar content//%
X_1	0.905 4	0.759 7	0.806 4	0.847 5	0.934 8	0.763 2	0.858 5
X_2	0.982 9	0.902 2	0.834 0	1.013 6	0.727 8	1.000 0	0.904 8
X_3	0.775 9	0.783 7	0.778 4	0.901 4	0.887 5	0.841 8	1.000 0
X_4	0.797 7	0.789 8	0.659 9	0.916 0	0.763 2	0.943 1	0.822 6
X_5	0.752 5	0.890 2	0.596 8	0.963 3	0.982 2	0.798 3	0.755 3
X_6	1.000 0	0.916 7	0.847 0	0.478 2	0.757 3	0.826 5	0.991 3
CK	0.898 3	0.857 1	0.797 1	0.468 5	0.828 4	0.728 5	0.946 2
X_7	0.922 0	1.000 0	0.886 4	0.530 4	0.798 7	0.874 7	0.958 0
X_8	0.756 0	0.949 0	0.910 7	0.465 5	1.000 0	0.759 5	0.802 8
X_9	0.879 9	0.820 4	1.000 0	0.527 5	0.739 6	0.957 0	0.873 3

Lines	Stalk yield t/hm^2	Sugar yield t/hm^2	Fiber content//%	Reducing saccharide//%	Rate of withered leaves//%	Pokkah boeng
X_1	0.897 6	0.857 3	0.675 0	0.300 8	1.000 0	0.500 0
X_2	0.753 5	0.758 5	0.722 6	0.345 8	0.888 2	0.500 0
X_3	0.898 9	1.000 0	0.691 3	0.406 6	0.710 9	0.500 0
X_4	0.691 5	0.632 9	0.673 8	0.217 6	0.628 2	1.000 0
X_5	1.000 0	0.840 2	0.628 1	0.587 3	0.450 2	0.500 0
X_6	0.775 0	0.854 7	0.417 7	0.451 2	0.754 4	1.000 0
CK	0.702 9	0.739 9	0.415 4	1.000 0	0.671 5	1.000 0
X_7	0.874 8	0.932 4	0.458 5	0.373 7	0.716 1	0.500 0
X_8	0.845 8	0.755 4	0.461 9	0.740 0	0.644 6	0.500 0
X_9	0.747 2	0.725 9	0.414 6	0.513 9	0.385 4	1.000 0

2.3 Differential series value The difference between measured value of each character and the optimum series value is the differential series value, and the results are listed in Table 3. From Table 3, we can obtain two ranges M and m of the differential series value, M = maxmax Δi, (k) = 0.7824, m = minminΔi, (k) = 0.

Table 3 Absolute difference between reference varieties and experimental materials

Lines	Sprouting rate//%	Seedling emergence rate//%	Tillering rate//%	Stalk diameter//cm	Effective stalks//hm^2	Single stalk weight//kg	Sugar content//%
X_1	0.094 6	0.240 3	0.193 6	0.152 5	0.065 2	0.236 8	0.141 5
X_2	0.017 1	0.097 8	0.166 0	0.013 6	0.272 2	0.000 0	0.095 2
X_3	0.224 1	0.216 3	0.221 6	0.098 6	0.112 5	0.158 2	0.000 0
X_4	0.202 3	0.210 2	0.340 1	0.084 0	0.236 8	0.056 9	0.177 4
X_5	0.247 5	0.109 8	0.403 2	0.036 7	0.017 8	0.201 7	0.244 7
X_6	0.000 0	0.083 3	0.153 0	0.521 8	0.242 7	0.173 5	0.008 7
CK	0.101 7	0.142 9	0.202 9	0.531 5	0.171 6	0.271 5	0.053 8
X_7	0.078 0	0.000 0	0.113 6	0.469 6	0.201 3	0.125 3	0.042 0
X_8	0.244 0	0.051 0	0.089 3	0.534 5	0.000 0	0.240 5	0.197 2
X_9	0.120 1	0.179 6	0.000 0	0.472 5	0.260 4	0.043 0	0.126 7

Lines	Stalk yield t/hm^2	Sugar yield t/hm^2	Fiber content//%	Reducing saccharide//%	Rate of withered leaves//%	Pokkah boeng
X_1	0.102 4	0.142 7	0.325 0	0.699 2	0.000 0	0.500 0
X_2	0.246 5	0.241 5	0.277 4	0.654 2	0.111 8	0.500 0
X_3	0.101 1	0.000 0	0.308 7	0.593 4	0.289 1	0.500 0
X_4	0.308 5	0.3671	0.326 2	0.782 4	0.371 8	0.000 0
X_5	0.000 0	0.159 8	0.371 9	0.412 7	0.549 8	0.500 0
X_6	0.225 0	0.145 3	0.582 3	0.548 8	0.245 6	0.000 0
CK	0.297 1	0.260 1	0.584 6	0.000 0	0.328 5	0.000 0
X_7	0.125 2	0.067 6	0.541 5	0.626 3	0.283 9	0.500 0
X_8	0.154 2	0.244 6	0.538 1	0.260 0	0.355 4	0.500 0
X_9	0.252 8	0.274 1	0.585 4	0.486 1	0.614 6	0.000 0

2.4 Calculation of relational coefficient, relational grade and weight coefficient With reference to methods of Wei Yongqiang *et al*[4], we calculated the relational coefficient ξi (k) between differential series value and optimum series value of characters of each variety, and the resolution coefficient $\rho = 0.5$. The relational coefficient reflects consistency between each character and ideal value. The higher the relational coefficient, the closer to ideal value of a certain character, and the better the performance (as listed in Table 4). Later, we calculated relational grade ri of each character. Taking normalized processing of ri, we obtained the weight value ωk of each character.

Table 4 Relational coefficient of major characters of experimental materials

Lines	Sprouting rate//%	Seedling emergence rate//%	Tillering rate//%	Stalk diameter//cm	Effective stalks//hm^2	Single stalk weight//kg	Sugar content//%
X_1	0.805 2	0.619 4	0.668 9	0.719 5	0.857 2	0.050 9	0.734 3
X_2	0.958 1	0.800 0	0.702 1	0.966 4	0.589 6	0.081 7	0.804 3
X_3	0.635 8	0.643 9	0.638 4	0.798 6	0.776 6	0.058 2	1.0000
X_4	0.659 2	0.650 5	0.534 9	0.823 2	0.622 9	0.071 4	0.688 0
X_5	0.6124	0.780 8	0.492 4	0.914 2	0.956 4	0.053 9	0.615 1
X_6	1.000 0	0.824 4	0.718 9	0.428 5	0.617 1	0.056 6	0.978 4
CK	0.793 7	0.732 5	0.658 5	0.424 0	0.695 1	0.048 2	0.879 2
X_7	0.833 7	1.000 0	0.775 0	0.454 4	0.660 2	0.061 9	0.903 0
X_8	0.615 9	0.884 6	0.814 1	0.422 6	1.000 0	0.050 6	0.664 9
X_9	0.765 1	0.685 4	1.000 0	0.452 9	0.600 4	0.073 6	0.755 3
ri	0.767 9	0.762 1	0.700 3	0.640 4	0.737 6	0.742 8	0.802 3
ωk	0.095 7	0.095 0	0.087 2	0.079 8	0.091 9	0.081 7	0.099 9

Lines	Stalk yield t/hm^2	Sugar yield t/hm^2	Fiber content//%	Reducing saccharide//%	Rate of withered leaves//%	Pokkah boeng
X_1	0.792 5	0.732 7	0.546 2	0.358 8	1.000 0	0.438 9
X_2	0.613 4	0.618 3	0.585 1	0.374 2	0.777 7	0.438 9
X_3	0.794 6	1.000 0	0.558 9	0.397 3	0.575 0	0.438 9
X_4	0.559 1	0.515 9	0.545 3	0.333 3	0.512 7	1.000 0
X_5	1.000 0	0.710 0	0.512 6	0.486 6	0.415 7	0.438 9
X_6	0.634 8	0.729 2	0.401 8	0.416 2	0.614 3	1.000 0
CK	0.568 3	0.600 7	0.400 9	1.000 0	0.543 6	1.000 0
X_7	0.757 6	0.852 6	0.419 4	0.384 5	0.579 4	0.438 9
X_8	0.717 2	0.615 3	0.421 0	0.600 7	0.524 0	0.438 9
X_9	0.607 4	0.588 0	0.400 6	0.445 9	0.388 9	1.000 0
ri	0.704 5	0.696 3	0.479 2	0.479 7	0.593 1	0.663 4
ωk	0.087 8	0.086 7	0.059 7	0.059 8	0.073 9	0.082 6

2.5 Grey comprehensive evaluation value With reference to calculation method of Wei Yongqiang et al[4], we calculated the grey comprehensive evaluation value ri′ of each variety (line), as listed in Table 5.

Table 5 Calculation results of relational analysis method for experimental materials

Lines	ri'	Rank	Stalk yield//t/hm^2	Rank	Sugar yield//t/hm^2	Rank
GNY 08 – 320	0.7502	1	92.0	6	14.7	4
GNY 08 – 336	0.7409	2	103.8	4	16.1	2
GNY 08 – 186	0.7369	3	89.4	7	13.1	6
GNY 08 – 225	0.7277	4	88.7	8	12.5	9
ROC22	0.7221	5	83.4	9	12.8	8
GNY 08 – 212	0.7211	6	106.7	2	17.3	1
GNY 09 – 353	0.7083	7	106.5	3	14.8	3
GNY 08 – 116	0.6948	8	100.4	5	13.0	7
GNY 08 – 516	0.6788	9	118.7	1	14.5	5
GNY 08 – 358	0.6541	10	82.1	10	10.9	10

3 Results and analyses

According to the grey relational analysis method, varieties (lines) with higher weighted relational grade ri' have better comprehensive characters. From Table 5, we can see that lines with weighted relational grade ri' higher than ROC22 include GNY08 – 320, GNY08 – 336, GNY08 – 186, and GNY08 – 225, indicating that comprehensive characters of these 4 lines are better than the control group, and we carried out further experiment. Comprehensive characters of other materials are worse than the control group and need further observation or rejection. GNY08 – 320 belongs to medium stalk lines, has higher tillering ability, better ratoon, higher ability of resisting Pokkah boeng, and sucrose content is 3.48% higher than the control group; GNY09 – 336 belongs to big stalk lines, has powerful growth situation, rapid sprouting speed, many effective stalks, better ratoon, and the yield is 24.46% higher than the control group, sugar content is about equal to the control group ROC22, and easier leaf stripping, so it is worth of expectation and necessary to note the prevention and control of Pokkah boeng; GNY08 – 186 belongs to medium stalk lines, has rapid sprouting speed, higher tillering ability, but it is required to take notice of preventing and controlling borers; GNY08 – 225 belongs to big stalk lines, has better sprouting, higher tillering ability, and better ratoon, and the sucrose yield is about equal to the control group, so it is necessary to continue making comparative observation. We used the grey relational analysis method to make comprehensive evaluation on self-cultivated sugarcane lines, and the results are consistent with production practice of sugarcane lines. This avoids the evaluation of quality of sugarcane only relying on sugarcane yield. Thus, the evaluation is more objective and comprehensive, and the grey relational analysis method can be applied in evaluation and selection of sugarcane varieties (lines), which is also similar to conclusions of related researches[2,5 – 6].

4 Discussions

In the grey relational analysis, as the standard scale, X_0 should not be set too high or too low. This needs breeders' rich experience and setting in accordance with practice. Using the grey relational analysis to make comprehensive evaluation of new sugarcane varieties and liens can overcome subjectivity and one – sidedness of taking single character sugarcane stalk yield as major evaluation criterion, increase the accuracy and reasonableness of seed selection, and is favorable for selecting proper materials. There are many methods for determining weight coefficient, such as Delphi method, efficiency coefficient method, and judgment matrix method. These methods can scientifically, objectively and reasonably control breeding direction through strict and careful calculation, so as to realize coordination of major agronomic characters and target characters[7]. At present, most areas plant sugarcane in large scale and adopt regional cultivation. Therefore, it is required to pay closer attention to selection of stress resistant varieties, making screening of disease resistance at the early stage of sugarcane material selection, to reject those lines or varieties without disease resistance character. Besides, with reduce of labor in China, reducing manual cost and improving mechanization level will become development trend of future sugarcane industry. Therefore, it is recommended to increase more physiological indicators and stress resistance such as dust-brand and lodging resistance, to make comprehensive evaluation on excellent characters of sugarcane varieties (lines). The data we used in this study were experimental data of one year one region, thus the conclusion needs repeated demonstration of 2 years planting and one year ratoon or many areas of experiment, especially the selection of ratoon, and the disease resistance needs further inoculation test.

References

[1] LU X, CAI Q, WANG LP, *et al*. Evaluating crossing combinations of *Saccharum officinarum* L. × *Erianthus arundinaceus* by grey correlative analysis [J]. Southwest China Journal of Agricultural Sciences, 2007, 20(1): 103 – 106. (in Chinese).

[2] HUANG JY, HUANG HR, LI X, *et al*. Analysis of new sugar and energy cane varieties based on grey relational method[J]. Journal of Anhui Agricultural Sciences, 2010, 38(33): 18711 – 18713. (in Chinese).

[3] DENG JL. Agricultural system grey theory and methods[M]. Ji'nan: Shandong Science & Technology Press, 1998: 1 – 8. (in Chinese).

[4] WEI YQ, ZHAO BX, LEI XB, *et al*. Comprehensive evaluation of new corn varieties by gray relational analysis and DTOPSIS method[J]. Acta Agriculturae Jiangxi, 2009, 21(6): 11 – 14. (in Chinese).

[5] WU CW, FAN YH, YANG HC, *et al*. Manifestation and evaluation of several exotic sugarcane clones from abroad[J]. Sugarcane and Canesugar, 2003(5): 15 – 17. (in Chinese).

[6] WEN JC, FU JF, CHEN XK, *et al*. Comprehensive evaluation of sugarcane varieties by fuzzy analysis[J]. Sugar Crops of China, 2001(3): 5 – 8. (in Chinese).

[7] JIANG YR, LU HH, PAN BG, *et al*. Grey correlation degree analysis of main agronomic character of barley and the output[J]. Barley and Cereal Sciences, 2009(3): 9 – 11. (in Chinese).