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Full Length Article

Influence of Water-saving Irrigation and Nitrogenous Fertilizer Application on Assessment of the Rice Quality

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Abstract

In order to analyze the response relationship between water-saving irrigation, nitrogenous fertilizer application with rice quality a rice field experiment was carried out. Six nitrogenous fertilizer levels (0, 60, 85, 110, 135 and 160 kg/hm^2) were applied to find its influence on the rice quality under the black soil water-saving irrigation conditions in the northeast cold regions. The TOPSIS (technique for order preference by similarity to ideal solution) model improved on the basis of game theory to comprehensively assess the rice quality was also applied. The results showed that the low and high fertility are bad for the rice quality formation under the water-saving irrigation conditions specifically, the three quality indicators, which are processed by WS110 are higher than other processing products, except for chalkiness degree, followed by WS135, WS160, WS85, WS60 and WS0. According to the variability and spatial distribution, it is indicated that the field data acquisition processed by WS110 is better than others with small distribution and dispersion degree. Meanwhile, it can also reflect the better uniformity of three quality indicators of rice than others. Comparing with the traditional TOPSIS model, the improved TOPSIS model can lead to the desired assessment results. Considering that the curve fitting degree is relatively high with the fitting coefficient R^2 of 0.88 and the assessment results can conform to the reality. Thus, it is feasible to apply improved TOPSIS model on the basis of game theory to assess the rice quality, as a result, we can provide the relatively reliable scientific basis for the field changing scheme and offer a kind of new thought to the assessment method. © 2017 Friends Science Publishers

Keywords: Water-saving irrigation; Nitrogenous Fertilizers; Quality; TOPSIS; Assessment

Introduction

The excessive water and fertilizer during the rice field production will not only waste resources, damage the soil fertility structure, pollute the environment, but also decrease the rice quality (Li *et al.*, 2002; Guo *et al.*, 2005). The researchers always lay emphasis on the water-fertilizer interaction's influence (Das *et al.*, 2009; Krishna *et al.*, 2010; Fukushima *et al.*, 2015) on the rice yield, greenhouse gas and environmental pollution. There are few researches which can pay attention to the more water and fertilizer, as well as their interaction's influence on the rice quality. In recent years, the rice quality has attracted more attention from customers therein it should include appearance quality, nutritional quality, cooking quality and others. Considering that each of quality parameters will be assessed by multiple indicators and there is a certain correlation between different them, therefore, it is difficult to accurately analyze and assess the response relationship between rice quality, water and fertilizer. The crop quality indicator is closely related to the climatic conditions, soil characteristics and farming level, however, the water fertilizer regulation, as the nutrient, is considered as the main factor which can affect the crop quality indicator because the water fertilizer regulation can change the basic property of soil nutrient while the crop quality indicator can directly reflect the water fertilizer regulation function.

As a kind of multi-objective decision method, TOPSIS which is called the Almost Ideal Solution has been widely applied to the engineering, economical and agricultural fields (Wang and Leeb, 2007; Wang *et al.*, 2011; Li *et al.*, 2013) by right of its authenticity, intuition and reliability. In this experiment, the rice quality indicator in the mature period is measured, and classical statistics principle is used for analyzing. Protein, amylose and chalkiness degree in mature period under water-saving and nitrogenous fertilizer application conditions are assessed comprehensively by improved TOPSIS model based on game theory thought. Rice quality formation rules affected by different water and fertilizer regulations are obtained, providing a scientific basis for the further study on the physiological quality of field crops.

Materials and Methods

Experimental Site and Details

The experiment was conducted in the Rice Irrigation Test

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Center of Heilongjiang Province in 2016 located at 125º44'° E and 45º63' °N, namely, Heping Town of Anqing County. As the typical black soil areas in the cold regions, the test field has 2~3 degree perennial mean temperature, 550 mm average annual precipitation and 750 mm average annual evaporation from water surface. The hydrothermal growth period of crop can last for 156–171 days, and the frost-free season includes 128 days. Therefore, its climatic characteristic belongs to the cold-temperate zone continental monsoon climate. As the white pulp soil type, it has the unit weight and porosity degree of 1.01 $g \cdot cm^{-3}$ and 61.8% respectively. The basic physicochemical property of soil are organic contents: 41.4 $g \cdot kg^{-1}$, pH value: 6.40, total nitrogen: 15.06 $g \cdot kg^{-1}$, total phosphorus: 15.23 $g \cdot kg^{-1}$, total potassium: 20.11 $g \cdot kg^{-1}$, alkali-hydrolysable nitrogen: 154.36 $mg \cdot kg^{-1}$, available phosphorus: 25.33 $mg \cdot kg^{-1}$ and rapidly available potassium: 157.25 $mg \cdot kg^{-1}$.

Design of Experiments

According to the local agricultural production conditions and actual soil fertility, the nitrogen application level used were 0, 60, 85, 110, 135 and 160 kg/hm^2. When water-saving irrigation is applied, the suitable water layer will be established in the seedling establishment period, however, in order to reduce the ineffective tillering, the water layer will be rejected, and the upper limit of soil water control shall depend on the saturated moisture percentage. As for the lower limit of control in the growth period, please refer to Table (1), then please carry out the comprehensive test under the water-saving irrigation conditions. Therein, the nitrogenous fertilizer is purity conversion, and the fertilizer application amount is obtained according to the local test experience conditions for many years, therefore, which can conform to the actual quantity. The test is divided into 6 processing areas for three times, please refer to Table (2), as a result, there are 18 sub-regions. The nitrogenous fertilizer shall be applied according to 5:3:2 ratio between the base fertilizer, tillering fertilizer and panicle fertilizer. Therein, the phosphatic fertilizer shall be applied at a time as the base fertilizer, and the potash fertilizer will be applied in twice, namely, as base fertilizer and 8.5 leaf age (seedling differentiation period) with the specific ratio of 1:1. Every sub-region plot area is 10*10=100 m^2, therefore please plant rice guarding rows around the sub-regions. The rice variety, seedling cultivation, transplantation, plant protection, medication usage, other technical measures and the rice field management conditions are identical with each other. In order to reduce the lateral infiltration's influence on the test, please apply seepage insulation treatment between sub-regions, namely, embed the plastic boards and cement banks in the earth surface for 40 cm depth as the seepage insulation materials around the sub-plots will be applied regions. The tested rice category variety is will be No. 3 Longqing Rice. Base fertilizer will be applied , make before transplantation, apply then at tillering fertilizer, panicle fertilizer and crop harvests will be taken on May 6, May 17, May 31, Jul. 19 and Sept. 20, respectively. The growth period of rice will last for 128 days, including seedling establishment period (May 17 to 30), tillering period (May 31 to Jul. 7), jointing-booting period (Jul. 7 to 25), full heading period (Jul. 26 to Aug. 4), milk-ripe period (Aug. 5 to 24) and yellow ripening period (Aug. 25 to Sept. 20).

Observable Indicators and Methods

The chalkiness indicator will be measured by applying SDE-A rice chalkiness visualizer, which is produced by the Rice and Products Quality Inspection Center of Ministry of Agriculture. The rice amylose and protein contents will be measured by applying Infratec1241 grain analyzer (FOSS-TECATOR). Rice plot sample points as shown in Fig. 1, the ranks of spacing are 2 m.

Data Processing

Microsoft Excel 2003 and DPS7.05 will be used for data analysis and Matlab7.0 and Origin8.5 software to the test data.

Model and its Improvement

Game theory aggregation model: When the game theory aggregation model is applied to make calculation, the basic thought lies in seeking for the conformity or concession between different objects, and finding out the most satisfied results, including the vector quantity u^* which has the highest satisfaction degree. If game theory aggregation model is applied to make solution, its aggregation model is shown as follows, and its calculation process is illustrated in the bibliography (Chi *et al.*, 2008).

$$Min\left\|\sum_{j}^{l}\alpha_j u_j^T - u_i\right\|_2 \quad (i=1,2,...l) \qquad (1)$$

Wherein: *The* a_j *refers to the optimal linear combination coefficient, namely, minimize the deviation between* u^* *and sector quantity to obtain the most satisfied weight vectors.* According to the differential property of the matrix, we know that the optimal first-order derivative conditions as specified in formula (2) can be translated into the following linear equation system.

$$\begin{vmatrix} u_1 \cdot u_1^T & u_1 \cdot u_2^T & \cdots & u_1 \cdot u_l^T \\ u_2 \cdot u_1^T & u_2 \cdot u_2^T & \cdots & u_2 \cdot u_l^T \\ \cdots & \cdots & \cdots & \cdots \\ u_l \cdot u_1^T & u_l \cdot u_2^T & \cdots & u_l \cdot u_l^T \end{vmatrix} \begin{vmatrix} \alpha_1 \\ \alpha_2 \\ \cdots \\ \alpha_k \end{vmatrix} = \begin{vmatrix} u_1 u_1^T \\ u_2 u_2^T \\ \cdots \\ u_l u_l^T \end{vmatrix} \qquad (2)$$

Then, make the normalization processing for the obtained (α_1, a_2 and a_k). The calculation formula is shown as follows:

$$\alpha_k^* = \alpha_k \Big/ \sum_{k=1}^{l} \alpha_k \qquad (3)$$

Table 1: Water management of different irrigation management pattern in rice growth stages

Processing	Seedling establishment period	Preliminary period of tillering	Growing period of tillering	Last period of tillering	Elongation stage	Heading stage	Niblet forming stage	Yellow ripening period
Water-saving irrigation	0~30	0.85θs	0.85θs	Field drying	0.85θs	0.85θs	0.85θs	Drainage

Note: The units of the figures in the table are mm, therein, θs refers to soil saturated water content mass fraction in the root layer

Table 2: Treatment of field experiment

Treatment No.	Treatment code
1	WS0
2	WS65
3	WS85
4	WS110
5	WS135
6	WS160

Note: The letter WS refers to the water-saving irrigation and treatment code figure refers to the nitrogenous application quantity kg/hm^2

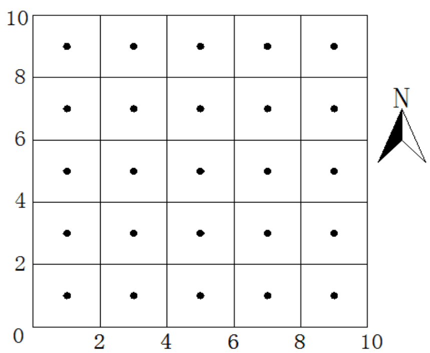

Fig. 1: Spatial distribution of sampling site

Topsis model and its improvement: Considering that we are unable to assess the advantages and disadvantages of traditional TOPSIS model rationally due to its limitations in the weight determination and close degree calculation, we have improved and calibrated the TOPSIS model according to the foregoing limitations. As for the modeling steps of TOPSIS, please refer to the bibliography (Li *et al*., 2013).

When the weightiness is calculated on the basis of RAGA-PPC method, the searching performance will be significantly enhanced with the higher precision. The main purpose lies in determining an optimal projection indicator function, finding out an optimum projection direction a= [a(1), a(2). a (i)], which can disclose the characteristic structure of high-dimensional data. Then, calculate the weightiness of all indicators, namely, $W_1=[a^2(1)$, $a^2(2).a^2(m)]$. For the projection direction, please refer to the bibliography (Friedman and Tukey, 1974). When the entropy weight method is applied to calculate the weightiness, the basic thought is that the indicator will put larger influence on the decision when it carries more information, namely, the larger entropy weight, the smaller entropy, at this moment, the system will have smaller disorder degree, and its calculation results will conform to the reality, therein, the indicator weightiness $W_2=[w_1, w_2,.w_m]$,As for the entropy weight, please refer to the bibliography (Lin, 2014). The most satisfied weightiness will be obtained after applying game theory aggregation model in the compound assignment.

When Kullback-Leibler distance method (Zhao *et al*., 2010) and chi-square distance method (Liao *et al*., 2011) are applied to calculate the distance from assessment object to ideal solution and negative-ideal solution, these two kinds of methods can favorably solve the following problems which can't be solved by the traditional TOPSIS mode, namely, the assessment object has equidistance with the positive-ideal solution and negative-ideal solution, and the distance from assessment object to positive and negative ideal solution is excessively small. Then, apply game theory aggregation model to seek for the specific points and bring it in the compound assignment to obtain the most satisfied close degree.

Chi-square distance method:

$$D_j^+ = \sum_{i=1}^{m} \left\{ \frac{\left[y_{ij} - e_{ij}^+\right]^2}{e_{ij}^+} + \frac{\left[y_i^+ - e_i^+\right]^2}{e_i^+} \right\} \quad (4)$$

$$D_j^- = \sum_{i=1}^{m} \left\{ \frac{\left[y_{ij} - e_{ij}^-\right]^2}{e_{ij}^-} + \frac{\left[y_i^- - e_i^-\right]^2}{e_i^-} \right\} \quad (5)$$

$$C_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad 0 \leqq C_j \leqq 1 \quad (6)$$

KL-Distance method:

$$S_j^- = \sum_{i=1}^{m} \left\{ y_i^- \lg \frac{y_i^-}{y_{ij}} + \left(1 - y_i^-\right) \lg \frac{1 - y_i^-}{1 - y_{ij}} \right\} \quad (7)$$

$$S_j^+ = \sum_{i=1}^{m} \left\{ y_i^+ \lg \frac{y_i^+}{y_{ij}} + \left(1 - y_i^+\right) \lg \frac{1 - y_i^+}{1 - y_{ij}} \right\} \quad (8)$$

$$H_j = \frac{S_j^-}{S_j^+ + S_j^-} \quad 0 \leqq H_j \leqq 1 \quad (9)$$

In the formula, D^+_j, D^+_j and S^+_j, S^-_j refer to the KL-distance and chi-square distance from the assessment object j and the ideal solution and negative-ideal solution; The y^+_i and y^-_i refer to the maximum value and minimum value of assessment indicator i; The y_{ij} refers to the weightiness of the assessment object j and the i the assessment indicator. The close degree is H_j, C_j, e^+_{ij}, e^+_i, e^-_{ij} and e^-_i. As for the calculation, please refer to the bibliography (Liao *et al*., 2011).

Results

Water-saving Irrigation and Nitrogenous Fertilizer Application's Influence on the Rice Quality Indicator

Classic statistical value analysis: After inspecting and correcting the rice quality indicator data which apply water-saving irrigation as well nitrogenous fertilizer application (Tables 3–5), and use of SPSS19.0 software to check K-S, it is indicated that the collected data can conform to the normal distribution. Comparing with the control treatment (WS0), the mean items, such as, WS60, WS85, WS110, WS135 and WS160 amyloses increased by 4.8, 8.2, 15.9, 15.7 and 15.1%; the protein increased by 8.1, 9.8, 42.1, 41.03 and 28.1%; and the chalkiness degree increased by 3.7, 14.2, 30.18, 33.9 and 29.2%. The nitrogen application rate of WS110 has increased for 135 and 160 kg/hm^2 with obvious growing rate. Therein, the three quality indicators processed by WS110 are higher than others, except for chalkiness degree, followed by WS135, WS160, WS85, WS60 and WS0, meanwhile, chalkiness processed by WS135 has the maximum average value however, the difference value between the average values processed by SW110 and WS135 in the aspect of three quality indicators is not large, therefore, it is indicated that WS110 and WS135 have the best treatment results. As shown in the variance and standard deviation, the three quality indicators processed by WS110 are smaller than others, therefore, it is indicated that the test field data acquisition processed by WS110 is better than others with small dispersion degree, as a result, which can reflect the better uniformity than others in the aspect of three quality indicators of rice.

Variability Influence

When the standard deviation is larger, the indicator will have larger dispersion degree however, comparing with the standard deviation, the variable coefficient can favorably reflect the spatial variable intensity of all indicators. As shown in Tables 3–5, there is a certain spatial variation in the three quality indicators of water-saving irrigation and nitrogenous fertilizer rice. Therefore, we can classify the variability of three quality indicators via variable coefficients: When Cv<10%, the weak variability shall prevail; When 10%≤Cv<100%, the medium variability shall prevail; When Cv>100%, the strong variability shall prevail. The protein Cv which is processed by WS0 is 11.38% medium variability however, the amylose and chalkiness belong to the wear variability under the different water-saving irrigation nitrogenous fertilizer application conditions, specifically speaking, the variability range is 3%~9.3%. The variation intensity of different quality indicators is shown as follows, namely, WS0>WS60>WS85>B160>WS135>WS110. We will take the six treatments about rice protein indicator as an example to draw its planar graph about spatial distribution (Fig. 2). It is observed that the protein indicators processed by the fertilizers are different from each other in the spatial distribution meanwhile the spatial distribution characteristics are basically identical with the variation intensity. The spatial distribution of WS0 and WS60 treatment is uneven with non-uniform spatial distribution. According to the WS110 treatment results, the treatment spatial distribution is relatively flat with favorable uniformity. Although the spatial distribution of WS85, WS135 and WS160 is superior to the WS0, S60 treatment, it is inferior to WS110 treatment. It is indicated that the nitrogenous fertilizer has certain influence on the spatial variation of quality indicator. Given this, the spatial variation and structural discriminant which are conducted for the rice quality indicators under the water-saving irrigation and different nitrogenous fertilizers application still need the future research.

Comprehensive Analysis about Rice under the Water-saving Irrigation and Nitrogenous Fertilizer Application

Assessment indicator weight and close degree determination: Consider rice amylose, protein and chalkiness degree as the comprehensive assessment indicators for the water-saving and nitrogenous fertilizer application, then, apply RAGA-PPC method and entropy weight method to calculate the indicator weights, make use of chi-square distance method and KL-distance method to calculate the close degree of the treatment, and adopt game theory aggregation model to seek for the optimization, of which the calculation results are shown in Table 6 and 7.

Model Verification

Improved TOPSIS model and the traditional model, as shown in Fig. 3(a–b) as a result the rational value of optimal close degree of model shall be 0–1. Fit the foregoing value with the different nitrogen application rates, as a result, the close degree range of TOPISS model (Fig. a) which is improved on the basis of game theory is within the rational range, and all points are evenly distributed on both sides of the curve with the fitting coefficient of R^2=0.88, however, the fitting curve of the traditional TOPISS (Fig. b) model has negative value when the fertilizer application is 0~60 kg/hm^2, in other words, which fails to be 0–1, therefore, we can say that the curve has low uniformity and certain limitation. It is bad for applying water-saving irrigation and nitrogenous fertilizer application to assess the rice quality in this test.

Table 3: Classic value of rice amylose

Characteristic Value	Capacity	Max	Min	Average	Variance	Standard Deviation	Mutation/%
WS0	25	17.5	14	15.98	1.23	1.11	7.66
WS60	25	18.63	15.44	16.75	0.92	0.96	5.43
WS85	25	19.67	16.12	17.82	0.91	0.95	5.10
WS110	25	20.30	16.50	18.52	0.72	0.85	3.91
WS135	25	20.60	16.60	18.50	0.84	0.97	4.54
WS160	25	19.81	16.01	18.04	0.95	0.98	5.27

Table 4: Classic value of rice protein

Characteristic Value	Capacity	Max	Min	Average	Variance	Standard Deviation	Mutation/%
WS0	25	8.8	5.50	7.37	0.84	0.92	11.38
WS60	25	9.60	6.22	7.99	0.54	0.74	6.81
WS85	25	9.80	6.86	8.12	0.36	0.61	4.54
WS110	25	11.66	9.64	10.47	0.30	0.55	2.92
WS135	25	10.6	9.61	10.42	0.31	0.56	3.25
WS160	25	10.40	7.92	9.47	0.39	0.63	4.21

Table 5: Classic value of rice chalkiness

Characteristic Value	Capacity	Max.	Min.	Average	Variance	Standard Deviation	Mutation/%
WS0	25	1.60	0.43	1.06	0.098	0.32	9.28
WS60	25	1.70	0.65	1.10	0.096	0.31	8.72
WS85	25	1.85	0.80	1.21	0.090	0.30	7.42
WS110	25	1.95	1.05	1.37	0.088	0.29	6.44
WS135	25	1.96	1.01	1.42	0.099	0.31	6.95
WS160	25	1.91	0.92	1.37	0.114	0.34	8.21

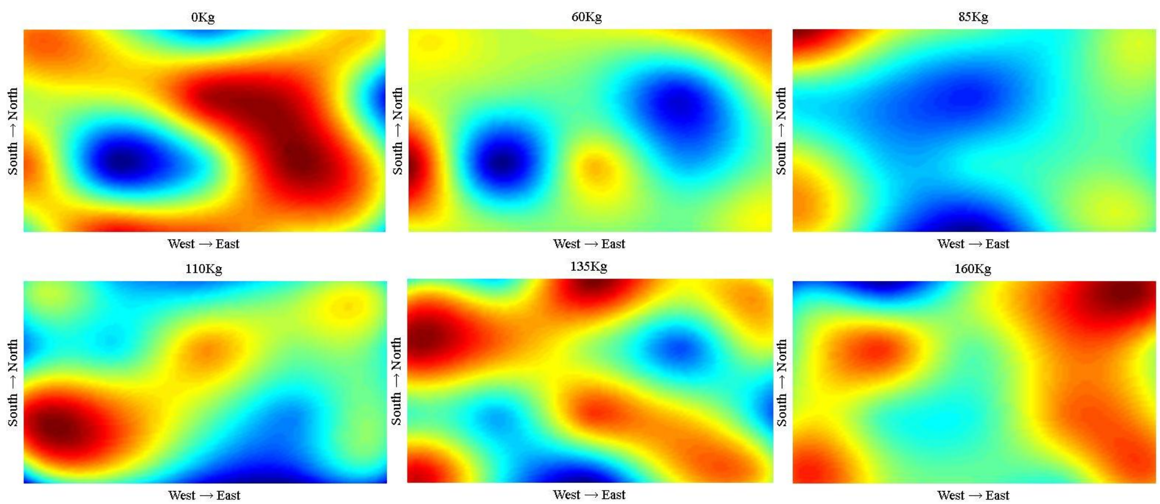

Fig. 2: The Spatial planar distribution of protein indicators under different fertilization treatments

As shown in Fig. 3a, the comprehensive assessment indicator about rice quality under water-saving irrigation and nitrogenous fertilizer application shows the curve changes with the nitrogen application rate, namely, which will increase and decrease along with the nitrogen application rate. When the nitrogen application rate is assessed comprehensively, the close degree values processed by WS110 and WS135 are the best, followed by WS160, therefore, the indicator ranking is shown as follows: WS135> WS110> WS160> WS85> WS60> WS0. Considering that the comprehensive assessment results are identical with the classic statistic value analysis results, it is indicated that the TOPSIS model, which is improved on the basis of game theory thought is feasible when the model is used for assessing the rice quality.

Discussion

Considering that the demands for the high-quality rice is becoming larger and larger along with the increasing living standards of people, the rice quality research in the rice production process has developed into an important topic. Given this, we have found the response relationship between water-saving irrigation as well nitrogenous

Table 6: Indicators weight

Index	Amylose	Protein	Chalkiness degree
Entropy weight method	0.095	0.504	0.401
RAGA-PPC	0.027	0.001	0.972
Game theory aggregation model	0.035	0.056	0.908

Table 7: Different treatments of close degree

Index	WS0	WS60	WS85	WS110	WS135	WS160
Chi-square distance method	0.397	0.397	0.395	0.396	0.396	0.394
KL-Distance method	-3.4E-17	0.002	0.035	0.300	0.495	0.297
Game theory aggregation model	0.438	0.439	0.441	0.469	0.489	0.466

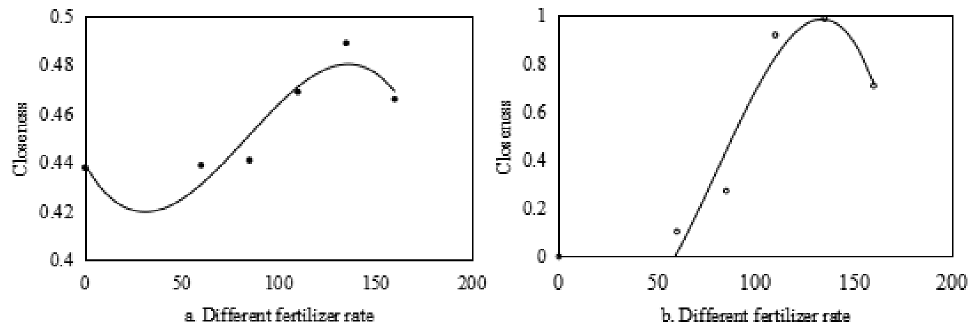

Fig. 3: The fitting of different fertilizer amount and close degree

fertilizer application and rice quality in this test and deeply discussed its changing rules. According to the related results, the three rice qualities show parabola changing trend along with the increasing nitrogen application rate. The rice protein and amylose reach the maximum value when processed by WS110, however, it start to decline when the fertilizer amount exceeded 110 kg/hm^2. The rice chalkiness degree reaches its top when it is processed by WS135. In the view of the increasing range of three quality indicators, the amylose has relatively unchanged fluctuation, however, the protein is subject to obvious fluctuation, therefore, it is indicated that the water-saving irrigation and different nitrogen amount have reduced the protein contents regardless of its little influence on the amylose. Given this, it is observed that the different nitrogen fertilizers application has influence on the rice quality under the water-saving irrigation conditions, however, the influence degrees of different indicators are different from each other, meanwhile, the low nitrogen amount and high nitrogen amount will restrain the rice quality. Moreover, different quality indicators between different nitrogen amounts have different variation degrees when observed with the variation coefficients of classic statistical values. The protein indicator which is processed by WS0 is medium variation, and the indicators processed by others are weak with the variation coefficient of 3–9/3%, as a result, the variation coefficients are sorted as follows in order of size: WS0>WS60>WS85>B160>WS135>WS110. When the difference value is analyzed between the variation coefficients' maximum and minimum value of three indicators processed by six fertilizer treatments, the amylose, protein and chalkiness degree are 3.75%, 8.46% and 2.84% respectively. Considering that the protein contains nitrogen element, it is indicated that the nitrogenous fertilizer can exert the largest influence on the rice protein indicator, as a result, the foregoing results are consistent with the reality. Given this, the spatial variation and structural discriminant which are conducted for the rice quality indicators under the water-saving irrigation and different nitrogenous fertilizers application still need the future research.

Many reserachers have improved TOPSIS model, such as, Wang *et al.* (2012) have established KL-TOPSIS model to solve the overdot problem on the perpendicular bisector during the positive and negative ideal solutions, and others apply chi-square thought to replace the traditional thought for the sake of solving the short distance problem from assessment object to the positive and negative ideal solutions, Qu *et al.* (2008) and Liu *et al.* (2014) have improved the indicator weight algorithm, however, these single improvement will only solve one defect and disadvantage of the traditional model. In this paper, we have further improved the traditional TOPSIS model on the basis of the predecessors, and applied RAGA-PPC method and entropy weight method to calculate the weight, as a result, the optimization performance is significantly enhanced with the higher precision. After applying chi-square distance and KL-distance method to calculate the positive and negative ideal solutions of assessment indicators, the following problems which can't be solved by the traditional TOPSIS model, namely, the assessment object has the equidistance with the positive and negative ideal solutions and the distance from assessment object to the positive and negative ideal solution is excessively small. Moreover, when we apply game theory thought to combine the advantages and disadvantages of the algorithm, it favorably solved the predecessors' disadvantages Namely, they only improve one defect of the traditional model. What's more, the game theory aggregation model is applied to seek for its advantages and make the weight assignment and close degree assignment, as a result, the assessment results are consistent with the reality and identical with the predicated effects. Given this it is feasible to apply TOPSIS model which is improved on the basis of game theory thought to assess the rice quality, what's more, which can provide the reliable scientific basis for the scheme decision and offer a kind of new thought to the assessment method.

According to the actual rice production conditions in Heilongjiang Province, the new fertilizer application technology which is applied under the water-saving irrigation and nitrogenous fertilizer application of present study will be more favorable for the production demands, as a result, we can save water, reduce fertilizer and improve the rice quality. In order to enhance the rice yield and quality, save water, reduce fertilizer and realize the high-yield high-quality cultivation of rice in the black soil in Heilongjiang Province, there is need to make the comprehensive consideration according to the local production, environment, soil fertility, climate and other factors.

Conclusion

Water-saving irrigation and nitrogenous fertilizer application's influence and assessment on rice quality indicators via taking the planting rice on the black soil in the cold regions as an example, the following conclusions are made. According to the classic statistical value analysis, we know that the three qualities of rice will rise and decline along with the increasing nitrogen amount in the parabolic-shape distribution, moreover, the low and high nitrogen application rate are bad for the rice quality under the water-saving irrigation conditions. As shown in the variable coefficient analysis about classic statistical values, the rice quality indicator has certain variation under different nitrogen application rates in the space, specifically speaking WS110 treatment has the minimum variation coefficient, small dispersion degree, flat distribution in the spatial planar graph and favorable uniformity. Its variability is sorted as follows: WS110>WS135, WS160>WS85 and WS60>WS0. The TOPSIS model improved on the basis of game theory thought can bring about relatively ideal results when the rice quality indicators are comprehensively assessed under the water-saving irrigation and nitrogenous fertilizer application, moreover, the curve fitting is relatively good and the fitting coefficient R^2 can reach up to 0.88. Of which, the assessment results of WS135, WS110 are the best and conform to the reality, and it is feasible to apply TOPSIS model improved on the basis of game theory to assess the rice quality, as a result, it can provide the relatively reliable scientific basis for the field changing scheme and offer a kind of new thought to the assessment method.

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