Korean J. Crop Sci. 46(2): 125~129(2001)

Effect of Root Media Formulation and Fertilizer Application on Potato Plug Seedling Growth and Field Performance

Bong-Kyoon Kang*†, Young-Kil Kang*, Si-Yong Kang, and Yang-Mun Park***

*College of Agriculture, Cheju National University, Jeju 690-756, Korea
**Subtropical Horticulture Research Center, Cheju National University, Jeju 690-756, Korea.

ABSTRACT: 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 (*Solanum tuberosum* L.) and a commercial root medium were evaluated in 2000 to develop the root media suitable for potato plug seedling production. The eight media consisted of various ratios of vermiculite, perlite, peatmoss, and compost. In addition, 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. 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. Addition of the complex fertilizer to root media enhanced seedling growth and increased the number of tubers per plant and tuber yields. The results suggest that root media containing 50% vermiculite, 0 to 20% peat moss, 10% perlite, 20 to 40% compost, and 2 g/L complex fertilizer for potato appear suitable for potato plug seedling production.

Keywords : potato, mini-tuber, plug seedlings, root medium, field performance.

In South Korea, potatoes are grown on 25,000 ha and the demand for seed potatoes 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 plug 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 mm had higher emergence rate than those of 3 to 4 mm. 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).

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.

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 seedling 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

†Corresponding author: (Phone) +82-064-754-3391 (E-mail) kangbong@cheju.cheju.ac.kr <Received May 14, 2001>

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.

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/kg T-N, 10.0 g/kg P, 7.5 g/kg K, 344.2 g/kg organic matter (OM), 40.02 C/N, and 54.48 g/kg 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°C 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.

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°C) 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 plug seedling growth and field performance of plug seedlings

Four rates (0, 1, 2, or 4 g/L) of the complex fertilizer for

Table 2. Chemical properties of nine root media.

Medium no.†	pH (1: 5)	EC (dS/m)	OM	T-N	P	K	Ca	Mg	Na
			--- (g/kg) ---		(mg/kg)	---------- (cmol$^+$/kg) ----------			
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.

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	T-N	P	K	Ca	Mg	Na
		--- (g/kg) ---		(mg/kg)		---------- ($cmol^+$/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

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.

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).

Table 4. 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	Root fresh weight
					----- (mg/plant) -----	
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.

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 4. 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 5). These results indicate that compost greatly contributed to seedling growth in this experiment by supplying N to root media.

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 5. 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.

Table 6. 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)		
	>80 g	<80 g	Total		>80 g	<80 g	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 6). 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 7).

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.

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

Plug seedling growth

Plant height increased from 12.9 to 16.4 cm with increasing the addition of complex fertilizer to root media from 0 to 4 g/L (Table 8). 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).

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 9). 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 7. 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.

Table 8. 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.

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 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.

ACKNOWLEDGEMENTS

This work was supported by the Korean Science and Engineering Foundation (KOSEF) through the Subtropical Horticulture Research Center at Cheju National University, 2000.

REFERENCES

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, 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.