Technical Summary of Rice Yield Exceeding 10 Tons per Hectare for Three Consecutive Years

Guanghao JIN*, Xiaodong DU, Yongsheng CAI

Jiamusi Rice Research Institute, Heilongjiang Academy of Agriculture Sciences, Jiamusi 154026, China

Abstract In Heilongjiang Province, rice planting area increased year by year. However, due to improper cultivation methods, farmers did not have knowledge about characteristics of rice varieties, there was still no complete cultivation technology system. The yield of different regions varied widely. The increase in rice yield was relatively low, and yield per hectare remained at 7 tons. Through the recent three years of large-scale demonstration, it was known that the high-yielding varieties and high-yielding cultivation methods should be promoted at the same time. In the cultivation process, it was recommended to take reliable, effective, and simple and feasible technical procedures.

Key words Rice, Yield, Technology

1 Introduction

In recent years, the rice production in Heilongjiang Province had realized rapid development[1]. Firstly, there was the substantial increase in the planting area. It had reached 4.33 million hectares, made Heilongjiang Province become a large rice production province and the great contribution to the national grain stability. However, due to various reasons, the increase in rice yield was relatively slow[2], and the average yield was only about 7 t. In Heilongjiang Province, the organic matter of farmland is generally 2.5% -3.5%, and the accumulated temperature of most rice planting areas is in the range of 2000℃ -2800℃[3]. The accumulated temperature is sufficient and the sunshine is strong during the growth period. Therefore, there is potential for yield increase. In recent years, there is frequent occurrence of yield per hectare exceeding 10 t, proving that it is possible that the yield of per hectare has reached or exceed completely 10 t in Heilongjiang Province.

In order to better develop the production advantages and production potential of rice in Heilongjiang area[4], to promote the increase in farmers' income, and then to achieve the purpose of high and stable yield, from 2013, Heilongjiang Province has made an attempt for three consecutive years according to many years of high yield cultivation practice, made the rice planting scheme suitable for production practice, suitable variety characteristics, and suitable for planting in high and cold regions, and acceptable to farmers, the effect is significant[5].

2 General situations

The experimental area was located in Dongfeng District of Jiamusi City and geographical location was N46°48′, E 130°22′. The soil organic matter content of the experimental farmland was 1.99%, available nitrogen was 98.1 mg/kg, available phosphorus was 5.60 mg/kg, available potassium was 93.79 mg/kg, and pH was 5.95. It was paddy field about 60 years[4-5]. Planting area: 1.5 ha in 2013, 3.1 ha in 2014, and 3.3 ha in 2015. Planting variety: Longjing 31.

3 Seedbed management

3.1 Seedbed preparation On April 10, the seedbed was ploughed shallowly at the depth about 12 cm. And the seedbed was prepared using barrow. The key to the seedbed was leveling. The leveling criterion of height difference of the 1 m seedbed was not defined in 0.5 cm and soil block diameter was less than 1 cm[5].

3.2 Seedbed soil preparation In the autumn of the previous year, soil with high content of organic matter, no pesticide residue, looseness, and good permeability was selected and delivered to the area near the greenhouse, and piled to round shape for use[6]. When seedbed was completed in spring, screened the prepared soil with a sieve, then mixed the sieved soil 2.5 m^3 and 6 bags of Miaofu Seedling Fostering Agent (other brands of Seedling fostering agent could be used), the mixed nutritional soil could be used for 1 hectare paddy field, approximately 100 m^2 -110 m^2 seedling field[7].

3.3 Sowing The sowing period was April 15 -20; seeding rate was 500 feed wheels per hectare, each feed wheel had 140 g, and it needed 70 kg/ha seeds. After feed wheel sowing, built 10 cm wide and 5 cm high ridge around the edges of seedbed, to prevent the loss of water during watering from influencing the seepage. Technical points: first, before sowing, repeatedly watering for 1 -2 day, but did not water until the last time of water has completely seeped; second, took well connection between the watering and ground water, to ensure full water supply during seedling growth and make the seedlings become full, uniform, and strong[8].

3.4 Temperature management In the one-leaf one-bud period, started implementing the ventilation and seedling hardening,

Received: February 12, 2017 Accepted: March 10, 2017

* Corresponding author. E-mail: 13845459342@163.com

and the temperature of the greenhouse should be controlled below 28 ℃. In the 1.5 – 2.5 leaf period, increased the volume of ventilation and controlled the temperature of the greenhouse below 25 ℃. After it entered the 2.5 leaf period, the temperature of the greenhouse should be controlled below 20 ℃[9].

3.5 Moisture management In the one-leaf one-bud period, watering should be avoided as much as possible. After the one-leaf one-bud period, watering also should not be carried too frequently, to prevent the seedbed being too wet. Generally, watering should be carried out one time fully after the seedbed surface became dry. After 2-leaf one-bud period, paid attention to prevent crack of seedbed due to dryness, watering should be carried out in the morning or evening, but should not be done frequently, and watering should be carried out fully each time.

3.6 Weeding of seedbed About the 1.5 leaf period, sprayed 10% Clincher 900 mL/ha, 48% Bentazone 2400 – 2700 mL/ha, plus 225 L/ha water, to eliminate Echinochloa crusgalli and broad-leaved weeds[10].

3.7 Prevention and control of plant diseases The diseases of seedbed mainly include dripping disease and bacterial wilt, Prevention method was that prevention was the main and treatment for the second, making seedlings become strong and prevent the occurrence of disease. Specific methods: (i) Conditioning acid for second, that was, in the one-leaf one-bud period, used the Seedling Fostering Agent, one bag for every 40 m^2, evenly sprayed on the seedbed, and then poured some water on the seedlings to wash out the Seedling Fostering Agent; (ii) after seedlings came out, spray for using 0.3% g hymexazol 1.5 mL/m^2 or Ruimiaoqing 1.5 mL/m^2, with 2.5 kg – 3.0 kg water. Then, after 5 – 7 days, repeated spraying using the same method one time; (iii) sprayed the rooting powder twice 4 – 5 days ahead of 2 leaf period and the transplantation, to promote root growth, control disease, and speed up green turning after transplantation.

4 Paddy field management

4.1 Land preparation After the rice harvest in the last year, the land was ploughed, when the soil moisture dropped to about 30% and the the depth was 18 cm. About May 1 in that year, the field was steeped for 5 – 7 days and then harrowed. During harrowing, the water depth should be adjusted to the level that 1/2 upturned soil was exposed out of water. After the tractor entered to the paddy field, the upturned soil in the high area was dragged to the low-lying area. Then, the overall harrowing was carried one time and made the field become flat. Repeated operation should be reduced as much as possible, to avoid too fine soil. Otherwise, it may lead to seedling was vacancy during transplanting rice seedlings.

4.2 Rice seedling transplantation According to the weather and seedling growth, the seedlings are generally transplanted during May 15 and May 20 in 2.5-leaf period. Specifications of seedling transplantation used 30 cm × 12 cm, 28 holes / m^2, 5 seedlings per hole, at the planting depth of about 2 cm.

4.3 Water depth management According to the survey of height difference of paddy field flatness, the general level difference was in the 6 cm – 12 cm, and the maximum difference was up to 15 cm or above[10]. This posed a difficult problem for the water depth management. Especially in the early period, deep water depth will drown seedlings, while shallow water depth would restrict growth in high area, in the event of continuous hot days, seedlings may be sun-dried. In case of low temperature, the growth will be delayed, thus affecting the growth and development of the whole growth period. Both cases were main reasons for vacancy of rice seedling and unbalanced growth and development of rice. According to the survey, if the water depth exceeds 10 cm, the rate of seedling being drowned is about 30%, and the harvest will be less than 300 spikes per hectare, and the death rate of seedlings in high area is about 7%. The number of grains per spike was significantly reduced, reducing by 30 grains compared with the normal rice, and the 1000 grain weight decreased by 0.7 g. For many reasons, the water depth management after transplantation should adopt water to hold the temperature and take the preservation of seedlings as the primary principle. The specific method: after transplanting, every 6 d was taken as an irrigation cycle, shallow irrigation 3 d and deep irrigation 3d. In the shallow irrigation, the upper leaves of the deep-water area were exposed to the water surface; in the deep irrigation, the water level at the high area reached 0.5 cm. After three cycles, properly increased the water depth, to make the highest area reach 2 cm. After 3 – 4 days later, the field to expose the soil and then restored to the above water depth. In early stage, the paddy field should be taken response measures, when weather forecast encountered extreme weather. If the temperature was below 13 ℃ for more than 3 consecutive days, the water depth should be greater than 3 cm for the whole day; if the temperature was above 25 ℃ for more than 3 consecutive days, water depth in deep water area should ensure the leaf ear exposes out of the water surface, for fear of being drowned.

According to different years, from June 5 to June 10, the irrigation should comply with two principles: the entire paddy field surface should not expose soil, and water depth should be changed according to the temperature. When the maximum temperature was below 25 ℃, the high area should keep 1 cm water depth; when the temperature was higher than 25 ℃, the whole field should ensure minimum 3 cm water depth. Shallow and wet combination or shallow and deep combination may be adopted, the goal was to ensure that the seedlings were full and strong, facilitate early tillering of rice. In June 15 to June 25, deep water irrigation was implemented[11], because this period was the high temperature season, deep water could reduce soil temperature and inter-plant temperature, reduce the respiratory strength and nutrient consumption, to prevent premature and reproductive growth of rice, ensure reasonable plant growth, and promote rice to foster large spikes and increase the number of grains per spike. In this period, it should keep the water depth about 6 cm.

On June 25, water should be discharged, and the paddy field should be dried according to weather conditions for about 10 days. The drying was to prevent rice excessive growth, over-green, and lodging, and reduce the occurrence of pests and diseases. In July 5 to July 10, after the completion of field drying, restored the water depth to 6 cm. If the temperature was below 17 ℃ for more than 3 consecutive days, the water depth should be added to more than 10 cm, to prevent occurrence of cold damage. After the rice heading, the second time field drying should be carried out, to promote the rooting of the roots and reduce the humidity between strains and enhance the plant elasticity. One was to prevent rice lodging, and the other was to reduce occurrence of spike neck disease. After 10 days, restored the irrigation and implemented the wet irrigation. In the end of August, discharged the water, the irrigation completed.

4.4 Fertilizer application The general principle of paddy field fertilizer application was high amount in the early stage, supplementary in the middle stage, and controlled in the late stage. The total application amount of fertilizer in the whole growth period was 150 kg/ha of diammonium phosphate (DAP), 150 kg/ha of potassium sulfate and 450 kg/ha of urea. Application amount of fertilizer for each period: before steeping the field, applied urea 75 kg/ha as the base fertilizer, 150 kg/ha of diammonium phosphate (DAP), 75 kg /ha of potassium sulfate, mixed evenly and applied at the same time; May 25 to May 28, topdressing urea 80 kg/ha; June 5 to June 8, topdressing urea 80 kg/ha; before June 15, topdressing urea 165 kg/ha; about June 22, topdressing urea 50 kg/ha, but this time should depend on seedlings, applied the urea at the place where it lacked; the last time was at the end of June, topdressing potassium sulfate 75kg/ha, then the application of fertilizer completed for the whole growth period[12].

4.5 Chemical weeding of the paddy field Before transplanting of 7 to 10 days, used 1500 g/ha 25% oxadiazone to seal the grass; after seedlings turning green, implemented the second time grass sealing combined with the second topdressing, and applied with 1200 g/ha benzopyr-benzoyl evenly mixed with urea[10]. The third time weeding was carried out on the next day after discharging and drying on June 26, sprayed 600 g/ha 60% dimethyl tetrachloride, plus 1000 g/ha 25% basagran (bentazon) mixed with water (dimethyl Tetrachloride could reduce the cost of chemical herbicides, but also enhance the elasticity of rice plants, and improve rice lodging resistance).

4.6 Prevention and control of plant diseases After transplanting seedlings for 7 days and 14 days, applied 1 000 g/ha 40% dimethoate to prevent and control phytomyza nigricornis. If there was Crioceridae on the middle of June, applied the topdressing urea, and sprayed 1500 g/ha poisonin.

4.7 Prevention of rice blast It is required to prevent the occurrence of rice blast by three times, namely, in early July, 7 days before heading and at full heading stage. Applied 40% tricyclazole or 40% rice blast killer and the amount was 750 mL/ha tricyclazole,1500 mL/ha rice blast killer.

4.8 Prevention of rice over-green and lodging Over-green and lodging were essential factors of the rice yield reducing, and farmers often excessively applied chemical fertilizer, especially the urea, for the pursuit of high yield[7]. Years of experience tell us that the urea should not be used at later stage of the growth period. Discharging and drying and spraying dimethyl tetrachloride are also an important measures for preventing lodging[13].

5 Demonstration results

In 2013, the demonstration area was 1.5 ha and the total grain yield was 15 975 kg, equivalent to 10 650 kg/ha; in 2014, the demonstration area was 3.1 ha and the total grain yield was 30 102 kg, equivalent to 10 034 kg/ha; in 2015, the demonstration area was 3.3 ha and the total grain yield was 33 538 kg, equivalent to 10 163 kg/ha; the average yield of the three years exceed 10 t/ha.

6 Analyses and discussions

Results of the three years of demonstration indicated that the present potential of high yield of rice was high in Heilongjiang Province[14], the yield can reach 10 t/ha level. Compared with the yield 7 – 8 ton level of large area paddy field, there was a large space of yield increase. Therefore, the high-yielding varieties and high-yielding cultivation methods should be promoted at the same time. From the results of the three-year experiment, the yield of each year was above 10 t/ha, indicating that the technical scheme developed by this procedure was reliable, effective, simple, and feasible. It could be applied in relatively extensive farmland, it saved work and money, and it was also high and stable yield[15]. If we continued to reduce the seedlings, improved the quality of seedlings and the quality of paddy field, and kept the height difference in the paddy field within 5 cm under this technical procedure, the yield would further increase.

References

[1] WANG WM. The current situation and outlook of rice breeding for super high yield[J]. Southwest China Journal of Agricultural Sciences, 1998 (s2):11 – 16. (in Chinese).

[2] ZHENG JS, HUANG YM. Thrust and practice of super high-yielding rice production in China[J]. Molecular Plant Breeding, 2003, 1(5/6):585 – 596. (in Chinese).

[3] XU YR, QIU LY. On the cultivation techniques of rice shoot with rsgun and wide planting in the cold region[M]. Harbin: Hilongjiang Science and Technology Press, 1996:56 – 11. (in Chinese).

[4] HAN GQ. Japonica rice in cold region in China[M]. Beijing: China Agriculture Press, 2011:122 – 123. (in Chinese).

[5] ZHANG S, XU YR. Rice production in cold region[M]. Harbin: Hilongjiang Science and Technology Press, 1990:296 – 298,407. (in Chinese).

[6] XU YR, XIE BS, SUN ZZ, *et al.* On agricultural reclamation of Heilongjiang rice[M]. Harbin: Hilongjiang People's Publishing House, 1999:152 – 154. (in Chinese).

[7] LING QH, ZHANG HC, DING YF, *et al.* Development of rice high-yielding techniques——Precisely fixed quantity planting[J]. China Rice, 2005(1):3 – 7. (in Chinese).

(To page 79)

an extremely significant positive correlation between yield of cross combination and genetic distance between parental inbred lines. By analyzing field test results (Table 4), it was found that the parents of eight combinations with the highest yield were from different groups (I, II, IV, V), respectively; for the eight cross combinations with the lowest yield, the male and female parents of most combinations were from the same group, and the parents of only two combinations ($B_{10} \times B_9$, $B_7 \times B_8$) were from different groups. This suggested that it was most likely to select the cross combinations with a strong advantage from different groups, while due to small genetic differences between inbred lines within group, there was a weak advantage, and it was hard to select the combinations with high yield. Therefore, in breeding practice, in order to improve the breeding efficiency, it was necessary to conduct hybridization between groups and avoid hybridization within groups. In a certain range, the greater the genetic distance between inbred lines, the higher the yield of hybrids between inbred lines; on the contrary, the yield of hybrids between inbred lines would be lower. Therefore, the analysis of genetic distance could be used as an important basis for hybrid selection (yield increase). The above analysis results indicated that there was a significantly positive correlation between genetic distance and mid-parent heterosis, super heterosis, yield SCA or plot yield, so it was possible to predict normal maize heterosis.

Table 4 Top (last) eight cross combinations in terms of yield and genetic distance between inbred lines

Top eight				Last eight			
No.	Combination	Genetic distance	Yield (kg)	No.	Combination	Genetic distance	Yield (kg)
1	$B_{10} \times B_{19}$	0.900	8.724	1	$B_10 \times B_{18}$	0.455	3.184
2	$B_1 \times B_{19}$	0.900	8.711	2	$B_4 \times B_{18}$	0.364	3.254
3	$B_2 \times B_{18}$	0.714	8.299	3	$B_7 \times B_5$	0.134	3.414
4	$B_{14} \times B_8$	0.833	8.187	4	$B_6 \times B_{18}$	0.455	3.504
5	$B_2 \times B_{19}$	0.789	8.064	5	$B_{14} \times B_{18}$	0.333	3.753
6	$B_4 \times B_{19}$	0.879	8.007	6	$B_{10} \times B_9$	0.583	6.143
7	$B_2 \times B_3$	0.895	7.980	7	$B_7 \times B_9$	0.250	6.482
8	$B_2 \times B_5$	0.727	7.949	8	$B_7 \times B_8$	0.840	6.739

4 Conclusions

In this experiment, the results showed that in a certain range, the greater the genetic distance between parental inbred lines, the stronger the heterosis, which was consistent with the results of previous studies. Therefore, in the practice of breeding, it was necessary to take the molecular genetic distance between inbred lines as an important reference. From this experiment, it was found that almost all combinations with strong advantages were constituted by hybrids between inbred lines from different groups, but the combinations constituted by hybrids between inbred lines might have no strong advantage, which was in line with the findings about maize inbred lines from Ajmone *et al.*, Wu Minsheng *et al.*, Cao Yongguo *et al.*, and Huang Yiqin *et al.* Experimental results showed that there was a significantly positive correlation between genetic distance and mid-parent heterosis, super heterosis, yield SCA or plot yield, so it was possible to predict normal maize heterosis.

References

[1] CAO YG, XIANG DQ, HUANG LJ, *et al.* Studies on relations of SSR markers and heterosis in maize[J]. Journal of Agricultural Biotechnology, 2002,10(2): 120 – 123. (in Chinese).

[2] DU JY, LI Y, WANG TY, *et al.* Studies of genetic diversity in maize inbred lines based on SSRs and AFLPs markers[J]. Acta Agriculturae Boreali-Sinica,2003,18(1): 59 – 63. (in Chinese).

[3] PAN XM, ZHANG SH, TAN J, *et al.* Heterotic grouping of quality protein maize inbreds divided by SSR markers[J]. Acta Agronomica Sinica, 2003,29(1): 105 – 110. (in Chinese).

[4] YUAN LX, ZHANG SH, FU JB, *et al.* Study on genetic diversity and heterotic groups in maize (*Zea mays* L.)[J]. Scientia Agricultura Sinica,2000, 33(C00): 9 – 4. (in Chinese).

[5] MELCHINGER AE, MESSROER MM, LEE M, *et al.* Diversity and relationships among U. S. maize inbreds revealed by restriction fragment length polymorphism[J]. Crop Science,2001,31(3): 669 – 678.

(From page 76)

[8] CHEN XY, CHEN L, DUAN K. On high-quality high-yield culture technique of rice[J]. Modern Agricultural Sciences and Technology, 2007 (15):117 – 117. (in Chinese).

[9] BAO SZ. On the application and development of high-yield culture technique of rice[J]. Southwest Horticulture, 2014, 8(18):65 – 67. (in Chinese).

[10] SUI YL. On high-yield culture technique of rice and main pest control [J]. Modern Agricultural Research, 2011(9):29 – 30. (in Chinese).

[11] AN CF, DING YX, HE YL. On the technology of high-yield cultivation and management of rice[J]. Bullenin of Agricultural Science and Technology,2009(5):131 – 132. (in Chinese).

[12] LIU CJ, GAO CS, JIN J, *et al.* Study on high-yield culture technique and mode of rice in Heilongjiang Province[J]. China Rice,2011,17 (5):49 – 52. (in Chinese).

[13] LI YS. Study and discussion on the rice planting technology in Heilongjiang Province[J]. Science & Technology View,2012,4(11):192 – 193. (in Chinese).

[14] JIAO J, XU XB, MENG Y, *et al.* Development question of rice cultivation technology in Heilongjiang Province[J]. Heilongjiang Agricultural Science,2007(2):3 – 5. (in Chinese).

[15] CHEN BC. Discussion on some problems of rice cultivation techniques in Heilongjiang Province[J]. Vigour, 2010(12):143 – 143. (in Chinese).