Growth characteristics of rice seedlings using direct sowing technology

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Abstract: To search the optimum planting technology of rice direct sowing and its corresponding production mechanization, the contrast paddy-field experiments on direct sowing of baby rice seedlings, the rice transplanting, and the rice broadcasting were done in Jingertun village of Liaoyang. The growth characteristics of the root length, amounts and the height of baby rice seedlings during the breeding period were studied. It was showed that the operation of training seedling had the restrained effects on the increment speed of the root length and the height of the baby rice, but it did not affect the increment of the amounts of the roots. Compared to the routine sowing methods, the direct sowing technology of baby rice seedlings has the advantages as follows, growing quickly in the period from May 20 to July 27, tillering and heading earlier and the node of tiller lower. But the method had the shortcoming of the lower effective tiller ratios because of heavy sowing densities. The spike density of the baby rice sowing was 5387000 head/hm^2, the grain ripened of each spike was 76.8, and the one thousand-grain-weight was 0.0246 kg.

Key words: direct sowing of baby rice seedling; growth characteristics of rice seedling; rice height; root length; tiller; grain amount per head
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1 Introduction

The technology of rice direct sowing was widely used in Europe, America and some other countries because of the advantages of lower cost, water saving, and higher operational efficiency, etc.[1~4]. Asian countries, especially Japan, had studied various rice planting technologies with paper mulching[5~9]. In China, rice direct sowing had been tested in Shanghai, Jiangxi, Jiangsu, etc. Up to 1998 the areas of baby rice direct sowing in Shanghai reached 8200 hm^2, accounting for 64.6% of the rice direct sowing[10]. In Jiangsu, Dai Qigen et al.[11,12] studied the eco-physiological characteristics of the growth, development and yield formation of broadcasted rice seedlings. The results by Gu Zhanggen and Wang Yuejun in Zhejiang Province showed that the yield was higher by direct seeding than that by transplanting[13]. In recent years, the baby rice direct sowing experiments were done in succession in Shenyang, Liaoyang, Donggang of Liaoning Province, Northeast of China[14,15]. It showed that the rice planting method had the advantages of higher benefit, lower cost, etc. But the studies on the characteristics of the seedlings using the technology of the baby rice direct sowing during their growth were seldom reported, and the producing technologies were not canonical and widely accepted, so the output was not stable, at last it restricted the extending and the using of the technology.

2 Materials and methods

Three treatments were used in the experiments. They were baby rice seedling direct sowing, routine rice transplanting and rice broadcasting. The total areas for baby rice direct seedling experiments were 20 hm^2, to study the optimum cultivating technology, and because of the large area with the lack of equipment and labor, it was divided into five batches with the area of 4 hm^2 for each batch. Except for the characteristic of the output which used the mean value of all batches, the experiment data of second batch were used as the results of the baby rice seedling direct sowing technology in this paper. The areas for routine transplanting experiments were 1 hm^2, and the areas for broadcasting were 1 hm^2. The experiments were conducted in Liaoyang Jingertun in 2002. Baby rice seedling direct sowing used laser-controlled land-leveling machine to level the paddy field, the standard deviation of the paddy field was no more than 2~3 cm. Cumulated percentage of the measured spots,

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which height difference was no more than 2 cm to the average value, was more than 80%[1,2]. The other treatments used routine rotary cultivator to cultivate and level the paddy field.

To obtain the characteristics of baby rice seedlings in the breeding period, such as the height of the seedlings and so on, 30 seedling samples were taken from every batch at one time by the method of accidental sampling. To obtain the characteristics of baby rice seedlings in the growth course such as the amount of the leaves and so on, in every batch 50 seedling samples were taken from 5 points (each point 10 seedlings) by the method of diagonal sampling. To test the characteristic of the rice in autumn, such as the density of the head, 5 m^2 samples were taken from 5 points with the area of 1 m^2 for every points by the method of diagonal sampling. Except for special explain, all the values used were average values of the samples.

2.1 Paddy field irrigating before sowing

Unlike the routine transplanting that needs 12~24 h irrigating before transplanting rice seedlings into the paddy field, the baby rice seedlings direct sowing technology needs only 10 h before sowing. The irrigated paddy fields for the sowing technology allow the height of mud in somewhere exposed above the water level no more than 1 cm while the depth of the water in somewhere was no more than 2 cm. The purpose of that demand was to let the surface water permeate into the earth sooner, and let the baby rice seedlings combine with the soil as soon as possible. It was to make the seedlings distributing uniformly so that the baby seedlings didn't flow with the surface water under the action of the wind.

2.2 Baby rice seedling breeding

The first step was to select the variety of the rice. It abides by the rules to select the rice of 150~155 days growing period, with the characteristics of more tiller, higher output and withstanding the lodge and the illness. Considering the climate, the variety No. 931 of Liaojing was used. The one thousand-grain-weight of the rice seeds was 0.02415 kg and the germinating rate was 91.825%.

The second step was to dry the seed under the sun and then to select the plump rice by using water. Put the seed on the plastic film spreading on the ground. After 2~5 hours under the sunlight, remove the impurities by using water and leave the plump rice seed.

The third step was to dip the rice by medicine. Put the selected plump seeds into a container, which was filled with the medicine of a mixture of thiran and metalaxgy or Trichloroisocyanuric acid, and dipped for 4~5 days. The one thousand-grain-weight was 0.03055 kg after it was dipped.

The fourth step was to accelerate germination of the seeds. Put the dipped seeds into hot water (55℃) for 2~5 minutes, then take them out, spread them on the plastic film in the greenhouse, and then cover the seeds with wet cloth or knitted sack. To accelerate germination of the seeds needs the time of 48 hours, irrigating water and turning them over 3~4 times each day. It is to ensure the humidity of the seeds to keep the temperature of 25~35℃ by irrigating. The standard of germination hastening was that the seeds white sprouts length was 1~2 mm, not too long. The timetable of breeding baby rice seedlings was shown in table 1.

Table 1 Timetable of breeding baby rice

Batches	Sunning the seed	Dipping the seed	Accelerating germination	Enveloping the seed	Exercising the seedlings	Direct sowing
1	23rd, April 2h	23rd, April 11:00	28th, April 8:00	30th, April 7:10	4th, May~7th, May	8th, May
2	25th, April 2h	25th, April 11:00	30th, April 9:25	2nd, May 9:00	6th, May~9th, May	10th, May
3	28th, April 2h	28th, April 10:05	2nd, May 9:30	4th, May 7:20	8th, May~11th, May	12th, May
4	30th, April 1.5h	30th, April 10:25	4th, May 10:30	6th, May 14:10	10th, May~13th, May	14th, May
5	2nd, May 1h	2nd, May 9:20	6th, May 7:45	8th, May 13:50	12th, May~15th, May	16th, May

The fifth step was to envelop the sprouted seeds. The used materials were as follows: sprouted seeds 10 kg, clay 2.2 kg, fine sand 2.2 kg, plant and grass ash 0.4 kg, the plant growth hormone of Plantpower 2003 liquor 13.5 kg. Mix those materials equably to form a protecting layer over the sprouted seeds. Extend the enveloped seeds on the plastics in the greenhouse with the thickness of the seed about 5 cm, and then cover them with knitted sack. The time for breeding after enveloped needs 7~8 days, irrigating and turning over them 2~3 times every day. It is important to keep the humidity of the seed and maintain the temperature among 24~30℃. If the time of enveloping was too long, it would result in the sprouts and the roots too long to be broken when they were sowing. As a result it would reduce the survival ratio of the baby rice seedlings. On the other hand, if the time was too short, it would result in the baby rice seedlings

effeminatness, and the baby rice seedlings could not bear the low temperature in the paddy field, and it would also reduce the survival ratio of the baby rice seedlings. At last it would affect the output and the quality of the rice.

The last step was to exercise the baby rice seedlings. From the fourth day of beginning of enveloping seeds, uncover the greenhouse shed from 10: 00 am to 13: 00 pm everyday. The purpose was to let the baby rice seedlings to adapt to the change of the climate outside. Turn over the seedlings often to avoid the roots too long to be tangled together. The one thousand-grain-weight of the baby seedlings before sowing was about 0. 046 kg.

2 3 Sowing in good time and suitable quantity

The baby rice seedlings were sowed into the paddy field with the density of 110 grains/m^2, which were enveloped with 8 days, the sprouts length were 1. 2～1. 5 cm, the root length were 1. 5～2. 0 cm. The direct sowing machine was manufactured by Agricultural Mechanization Academy of Liaoning Province improved from WFB-18 spray powder machine. The working width was 10 meters and the working efficiency was 2 hm^2/2 persons. The transplanting and broadcasting methods were used at the same time of May 8th, and the same rice seedlings that were bred on April 5th were used. The transplanting row width was 30 cm with the hill distance of 20 cm and 3 seedlings per hill. The broadcasting was a kind of random throwing sowing method with the average density of seedling distributing of 37 hill/m^2 and 3 seedlings/hill.

2 4 Water and fertilizer management

The period from the baby rice seedling sowing to the tillering was the key time. The irrigation should abide by the rule of "wet-dry-wet", "wet" means the water lower than the top of the seedlings, it usually was 3 cm; "dry" means that the land surface should not crack, it should ensure humidity enough. In general situations, it should be irrigated with interval of 2～3 days. If the weather is cold, it must be irrigated to protect the seedlings from frostbite, and then be drained to sun the paddy field after the cold snap. Fertilizer was the same as routine rice transplanting.

2 5 Weed controlling

The key to baby rice seedling direct sowing was to control the weeds. It was because when the baby rice seedlings were sowed into the paddy field, they grew at the same time with the weeds, while the life-force of the weeds to contest the nutrient and the sunshine was stronger than the seedlings. It applied the chemical technology of broadcasting blocking weed medicine named Ronstar of 12% when irrigating the paddy field before sowing the rice. The baby rice seedlings should be planted after 10 hours. Then throw herbicide when the seedlings grew to the fourth leafage.

3 Results and discussion

3 1 Characteristics of the baby rice seedlings in the period of breeding

The baby rice seedlings absorbed the nutrition and the moisture rapidly in the eight days from the enveloped to the sowed. It showed that the roots and sprouts grew rapidly and the leaves came to green. The heights of the seedlings, the lengths and the amounts of the roots along with the time were as shown in Fig. 1.

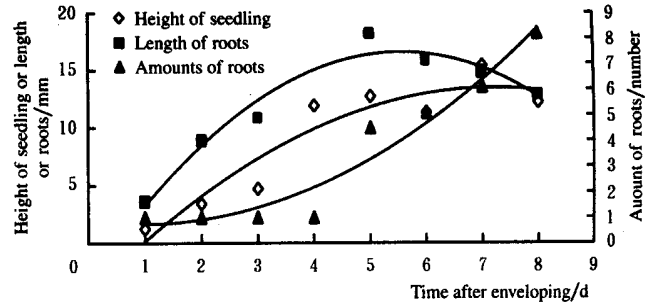

Fig. 1 Characteristics of baby rice seedlings in 8 days from the enveloped

It showed that the relationship between root length y_1 (mm) and the breeding time x (d) in breeding period was:

$$y_1 = -0.643x^2 + 7.1369x - 3.2521 \quad (x = 1, 2, 3, \cdots) \qquad (1)$$

The correlation coefficient of the regression equation was $R = 0.9784 > (R_{0.01} = 0.8343)$. The root length arrived at the peak in the fifth day after the seedlings enveloped, then began to shorten because the higher containing moisture root shrank when they met the sunshine and the dry cold atmosphere.

The relationship between the seedling height y_2 (mm) and breeding time x (d) was:

$$y_2 = -0.346x^2 - 4.9864x - 4.5121 \quad (x = 1, 2, 3, \cdots) \qquad (2)$$

The correlation coefficient of the regression equation was $R = 0.9423 > (R_{0.01} = 0.8343)$. The height of the seedlings increased slowly when the exercising seedlings course began.

The relationship between the amount of the root y_3 (mm) and the breeding time x (mm) was as follows:

$$y_3 = 0.153x^2 - 0.2851x + 0.9696 \quad (x = 1, 2, 3, \cdots) \qquad (3)$$

The correlation coefficient of the regression equation was $R = 0.9697 > (R_{0.01} = 0.8343)$. It could be seen that the amounts of the roots were not influenced by the seedling exercising course.

3.2 Development characteristics of the seedlings in growth course

The measured characteristics of the seedlings such as the amount of the leaves, the length and the width of the largest leaf, and the height of the stem among the three different sowing methods from May 20 to July 27 were listed in table 2. The results showed that the above mentioned characteristics of the baby rice seedlings were smaller than those of the other planting methods in May 20. Till July 27 the height of the stem of the baby rice seedlings was higher than those of the other planting methods, the rest characteristics were still smaller but the differences were decreased obviously.

On May 20, the amount of the leaves in baby rice seedlings was 3.3, lower respectively by 32.65% and 17.50% than those of the broadcasting and the transplanting. On July 27, the amount of the leaves increased to 11.6, lower respectively by 17.73% and 14.07% than those of the other two sowing methods. It showed that the amount of the leaves increased quickly using the baby rice seedlings direct sowing technology in this period.

On May 20, the length of the largest leaf in baby rice seedlings direct sowing was 21.6 mm, lower respectively by 70.41% and 80.15% than those of the broadcasting and the transplanting. The width of the largest leaf was 3.0 mm, lower by 23.08% respectively than those of the other two methods. But on July 27, the length of the largest leaf increased to 384.06 mm, lower respectively by 10.70% and 20.00% than those of the other two methods. The width of the largest leaf increased to 15.26 mm, lower respectively by 13.14% and 15.56% than those of the other two methods. It showed that the size of the leaf increased quickly using the baby rice seedlings direct sowing technology in this period.

On May 20, the height of the stem in baby rice seedlings direct sowing was 30.3 mm, lower respectively by 40.48% and 60.42% than those of the broadcasting and the transplanting. But on July 27, the length increased to 320.2 mm, higher respectively by 13.14% and 8.54% than those of the other two methods. It showed that the height of the seedlings stem grew quickly in this period.

Table 2 Development characteristics of the seedlings in growth course

Date /month-day	Amount of the leaves/piece·stem^{-1}			Length of the largest leaf/mm			Width of the largest leaf/mm			Height of the stem/mm		
	Direct sowing	Broadcasting	Transplanting	Direct sowing	Broadcasting	Transplanting	Direct sowing	Broadcasting	Transplanting	Direct sowing	Broadcasting	Transplanting
05-20	3.3	4.9	4.0	21.6	73.0	108.8	3.0	3.9	3.9	30.0	50.4	75.8
05-21	3.2	5.0	5.7	34.8	80.4	76.6	3.1	3.8	5.0	32.6	60.8	61.0
05-22	3.7	5.0	5.0	22.8	67.6	149.6	2.8	3.7	6.2	29.0	46.8	93.8
05-23	4.1	4.7	5.1	29.6	88.6	124.0	2.5	3.6	4.7	26.0	52.6	85.4
05-24	4.1	5.5	5.0	37.8	83.6	129.6	3.2	3.7	4.5	39.0	57.6	100.0
05-25	4.4	5.6	4.7	36.6	76.6	118.6	2.9	3.7	5.0	36.0	53.8	73.6
06-01	5.9	6.4	5.9	73.6	146.2	186.0	3.8	5.8	4.3	65.8	98.0	133.0
06-08	6.5	7.7	6.7	108.0	140.6	222.6	5.1	7.0	6.0	91.2	94.0	128.2
06-15	6.8	8.3	7.4	167.0	166.0	253.0	7.2	7.5	9.5	128.4	121.8	158.4
06-22	7.0	8.6	8.1	186.0	193.0	287.0	7.4	9.8	12.2	124.0	130.0	186.0
06-29	8.1	9.9	9.3	235.0	230.0	300.0	8.8	10.6	12.4	166.0	140.0	194.0
07-06	9.8	11.2	10.7	305.0	262.5	367.5	10.9	10.6	11.9	201.0	196.3	216.3
07-13	10.7	12.1	11.5	369.0	350.0	400.0	12.0	11.5	14.5	236.4	220.0	235.0
07-20	11.0	13.3	12.7	362.0	390.0	450.0	12.5	14.5	16.0	253.8	253.0	260.0
07-27	11.6	14.1	13.5	384.0	430.0	480.0	15.2	17.5	18.0	320.2	283.0	295.0

The curves for the heights of the seedlings in three treatments from May 15 to October 1 were as shown in Fig. 2. The x axis was the growing days of the baby rice seedlings direct sowing (the 14th days represented the date of May 15).

Figure 2 showed that on the 16th days of the baby rice seedlings direct sowing, the heights of the seedlings were 3.76, 10.62 and 4.82 cm for the baby rice seedlings direct sowing, for the seedling transplanting and for the rice broadcasting, respectively. The seedling height of the direct sowing was relatively lower by 64.60% and 21.99% than those of the transplanting and the broadcasting respectively. On the 30th days, the height of the seedlings of the baby rice seedlings direct sowing was 11.52 cm, lower 21.20% than transplanting but

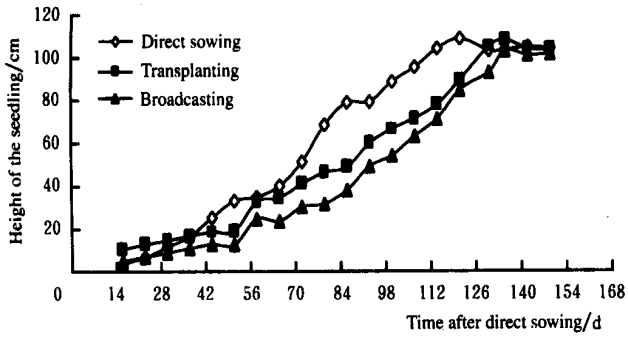

Fig. 2 Comparisons of the seedling heights among the three planting methods in growth duration

higher 30.61% than broadcasting. On the 44th days, the height was 25.28 cm, relatively higher by 35.77% and 97.35% than those of the other two methods, respectively. On the 86th days, the height reached the argest eariler than those of the other two methods, which was 78.90 cm, higher by 61.68% and 107.63% respectively than those of the other two methods. It showed that the height of the baby rice seedlings increased quickly in this period. To the treatment of the baby rice seedlings direct sowing, the height of the seedlings reached the largest value of 108.7 cm on 121st days, while the height of the other two methods reached the largest value of 108 cm and 103 cm on 135th days (the value were the max height of the stalk of the rice seedlings, at this time the highest points of seedlings were usually on the leaves). It also showed that, when the rice came into autumn, the height reduced little and at last it came to stabilization. When they were in stabilization, the height of the three treatments was about 105 cm without obvious distinction.

Table 3 Comparisons of the tiller and the head among the three cropping patterns in growth duration

Treatment	Start time of tillering /d	Start time of heading /d	Average amount of tiller /unit · stem^{-1}	Effective amount of tiller /unit · stem^{-1}	Lowest knot of tiller
Transplanting	70	120	4.8	4.3	4
Broadcasting	57	127	7.1	6.3	3
Baby rice seedlings direct sowing	39	100	4.5	3.9	2

The characteristics of the seedlings in growth duration were listed in table 3. It showed that, the tillering by baby rice seedlings direct sowing is earlier than those by the other two methods, but the effective amount of tiller was lower than those of the others because the heavy density of the seedlings in the field with less nutrition and the sunshine.

3.3 Characteristics of the rice in autumn

The characteristics of the output of the rice on October 1 were listed in table 4. It showed that the density of the heads of the baby rice seedlings direct sowing was 5387000/hm^2, lower respectively by 7.76% and 16.79% than those of the transplanting and broadcasting treatments. The ripened grain of each head was 76.8, higher respectively by 26.52% and 17.43% than those of the other two treatments because the lower tiller led to the centralized nutrition. The one thousand-grain-weight was 0.0246 kg, 3.15% lower than that of the rice sowing transplant, 2.93% higher than that of the rice broadcasting method. The theoretic output was 10177.55 kg, higher by 13.03% and 0.58% than those of the other two treatments, respectively. The practical output of the baby rice seedlings direct sowing treatment was the mean value of the 5 batches. In these 5 batches, the output were 6900, 7200, 7050, 9000, 7350 kg/hm^2 for the first, second, third, fourth, and fifth batches respectively. There were great differences for the rice output among the batches, so the mean value (7500 kg/hm^2) of the output of baby rice seedling direct sowing treatment was used as the practical output. The reasons for lower output for the some batches were both the too deep irrigation water (about 10 cm) when the seedlings were small (about 5 cm) in the early days of the growth and the too late application of the herbicide when the seedlings had been sowed in the field for 3 days. So the water management and weed control were the key technologies for the baby rice seedling direct sowing method.

Table 4 Characteristics of the rice in autumn

Treatment	Densities of head /10000 head · hm^{-2}	Ripened grain of each head/unit	One thousand-grain-weight/kg	Theoretic output /kg · hm^{-2}	Practical output /kg · hm^{-2}
Transplanting	584.0	60.7	0.0254	9003.99	8683
Broadcasting	647.4	65.4	0.0239	10119.25	9593
Baby rice seedlings direct sowing	538.7	76.8	0.0246	10177.55	7500*

4 Conclusions

1) The lengths and amounts of the roots, the lengths of the sprouts were all accorded with the relationship of parabola with time for the three rice planting methods. The course of exercising seedlings restrained the increasing of the root length and the sprout length, but it did not affect the amounts of the root. The height of the seedling planted by baby rice seedling direct sowing technology was lower than those of the other methods in the beginning, but it increased quickly in the metaphase period, at last the heights of the three treatments were almost the same.

2) The start time of tillering of the baby seedlings by direct sowing was earlier than those of the other two methods. The average amounts of tiller and the effective amounts of it were lower than those of the others because of the heavy densities. The density of the head of the seedlings planted by baby rice seedlings direct sowing technology was the lowest in the three treatments. It also showed that the one thousand-grain-weight by using rice seedling direct sowing was higher than that by the broadcasting and lower than that by the transplanting, but its plump grain of each head was the highest obviously.

3) The experiments were done only in Liaoning Province, Northeast of China, so the results were only referential for this area or the similar areas. To get the optimum planting technology and realize its mechanization, the further studies are still necessary.

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乳芽直播种植技术条件下水稻生长特性的研究

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摘　要: 为了探索水稻直播的最佳种植工艺及其相应的机械化生产, 采用田间试验方法, 在辽阳市景尔屯村的 20 hm^2 水田进行了乳芽直播、常规插秧和抛秧 3 个处理的水稻种植对比试验。对培育期乳芽的根长、根数和高度等生长特征的研究结果表明, 练苗环节对根长和乳芽高度的增长速度有明显的抑制作用, 但对乳芽根数的增加无影响。对秧苗生长中期的性状特征研究结果表明, 与其它 2 个处理相比, 乳芽直播的秧苗在 5 月 20～7 月 27 日期间生长较快, 分蘖和抽穗开始时间早, 分蘖节位低, 但由于播种密度太大, 有效分蘖率较低。对 3 个处理的产量形成指标检测结果表明, 乳芽直播处理的穗数密度为 538. 7 万穗/hm^2, 每穗结实粒数为 76. 8 粒, 千粒重为 0. 0246 kg。

关键词: 水稻乳芽直播; 秧苗生长特性; 苗高; 根长; 分蘖; 穗粒数