Effect of Different Sowing Dates in South Henan's Rice-growing Areas on the Growth and Yield of Ratoon Rice

Xiangchen LIU[1], Daqing FENG[1*], Guilong YU[1], Haiying ZHAO[1], Li QIAO[1], Yanting LI[1], Xuejun FAN[1], Mingcheng LIU[2], Qiuju ZHANG[3]

1. Xinyang Academy of Agricultural Sciences, Xinyang 464000, China; 2. Xinyang Municipal Bureau of Agriculture, Xinyang 464000, China; 3. Gushi Agricultural Technology Promotion Center, Gushi 465200, China

Abstract In order to determine the optimal sowing date of ratoon rice in South Henan's rice-growing areas, this paper performs a comparative analysis of rice growth process, seedling quality and yield of first season rice and ratoon rice under different sowing date treatments. The results show that under climatic conditions (2014), by using dry seedling cultivation in a small plastic shed, the growth of seedling sown on February 21 was affected, while the sowing treatments from March 1 to April 11 can breed normal seedlings, and in this period, the maturity period of first season rice was delayed with prolonged sowing date, and ratoon rice yield declined with prolonged sowing date (total production of rice sown on 11 March reaching a peak). Thus, it is considered that the optimal sowing date of ratoon rice in South Henan's rice-growing areas is mid-March.

Key words Sowing date, First season rice, Ratoon rice, Yield

1 Introduction

The fourth assessment report of IPCC in 2007 reveals that the global climate is warming and the impact of warming on agriculture is looming large. Global warming has an impact on China's cropping systems, and the planting scope, yield and quality of major crops will vary[1]. Therefore, it is necessary to conduct further study on cropping system design and production measure adjustment based on the agricultural climate resource change. South Henan's rice-growing areas are Henan's major rice producing areas, and the perennial planting area is nearly 431000 ha, accounting for 83.4% of the province's total rice planting area. The frost-free period is 230 d, and the effective accumulated temperature is more than 5000℃. From early March to early November, there are nearly 250 d for rice growing. The perennial planting area in Xinyang rice-growing areas (including Gushi County) is nearly 376000 ha, accounting for 87.3% of South Henan's total rice planting area. In the central and southern part, due to clay paddy soil, there is poor benefit in planting wheat or rape, and most areas take the cropping pattern of "single-season rice + wintry idle cropland". The mid-season variety of hybrid indica is generally used, and the growth period is around 150 d (sowing in early April and harvesting in late August to early September). For this planting pattern, there will be 60-80 d from rice harvest to early frost period for rice growth, but the paddy is idle, resulting in waste of natural resources. And with global warming, this waste will become more obvious[2-3]. To solve this problem, our research team carried out the study on key ratoon rice technologies in South Henan's rice-growing areas, analyzed the light, temperature, water and other natural resource conditions, and conducted multi-point demonstration, to prove that the region can be suitable for growing ratoon rice[4-7]. Ratooning is a method of harvesting a crop which leaves the roots and the lower parts of the plant uncut to give the ratoon or the stubble crop. The main benefit of ratooning is that the crop matures earlier in the season. Ratooning can also decrease the cost of preparing the field and planting. Ratoon rice is commonly known as "the second crop of rice". Ratoon rice is suitable for the regions where temperature, light, water, heat and other resources are surplus for planting one season rice but insufficient for planting double cropping rice. When conditions permit, double cropping rice yield is generally 50% more than one season rice yield, and ratoon rice has become a new way to develop and use autumn paddy resources and increase food production. The new ratoon farming system has been basically formed in China, which is vital to food production growth[8-11].

2 Materials and methods

2.1 Experimental materials The experiment was conducted in the plots (114°05'E, 32°07'N) of Xinyang Academy of Agricultural Sciences in 2014. The variety for experiment is Y Liangyou 8901 (indica two-line hybrid rice) and the test soil is paddy soil. The physical and chemical properties of soil before soil preparation and fertilization: pH 6.4; available nitrogen 54.3 mg/kg; available phosphorus 9.7 mg/kg; available potassium 75.1 mg/kg; organic matter 22.4 g/kg. The previous crop is milk vetch. Before plowing, the fresh grass amount is 30000 kg/ha; the dry matter content is 2730 kg/ha (converted by 9.1%); the nitrogen (N) content is 100.7 kg/ ha (converted by 3.69%); the phosphorus (P_2O_5) content is 19.7 kg/ha (converted by 0.72%);

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* Corresponding author. E-mail: fdqkyk@126.com

the potassium (K_2O) content is 114.7 kg/ha (converted by 4.2%).

2.2 Experimental design and methods The experiment includes six sowing dates: February 21 (A), March 1 (B), March 11 (C), March 21 (D), April 1 (E), April 11 (F). Sprouting is forced. A and B (transplanting on April 10); C and D (transplanting on April 25); E and F (transplanting on May 10). Each sowing date treatment is repeated three times, and there are a total of 18 plots, randomly arranged. A small ridge is between plots, and independent water and fertilizer management is implemented. Row spacing is 0.30 m × 0.17 m, and a single seedling is planted per hole, with 300000 holes/ha.

2.3 Data acquisition and processing

2.3.1 Meteorological data. Meteorological data are from Bureau of Meteorology in Xinyang City.

2.3.2 Growth process observation and recording. Recording items are as follows: sowing date (date of the day when rice is sown); seedling date (the first leaf shoots out, and more than 50% of seedlings in seedling bed are 2 cm or more); initial heading date (half of leaf sheath shoots out from 10% of rice spikes); full heading date (half of leaf sheath shoots out from 80% of rice spikes); maturity period (90% of rice spikes are mature).

2.3.3 Seedling quality survey. Before transplanting, 10 representative seedlings are selected in each treatment, to record seedling leaf age, tillers, plant height and root number, and 100 representative seedlings are selected to measure the fresh and dry weight.

2.3.4 Recording of leaf age and tillers. After transplanting, five adjacent plants in each plot are selected as observational plants, and the leaves are marked. It is surveyed once a week, to record leaf age and tiller, and the recording is completed after the initial heading.

2.3.5 Seed selection and yield calculation. Before maturity, the ears of 50 rice plants are surveyed in each plot, and five plants are randomly selected for seed selection. The yield of each plot is calculated independently.

2.3.6 Data processing. Excel 2003 and SPSS 16.0 are used for compilation and statistical analysis of the experimental data.

3 Results and analysis

3.1 Effect of different sowing dates on rice growth process

The growth of rice depends on the genetic factors, and changes with different external environmental conditions such as light, temperature, fertilizer and water, and it is most significantly affected by temperature. From Fig. 1, we can see that the spring temperature in 2014 rose quickly, the temperature in late February was almost the same as normal temperature, and it rose to 18.74℃ in late March, an increase of 0.34℃ per day, which was conducive to early seedlings; the temperature in mid-April and late April was lower than the historical average temperature, but there was no great fluctuation, having no significant effect on rice growth; from late April to mid-July, the average temperature was the same as the previous average temperature despite fluctuations; from late July to mid-September, the temperature was significantly lower than the average, and especially in mid-September, affected by "West China autumn rain", there was a great impact on the growth of ratoon rice; from late September to October, the temperature was higher than the average, but the ratoon rice with late sowing period is difficult to mature due to the cold damage of "West China autumn rain".

3.2 Effect of different sowing dates on seedling quality and ratoon rice growth period before transplanting Considering the seedling age factor, every two sowing dates set the same transplanting date: A and B (transplanting on April 10); C and D (transplanting on April 25); E and F (transplanting on May 10). From Fig. 2, it can be found that from February 21 to March 13, April 6 to May 10, 2014, there was no big difference between the average temperature and previous average temperature, having a certain impact on seedling growth; from March 14 to April 5, the average temperature was higher than the previous average temperature, in favor of seedling growth. Due to the impact of temperature in early spring, there is a relationship between sowing date and rice seedling quality. It can be seen from Table 1 that the seedling under A is sown 8 d earlier than under B and the emergence of seedling under A is 2 d earlier than under B, but the leaf age decreases by 1.38, plant height decreases by 5.2 cm and total root number decreases by 6.3, with difference reaching a significant level, and there is no tillering, indicating that the seedling quality under A is significantly lower than under B. It is also a key factor making the maturity period later than under B and C. Except A, although there is difference in the plant height and root number of seedlings under other treatments, the fresh weight and dry weight are at the same level, indicating that B can cultivate normal seedlings, but the seedlings with late sowing date may be stronger and the seedling quality may be higher. Under the climatic conditions in 2014, dry seedling cultivation in a small plastic shed can not cultivate normal seedlings until at least March 1. Fig. 1 shows that the temperature in late February and and early March 2014 was almost the same as the average annual temperature, so it can be inferred that under dry seedling cultivation in a small plastic shed, the sowing date of ratoon rice in South Henan's rice-growing areas is earlier than March 1, and there is a certain risk. As can be seen from Table 2 and Fig. 1, there are certain differences in temperature, light and other conditions in different sowing dates, causing corresponding changes in rice growth process. In early spring when the outside temperature is low, the rice growth is significantly delayed, and the sowing to emergence under A lasts 13 d, indicating that when sowing on February 21, the emergence and growth are slow, resulting in poor seed internal metabolism, which is not conducive to the formation of robust seedlings. The seedling rate is low, and the seeds sprout late after transplanting, with 139 d from sowing to heading (117 d and 115 d for B and C, respectively). However, the heading date is later than under B and C, and early sowing of ratoon rice does not lead to early ripeness. With rising temperatures, the sowing to emergence under B lasts 8 d, and the germination rate and seedling rate are normal. The maturity period of first season rice is brought forward to August 5, freeing up time for the ratoon rice development and improving the success rate of ratoon rice. Under other treatments, with increasing temperature, the germination rate, seedling rate and growth are normal; both the stage from sowing to emergence and the stage from emergence to heading are shortened with delayed sowing date, and the heading is also delayed accordingly. Especially with delay of sowing date, E and F are greatly influenced by "West China autumn rain", the heading stage of ratoon rice is postponed to October, and the low temperature makes it impossible to complete pollination and causes low seed rate. Thus, under the temperature conditions in 2014, the sowing date of ratoon rice in South Henan's rice-growing areas should be scheduled before April.

3.3 Effect of different sowing dates on the first season rice yield and its components As can be seen from Table 3, the first season rice yield is in the order of C > D > B > E > F > A, and the impact of sowing date on yield shows a parabolic relationship. The yield is highest under C, reaching 10377 kg/ha; it is slightly lower under D, but it is at the same level with C; B and E are at the same level, and the difference between B, E and C, D reaches an extremely significant level; the yield under F is significantly lower than under B, E but significantly higher than under A. Thus, under weather conditions in 2014, in terms of hybrid indica rice Y Liangyou 8901, the first season rice yield is highest on March 11 (C) and March 21 (D). Before March 11, the rice yield is reduced with the sowing date ahead of time; after March 21, the rice yield is reduced with the delay of sowing date. It can be seen that without considering the ratoon rice yield in South Henan's rice-growing areas, the best sowing date of single-season rice is March 11.

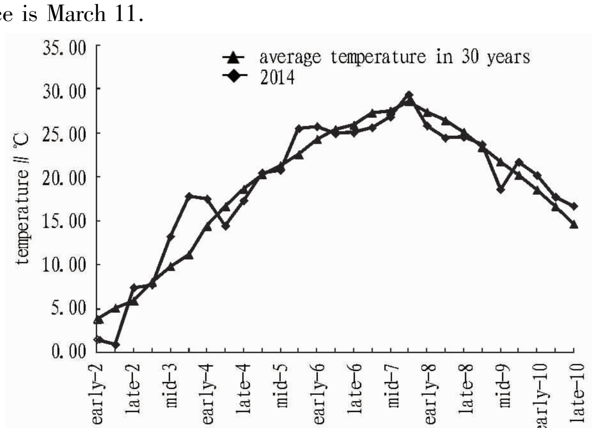

Fig. 1 The average temperature from 1984 to 2013 and the temperature over the same period in 2014

3.4 Effect of different sowing dates on ratoon rice yield and its components as well as total yield As can be seen from Table 4, there is no significant difference in ratoon rice spike number between different treatments, indicating that in the above treatments, temperature, light and other environmental factors do

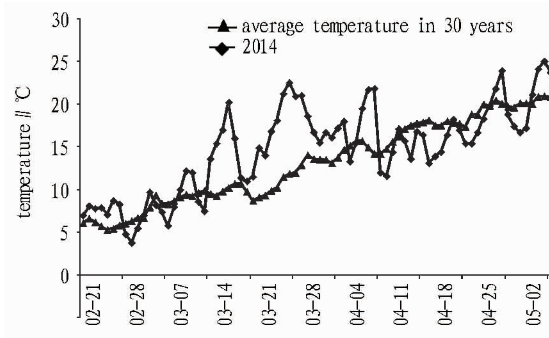

Fig. 2 The average daily temperature from February 21 to May 10, 2014 and the temperature over the same period from 1984 to 2013

not adversely affect the development of renewable bud. In terms of total kernel number per ear, A, B and C are significantly higher than D, E and F, indicating that the low temperature in August and September when "West China autumn rain" is formed, mainly affects the ratoon rice spikelet, reduces total spikelet number and lowers setting rate. The setting rate under A, B, C and D is less than 70%; the heading and flowering date under E, F is in October when the daily average temperature drops below 20℃, making the setting rate less than 10%, and it does not form effective yield. The actual yield and two-season total yield of ratoon rice are highest under B, significantly different from other treatments, and the reason may be that the first season rice is mature in early August, leaving ample development space for ratoon rice growth. C is significantly different from D; both the actual yield and two-season total yield of ratoon rice under A are significantly lower than under D, indicating that too early sowing can not contribute to the early maturing of ratoon rice but result in poor quality seedlings and low first season rice yield. In order to further determine the optimal sowing date of ratoon rice in South Henan's rice-growing areas, we use the data processing system to calculate the correlation coefficients between sowing date and first season rice yield, ratoon rice yield or two-season yield (0.1152, −0.1027 and 0.5619, respectively). By conducting significance test on correlation coefficient, it is found that first season rice yield and ratoon rice yield are weakly correlated with sowing date while two-season yield is positively correlated with sowing date. In order to better determine the best sowing date of ratoon rice in South Henan's rice-growing areas, we continue to perform the regression analysis of sowing date and two-season yield, and establish the regression equation between the two variables. We see that there is a cubic curve relationship between different sowing dates of ratoon rice in South Henan's rice-growing areas (x) and two-season yield (y). The fitted equation is as follows: $y = 0.596x^3 - 33.52x^2 + 541.7x + 10164$ ($R = 1.000^{**}$), $x_{opt} = 18.75$. From the relationship between different sowing date of ratoon rice and two-season yield, it is found that the optimal sowing date of ratoon rice in South Henan's rice-growing areas is March 11. Given the impact of weather and other factors, we believe that the optimal sowing date of ratoon rice is around March 11. The above test results show that

March 1 (B) can be the starting point of suitable sowing date for ratoon rice in South Henan's rice-growing areas. In the production practice, sowing seedlings under C and D is easier to avoid the harm of low temperature and cold wave, which can not only give play to the first season rice advantages of early sowing and high yield, but also contribute to regeneration season bumper harvest. Thus, mid-March can be regarded as the suitable sowing date for ratoon rice in South Henan's rice-growing areas.

Table 1 The differences in seedling quality before transplanting under different sowing date treatments

Treatment	Seedling age//d	Leaf age	Number of tillers	Plant height//cm	Root number	Fresh weight for every 100 plants g	Dry weight for every 100 plants//g
A	48	4.03Aa	1.0Aa	10.5Aa	11.5Aa	24.1Aa	1.94Aa
B	40	5.41Ccd	2.9Bb	15.7Bbc	17.8Bc	28.6Bb	2.23Bb
C	45	5.41Ccd	1.9ABa	17.3Bc	17.5Bc	27.7Bb	2.19Bb
D	35	4.52ABab	1.5Aa	14.2Bb	15.8ABbc	27.1Bb	2.18Bb
E	39	5.63Cd	2.0ABa	13.9Bb	13.7ABab	28.4Bb	2.20Bb
F	29	4.85BCbc	1.7ABa	10.8Aa	11.6Aa	27.2Bb	2.11Bb

Note: Different lowercase, uppercase letters in the same column denote the significant difference level of 5% and 1%, respectively, the same below.

Table 2 Effect of different sowing dates on ratoon rice growth period

Treatment	First season rice								Ratoon rice			
	Sowing date month/day	Emergence date month/day	Seedling age//d	Initial heading stage month/day	Days from sowing to heading//d	Full heading date month/day	Maturity date month/day	Harvest date month/day	Initial heading stage month/day	Full heading date month/day	Maturity date month/day	Growth period d
A	2/21	3/6	48	7/10	139	7/12	8/14	8/15	9/20	9/27	11/6	259
B	3/1	3/8	40	6/28	117	7/2	8/5	8/5	9/15	9/24	11/2	247
C	3/11	3/17	45	7/5	115	7/7	8/12	8/15	9/20	9/26	11/5	240
D	3/21	3/26	35	7/10	111	7/14	8/15	8/15	9/22	9/30	11/10	235
E	4/1	4/6	39	7/18	109	7/23	8/25	8/25	9/30	10/9		
F	4/11	4/15	29	7/21	102	7/25	8/26	8/26	10/2	10/11		

Table 3 Effect of different sowing dates on the first season rice yield and its components

Treatment	Effective ears//10^4/ha	Kernel number per ear	Setting rate//%	Thousand-grain weight//g	Yield kg/ha	Actual yield kg/ha
A	330.0Cd	137.0Aa	76.11Aa	28.0BCcd	9595.5Aa	8893.5Aa
B	270.0ABab	160.5Aab	82.31ABab	28.2Cd	10098.5Aa	10162.5Cc
C	297.0ABCbc	157.1Aab	78.82Aab	27.7Bb	10194.1Bb	10377.0Dd
D	279.0ABab	171.1Ab	81.86ABab	27.8Bbc	10826.4Aa	10318.5Dd
E	258.0Aa	159.2Aab	90.02Bc	28.6De	10575.3Aa	10140.0Cc
F	312.0BCbc	148.3Aab	84.29ABb	27.3Aa	10637.4Aa	9274.5Bb

Table 4 Effect of different sowing dates on ratoon rice yield and its components as well as total yield

Treatment	Regeneration ears//10^4/ha	Kernel number per ear	Setting rate//%	Thousand-grain weight//g	Yield kg/ha	Actual yield kg/ha	Two-season total yield//kg/ha
A	280.0Aa	92.6Bb	65.6Cc	26.0BCb	5211.0Ee	1779.0Aa	10672.5Aa
B	324.0Aa	90.8Bb	61.8BCb	26.4Cc	4804.5Dd	2596.5Cc	12759.0Cd
C	279.0Aa	94.8Bb	59.5Bb	26.9Cc	4233.0Cc	2068.5Bb	12445.5Bc
D	315.0Aa	69.1Aa	64.5Cc	25.8Bb	3624.0Bb	1906.5ABa	12225.0Bb
E	321.0Aa	70.3Aa	4.6Aa	22.4Aa	232.5Aa		
F	327.0Aa	74.2Aa	3.4Aa	22.1Aa	182.3Aa		

Note: Setting rate of ratoon rice is low under E, F, never forming effective yield.

4 Conclusions and discussions

The annual effective accumulated temperature is more than 5000℃ in South Henan's rice-growing areas, and the temperature and light resources are ample for planting single-season Indica rice in mid and early April (spring seedlings) or early May (summer seedlings), but due to low comparative farming benefit in recent years, the phenomenon of only planting single-season Indica rice and leaving white stubble fields in winter is prevalent, and a lot of temperature and light resources are wasted. Research and exploration on the rice ratooning technology is not only an important way to improve resource utilization rate, but also an important measure to actively explore the cropping system changes in response to global warming. Affected by "West China autumn rain", South Henan's rice-growing areas had 16 days of rainy weather in August 2014, the monthly average temperature decreased by 1.3℃; in September, the monthly average temperature decreased by 0.6℃, and the sunshine hours were half of the historical average. Low temperature, rainy days and inadequate sunshine hours not only affect the growth of ratoon rice, but also increase the incidence of sheath blight. However, in such extreme weather conditions, through early sowing (March 1), ratoon rice still achieved production level of 2596.5 kg/ha, further demonstrating the feasibility of developing ratoon rice in South Henan's rice-growing areas. This study shows that under weather conditions in 2014, using dry seedling cultivation in a small plastic shed can safely breed normal seedlings in early March, and shift the maturity period of first season rice to early March, thereby ensuring the success of ratoon rice. But if it is sown in mid-March, the first season rice can be ripe before mid-August, and the first season rice yield is highest, in line with the expected goal of developing ratoon rice when the first season rice is not reduced in the new ratoon rice growing areas. The yield and two-season total yield of ratoon rice sown on March 11 are lower than on March 1, but in normal temperature years, the first season rice is harvested in mid-August, ratoon rice can be in full heading in mid-September, and both first season rice and ratoon rice have good yield. Thus, the optimal sowing date for ratoon rice in South Henan's rice-growing areas is mid-March, and if it is scheduled in late March, ratoon rice still get some yield, but if it is scheduled in early April, there may be a high risk.

References

[1] HUANG AJ, CHEN CQ, LEI CX, *et al*. Change characteristics of agricultural climatic resources and adaptation measures for crop production in Jianghuai region [J]. Journal of Nanjing Agricultural University, 2011, 34(5): 7–12. (in Chinese).

[2] SONG SZ, DUAN B, HE SJ, *et al*. Barriers to a full play of japonica hybrid rice advantages and cultivation strategy in single-cropping medium indica rice regions [J]. Hybrid Rice, 2010, 25(S1): 441–443. (in Chinese).

[3] FENG DQ, LIU XC, QIAO L, *et al*. Cause and improvement countermeasures of vacant land in southern rice area of Henan Province [J]. Modern Agricultural Sciences and Technology, 2010(6): 103–104. (in Chinese).

[4] FENG DQ, LIU XC, LIU CZ, *et al*. Analysis and practice of climate suitability of ratoon rice in south area of Henan [J]. Shandong Agricultural Sciences, 2012, 44(7): 41–44. (in Chinese).

[5] LIU XC, FENG DQ, QIAO L, *et al*. Planting performance and high yield cultivation technique of Liang-you6326 ratoon rice in south area of Henan [J]. Journal of Henan Institute of Science and Technology (Natural Science Edition), 2011, 39(2): 7–9. (in Chinese).

[6] LIU XC, FENG DQ, LI P, *et al*. Development strategy on ratoon rice in the south of Henan [J]. China Rice, 2014, 20(2): 29–31, 34. (in Chinese).

[7] FENG DQ, LIU XC, QIAO L, *et al*. Grey relational analysis and evaluation of ratoon rice varieties in southern Henan Region [J]. China Rice, 2014, 20(6): 14–17. (in Chinese).

[8] SHI NP, JIAO SC. The cultivation of Chinese ratoon rice [M]. Beijing: China Agriculture Press, 1999: 10. (in Chinese).

[9] TANG WB, CHEN LY, XIAO YH, *et al*. Relationships among yield, yield components and some features of ratooning rice [J]. Journal of Hunan Agricultural University, 2002, 28(1): 1–3. (in Chinese).

[10] LIU GH, DENG HB, CHEN LY. Comparison of grain quality between main and ratooning crops of middle-season rice [J]. Hybrid Rice, 2002, 17(1): 45–47. (in Chinese).

[11] LIU YT. Preliminary study on comparative trial of middle season rice-ratoon rice varieties in 2011 [J]. Fujian Science and Technology of Rice and Wheat, 2012, 30(2): 78–81. (in Chinese).

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[4] BAO GM. Discussion on the direction of modern tourism innovation [J]. Social Sciences in Guizhou, 2006(1): 9–11. (in Chinese).

[5] YANG Y, ZHUANG DL. Tourism innovation systems and the related elements: Cases of Nanjing and Shanghai [J]. Ecological Economy, 2011(1): 41–44. (in Chinese).

[6] SONG HL, SONG HY. A Review on tourism innovation studies abroad [J]. Tourism Science, 2013, 27(2): 1–13. (in Chinese).

[7] ZHU D, YUAN L. The innovation of modern agriculture development: Creative agriculture promote the development of rural tourism: Taking the case of Chengdu City of Sichuan Province [J]. Rural Economy, 2009(9): 54–56. (in Chinese).

[8] SUN MH. Study on rural development of China and Its Innovative Development Strategies [J]. Journal of Anhui Agricultural Sciences, 2011, 39(29): 18060–18062. (in Chinese).

[9] CHEN XJ. The innovation path of rural tourism based on innovation theory: Taking the case of Chongqing [J]. Jiangsu Agricultural Sciences, 2012, 40(9): 391–393. (in Chinese).

[10] ZOU TQ. The panorama of Luanchuan: A classic case of county tourist destination [M]. Beijing: Economy & Management Publishing House, 2014: 17–20. (in Chinese).

[11] WANG ZF. Study on the ecologicalization of tourist industrial cluster [J]. Management World, 2009(9): 170–171. (in Chinese).

[12] LI S, HUANG FC, LI JZ. Public service of tourism: Connotation, characteristics and classification framework [J]. Tourism Tribune, 2010(4): 20–26. (in Chinese).

[13] DAI B. The historical background, strategic target and path choice of developing and managing tourism according to the law [J]. Tourism Tribune, 2015, 30(3): 1–2. (in Chinese).

[14] FANG YG, LIU JS. Diversified agriculture and rural development in China based on multifunction theory: Beyond modernization paradigm [J]. Acta Geographica Sinica, 2015, 70(2): 257–270. (in Chinese).

[15] WANG DW, WEI XA. Economics of tourism [M]. Shanghai: Shanghai People's Publishing House, 1998. (in Chinese).

[16] WANG Y, QIN Q. Study on the supply and demand situation and the countermeasures of rural tourism public service based on the investigation of Agritainment Village in Zhejiang Longquan [J]. Journal of Anhui Agricultural Sciences, 2013, 41(19): 8220–8222. (in Chinese).