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Studies on Production and Utilization of Potato Plug Seedlings Using Small Tubers

by

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DEPARTMENT OF AGRICULTURE

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Studies on Production and Utilization of Potato Plug Seedlings Using Small Tubers

Young-Lim Jwa

(Superivised by professor Young-Kil Kang)

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF AGRICULTURE

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ABSTRACTS

This study was conducted in 2000 to develop vermiculite-based root media suitable for potato (*Solanum tuberosum* L.) plug seedlings and to evaluate the effect of seed tuber size on the growth and field performance of potato plug seedlings.

1. Root media formulation effects on the growth and field performance of plug seedlings

Eight vermiculite-based root media prepared with addition of complete fertilizer (2 g/L; N-P_2O_5-K_2O, 10-10-14) for potatoes and a commercial root medium were evaluated. The eight media consisted of various ratios of vermiculite, perlite, peatmoss, and compost. Compost addition to the media increased plant height, the number of leaves per plant, and top and root fresh weight of 15-day old plug seedlings. The seedlings raised in root media containing compost produced significantly higher total tuber yield. The data indicate that root media containing 50% vermiculite, 0 to 20% peat moss, 10% perlite, 20 to 40% compost appear suitable for potato plug seedling production.

2. Effects of addition rate of complex fertilizer to media on the growth and field performance of plug seedlings

Four rates (0, 1, 2, or 4 g/L) of the complex fertilizer for potato were added to a root medium (70% vermiculite, 10% perlite, 10% peat moss, and 10% compost by volume) to determine the optimum addition rate of the complex fertilizer for plug seedlings. Seedling height increased from 12.9 to 16.4 ㎝, and top and root fresh weight of seedlings increased 3.11

to 4.21 g and 2.91 to 3.45 g, respectively, with increasing the addition of complex fertilizer to root media from 0 to 4 g/L. Addition of the complex fertilizer to root media increased the number of tubers per plant and tuber yields but there was no significant difference between fertilized root media . The results suggest that addition of about 2 g/L of the complex fertilizer to vermiculite-based root medium appears suitable for potato plug seedlings.

3. Effects of seed tuber size on the growth and field performance of potato plug seedlings

Potato tubers of 10, 20, 30, 40, and 50 g were planted in plug trays with vermiculite-based root medium on 10 August 2000, grown for 15 days in a glasshouse, and then transplanted in a field. For a control, common potato tubers weighing 50 g were also planted. As size of seed tubers planted increased from 10 to 50 g, seedling height decreased from 24.6 to 20.0 ㎝ while shoot number per seedling increased from 2.03 to 3.53, main stem diameter from 4.30 to 6.14 ㎜, and fresh weight of root + top from 9.25 to 19.38 g/seedling. At 90 days after transplanting plug seedlings, the total number of tubers per plant increased from 3.62 to 4.72, average tuber weight from 62.9 to 72.8 g, and total tuber yield 20.5 to 23.6 t/㏊ with increase in seed tuber size. Plug seedlings raised from 50 g tubers produced 22% more tubers per plant and had 21% higher >80 g tuber yield than the directly planted potatoes.

Ⅰ. INTRODUCTION

Potatoes are grown on 25,000 ha in South Korea. The demand for seed potatoes in Korea is estimated to be 37,500 tons per year. However, government-run potato seed production facilities can supply only 10,000 tons per year which cover only about 25% of the total demand (Kim, 2000). Jeju Island accounted about 60% of the total potato acreage in Korea. Sprout rot which spoiled 10 to 96% of potato sprouts from 1995 to 1997 in Jeju Island was responsible for the crop failure of fall potatoes. Sprout rot prevent potato sprout from emerging. Biological and chemical control methods of sprout rot have not developed. Transplanting potato seedlings will prevent sprout rot in fields.

Recently, hydroponics technique has been widely used to produce high-grade seed potatoes. Most mini-tubers produced in hydroponics weigh less than 30 g. The mini-tubers generally have lower germination rate. This may markedly reduce potato yield when the mini-tubers were seeded directly in field. Lee *et al.* (2000) reported that potato plug seedlings produced from microtubers of 5 to 7 ㎜ had higher emergence rate than those of 3 to 4 ㎜. They also found that large microtubers had higher total tuber yield than small microtubers when planted directly in a field but microtuber size did not significantly affect total tuber yield when potato plug seedlings were transplanted. Potato plug seedlings raised from shoot cutting produced tuber yields similar to those of seed tubers under normal cultural conditions (Park *et al.*, 1999; Song *et al.*, 1999). However, there is little information on effects of seed potato size on the growth and field performance of plug seedlings.

Plug seedling was introduced to Korea in the early 1990s and was widely used in recent years because it saves labor for raising seedling, facilitates mass production of uniform seedlings, and allows division of

crop production labor (Kim *et al.*, 1999).

Various materials (peat moss, vermiculite, perlite, etc.) and mixtures of materials are used for plug media. Properties of the materials for root media have been described by Hartman et. al. (1990) and Styer & Koranski (1997). Peatmoss and vermiculite-based root media have been most widely used (Hartmann *et al.*, 1990; Styer & Koranski (1997). Most commercial root media used for plug seedlings in Korea have been imported because peatmoss are not produced in Korea. In Korea, extensive deposits of vermiculite are found and perlite is also produced.

The aim of this study was to develop vermiculite-based root media suitable for potato plug seedlings and to evaluate the effect of seed tuber size on the growth and field performance of potato plug seedlings.

Ⅱ. MATERIALS AND METHODS

This study was conducted during the 2000 growing season at the glasshouse and research farm of College of Agriculture, Cheju National University (33°27′ 20″ N latitude, 277 m altitude). The farm soil was a volcanic ash.

Root media formulation effects on the growth and field performance of plug seedlings

The mini-tubers of 'Dejima' produced in hydroponics were obtained from the Potato Technology Center, Jeju Agricultural Research and Extension Services in September 1999. Dejima is most widely grown in Jeju region. The seed potatoes were planted into 40-cm rows with 20-cm spacing in a screen house during the fall 1999 growing season to produce virus-free mini-tubers that were used for these experiments.

Treatments consisted of nine root media (Table 1). Eight root media contained different ratio of vermiculite (horticultural grade # 4, Silver Green, Misung, Seoul), perlite (horticultural grade, Paragreen, Samson, Seoul), peatmoss (Canadian sphagnum peat, BP-P, Berger Peat Moss, Quebec), and mature compost. A commercial growing mix (BM2, Berger Peat Moss, Quebec) was included. The compost contained 8.6 g/㎏ T-N, 10.0 g/㎏ P, 7.5 g/㎏ K, 344.2 g/㎏ organic matter (OM), 40.02 C/N, and 54.4.8 g/㎏ water. The above materials were air-dried, sieved (2 mm), and mixed thoroughly to make eight root media, to which 2 g/L of pulverized complex fertilizer for potato (N-P_2O_5-K_2O, 10-10-14) was added. Root media samples were collected and dried at 60℃ for measurement of pH and electrical conductivity, and for analysis of OM and mineral nutrients. The pH of the root media was measured at 1:5 medium to water ratio.

Organic matter was determined by the Walkley-Black method. Total N was analyzed using nitrogen auto-analyzer (Büchi 339, Germany), and K, Ca, Mg, and Na using inductively coupled plasma atomic emission spectrometer (model JY 138-Ultrace, France). The chemical properties of the root media are shown in Table 2.

Table 1. The volume percent formulation of nine root media.

Medium no.	Vermiculite	Peatmoss	Perlite	Compost	Fertilizer† (g/L)
1	50	30	10	10	2
2	60	20	10	10	2
3	70	10	10	10	2
4	80	0	10	10	2
5	50	20	10	20	2
6	50	10	10	30	2
7	50	0	10	40	2
8	70	20	10	0	2
9‡	10-15	70-80	10-20	0	0

† Complex fertilizer for potato ($N-P_2O_5-K_2O$, 10-10-14).

‡ Commercial growing mix.

Table 2. Chemical properties of nine root media.

Medium no.†	pH (1: 5)	EC (dS/m)	OM --- (g/kg) ---	T-N	P (㎎/kg)	K ---------- (cmol$^+$/kg) ----------	Ca	Mg	Na
1	4.24^{f‡}	0.67^{i}	177.1^{d}	9.2^{cd}	207.6^{e}	2.2^{c}	17.7^{d}	27.6^{de}	4.8^{e}
2	4.86^{d}	0.99^{f}	193.7^{cd}	8.2^{de}	190.8^{f}	1.9^{d}	15.4^{e}	32.8^{c}	6.9^{a}
3	4.65^{de}	1.08^{d}	126.8^{e}	7.4^{ef}	206.1^{e}	1.9^{d}	14.7^{ef}	29.5^{d}	5.6^{c}
4	6.63^{a}	1.37^{a}	122.1^{e}	6.7^{f}	343.6^{c}	2.1^{cd}	17.0^{d}	35.4^{b}	6.5^{b}
5	5.55^{c}	1.03^{e}	172.4^{d}	9.8^{c}	268.6^{d}	2.7^{b}	26.8^{b}	25.5^{e}	7.1^{a}
6	5.92^{b}	1.11^{c}	207.9^{bc}	12.8^{b}	348.9^{b}	2.8^{b}	25.0^{c}	27.3^{de}	5.3^{d}
7	6.52^{a}	1.23^{b}	222.9^{b}	14.6^{a}	546.1^{a}	3.8^{a}	24.6^{c}	32.6^{c}	2.7^{f}
8	4.55^{e}	0.91^{g}	95.8^{f}	4.5^{g}	152.1^{g}	2.1^{cd}	13.9^{f}	35.1^{bc}	5.5^{cd}
9	4.63^{e}	0.73^{n}	309.9^{a}	3.9^{g}	36.6^{h}	1.4^{e}	45.8^{a}	40.3^{a}	1.0^{g}

† See Table 1 for root media formulations.

‡ Mean separation by Duncan's multiple range test at 5% level.

The nine root media were soaked with predetermined amount of distilled water to retain adequate moisture for potato plug seedlings. The soaked media were stored in hermetically sealed plastic bags for 24 hours for obtaining uniform water content distribution in the root media.

Mini-tubers of uniform weight (20 ± 2 g per tuber) were planted in 50-cell polyethylene plug trays (depth 5.5 cm, volume 78.3 cm^3) with the nine media on 8 March 2000 and grown in a heated glasshouse (day/night temperature of 20/15℃) for 15 days. Each tray was considered as an experimental unit. Trays were arranged in a randomized complete block design with ten replicates.

At 15 days after planting, plant height, number of leaves, and shoots per plant, chlorophyll meter (SPAD-502, Minolta Camera Co., Japan) reading,

top fresh weight, and root fresh weight of ten seedlings per tray were determined.

The 15-day old plug seedlings were transplanted into 60-cm row with 20 cm spacing on 23 March. At transplanting, the plots were fertilized with 1,200 kg/ha of the complex fertilizer for potato. Individual plots had four rows with 3 m long. The experimental design was randomized complete block design with three replications. At 90 days after transplanting, two center 2 m rows were harvested to determine potato yields.

Effects of addition rate of complex fertilizer to media on the growth and field performance of plug seedlings

Four rates (0, 1, 2, or 4 g/L) of the complex fertilizer for potato were added to a root medium (70% vermiculite, 10% perlite, 10% peat moss, and 10% compost by volume) to determine the optimum addition rate of the complex fertilizer for plug seedling production. The other methods described above were also used in this experiment. Effects of fertilizer rate on chemical properties of root media were shown in Table 3.

Table 3. Effects of addition rate of complex fertilizer for potato (N-P_2O_5-K_2O, 10-10-14) on chemical properties of root media.

Fertilizer rate (g/L)	EC (dS/m)	OM (g/kg)	T-N (g/kg)	P (mg/kg)	K ($cmol^+/kg$)	Ca ($cmol^+/kg$)	Mg ($cmol^+/kg$)	Na ($cmol^+/kg$)
0	0.35	139.1	4.9	112.5	1.3	24.2	29.8	9.2
1	0.73	140.7	6.3	143.9	1.9	27.4	25.8	11.4
2	1.06	142.7	7.2	207.5	2.2	26.0	24.7	10.8
4	1.52	143.0	9.8	273.8	3.9	33.4	29.8	13.5

Effects of seed tuber size on the growth and field performance of plug seedlings

Root medium used in this test was prepared to contain 50% vermiculite (horticultural grade # 4, Silver Green, Misung, Seoul), 10% perlite (horticultural grade, Paragreen, Samson, Seoul), 10% peatmoss (Canadian sphagnum peat, BP-P, Berger Peat Moss, Quebec), and 30% mature compost by volume, and 2 g of complex fertilizer for potato (N-P_2O_5-K_2O, 10-10-14) per liter medium. The chemical properties of the root medium were shown in Table 4.

Table 4. The chemical properties of the root medium.

pH	EC	OM	T-N	P	K	Ca	Mg	Na
(1: 5)	(dS/m)	--	(g/kg) --		(㎎/kg)	------	($cmol^+$/kg)	-------
5.9	1.1	207.9	12.8	348.9	2.8	25.0	27.3	5.3

The mini-tubers of 'Dejima' produced from a above experiment (root media effects) were stored at room temperature. Evenly sprouted mini-tubers were sorted into five groups (10±2, 20±2, 30±2, 40±2, or 50±2 g/tuber). Mini-tubers of 10, 20, and 30 g were planted in 50-cell polyethylene plug trays (depth 5.5 cm, volume 78.3 cm^3) and those of 40 and 50 g in 32-cell polyethylene plug trays (depth 5.5 cm, volume 140 cm^3) on 10 August 2000. These tubers were grown in a heated glasshouse (day/night temperature of 20/15℃) for 15 days.

Treatments consisted of the five tuber sizes. Each 50-cell tray was considered as an experimental unit. For 32-cell trays, 50 cells were an experimental unit. The other methods described above were also used in this experiment.

Ⅲ. RESULTS AND DISCUSSION

Root media effects on seedling growth and field performance of plug seedlings

Characteristics of root media for plug seedlings

The optimum soil pH for potatoes is about 5.0 to 5.5 from the standpoint of both yield and scab retardation (Martin *et al.*, 1976). Most plug crops grow best in a slightly acid pH range of 6.2 to 6.8 in soil-based media and 5.8 to 6.2 in soilless media (Styer & Koranski, 1997). The pH values of the root media used in this experiment ranged from 4.24 to 6.63. The media 4 and 7 had higher pH of 6.63 and 6.52, respectively (Table 2) because the two media did not contained peatmoss which has a pH of about 3.5 to 4.0 (Hartman *et al.*, 1990).

Electrical conductivity (EC) of the root media ranged from 0.67 to 1.37, indicating no salinity problem. According to Hartman *et al.* (1990), at EC of below 2 dS/m, there is no salinity problem; at EC of 4 dS/m or over, most plants are likely to be affected; at EC of over 8 dS/m, only salt-tolerant plant will grow. Hwang & Yoon (1994) reported that the critical levels of EC in soil were 3.9 for carnation, 6.0 for chrysanthemum, and 5.9 to 6.5 dS/m for gerbera. The media 3 and 4 that were composed of 70 and 80% of vermiculite, respectively, had higher EC because vermiculite contains relatively high amount of K, Mg, and Ca. The media 5, 6, and 7 had higher EC because the three media had 20, 30, and 40% compost, respectively.

Medium 9, a commercial growing mix, had the highest OM content of 309.9 g/kg due to peatmoss. The media 5, 6, and 7 containing 20, 30, and 40% of compost, respectively, also had higher OM because compost contained 34.4% OM on the fresh weight basis. The medium 8 which did

not contain compost had the lowest OM content (95.8 g/kg)

The media 5, 6, and 7 had a higher content of total N, P, and K because of compost. Calcium and Mg contents were highest in medium 9 containing calcitic and dolomitic lime.

Plug seedling growth

The growth characteristics of 15-day old plug seedlings grown in the nine root media on 50-cell trays are shown in Table 5. The seedlings grown in media 6 and 7 had the greatest height, the number of leaves per plant, and top and root fresh weight. For SPAD reading value and the number of shoots per seedling, there was no significant difference between the root media except medium 8 which had the lowest values. Total N content in the media was significantly correlated with plant height, the number of leaves per seedling, SPAD read value, and top and root fresh weight (Table 6). These results indicate that compost greatly contributed to seedling growth in this experiment by supplying N to root media.

Table 5. Effects of root media formulation on plug seedling growth at 15 days after planting.

Medium no.†	Plant height (cm)	No. of leaves /plant	SPAD reading value	No. of shoots /plant	Top fresh weight ----- (mg/plant) -----	Root fresh weight
1	15.5^{b‡}	6.96^{c}	44.7^{ab}	2.12^{a}	3.88^{bc}	3.22^{cd}
2	15.5^{b}	6.10^{e}	44.1^{ab}	2.16^{a}	3.24^{e}	3.01^{d}
3	14.2^{c}	6.76^{cd}	44.6^{ab}	2.10^{a}	3.48^{d}	3.27^{c}
4	13.8^{c}	6.66^{cd}	44.5^{ab}	2.14^{a}	3.37^{de}	3.25^{cd}
5	15.2^{b}	7.46^{ab}	45.1^{ab}	2.04^{ab}	4.05^{b}	3.62^{b}
6	18.4^{a}	7.52^{a}	45.3^{ab}	2.12^{a}	4.54^{a}	3.92^{a}
7	18.1^{a}	7.58^{a}	45.5^{a}	2.22^{a}	4.67^{a}	4.02^{a}
8	13.8^{c}	5.78^{c}	43.8^{b}	1.78^{b}	3.39^{de}	3.14^{cde}
9	15.2^{b}	6.22^{b}	44.6^{ab}	2.12^{a}	3.72^{cd}	3.04^{de}

† See Table 1 for root media formulations.

‡ Mean separation by Duncan's multiple range test at the 5% level.

Table 6. Correlation coefficients (r) for chemical properties of root media with plug seedling growth parameters.

Parameter	pH	EC	OM	T-N	P	K	Ca	Mg	Na
Plant height	0.410	0.131	0.544	0.848**	0.598	0.717*	0.288	-0.309	-0.336
No. of leaves/plant	0.569	0.364	0.175	0.865**	0.735*	0.785*	0.127	-0.674*	-0.004
SPAD read value	0.564	0.295	0.436	0.827**	0.690*	0.753	0.367	-0.444	-0.298
No. of shoots/plant	0.416	0.270	0.532	0.525	0.435	0.275	0.249	-0.083	-0.230
Top fresh weight	0.471	0.155	0.427	0.834**	0.660*	0.826**	0.354	-0.405	-0.373
Root fresh weight	0.670*	0.484	0.135	0.890**	0.835*	0.922**	0.095	-0.494	-0.095

*, ** Significant at the 0.05, and 0.01 probability levels, respectively.

Field performance of plug seedlings

The number of tubers per plant ranged from 3.21 to 4.99. The seedlings grown in root media 1, 5, 6, and 7 produced higher number of tubers per plant than the other media (Table 7). Average tuber weight was not significantly affected by root medium. Total tuber yield ranged from 19.4 to 25.8 t/ha. The seedlings grown in root media 5, 6, and 7 produced significantly higher total tuber yield than the other media. The seedlings grown in medium 8 had the least tuber yield. The number of tubers per plant and tuber yield were positively correlated with height, leaf number, leaf SPAD reading values, shoot number, and top and root fresh weight of seedlings (Table 8).

The results of this experiment indicate that root media containing 50% vermiculite, 0 to 20% peat moss, 10% perlite, 20 to 40% compost by volume, and 2 g/L complex fertilizer for potato appear suitable for potato plug seedling production.

Table 7 Effects of root media formulation for plug seedlings on the number of tubers per plant, and average tuber weight per plant and tuber yield at 90 days after transplanting the plug seedlings.

Medium no.†	No. of tubers/plant			Tuber weight (g)	Tuber yield (t/ha)		
	>80g	<80g	Total		>80g	<80g	Total
1	1.78^{ab}‡	2.75^{ab}	4.53^{abc}	67.2^{a}	15.2^{bc}	8.0^{bc}	23.2^{cd}
2	1.53^{b}	2.65^{ab}	4.18^{bc}	65.9^{a}	14.3^{d}	8.3^{ab}	22.5^{d}
3	1.65^{ab}	2.59^{abc}	4.24^{abc}	66.7^{a}	15.1^{bc}	8.7^{a}	23.8^{bc}
4	1.81^{ab}	2.04^{c}	3.85^{cd}	66.8^{a}	14.9^{cd}	7.5^{cde}	22.4^{d}
5	1.83^{ab}	2.77^{a}	4.60^{abc}	66.3^{a}	17.4^{a}	7.5^{cde}	24.9^{ab}
6	1.95^{a}	3.04^{a}	4.99^{a}	67.0^{a}	17.6^{a}	7.7^{bcd}	25.3^{a}
7	1.80^{ab}	2.91^{a}	4.71^{ab}	66.4^{a}	17.9^{a}	7.9^{bc}	25.8^{a}
8	1.06^{c}	2.15^{bc}	3.21^{d}	63.8^{a}	12.4^{e}	7.1^{de}	19.4^{e}
9	1.61^{ab}	2.82^{a}	4.43^{abc}	66.7^{a}	15.8^{b}	6.9^{e}	22.7$^{c.d}$

† See Table 1 for root media formulations.

‡ Mean separation by Duncan's multiple range test at the 5% level.

Table 8 Correlation coefficients (r) for plug seedling growth parameters at 15 days after planting with the number of tuber per plant, average tuber weight, and tuber yield at 90 days after transplanting the plug seedlings.

Parameter	Plant height	No. of leaves/plant	SPAD reading value	No. of shoots/plant	Top fresh weight	Root fresh weight
No. of tubers/plant	0.853**	0.902***	0.942***	0.707*	0.858**	0.783*
Tuber weight	0.336	0.699*	0.702*	0.749*	0.415	0.327
Tuber yield	0.738*	0.922***	0.947***	0.717*	0.792*	0.788*

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

Effects of addition rate of complex fertilizer to media on e growth and field performance of plug seedlings

Plug seedling growth

Plant height increased from 12.9 to 16.4 ㎝ with increasing the addition of complex fertilizer to root media from 0 to 4 g/L (Table 9). The number of leaves per plant and SPAD reading value increased up to 2 g/L and then leveled off. Although shoot number per plant increased from 1.86 to 2.16 with increased addition of the fertilizer complete, there was no significant difference between fertilized media. Top and root fresh weight increased 3.11 to 4.21 g and 2.91 to 3.45 g, respectively, with increasing the addition of the complex fertilizer to root media. Increased growth is a common response of seedlings to fertilization of plug seedling root media (Chung *et al.*, 1998; Kyuper & Lambeth, 1980).

Table 9. Effects of addition rate of complex fertilizer for potato ($N-P_2O_5-K_2O$, 10-10-14) to a root medium on plug seedling growth at 15 days after planting.

Fertilizer rate (g/L)	Plant height (cm)	No. of leaves /plant	SPAD reading value	No. of shoots /plant	Top fresh weight	Root fresh weight
					----- (g/plant) -----	
0	12.9^{c‡}	4.86^{c}	42.4^{b}	1.86^{b}	3.11^{c}	2.91^{c}
1	14.4^{b}	5.46^{b}	42.6^{b}	2.08^{ab}	3.21^{c}	3.14^{a}
2	15.1^{b}	6.56^{a}	44.0^{a}	2.10^{ab}	3.67^{b}	3.30^{a}
4	16.4^{a}	6.46^{a}	44.1^{a}	2.16^{a}	4.21^{a}	3.45^{a}

† Mean separation by Duncan's multiple range test at the 5% level.

Field performance of plug seedlings

The number of tubers per plant and tuber yield increased from 3.87 to 4.49 and 20.3 to 23.9 t/ha, respectively, with increasing the addition of complex

fertilizer to root media from 0 to 4 g/L (Table 10). However, there was no significant difference between fertilized root media. The results suggest that addition of about 2 g/L of the complex fertilizer to vermiculite-based root medium appears suitable for potato plug seedlings.

Table 10. Effects of addition rate of complex fertilizer for potato ($N-P_2O_5-K_2O$, 10-10-14) to a root medium on the number of tubers per plant, and average tuber weight per plant, and tuber yield at 90 days after transplanting the plug seedlings.

Fertilizer rate (g/L)	No. of tubers/plant			Tuber weight (g)	Tuber yield (t/ha)		
	>80 g	<80 g	Total		>80 g	<80 g	Total
0	1.52[a‡]	2.16[b]	3.87[b]	63.3[a]	14.1[b]	6.2[a]	20.3[b]
1	1.56[a]	2.63[a]	4.19[ab]	64.5[a]	15.6[ab]	6.9[a]	22.5[a]
2	1.57[a]	2.76[a]	4.33[a]	65.0[a]	16.7[a]	6.8[a]	23.4[a]
4	1.59[a]	2.90[a]	4.49[a]	65.3[a]	16.7[a]	7.2[a]	23.9[a]

[†] Mean separation by Duncan's multiple range test at the 5% level.

Effects of seed tuber size on the growth and field performance of plug seedlings

Seedling growth

As size of seed tubers planted in plug trays increased from 10 to 50 g/tuber, plug seedling height at 15 days after planting linearly decreased from 24.6 to 20.0 ㎝ (Table 11 and 13). This probably resulted from the earlier emergence of the smaller tubers (Data not shown). Kim *et al.* (1998) found that smaller mini-tubers produced in hydroponics need shorter days to emergence. The number of days from planting to emergence of less than 15 g mini-tubers was 28 and 25 days and that of

more than 10 g tubers was 30 and 27 days, in spring and fall seasons, respectively. However, they reported that the larger the size of mini-tubers planted directly in field, the greater plant height at 60 days after planting probably because of greater growth rate of mini-tubers after emergence. However, Choi. *et al.* (1994) found that the larger the microtuber size, the earlier emergence. The seedling height is known to be greater for larger microtubers planted in plug trays than for smaller microtubers (Choi. *et al.*, 1994; Lee *et al.*, 2000).

Table 11. Plug seedling growth of mini-tubers at 15 days after planting.

Tuber size (g/tuber)	Plant height (cm)	No. of shoots /plant	Stem diameter (㎜)	Fresh weight (g/plant)			
				Root	Leaf	Stem	Total
10	24.7	2.0	4.3	2.2	3.8	3.3	9.3
20	22.4	2.2	4.5	3.2	4.7	3.2	11.1
30	21.6	2.4	4.9	5.1	5.0	5.1	15.1
40	20.9	3.0	6.0	7.8	5.8	5.8	19.4
50	20.0	3.5	6.1	7.4	6.1	5.9	20.8
Response †	L^{***}	$L^{***}Q^{*}$	$L^{***}C^{**}Qu^{*}$	L^{***}	L^{***}	$L^{***}C^{*}$	$L^{***}C^{*}$

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

† L, linear; Q, quadratic; C, cubic; Qu, quartic. Regression equations relating tuber size are presented in Table 4.

The number of shoots per plant quadractically increased from 2.03 to 3.53 with increased seed tuber size. Stem diameter ranged from 4.30 to 6.14 ㎜ and markedly increased up to 40 g/tuber and then slightly increased. Kim *et al.* (1998) also found that large mini-tubers had more shoots per plant and thicker main stem than small mini-tubers at 60 days after planting. However, there was no significant difference between microtuber sizes for the number of shoots per seedling (Lee *et al.*, 2000).

Root and leaf weights per plant linearly increased from 2.21 to 7.79 g and 3.78 to 6.09 g, respectively, with increase in tuber size. Relationship between stem weight per plant and tuber size was cubic because of no difference between 10 and 20 g tubers, markedly increased stem weight of 30 g tubers and slight increased stem weight of >40 g tubers. These results indicate that nutrients stored in seed potato largely influence the early growth of seedlings.

Field performance of plug seedlings

As the size of seed tubers planted for plug seedlings increased from 10 to 50 g/tuber, the number of >80 g tubers per plant at 90 days after transplanting linearly increased from 2.48 to 3.04, the number of <80 g tubers from 1.15 to 1.67, and the total number of tubers from 3.62 to 4.72 (Table 12 and 13). Kim *et al.* (1998) reported that the number of tubers per plant of potatoes directly planted increased from 9.4 to 13.4 and from 3.3 to 4.1, respectively, with increasing tuber size from <1 to >15 g in spring and fall croppings, respectively. However, there was no significant difference between microtuber sizes for the number of tubers per plant at maturity (Choi. *et al.*, 1994; *Lee et al.*, 2000). Plug seedlings raised from 50 g tubers produced 22% more tubers per plant than the directly planted potatoes probably because plug seedlings had already established root and shoot systems at transplanting. However, potato plug seedlings raised from stem cutting produced much less tubers per plant than seed tubers at 90 days after transplanting plug seedlings (Park *et al.*, 1999; Song *et al.*, 1999).

Table 12. Effects of tuber size for plug seedling production on the number of tubers per plant, and average tuber weight, and tuber yield at 90 days after transplanting plug seedlings.

Tuber size (g/tuber)	No. of tubers/plant			Tuber weight (g)	Tuber yield (t/ha)		
	>80g	<80g	Total		>80g	<80g	Total
10	2.48	1.15	3.62	62.9	11.5	9.0	20.5
20	2.50	1.24	3.74	66.7	12.5	9.4	21.9
30	2.53	1.33	3.86	71.0	13.3	11.4	22.0
40	2.75	1.28	4.02	72.7	17.7	8.6	23.3
50	3.04[a†]	1.67[a]	4.72[a]	72.8[a]	18.8[a]	7.7[a]	23.6[a]
Seed potato[‡]	2.55[a]	1.33[a]	3.88[b]	68.9[a]	15.5[b]	8.5[a]	21.3[a]
Response[§]	L*	L**	L**	L***	L***	Q**Qu*	L**

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively

† Means followed by the same letter within a column were not significantly different at the 0.05 probability level.

‡ Common seed potatoes weighing 50 g were directly planted.

§ L, linear; Q, quadratic; Qu, quartic. Regression equations relating tuber size are presented in Table 4. .

Table 13. Regression equations with coefficients of determination relating tuber size to various traits of 15 day-old plug seedlings and agronomic traits of potatoes at 90 days after transplanting the plug seedlings.

Variable	Regression equation	r^2 or R^2
	Plug seedling	
Plant height	$Y=25.126-0.108X$	0.923
No. of shoots/plant	$Y=2.013-0.006X+0.0007X^2$	0.993
Stem diameter	$Y=1.593+0.538X-0.0357X^2+0.001X^3-0.00001X^4$	1.000
Root fresh weight	$Y=0.060+0.179X$	0.975
Leaf fresh weight	$Y=3.344+0.058X$	0.962
Stem fresh weight	$Y=5.219-0.354X+0.0173X^2-0.0002X^3$	0.970
Root + top fresh weigh	$Y=12.339-0.633X+0.0367X^2-0.0004X^3$	0.999
	At 90 days after tansplanting the plug seedlings	
>80 g tubers/plant	$Y=2.246+0.014X$	0.832
<80 g tubers/plant	$Y=1.006+0.011X$	0.728
Total tubers/plant	$Y=3.252+0.025X$	0.822
Average tuber weight	$Y=61.457+0.257X$	0.900
>80 g tuber yield	$Y=8.831+0.198X$	0.911
<80 g tuber yield	$Y=30.114-4.198X+0.2696X^2-0.0067X^3+0.00006X^4$	1.000
Total tuber yield	$Y=19.966+0.076X$	0.926

Average tuber weight linearly increased from 62.9 to 72.8 g/tuber with seed tuber size. Kim *et al.* (1998), however, reported that average tuber weight increased up to 10 g tubers and thereafter leveled off. There was no significant difference for average tuber weight between the transplanted and directly planted potatoes.

Yields of >80 g tubers and total tubers linearly increased from 11.5 to

18.8 and 20.5 to 23.6 t/ha, respectively, with increase in the size of seed tubers, which was similar to previous research (Kim *et al.*, 1998). Yield of <80 g tubers ranged from 7.7 to 11.4 t/ha and considerably increased up to 30 g of seed tubers and thereafter dramatically decreased with seed size. It has been reported that there is a direct correlation between total yield and the size of seed tubers directly planted (Burton, 1989).

Transplanted seedlings produced 21% more >80 g tubers than directly planted potatoes. For yield of <80 g tubers and total tubers, there was no significant difference between transplanted and directly planted potato crops with the same seed tuber size. Potato plug seedlings raised from stem cutting had similar total tuber yield to seed tubers but had higher >80 g tuber yield than seed potatoes (Park *et al.*, 1999; Song *et al.*, 1999).

In conclusion, plug seedlings raised from 10 g tubers had only 4% less total tuber yield than 50 g tubers planted directly in field, indicating that smaller mini-tubers produced by hydroponics can be used for high-grade seed potato production if plug seedlings are transplanted.

적 요

본 연구는 감자 플러그묘 육묘에 알맞은 vermiculite 기초 배양토를 개발하고 소서 크기가 감자 플러그묘의 생육 및 포장 생산성에 미치는 영향을 평가하기 위해 2000년도에 수행되었다.

1. 배지 제형이 플러그묘의 생육 및 괴경수량에 미치는 영향

감자 전용복합비료(N-P_2O_5-K_2O, 10-10-14)를 2 g/L 첨가하여 만든 8 가지 배양토와 시판 상토가 평가되었다. 8가지 배양토는 vermiculite, perlite, petmoss, 퇴비가 다양한 비율로 배합하여 제조되었다. 배양토에 퇴비를 추가함으로써 15일 플러그묘의 초장, 주당 엽수, 경엽 및 뿌리의 생체중이 증가되었다. 퇴비가 추가된 배양토에서 육묘된 묘의 총괴경 수량은 유의성 있게 높았다. vermiculite 50% + peatmoss 0~20% + perlite 10% + 퇴비 20~40%를 포함한 배양토가 감자 플러그묘 생산을 위해 알맞은 것으로 보였다.

2. 배양토에 복합비료의 첨가량이 감자 플러그묘의 생육 및 괴경수량에 미치는 영향

감자 플러그묘 육묘를 위해 복합비료의 적정 첨가량을 결정하기 위해 4수준(0, 1, 2, 4g/L)의 감자전용복합비료를 배양토(부피로 vermiculite 70%, perlite 10%, peat moss10%, 퇴비 10% 혼합)에 첨가하였다. 감자전용복합비료를 배양토에 L당 0g에서 4g으로 증가시킴에 따라 묘의 초장은 12.9㎝에서 16.4㎝로, 지상부와 지하부 생체중은 각각 3.11g에서 4.21g, 2.91g에서 3.45g 증가하였다. 배양토에 복합비료를 첨가함으로 주당 괴경수와 총괴경수량은 증가되었으나 복합비료가 첨가된 배양토 사이에는 유의한 차이는 없었다. 이상의 결과로 볼 때 vermiculite 기초 배지에 감자전용복합비료를 약 2g 첨가가 감자 플러그묘 육묘에 알맞을 것 같다.

3. 소서의 크기가 감자 플러그묘의 생육 및 괴경수량에 미치는 영향

10, 20, 30, 40, 50g의 괴경을 2000년 8월10일에 vermiculite 기초 배양토가 든 플러그 묘판에 파종하여 온실에서 15일 육묘후 포장에 이식하였고 대조구로 50g 일반종서를 직파하였다. 감자 괴경의 크기에 0g에서 50g으로 증가됨에 따라 묘의 초장은 24.6㎝에서 20.0㎝로 감소된 반면 묘당 줄기수는 2.03개에서 3.53개로, 주경직경은 4.30에서 6.14㎜, 지상부+지하부 생체중은 9.25g에서 19.38g로 증가되었다. 괴경의 크기가 0g에서 50g으로 증가됨에 따라 플러그묘 이식 후 90일에 있어서 주당 괴경수는 3.62개에서 4.72개, 평균 괴경중은 62.9에서 72.8g으로, 총괴경수량은 20.5t/ha에서 23.6t/ha으로 증가되었다. 50g의 괴경으로 육묘된 묘가 직파한 감자보다 주당 괴경수가 22%, 80g이상 괴경수량이 21% 증가되었다.

REFERENCES

Burton, W. G. 1989. The potato. 3rd ed. Longman Group UK Limited, Essez CM20 2JE, England.

Choi. D. J., R. T. Yoon, H. S. Lee, J. S. Kim, S. G. Choi, and H. D. Chung. 1994. Effect of microtuber size on storability, growth, and yield of potato plants. *RDA. J. Agri. Sci.* 36(2)429-433.

Chung, H. D., Y. J. Choi, and S. H. Shin. 1998. Effects of top dressing fertilizers on grown of pepper plug seedlings in vermiculite-based root media. *J. Kor. Soc. Hort. Sci*. 39(1):1-7.

Hartmann, H. T., D. E. Kester, and F. T. Davies, Jr. 1990. Plant propagation. Principles and practices. p.199-255. 5th ed. Prentice Hall. Inc. Englewood Cliffs. NJ.

Hwang, K. S., and J. H. Yoon. 1994. The effect of salt concentration on the growth of chrysanthemum, carnation and gerbera in greenhouse soil. *RDA. J. Sci.* 36(2):268-272.

Kim, H, J., K. S. Kim, W. B. Kim, and K. S. Choi. 1993. Studies on small seed potato (*Solanum tuberosum* L.) multiplication by hydroponic and its practical use. *RDA. J. Agri. Sic.* 35(1):524-529.

Kim, K. T., S. B. Kim, S. B. Ko, K. H. Kim, and S. K. Jeong. 1998. Field growth and yield characteristics of mini-tubers of potato (*Solanum tuberosum* L.) produced by hydroponics. *RDA J. Hort. Sci.* 40(1):140-144,

Kim, Y. B., Y. H. Hwang, and W. K. Shin. 1999. Effects of root container size and seedling age on growth and yield of tomato. *Kor. J. Soc. Hort. Sci.* 40:163-165.

Kim, S. Y. 2000. Development of supply system and safe production of seed potato. 2000 symposium on improvement of potatoes production in Jeju. p. 57-75.

Kyuper, B. W. and V. N. Lambeth. 1980. Slow-release nitrogen studies with spinach grown in a clay-perlite-vermiculite medium. *HortScience* 15:799-800.

Lee, H. S., C. B. Kim, C. K. Kim, K. B. Choi, and B. S. Choi. 2000. Effect of plug cell and microtuber size on the growth and yield of 'Dejima' potato. *Kor. J. Hort. Sci.* 41(2):166-168.

Martin, J. G., W. H. Leonard, and D. L. Stamp. 1976. Principles of field crop production. p.898-932. 3rd ed. Macmillan publishing Co., Inc., New York.

Park Y. M., C. K. Song, B. K. Kang, and D. H. Ko. 1999. Mass propagation of plug seedling using stem and their tuber yield in potato. *Kor. J. Crop Sci.* 44(3):181-309.

Song, C. K. and B. K. Kang. 1999. Effects of foliar application of chitosan and wood extraction on rooting and tuber formation of plug seedlings in potatoes. *Kor. J. Organic Agri.* 8(1):89-99.

Styer, R. C. and D. S. Koranski. 1997. Plug & transplant production: a grower's guide. Ball publishing Batavia, Illinois.

Wattimena, G., B. McCown, and G. Weis. 1983. Comparative field performance of potatoes from microculture. *Am. Potato J.* 60:27-33.

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