Development and Rooting Capacity of Rice Nursling Seedlings Grown under Different Raising Conditions*

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Abstract : To reduce the raising period of rice nursling seedling and to obtain enough plant length (7 cm) for mechanical transplanting, nursling seedlings were raised under different light conditions and for different raising periods. The length of nursling seedlings which was raised in the dark (yellow nursling seedlings ; YNS) for 7 days was 9.6 cm long. While that raised in the natural light (green nursling seedlings ; GNS) for 2 days at 25°C and then placed in a vinyl house for 3 days was 5.5 cm long. The length of YNS raised for 4 days was 4.1 cm, which is not the adequate size required for mechanical transplanting. The differences between root numbers as well as that between the longest root length of YNS and GNS at 5 and 10 days after transplanting were not significant. The amount of dry weight increase of YNS until 10 days after transplanting was lower than that of GNS. There was high correlation ($r=0.984^*$) between the increase of dry weight and consumption of endosperm nutrient for all kinds of seedlings. In all treatments, a high correlation ($r=0.994^{**}$) was also observed between the increase of total dry weight and consumption of endosperm nutrient until 5 days after transplanting. The growth and development of seedlings at this interval depended on the nutrient in the endosperm. Based on these results, yellow nursling seedling might have been used as rice seedling.

Key words : Endosperm, Green nursling seedlings, Nursling seedlings, *Oryza sativa* L., Plant length, Rice, Transplanting, Yellow nursling seedlings.

育苗条件を異にした水稻乳苗の生育と活着について* : 星川清親・佐々木良治・長谷部 幹 (東北大学農学部)

要 旨 : 水稻乳苗の育苗期間を一層短縮化し、しかも機械移植に必要とされる苗丈(7 cm)の確保を目的として、育苗期間と光条件をかえた4種の乳苗の育苗をロックウールマットによりおこなった。そして育苗した乳苗の移植後(5, 10日後)に活着生長を調査した。出芽後も暗条件下で育苗した乳苗(イエロー乳苗)の苗丈は育苗期間7日で9.6 cm、一方、出芽後2日間緑化し(グリーン乳苗)さらに3日間ハウス内で育苗した乳苗の苗丈は5.5 cmであった。育苗期間4日のイエロー乳苗の苗丈は4.1 cmで、機械移植に必要とされる苗丈には達しなかった。移植後の根数、最長根長は、同じ育苗期間のイエロー乳苗とグリーン乳苗との間で有意な差はなかったが、移植後10日間の乾物重の増加は、イエロー乳苗が若干少なかった。4種の乳苗の育苗期間中の乾物重との増加は、胚乳養分の消費量と相関関係($r=0.984^*$)にあった。移植後5日間の乾物重の増加と胚乳養分の消費量の間でも相関関係($r=0.994^{**}$)があり、活着期の生育は、胚乳養分にかなり依存していた。以上の結果より、イエロー乳苗の活着は、グリーン乳苗に比較すると若干劣るものの、実用性があると思われた。

キーワード : イエロー乳苗、移植、イネ、*Oryza sativa* L., 草丈、グリーン乳苗、乳苗、胚乳。

For nearly the past 20 years, several efforts have been made to transplant seedlings younger than Chibyo (3.2-3.3 leaf age) by using the transplanting machine^{1,2,3,5}). The two to three leaf aged seedlings were defined as Nyubyo by the Ministry of Agriculture, Forestry and Fisheries in 1990. Hoshikawa⁵⁾ named Nyubyo the nursling seedlings in English. Nyubyo was more economical due to reduction in working time and cost^{1,11,12)}.

It has been reported that the raising period of nursling seedlings was 7 to 15 days¹⁾. From our experience, mechanical transplanting

could pose a problem, if nursling seedlings raised less than 10 days were used. The poor root spreading in the nursery soil was the factor. This problem could be solved by using a special rock wool mat^{4,6)}. The rock wool mat will solve the poor root spreading problem of the nursling seedling. Therefore, it was possible to reduce the raising period of seedling to less than 7 days when the rock wool mat was used.

In addition to poor root spreading, the short length of nursling seedlings was also a problem. The length made transplanting by machine difficult. Kiriya⁹⁾ reported that the minimum plant length of nursling seedlings

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for mechanical transplanting was 7 cm. Little is known about how plant length is influenced by light and temperature conditions during the raising period.

This experiment was conducted to investigate whether nursling seedlings grown under different light conditions and a reduced raising period of less than 7 days could attain the required plant length (7 cm), and develop enough rooting capacity as rice seedling.

Materials and Methods

Rice seeds, *Oryza sativa* L. cv. Sasanishiki, were encouraged to germinate, and then sown on the rock wool mat ("Chibikko Power Mat" sized 28 cm×58 cm×1.8 cm, Nippon Steel Chemical Co., Ltd.). Seeding density was 220 g/box. After sowing the seeds, the mat was saturated with 2.5 L water, and covered with a thin soil layer. Nursery boxes were placed in the nursery chamber and maintained at 32°C in the dark. It took 2 days to develop about 1 cm long buds. The seedlings were raised under different raising periods and lighting conditions as follow (1) 25°C, in the natural light for 2 days (4d-GNS), (2) 25°C, in the dark for 2 days (4d-YNS), (3) the same as in (1) and then placed in a vinyl house for 3 days (7d-GNS) at 15-27°C, (4) 25°C in the dark for 5 days (7d-YNS). Just before transplanting, 60 seedlings were sampled to measure plant length and root numbers. For dry weight observation about 150 seedlings were taken. Samples were held in three replicatons.

After treatment, nursling seedlings were transplanted into 16 cm diameter plastic pots (3 plants per hill and 9 hills per pot) which contained unfertilized soil. Transplanting depth was 2 cm. The water was kept in 1.5 cm

depth from the soil surface. In early October of 1991, the pots were placed into the glass house for 10 days. The glass house temperature was in the range of 15-25°C.

Plants were washed free of soil at sampling. Two pots per treatment were taken at 5 days after transplanting (5 DAT) and 10 DAT. Plant length, longest root length and root numbers were measured. For dry weight measurement, shoot, root and seed were carefully separated. The consumption of endosperm nutrient was regarded by decrease in seed dry weight.

Results

1. Growth and development during raising period

Nursling seedlings raised in the dark showed spindly growth. We named these seedlings yellow nursling seedlings (YNS)^{7,8)}. On the contrary, those which were raised in the light showed normal growth. We designated it green nursling seedlings (GNS)^{7,8)}.

Plant length was significantly ($p<0.05$) higher for YNS compared with GNS as shown in Table 1. Plant length of nursling seedlings except 7d-YNS was less than 6 cm.

Regardless of light condition, there was similarity ($p<0.05$) in root numbers between 4d-GNS and 4d-YNS, or between 7d-GNS and 7d-YNS (Table 2). All the seedlings had one seminal root and 4 or 5 crown roots which developed at the coleoptilar node. The longest root of GNS was significantly ($p<0.05$) shorter than YNS (data not shown).

At transplanting, the shoot dry weight of YNS were higher than of GNS. On the contrary, the root dry weight of YNS were lower than of GNS (Table 3). Total dry weight (calculated from the shoot dry weight and the

Table 1. Changes in plant length (cm).

Seedlings	Days after transplanting		
	0	5	10
4-day-old nursling seedlings			
4d-GNS	3.4a*	10.3a	14.6a
4d-YNS	4.1b	10.0a	14.4a
7-day-old nursling seedlings			
7d-GNS	5.5a	10.5a	14.1a
7d-YNS	9.6b	14.6b	18.1b

*Within columns and periods of raising, means followed by the same letter are not significantly different at $P<0.05$.

Table 2. Changes in root numbers per plant.

Seedlings	Days after transplanting		
	0	5	10
4-day-old nursling seedlings			
4d-GNS	5.2a*	6.3a	6.9a
4d-YNS	5.3a	5.6a	7.1a
7-day-old nursling seedlings			
7d-GNS	6.0a	7.4a	7.9a
7d-YNS	5.9a	7.3a	8.1a

*Within columns and periods of raising, means followed by the same letter are not significantly different at $P<0.05$.

Table 3. Dry weight of seedlings and increase of dry weight after transplanting.

Seedlings	Dry weight of seedling (mg/plant)		Increase of dry weight (mg/plant)			
			Transplanting to 5 DAT		5 DAT to 10 DAT	
	Shoot	Root	Shoot	Root	Shoot	Root
4-day-old nursling seedlings						
4d-GNS	2.5	1.6	5.2	2.4	3.8	2.3
4d-YNS	2.7	1.4	4.7	2.9	3.0	1.9
7-day-old nursling seedlings						
7d-GNS	4.6	2.8	3.6	2.5	1.8	0.3
7d-YNS	5.9	2.6	2.6	1.8	1.9	0.3

Fig. 1. Relationships between the increase of total dry weight and consumption of endosperm nutrient. (A) from sowing to transplanting, (B) from transplanting to 5 DAT, (C) from 5 DAT to 10 DAT. *, **: 5%, 1% level of significance. ns: 5% level of no significance. ○: 4d-GNS, ●: 4d-YNS, □: 7d-GNS, ■: 7d-YNS.

root dry weight) of 4d-YNS was same as 4d-GNS. However, total dry weight of 7d-YNS was 15% higher than that of 7d-GNS.

The relationships between increase of total dry weight (shoot and root) and consumption of endosperm nutrient of the nursling seedlings is shown in Fig. 1-A. Regardless of treatment, there was significant correlation ($r = 0.984^*$) between the increase of total dry weight and consumption of endosperm nutrient.

2. Growth and development after transplanting

At 10 days after transplanting (10 DAT),

seedlings in all pots showed a survival growth. There was no significant ($p > 0.05$) difference between plant length of 4d-YNS and that of 4d-GNS at 5 DAT and 10 DAT. However, plant length of 7d-YNS was 4.0 cm higher than that of 7d-GNS at 5 DAT and 10 DAT (Table 1).

The root numbers at 5 DAT and 10 DAT were not significantly ($p > 0.05$) different between 4d-YNS and 4d-GNS, or between 7d-YNS and 7d-GNS (Table 2). The longest root length of YNS was not significantly ($p > 0.05$) different from that of GNS at 10 DAT.

From transplanting to 5 DAT, increase of shoot dry weight of GNS was higher than that of YNS (Table 3). There was similar trend in increase of the root dry weight between 7d-GNS and 7d-YNS. Increase of the shoot dry weight and the root dry weight for a 5-day period from transplanting to 5 DAT were higher compared to those of 5 DAT to 10 DAT. Increase of the shoot dry weight of 4d-GNS was higher than that of 4d-YNS from 5 DAT to 10 DAT. These results were similar to the increase of the root dry weight. Increase in the shoot dry weight and the root dry weight of 7d-GNS or 7d-YNS was lower than that of 4d-GNS or 4d-YNS. Especially, the increase of the root dry weight of 7d-GNS or 7d-YNS was smaller than that of 4d-GNS or 4d-YNS. The increase was about 0.3 mg per plant from 5 DAT to 10 DAT.

There was high correlation ($r = 0.994^{**}$) between the increase of total dry weight and consumption of endosperm nutrient from transplanting to 5 DAT (Fig. 1-B). However, no significant ($r = 0.936^{ns}$, $p > 0.05$) relationships was observed from 5 DAT to 10 DAT (Fig. 1-C).

Fig. 2. Changes in the consumption ratio of endosperm nutrient. The consumption ratio of endosperm nutrient was calculated by dividing the residual mass of seed (dry weight basis) by initial seed dry weight. Symbols are the same as those in Fig. 1.

Discussion

The lighting conditions in the raising period affected shoot length, longest root length, shoot and root dry weights, dry weight of endosperm and production of chlorophyll. However, the light conditions did not affect the number of crown roots.

Generally, the length of plants grown in the dark was longer than those grown in the light. Plant length of 4d-YNS was longer than that of 4d-GNS, i.e. 4.1 cm, but it was not fulfilled the required length (about 7 cm long) for mechanical transplanting. As the raising period increased, the plant length of 7d-YNS showed enough length for mechanical transplanting, i.e. 9.6 cm. Wang et al.¹³⁾ reported that the plant length of nursling seedlings raised in the dark and at 32°C was 6.5 cm for 4 days, 9.8 cm for 5 days, respectively. Based on the results obtained in the present experiment and the results by Wang et al., we assumed that the YNS raised at 32°C for 2 days and then at 25°C for 3 days could give enough plant length for mechanical transplanting. Yamamoto et al.^{14,15)} reported that plant length of nursling seedlings raised under low irradiation (500 or 170 lux) was mostly the same as that of nursling seedlings raised in the dark. After transplanting growth of seedlings raised under low irradiation was superior to that of nursling seedlings raised in the dark. It is of interest to further investigate the effect of light conditions on the raising of nursling seedlings.

The root numbers after transplanting were not affected by the light conditions in both raising periods. Nakatani¹⁰⁾ reported that nursling seedlings raised for 3.5 days in the nursery chamber kept at 32°C showed no damage in plant growth after transplanting. In the present study, the root dry weight of 7d-YNS was lower than that of 7d-GNS at 10 DAT. The root numbers of 7d-YNS were not significantly different from that of 7d-GNS at 10 DAT. Therefore, YNS had enough rooting capacity for transplanting.

During the raising period, although photosynthesis did not occur, YNS could continue growth by using the endosperm nutrient. This fact was shown by the significant correlation ($r=0.984^*$) between the increase of total dry weight and consumption of endosperm nutrient in all treatment. This indicates that GNS as well as YNS used the nutrient contained in the endosperm for growth during the raising period.

Furthermore, the same result was observed for correlation ($r=0.994^{**}$) between the increase of total dry weight and consumption of endosperm nutrient during the period from transplanting to 5 DAT. This result indicates that the plant depends for part of its growth on endosperm nutrient during the period of early rooting. From 5 DAT to 10 DAT, the significant correlation between the increase of total dry weight and consumption of endosperm nutrient could not be observed. This might have caused by less residual nutrient in the endosperm at 5 DAT, especially in 7 days old nursling seedlings (Fig. 2). At 10 DAT, there were no residual nutrient in the endosperm that plants could use.

Concerning the relationships between the increase of total dry weight and consumption of endosperm nutrient, it was shown that the slope of the regression line changed as the seedlings developed. Its values changed from 0.62 in the raising period to 1.64 in the period from 5 DAT to 10 DAT (Fig. 1-A and C). This assumed that the dependence of seedlings on the endosperm nutrient became lower as the photosynthesis occurred. We thought that the expanding of the third leaf after transplanting was associated with the dry matter produced by photosynthesis.

The results of this investigation indicated that yellow nursling seedling was slightly infe-

rior to green nursling seedling in growth after transplanting. However it could be said that yellow nursling seedling and green nursling seedling have almost the same capacity to be used as rice seedling.

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