

## Seedling Conditions for Kimchi Cabbage, Head Lettuce, Cabbage and Broccoli for a Riding-type Transplanter

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### Abstract

**Purpose:** We have studied the necessary qualities of seedlings of some leafy vegetables for a riding-type two-row automatic transplanter. When seedlings are planted using a transplanter, long roots may be rounded in the bottom of the tray, and this can interfere with the separation of the seedlings. Uprightness related to leaf spread angle is an important quality for seedlings in mechanical planting. **Methods:** To select cultivars suitable for the transplanter, we compared varieties of Kimchi cabbage (*Chukwang*, *Daetong*, *Whipalam* and *Namdo*), head lettuce (*Abi* and *Sensation*), cabbage (*YR Onnuri*, *YR Hogel*, *Harutama*, and *Ogane*), and broccoli (*Nicegreen* and *Earlyyou*). To compare the effect of bed soil on root formation and growth, we used five types of soil: *Chologi*, *Burger*, *Wonjomix*, *Bio*, and *Baroker* with 2.6-3 L per tray. Growth increment and the degree of root formation were measured according to the RDA guidelines 25 days after sowing for Kimchi cabbage and head lettuce and 44 days after sowing for cabbage and broccoli. **Conclusions:** According to the plug tray, the optimum seedling age in both 128- and 200-hole trays was 28 days for Kimchi cabbage and 44 days for cabbage and broccoli. Head lettuce took 35 days in 128-hole trays and 31 days in 200-hole trays. *Burger* soil was most effective for root formation and growth of the four kinds of leafy vegetables; it appeared that smaller soil volume led to faster root formation.

**Keywords:** Bed soil, Leafy vegetables, Riding-type two-row automatic transplanter, Root formation, Seedling

### Introduction

As the demand for leafy vegetables has increased due to the increasing popularity of Ssam vegetables and salad dishes, domestic production areas have been increasing all year round. The mechanization of cultivating domestic horticultural crops is still insufficient, however, due to differences in growth and harvesting times for each crop. Only some farmers use a transplanter at the time of onion and garlic planting (Byeong et al., 2013). Mechanization should first be promoted in agricultural work such as

sowing, transplanting, harvesting, and selective packaging that requires a large amount of labor and a high concentration of labor (Yun, 1997). In case of Japan, it took 21.2 hours per 10a to transplant lettuce by hand, while the transplanter required only 21-26% of that time (4.5 to 5.5 hours). The transplanter can therefore significantly save labor (Bazo, 1994). In the case of Kimchi cabbage, transplanting with a KTP-3 transplanter took 11.6-13.4 hours per 10a, and it was thus about 50% more effective than manpower, which required 24.7 hours per 10 a transplanted (Joo et al., 1998). Agriculture in industrial societies has gradually undergone a division of labor, along with specialization and mechanization, and the aging of the agricultural workforce in Korea is increasing

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the need for mechanization. Since it was introduced in Korea in the 1990s, plug seedlings have been increasingly used because it is easy to produce uniform seedlings and reduce the effort of nursery stage, as well as being able to division crop production (Ito, 1992). One downside is that overgrowth of the tap root due to a poor environment or aging can cause root deformation, with the root circling in the bottom of the plug tray, which may interfere with separation of the seedlings from the tray. The most important factors for mechanical transplanting of seedlings are that the seedlings should be easily separated from the trays and at the same time the roots should be evenly distributed in the rhizosphere soil so that the soil is not broken during transplantation (Kang et al., 2012). Circling roots formed on the plug cell bottom can easily receive low- and high- temperature stress and inhibit healthy root formation (Arnold and Young, 1991). To prevent seedlings from being damaged when lifted by the picking-out and planting device of the machine, uprightness related to leaf spread angle may be necessary of seedling for the mechanical planting. In general, the larger the cell size and the longer the seedling growing period, the greater the fresh weight and leaf length and the worse the circling root problem (Yeoung et al., 2004). Late transplanting also makes mechanical planting difficult due to overgrowth of leaves (Kang et al., 2012). These reasons results in a decrease in the rate of planting. There is consequently a need for a vegetable-specific study on seedling qualities for compatibility with the transplanter. In the case of spinach, it was recommended to cultivate seedlings for 20 days in 288-hole plug trays because 30 days after sowing in 200- and 288-hole plug trays there is not much difference in the growth of the seedlings (Yeoung et al., 2004). In a study of grafted watermelon seedlings, seedlings grown in 78.4 cm<sup>3</sup> and 82.9 cm<sup>3</sup> plug cells needed to be planted after 20 to 25 days of seedling growth, whereas seedlings grown in 131.6 cm<sup>3</sup> cells could be maintained for 30 days (Yaping and Chen, 2005). There are few reports in Korea on plug tray seedlings suitable for a transplanter. This study was conducted to select suitable cultivars of some leafy vegetables for use with a transplanter when regarding root formation and the uprightness of plug seedlings.

## Materials and Methods

To investigate the optimal seedling qualities for a

riding-type two-row automatic pick-up transplanter under development by Tongyang Moolsan Co. Ltd., four leafy vegetables—Kimchi cabbage, head lettuce, cabbage, and broccoli—were cultivated using 128- and 200-hole plug trays specified for a two-row automatic pick-up transplanter. To select the most suitable varieties for use with transplanter among the cultivars cultivated in large-scale production areas of Yeongnam, Haenam, Asan, Jangseong, Jeongeup, Taean, Ohwol and Gwangyang, several varieties of Kimchi cabbage (*Chukwang*, *Daetong*, *Whipalam* and *Namdo*), head lettuce (*Abi* and *Sensation*), cabbage (*YR Onnuri*, *YR Hogel*, *Harutama*, and *Ogane*), and broccoli (*Nicegreen* and *Earlyyou*) were compared. In order to investigate the effect of the plug tray size and the type of soil on the formation of roots compatible with a transplanter, Kimchi cabbage and head lettuce with 3~4 leaves were measured at 25 days after sowing, and cabbage and broccoli with 4~5 leaves were measured at 47 days after sowing. To compare the effect of bed soil on root formation and growth, five soils—*Chologi*, *Burger*, *Wonjomix*, *Bio*, and *Baroker* were used with 2.6-3 L per tray. Growth increment and the degree of root formation were measured according to RDA guidelines, and a statistical analysis was performed using a two-factor test in SAS 9.1.2.

## Results and Discussion

### Identification of suitable cultivars and seedling days for leafy vegetables with a transplanter

For Kimchi cabbage, all varieties (*Chukwang*, *Daetong*, *Whipalam*, and *Namdo*) had a similar degree of root formation. The *Namdo* cultivar was selected for its relatively low root length and T/R ratio. For head lettuce, the root formation, root length, and T/R ratio of *Abi* were lower than those of *Sensation*. The degree of root formation of the four varieties of cabbage was the same, but the *Organe* cultivar was selected for having the smallest root length, leaf sheath, and T/R ratio. *Nicegreen* was selected for broccoli because it had a lower T/R ratio than *Earlyyou*.

When Kimchi cabbage was transplanted in a 128-plug tray, the plant height, leaf width and T/R ratio differed significantly between cultivars, but seedling age did not. The roots had formed enough to hold the bed soil 28 days after sowing (Table 1). With the 200-hole tray, plant

**Table 1.** Cultivars and seedling ages of Kimchi cabbage for a transplanter

Leafy vegetable	Cell size	Cultivar (A)	Seedling age (days) (B)	Plant height (cm)	Leaf width (cm)	T/R ratio	
Kimchi cabbage	128	Chukwang	28	8.6	3.7	5.7	
			31	7.7	3.2	6.0	
			35	8.0	3.7	6.0	
			38	7.6	3.2	6.5	
		Daetong	28	8.4	3.4	6.6	
			31	8.2	3.2	5.5	
			35	8.1	3.3	6.1	
			38	7.6	3.0	5.9	
		Whipalam	28	6.9	3.3	5.9	
			31	6.6	3.2	5.3	
			35	6.5	3.2	5.4	
			38	6.8	3.0	5.7	
		Namdo	28	6.6	2.8	4.7	
			31	6.8	2.9	4.9	
			35	6.8	3.2	4.8	
			38	6.2	2.7	5.5	
			A		***	***	***
			B		NS	NS	NS
			A*B		**	***	NS
		200	Chukwang	28	6.7	2.9	5.8
31				7.2	3.2	6.9	
35				6.7	3.1	5.7	
38				6.6	3.1	6.3	
Daetong			28	7.4	3.1	6.2	
			31	7.2	2.7	6.9	
			35	6.9	2.7	6.0	
			38	6.7	2.8	6.0	
Whipalam			28	5.5	2.7	5.9	
			31	6.2	2.9	6.0	
			35	6.2	2.9	5.8	
			38	6.0	2.9	5.6	
Namdo			28	5.4	2.3	4.2	
			31	6.0	2.8	5.6	
			35	5.6	2.4	4.9	
			38	5.7	2.6	5.1	
		A		***	***	-	
		B		***	NS	-	
		A*B		***	***	-	

NS Not significant, \*Significant at  $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

height differed significantly between cultivars and ages, while plant width differed significantly between cultivars but not significantly between ages. We therefore suggest that Kimchi cabbage seedlings should have a plant height

of 6.6-8.6 cm in 128-hole trays and 5.4-6.7 cm in 200-hole trays for compatibility with a transplanter.

For head lettuce, there was not a significant difference in plant height, leaf width or T/R ratios between cultivars

**Table 2.** Cultivars and seedling ages of head lettuce for a transplanter

Leaf vegetable	Cell size	Cultivar (A)	Seedling age (days) (B)	Plant height (cm)	Leaf width (cm)	T/R ratio
Head lettuce	128	Abi	28	7.3	2.2	13.2
			31	7.6	2.4	5.5
			35	7.5	2.5	4.0
			38	7.4	2.9	2.9
		Sensation	28	-	-	-
			31	-	-	-
			35	-	-	-
			38	-	-	-
	200	Abi	28	8.2	2.8	6.5
			31	8.1	2.6	4.7
			35	8.4	2.7	4.1
			38	7.7	2.7	5.7
Sensation	28	7.8	2.5	5.1		
	31	7.7	2.5	3.8		
	35	8.2	3.0	4.5		
	38	6.7	2.9	4.7		
				7.7	2.6	5.4
		A		NS	NS	***
		B		***	NS	***
		A*B		***	NS	***

<sup>NS</sup> Not significant, \*Significant at  $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

in a 128-hole tray (Table 2). In the 200-hole tray, plant height did not differ significantly between cultivars, but did between seedling ages. Leaf width did not differ between cultivars and seedling ages. The root formation of head lettuce was completed 35 days after sowing in the 128-hole tray and 31 days after sowing in the 200-hole tray. We suggest that head lettuce seedlings should have a plant height of 7.3 cm in 128-hole trays and 7.8-8.2 cm in 200-hole trays for compatibility with a transplanter.

For cabbage, there was a significant difference among the plant height and leaf width between cultivars and seedling ages in the 128-hole tray (Table 3). In the 200-hole tray, the plant height differed significantly between cultivars and seedling ages. Leaf width differed significantly between cultivars but not between seedling ages. Root formation of cabbage was completed 44 days after sowing in both the 128- and 200-hole trays (Table 3). The *Ogane* variety was found to be suitable for the mechanical planting as it had the lowest T/R ratio. We

therefore suggest that cabbage seedlings should have a plant height of 6.6-8.6 cm in 128-hole trays and 5.4-6.7 cm in 200-hole trays for compatibility with a transplanter

In broccoli, there was not a significant difference in plant height and leaf width between cultivars and seedling ages in the 128-hole and 200-hole trays. The broccoli roots formed at 44 days in both trays. Because root length and the T/R ratio were similar, depending on the cell size, a 200-hole tray would be more economical (Table 4). We thus suggest that broccoli seedlings should have a plant height of 8.2 cm in 128-hole trays and 6.4-6.6 cm in 200-hole trays for compatibility with a transplanter

### Identification of suitable bed soil for plant growth

To investigate the effect of bed soil on root formation and growth, *Chologi*, *Burger*, *Wonjomix*, *Bio*, and *Baloker* soils were compared. *Burger* soil was found to be more effective for the growth of the four kinds of leafy vegetables

**Table 3.** Cultivars and seedling ages of cabbage for a transplanter

Leaf vegetable	Cell size	Cultivar (A)	Seedling age (days) (B)	Plant Height (cm)	Leaf width (cm)	T/R ratio	
Cabbage	128	YR Onnuri	44	8.6	3.7	5.7	
			47	7.7	3.2	6.0	
			50	8.0	3.7	6.0	
			54	7.6	3.2	6.5	
		YR Hogel	44	8.4	3.4	6.6	
			47	8.2	3.2	5.5	
			50	8.1	3.3	6.1	
			54	7.6	3.0	5.9	
		Harutama	44	6.9	3.3	5.9	
			47	6.6	3.2	5.3	
			50	6.5	3.2	5.4	
			54	6.8	3.0	5.7	
	Ogane	44	6.6	2.8	4.7		
		47	6.8	2.9	4.9		
		50	6.8	3.2	4.8		
		54	6.2	2.7	5.5		
			A		***	***	-
			B		***	***	-
			A*B		NS	NS	-
		200	YR Onnuri	28	6.7	2.9	5.8
31				7.2	3.2	6.9	
35				6.7	3.1	5.7	
38				6.6	3.1	6.3	
YR Hogel			28	7.4	3.1	6.2	
			31	7.2	2.7	6.9	
			35	6.9	2.7	6.0	
			38	6.7	2.8	6.0	
Harutama			28	5.5	2.7	5.9	
			31	6.2	2.9	6.0	
			35	6.2	2.9	5.8	
			38	6.0	2.9	5.6	
Ogane		28	5.4	2.3	4.2		
		31	6.0	2.8	5.6		
		35	5.6	2.4	4.9		
		38	5.7	2.6	5.1		
		A		***	***	-	
		B		***	NS	-	
		A*B		***	NS	-	

<sup>NS</sup> Not significant, \*Significant at  $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

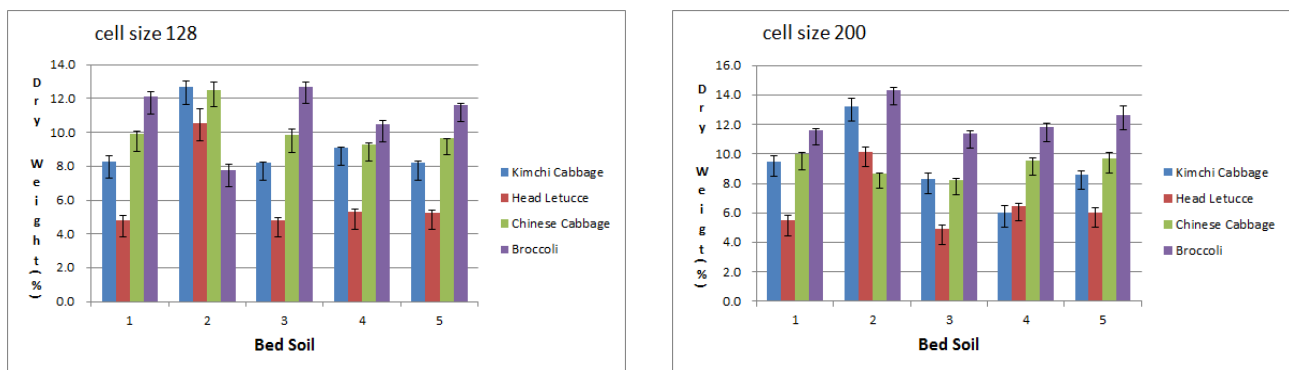
(Figure 1). In the *Burger* soil without fertilizer components, root growth was promoted and growth of the top was suppressed, resulting in a low T/R ratio for all four vegetables.

We suggest optimal seedling properties of leafy vegetables for the riding-type two-row automatic pick-up transplanter in Table 5. The period of seedling cultivation was between 25 and 35 days for Kimchi cabbage and head lettuce and

**Table 4.** Cultivars and seedling ages of broccoli for a transplanter

Leaf vegetable	Cell size	Cultivar (A)	Seedling age (days) (B)	Plant Height (cm)	Leaf width (cm)	T/R ratio		
Broccoli	128	Nicegreen	44	8.2	3.8	3.2		
			47	8.5	3.7	3.2		
			50	8.4	3.7	3.8		
			54	8.1	3.5	3.9		
		Earlyyou	44	8.2	3.9	4.8		
			47	8.1	3.4	4.1		
			50	8.4	3.6	4.2		
			54	8.3	3.8	4.4		
				A		NS	NS	-
				B		NS	NS	-
				A*B		NS	NS	-
			200	Nicegreen	44	6.6	2.9	3.0
					47	6.6	3.1	3.6
					50	6.1	2.9	3.5
54	6.8				3.1	3.8		
Earlyyou	44			6.4	2.9	4.3		
	47			6.8	3.0	4.9		
	50			6.8	3.0	4.6		
	54			6.7	2.9	4.7		
				A		NS	NS	-
				B		NS	NS	-
				A*B		***	NS	***

<sup>NS</sup> Not significant, \*Significant at  $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .



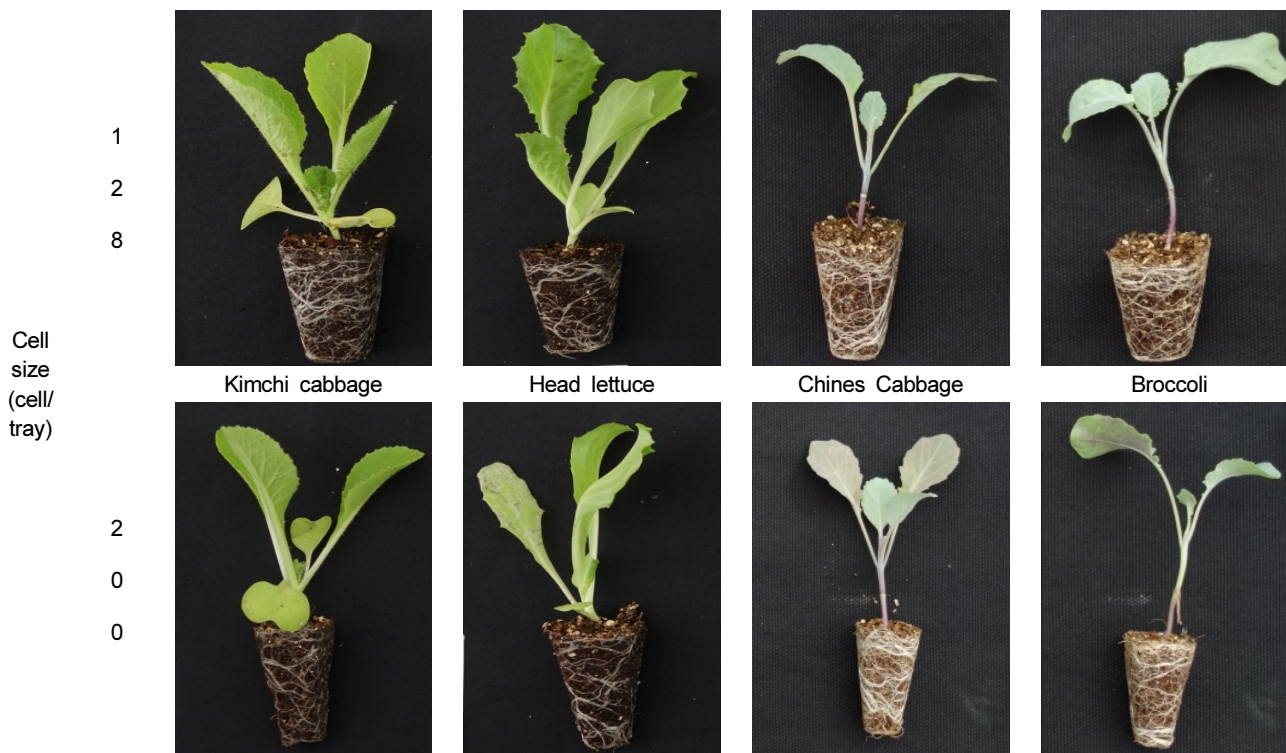
**Figure 1.** Effect of bed soils on dry weight of 4 leafy vegetables grown in plug trays: 1. *Chologi*, 2. *Burger*, 3. *Wonjomix*, 4. *Bio*, 5. *Baloker*. Bars indicate standard errors of means (n=9).

between 40 and 50 days for cabbage and broccoli. The root formation and growth of the four leafy vegetables were similar in the 128- and 200-hole trays. We therefore recommend 200-hole trays in terms of economy, based on the amount of soil and the number of seedlings available (Figure 2). However, it has been shown that the

smaller the volume of soil, the faster the root formation (Lindstrom and Rune, 1999). When the root tip touches the inner surface of the tray, horizontal root growth stops and only vertical growth occurs, at which point a circling root can form quickly. Seedlings should thus be grown for an accurate number of days. The T/R ratio and root

**Table 5.** Plug seedling conditions of leafy vegetables for a transplanter

Leafy vegetable	Cell size (cells/ tray)	Seedling age (days)	No. of leaves	Height (cm)	Vol. of bed soil (L/tray)
Kimchi Cabbage	128, 200	25~35	3~4	6.9~7.4	2.6~3
Head lettuce	"	25~35	3~4	8.1~8.4	"
Cabbage	"	40~50	4~5	6.8~7.8	"
Broccoli	"	40~50	3~4	8.2~8.3	"



**Figure 2.** Proper root formation of leafy vegetables for mechanical planting.

formation were found to be factors in determining the optimal seedling age (Yeoung et al., 2004). In this experiment, we compared the optimal seedling quality based on the T/R ratio of the four leafy vegetables. A low T/R ratio indicates that the seedling has grown properly and a high root density (g/100 ml) indicates that the roots are sufficiently developed to be highly adaptable to mechanical plantation (Shin et al., 2000). The correlation between T/R ratio and cell size in watermelon grafted seedlings was not significantly for 20-day seedlings, but was significantly higher for 25-day seedlings (Yaping and Chen, 2005). The 20-day period is assumed to be a short period of growth for optimal leaf number and leaf area.

## Conclusions

Based on total dry weight, root length and T/R ratios,

the most suitable varieties for mechanical planting were *Namdo* for Kimchi cabbage, *Abi* for head lettuce, *Ogane* for cabbage and *Nicegreen* for broccoli. For the proper seedling conditions of leafy vegetables for the riding-type two-row automatic pick-up transplanter, we suggest that plug trays with either 128 or 200 holes can be used for Kimchi cabbage, head lettuce, cabbage and broccoli. Any bed soil can be used for leafy vegetables seedling and the proper volume of the bed soil is 2.6~3 L per tray. Recommended seedling ages are 25-30 days for Kimchi cabbage and head lettuce and 40-50 days for cabbage and broccoli. Recommended leaf number is 3-4 leaves for Kimchi cabbage, head lettuce and broccoli and 4-5 leaves for cabbage. The plant height is also important when using a transplanter and is suggested to be 6.9~7.4 cm for Kimchi cabbage, 8.1~8.4 cm for head lettuce, 6.8~7.8 cm for cabbage, and 8.2~8.3 cm for broccoli.



## Conflict of Interest

The authors have no conflicting financial or other interests.

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