Korean J. Crop Sci. 44(2):122~128(1999)

Effects of Seedling Age on Growth and Yield of Machine Transplanted Rice in Southern Plain Region

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ABSTRACT

Three rice cultivars, Namweonbyeo (early maturing), Hwaseongbyeo (medium maturing) and Dongjinbyeo (medium-late maturing) were transplanted with 3 different seedling ages to investigate their growth habits and to improve the cultural method in paddy fields in the southern plain area of the Honam region in 1993.

The 10-day old seedlings had more vigorous elongation of plant height and higher tillering ability but lower effective tiller rate, when compared with 35-day or 40-day old seedlings. Leaf area index and top dry weight were lower in 10-day old seedlings up to 40 days after transplanting but thereafter, were not different among seedlings ages. CGR was later in 10-day old seedlings, up to 30 days after transplanting, but in 30 to 40 days after transplanting, it was reversed. RGR was the highest in infant seedlings to 40 days after transplanting, while in 50 days after transplanting, it was reversed. Panicle number and spikelet number per square meter were the highest in 40-day old seedlings, next highest in 35-day old seedlings and the lowest and in adult seedlings up to 40 days after transplanting, while spikelet number per panicle was vice versa. Milled rice yield did not vary significantly by seedling ages, but among the varieties, it was less in Hwaseongbyeo compared with Naweonbyeo and Dongjnbyeo.

Keywords : rice, machine transplanting, seedling age, dry matter production, crop growth rate, yield.

In Korea, rice had been transplanted mainly by hand until the 1970s, but after that machine transplanting technique were studied. After 1978, machine transplanters were supplied to farmers to solve the shortage of farm labor shortage as well as reduce the cost of rice production.

Early studies on machine transplanting emphasized transplanting of semi-adult or 20-day old seedlings of Tongil type rices sensitive to low temperature. The 20-day old seedling was in shortage of one leaf, when compared with semi-adult seedlings with 3.5 to 4.5 leaves, resulting from the 10 days shorter seedling nursery period in 20-day old seedlings than in semi-adult seedlings. Heading was delayed 2-3 days in 20 day old transplanted seedlings compared to that of semi-infant seedlings and thus were easily exposed to cold damage during the grain ripening period (Hwang et al., 1905; Oh, 1992; Park, 1992). As a result, the machine transplanting technology of semi-adult seedlings was released to farmers.

Also, in mid-mountainous area and in double cropping of rice, heading of rice was delayed, which resulted in lower ripened grain rate and lower rice yield. To solve these problems, the study on machine transplanting of adult seedlings which had 2 more leaves than semi-adult seedlings was conducted (Kim et al., 1988).

Since 1987 machine transplanting of infant seedlings has been investigated and recommended to farmers. Eight to ten day old infant seedlings in nursery boxes have some merit such as a two-thirds reduction in nursery box numbers required for semi-adult seedling, as well as the efforts and the cost for raising rice seedlings (Imai, 1992; Kim et al., 1986, 1989, 1990). Semi-adult seedlings were raised in nursery boxes for 35 days, the endosperm was exhausted before transplanting, and the root was cut when transplanted. But infant seedlings were raised for only 8 to 10 days, up to 30~40% of the endosperm still remained, the root was not cut, rooting ability was greater, adaptability for bad environment was higher, and early growth was more vigorous, when compared with semi-adult seedlings (Danjo, 1949; Hosikawa, 1976; Kim et al., 1986; Oh et al., 1992; Park, 1992; Yun and Park, 1984).

Therefore, the present study was performed to investigate the different growth habits under machine transplanting of different seedling ages and to establish the technique of machine transplanting of infant seedlings.

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MATERIALS AND MEHODS

A field study was conducted at the National Honam Agricultural Experiment Station (NHAES) on a silty loam soil in 1993, using Namweonbyeo as early maturing cultivar, Hwaseongbyeo as medium maturing one and Dongjinbyeo as medium late maturing one.

Seeding rate consisted of 200 g per nursery box for infant seedlings, 130 g per nursery box for semi-adult seedlings and 100 g per square meter for adult seedlings. Rice seedlings were raised for 10 days for infant seedlings, 35 days for semi-adult seedlings and 40 days for adult seedlings. Infant (10-day old) seedlings and semi-adult (35-day old) seedlings were transplanted by machine, and adult (40-day old) seedlings by hand with 23 hills per square meter with 4 plants per hill on May 31, 1998. Experimental plots were arranged in a split plot design of main plot for rice varieties and sub-plot for seedling types with three replications.

Fertilizer was applied at a rate of 11-7-8kg/10a (N-P_2O_5-K_2O). Forty percent of nitrogen was applied before transplanting, 30% at 14 days after transplanting and 30% at the panicle formation stage. All the phosphorus and 70% of the potassium were applied before transplanting and 30% of potassium was applied at the panicle formation stage.

Leaf area index was measured with AAM-7 automatic leaf area meter (AAM-7, Hayashi Denko) for 5 hills per plot at each growth stage, for the leaf dry matter determination, and the leaves were dried at 100℃ for 30 minutes and thereafter, at 80℃ for 2 days, and were weighed.

RESULTS AND DISCUSSION

Seedling characteristics

Table 1. shows the varietal differences in seedling characteristic at the different seedling ages. Plant height was longer in the order of 40-day old seedling, 35-day old seedling and 10-day old seedling regardless of varieties. The plant height ranged from 9.8 to 12.7 cm, which was long enough to be suitable for machine transplanting (8 cm).

The 10-day old seedlings had 2.0 leaves, which was less than that of semi-adult seedlings and adult seedlings, 4.5 and 4.8 respectively, as reported by Imai (1992), Imai et al. (1986), Kim (1996), Oh (1992) and Park (1992). Although top or root dry weight was heavier in the order of adult, 35-day old and 10-day old seedlings, 10-day old seedling formed enough suitable root mat to be transplanted by a machine. Top/root ratio was higher in the order of 10-day old, 35-day old and 45-day old seedlings.

Plant height and tiller number

Changes in plant height of transplanted seedlings are shown in Table 2. Even if plant height of 10-day old seedling was 12 to 16 cm or 15 to 20 cm shorter than that of 35-day old or 40-day old seedling at transplanting, plant height of 10-day old seedling was only 5 cm or 6 to 7 cm shorter than that of 35-day old or 40-day old seedling at maximum tiller stage. As transplanted seedlings grew to later growth stage, the variation in plant height by different seedling ages decreased.

This phenomenon implies that 35-day and 40-day old seedlings completely exhausted the endosperm

Table 1. Seedling characteristic at the transplanting date under different seedling age.

Variety	Seedling age	Plant height (cm)	No. of leaves	Top dry weight (mg/plant)	Root dry weight (mg/plant)	T/R ratio (%)
Namweonbyeo	10-day old	9.8	2.0	8.0	1.9	421
	35-day old	26.1	3.9	24.0	6.0	400
	40-day old	30.5	6.5	94.0	28.6	329
Hwaseongbyeo	10-day old	12.2	2.0	8.5	2.0	425
	35-day old	23.7	3.7	26.0	6.6	394
	40-day old	29.5	6.8	86.0	26.6	323
Dongjinbyeo	10-day old	12.7	2.0	8.0	2.0	400
	35-day old	23.3	3.9	26.0	6.6	394
	40-day old	27.1	6.8	96.0	32.0	300
LSD (5%)	Variety (A)	0.8	0.2	0.6	0.6	24
	Seedling (B)	0.9	0.1	0.7	0.5	14
	A×B	1.6	0.2	1.1	0.9	23

Table 2. Changes in plant height at the different seedling age.

Variety	Seedling age	Plant height (cm)					
		10DAT	20DAT	30DAT	40DAT	50DAT	HD*
Namweonbyeo	10-day old	18.8	34.5	43.2	60.5	73.4	73.5
	35-day old	27.7	41.0	48.5	65.2	74.9	73.4
	40-day old	31.1	47.1	55.6	66.7	77.2	73.0
Hwaseongbyeo	10-day old	16.8	30.1	36.5	47.6	64.5	72.3
	35-day old	24.6	35.2	40.6	52.7	65.0	72.6
	40-day old	27.1	37.7	42.1	54.0	65.5	72.7
Dongjinbyeo	10-day old	14.9	27.0	33.7	46.0	68.3	73.9
	35-day old	21.7	32.3	37.3	51.0	68.5	73.5
	40-day old	25.0	36.2	40.2	54.1	70.8	74.4
LSD (5%)	Variety (A)	0.8	3.3	3.4	4.1	4.8	4.5
	Seedling (B)	1.0	2.4	2.9	2.8	3.8	3.2
	A×B	1.8	4.2	5.0	4.8	4.1	4.9

* DAT : days after transplanting, HD : heading date
Figures at HD indicate the culm length

before transplanting, root was severely cut in transplanting and rooting was delayed, while 10-day old seedling avoids the mentioned defects, seedling is not damaged in transplanting, and rooting is accelerated (Imai, 1992; Kim et al., 1996; Lee at al., 1988 and Oh et al., 1992).

On the other hand, culm length did not vary among different ages.

Table 3. shows changes in tiller number per square meter and effective tiller rate as affected by seedling age. There was no varietal difference in tiller number at any growth stage. But the number of tillers was in order of 10-day old, 35-day old and 40-day old seedling. This result implies that 10-day old seedling has higher tillering ability and the lower tillering internode than 35-day old or 40-day old.

Maximum tillering stage was about 40 days after transplanting and was not different among seedling ages. Effective tiller rate was higher in the order for adult, semi-adult to infant seedling, and tiller number showed the opposite tendency.

Therefore to increase the effective tiller rate of transplanted 10-day old seedlings, the intermittent drainage should be needed earlier than 40-day or 35-day old seedling by reduction in non-effective tillers. Otherwise, application of fertilizer should be done in a different manure from 35-day or 40-day old seedling.

Leaf area and top dry weight

Changes in leaf area index (LAI) as affected by seedling age is shown in Table 4. LAI was higher in the order of adult, semi-adult and infant seedlings

Table 3. Changes in the number of tillers per m^2 and effective tiller rate as affected by seedling age.

Variety	Seedling age	Number of tiller per m^2						Effective tiller rate
		10DAT	20DAT	30DAT	40DAT	50DAT	HD	
Namweonbyeo	10-day old	115	345	509	553	452	371	67.0
	35-day old	99	300	415	449	380	359	80.0
	40-day old	97	245	387	403	364	332	82.4
Hwaseongbyeo	10-day old	113	362	493	509	447	368	72.3
	35-day old	106	300	449	463	403	357	77.1
	40-day old	92	288	417	426	382	345	81.0
Dongjinbyeo	10-day old	111	359	518	546	431	362	66.3
	35-day old	104	334	484	477	408	355	74.4
	40-day old	97	309	472	486	406	348	71.6
LSD (5%)	Variety (A)	NS	10	14	14	11	18	5.8
	Seedling (B)	NS	6	6	5	4	7	1.5
	A×B	NS	9	11	7	6	13	2.7

Table 4. Changes in leaf area index as affected by seedling age.

Variety	Seedling age	20DAT	30DAT	40DAT	50DAT	HD
Namweonbyeo	10-day old	0.4	1.6	3.5	4.1	5.9
	35-day old	0.5	1.7	3.6	4.1	5.7
	40-day old	0.7	2.0	3.8	4.2	5.6
Hwaseongbyeo	10-day old	0.5	1.7	3.5	4.2	6.0
	35-day old	0.6	1.9	3.7	4.1	5.8
	40-day old	0.8	2.0	3.8	4.3	5.7
Dongjinbyeo	10-day old	0.3	1.5	3.2	3.5	6.3
	35-day old	0.4	1.7	3.3	3.4	6.2
	40-day old	0.6	1.8	3.5	3.6	6.2
LSD (5%)	Variety (A)	0.1	0.2	0.2	NS	NS
	Seedling (B)	0.1	0.1	0.1	NS	NS
	A×B	0.2	0.2	NS	NS	NS

* DAT : days after transplanting, HD : heading stage.

from 20 days to 40 days after transplanting, owing to the shorter plant height in the order of infant, semi-adult and adult seedlings. But thereafter, in 50 days after transplanting or at heading stage, there was no difference among seedling ages.

Among varieties, up to 50 days after transplanting LAI was higher in Namweonbyeo or Hwaseongbyeo than in Dongjinbyeo, but at heading stage it was reversed.

Table 5 shows changes in top dry weight as affected by seedling age.

Top dry weight was heavier in the order of 40-day, 35-day and 10-day old seedlings during the early growth stage, but it was not affected by different seedling ages at heading stage. This may be due to the shorter plant height of infant seedlings even if they have the higher tiller number. Top dry weight was heavier in Namweonbyeo or Hwaseongbyeo than in Dongjinbyeo during early growth stage but at heading stage it was reversed.

Crop growth rates, relative growth rates and leaf number

Table 6 shows changes in crop growth rates (CGR) under transplanting of different seedling ages. CGR was the highest in adult seedlings, second highest in 35-day old seedlings and the lowest in infant seedlings up to 30 days after transplanting, resulting from the narrower leaf area as photosynthetic organ in 10-day old seedlings. But in 30 to 40 days after transplanting it was reversed. It was implied that earlier canopy formation in 35-day or 40-day old seedlings than in infant seedlings prevented sunlight from being transmitted to the lower part of the rice plant and reduced leaf photosynthetic activity.

On the other hand, from 50 days after transplanting to heading stage, CGR showed the same tendency of that during the early growth stage, implying that 35-day and 40-day old seedlings reached the reproductive growth stage earlier than infant seedlisngs.

Relative growth rate (RGR) was higher in the or-

Table 5. Changes in top dry weight as affected by seeing age.

Variety	Seedling age	Top dry weight (g/m^2)				
		20DAT	30DAT	40DAT	50DAT	H.D
Namweonbyeo	10-day old	30.3	108.5	233.6	385.0	569.1
	35-day old	35.4	122.3	245.5	390.8	561.3
	40-day old	55.2	153.1	251.6	398.4	565.1
Hwaseongbyeo	10-day old	31.7	102.1	209.7	362.0	753.6
	35-day old	43.7	122.3	231.4	364.1	742.8
	40-day old	58.4	137.9	244.6	389.9	740.0
Dongjinbyeo	10-day old	27.1	92.0	199.4	325.5	785.1
	35-day old	31.7	110.4	205.5	336.6	773.4
	40-day old	42.8	124.5	208.7	345.3	771.5
LSD (5%)	Variety (A)	1.8	8.4	12.3	NS	NS
	Seedling (B)	1.3	4.7	6.0	NS	NS
	A×B	2.5	11.5	NS	NS	NS

Table 6. Changes in crop growth rate(CGR) as affected by seedling age.

Variety	Seedling age	CGR ($g/m^2/day$)				
		TD ~ 20 DAT	20 DAT~ 30 DAT	30 DAT~ 40 DAT	40 DAT~ 50 DAT	50 DAT~ HD
Namweonbyeo	10-day old	1.48	7.82	12.51	15.14	10.83
	35-day old	1.66	8.69	12.32	14.53	14.21
	40-day old	2.33	9.79	9.85	14.68	16.67
Hwaseongbyeo	10-day old	1.55	7.04	10.76	12.23	13.60
	35-day old	2.07	7.86	10.91	13.27	16.47
	40-day old	2.53	7.95	10.67	14.53	17.51
Dongjinbyeo	10-day old	1.32	6.49	10.74	12.61	12.42
	35-day old	1.47	7.87	9.51	13.11	13.65
	40-day old	1.70	8.17	8.42	13.66	14.70
LSD (5%)	Variety (A)	0.10	0.31	0.71	0.37	0.43
	Seedling (B)	0.06	0.19	0.34	0.44	0.45
	A×B	0.11	0.35	0.67	0.76	0.77

* TD : transplanting date

Table 7. Changes of relative growth rate(RGR) as affected by seedling age.

Variety	Seedling age	RGR				
		T.D~ 20 DAT	20 DAT~ 30 DAT	30 DAT~ 40 DAT	40 DAT~ 50 DAT	50 DAT~ HD
Namweonbyeo	10-day old	0.079	0.057	0.033	0.022	0.010
	35-day old	0.060	0.055	0.030	0.020	0.013
	40-day old	0.040	0.044	0.022	0.020	0.015
Hwaseongbyeo	10-day old	0.080	0.051	0.031	0.024	0.010
	35-day old	0.063	0.045	0.028	0.020	0.013
	40-day old	0.044	0.037	0.025	0.020	0.014
Dongjinbyeo	10-day old	0.080	0.053	0.034	0.021	0.010
	35-day old	0.056	0.053	0.027	0.021	0.011
	40-day old	0.035	0.046	0.022	0.022	0.012

* $RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$, W_1 = D.W at t_1, W_2 = D.W. at t_2

der of 10-day, 35-day and 40-day old seedlings up to 40 days after transplanting, reasoning that 10-day old seedlings had earlier rooting, higher tillering ability, later canopy formation and finally, higher photosynthetic activity (Kim and Lee, 1988; Oh et al., 1992; Park, 1992). But from 50 days after transplanting to heading stage RGR was reversed (Table 7).

Heading date, yield components, and yield

The number of total leaves at main culm (Table 8)

Table 8. Changes of number in total leaves on main culm, and heading date as affected by seedling age.

Variety	No. of total leaves			Heading date		
	10-day old	35-day old	40-day old	10-day old	35-day old	40-day old
Namweonbyeo	12.0	13.0	14.0	7 Aug.	2 Aug.	30 July
Hwaseongbyeo	14.4	15.6	16.0	18 Aug.	12 Aug.	9 Aug.
Dongjinbyeo	15.5	16.0	17.0	26 Aug.	21 Aug.	18 Aug.

Table 9. Changes of yield and yield components as affected by seedling age.

Variety	Seedling age	No. of panicles per m^2	No. of spikelets per panicle	No. of spikelets per m^2 (×1,000)	Percent ripened grains	1,000 grain weight (g)	Milled rice yield (kg/10a)	Yield index
Namweonbyeo	10-day old	371	76.3	28.3	90	24.2	535	99
	35-day old	359	76.5	27.5	91	24.2	520	96
	40-day old	332	79.7	26.5	91	24.3	525	97
Hwaseongbyeo	10-day old	368	80.6	29.7	95	21.9	482	89
	35-day old	357	82.1	29.3	94	22.0	488	91
	40-day old	345	83.7	28.9	93	22.1	494	92
Dongjinbyeo	10-day old	362	70.7	25.6	96	24.4	535	99
	35-day old	355	71.7	25.5	97	24.4	521	97
	40-day old	348	73.0	25.4	97	24.5	539	100
LSD(5%)	Variety (A)	13	0.9	1.2	1	0.1	21	-
	Seedling (B)	9	0.5	0.8	1	0.1	19	-
	A×B	11	0.8	1.5	2	0.1	33	-

in Namweonbyeo, an early maturing cultivar was one or two leaves fewer in 10-day old seedlings than in 35-day or 40-day old seedlings. Those in Hwaseonbyeo, a medium maturing cultivar, and Dongjinbyeo, a medium late maturing cultivar, were 0.5 to 1.5 leaves fewer in 10-day old seedling when compared with two older seedling ages. Namweonbyeo had one or two to three fewer leaves than Hwaseongbyeo or Dongjinbyeo.

Heading date (Table 8) was delayed 5 to 6 or 8 to 9 days in infant seedling compared to semi-adult or adult seedlings, as was consistent in Kim et al.'s (1990) and Park's (1992) previous reports.

Changes of yield and yield components as affected by seedling age is shown in Table 9.

The number of panicles was more in the order of 10-day, 35-day and 40-day old seedlings regardless of variety. The number of spikelets per panicle was more in order of 40-day, 35-day and 10-day old seedlings but the number of spikelets per square meter was reversed owing to more panicles per square meter in infant seedling.

Percent ripened grains was not significantly different among seedling ages. Among varieties, Dongjinbyeo had higher percent ripened grains than Hwaseongbyeo or Namweonbyeo. It was reasond that the heading date of Namweonbyeo was approximately the early part of August when meteorological productivity was low in the Iksan region but that of Dongjinbyeo was around the latter part of August when meterologica productivity was high (Kim et al., 1990).

Milled rice yield did not apparently varied among seedling ages. Hwaseongbyeo yielded the lowest and Dongjinbyeo and Namweonbyeo was similar.

Ten-day old seedlings were lower in growth at the transplanting date but more vigorous at early growth stage, when compared with 35 or 40-day old seedlings, and there was no difference in rice yield among seedling ages. Therefore, 10-day old seedlings would be desirable for machine transplanting of rice, because there are some merits of the reduction of seedling raising effort and materials required to raise rice seedlings, compared with the two older seedlings. However the decision of optimum seedling ages should be preceded by culturing location and time, because younger seedling delayed heading and reduced the ripened grain rate in late seasonal culture or in alpine area culture.

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