

Trial of Green Asparagus Out-of-Season Production for Establishing Year-Round Production in Kyushu, a Warm Area of Japan

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Abstract

Kyushu island, in southern Japan, is one of the main producers of green asparagus (*Asparagus officinalis* L.) in Japan, accommodating protected mother-fern culture in plastic greenhouses (PMC) as a conventional crop. In PMC, since few spears are produced from November to January, we attempted to produce spears during this period by prolonging the harvest of PMC to November and introducing "Fusekomi" forcing culture (FFC), in which rootstocks grown outdoors are transplanted into heated and/or thermal-retained culture beds in a plastic greenhouse in late autumn or early winter and spears are generally harvested for the following two or three months. In PMC, a combination of a foliage spray of Benzyladenine solution with thermal retention treatment in autumn prolonged the harvest period to the end of November without any significant decrease in yield the following spring. In FFC, rootstocks grown in the lowlands showed inferior spear productivity when transplanted into a greenhouse in late November, probably due to insufficient exposure to low temperature for breaking dormancy. In contrast, rootstocks grown in the highlands showed superior productivity because they would be sufficiently exposed to low temperature for breaking dormancy by the time of transplanting. In lowlands, heating of greenhouses was unnecessary for FFC throughout the harvest period due to the mild winter climate. These results suggested that profitable year-round production of green asparagus without heating could be realized in Kyushu by combining PMC and FFC cropping types.

Discipline: Horticulture

Additional key words: Benzyladenine, forcing culture, mother-fern culture, protected cultivation, thermal retention

Introduction

Kyushu lies in southern Japan and is one of the main green-asparagus producing districts in the country (MAFF). A typical crop type there is the protected mother-fern culture in a plastic greenhouse (PMC) (Inoue 2008, Shigematsu 2012). The mean spear yield per unit land area (approximately 200kg/a) in PMC in the district is the highest of all districts in Japan, and the yield peaked at 600kg/a (Motoki et al. 2008). Such high yields are due to the fact that spears can be continuously harvested from February to October because of the mild climate, particularly in spring and autumn (Fig.

1). However, during winter, the mother ferns are blasted and the low temperatures mean spears hardly sprout, particularly from November to January. Therefore, year-round production of asparagus without heating has not been established completely in PMC in the district. It was reported that foliage spraying of benzyladenine (BA) was effective for prolonging the harvest period of asparagus (Mouri et al. 1995, Uesugi et al. 1996, Ikeuchi & Kobayakawa 2000). Because only one or two-year-old rootstocks were applied with BA in warm regions (Mouri et al. 1995, Ikeuchi & Kobayakawa 2000), the BA effect should be confirmed using older plants, which are major components of actual production in warm

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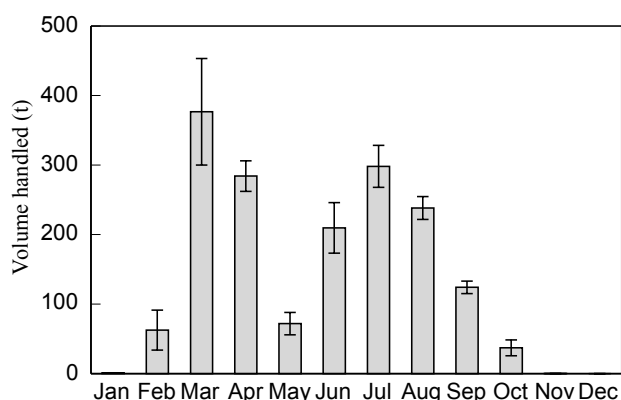


Fig. 1. Kyushu-grown asparagus volume handled at the Tokyo Metropolitan Central Wholesale Markets

Columns indicate the mean values from 2010 to 2013. Vertical bars indicate SD (n=4). This graph was made by data obtained from the Vegetable Total and Aggregate Information Network (<http://vegetan.alic.go.jp/sch7.do?outPutKbn=1>).

areas.

Another unique cropping type, the “Fusekomi” forcing culture (FFC), has been developed in Japan (Matsubara 1981, Haruyama et al. 1985, Uchida & Takahashi 1991, Koizumi et al. 2002, 2003, Jishi et al. 2008). In FFC, rootstocks grown outdoors for one or two years are transplanted into culture beds in a plastic greenhouse with multiple coverings in late autumn or early winter, and spears are generally harvested for two or three months, from winter to early spring, when domestic asparagus production is very limited. After harvesting, the used rootstocks are discarded, and new rootstocks are grown every year. Although plastic greenhouses must be equipped with soil (and air, if needed) heating equipment in FFC in cold regions (Haruyama et al. 1985, Koizumi et al. 2002, 2003, Jishi et al. 2008), FFC could be conducted without heating in temperate regions such as Kyushu. Although Uchida & Takahashi (1991) reported that sufficient spear yield was obtained by FFC without heating; mainly during February and March in Kyushu, the spear yield should be estimated in earlier months, such as December and/or January, to achieve year-round production in the district.

In this study, we sought to develop a year-round asparagus production system without heating equipment (only thermal retention) by combining BA-applied PMC and FFC, utilizing the mild Kyushu climate from autumn to spring.

Materials and methods

1. Effect of combined treatment of BA foliage spraying with thermal retention on the extension of the harvest period in PMC (Expt. 1)

‘UC157’ asparagus plants were planted 25cm apart

in 1997 and grown in single rows spaced 1.5m apart from the bed center in a polyolefin (PO) greenhouse (6m wide, 30m deep, and 3m high) at the Nagasaki Agriculture and Forestry Experiment Station (Nagasaki, 40m above sea level, yellow soil dressed by andosol, red and yellow soils). The experiment was conducted twice, from autumn 2006 to spring 2007 (11- and 12-year-old plants) and from autumn 2007 to spring 2008 (12- and 13-year-old plants). Mother ferns were arranged at a density of 7.5/m² and topped at 140 cm above the surface level of the rows, while all lateral blanches were removed up to 50 cm above the surface of the rows. Fertilization and pest control were performed in line with conventional methods. To extend the harvest period, 60 mg/L of BA solution was sprayed once on the mother ferns with a volume of 25 L/a in mid-October (BA spraying treatment), and the ventilation area of the greenhouse was automatically closed when the air temperature inside went below 25°C during October and November (thermal retention (TR) treatment). In the control, BA was not sprayed, and the greenhouse was kept open, as per the conventional way. Spear yields in November and the following spring were examined and air temperatures 10 and 100 cm above ground and the soil temperature 10 cm below ground in the central part of the house were recorded at 60-minute intervals. The mean air and soil temperatures over a 10-day period of the month were calculated from recorded data.

2. Effect of transplanting time to a plastic greenhouse and growing site of rootstocks on FFC spear yield (Expt. 2)

Rootstocks were grown in open fields at two sites, the Kurume Research Station of NARO Kyushu Okinawa Agricultural Research Center (Kurume) (30m above sea level, red soil) and the Kuju Experiment Field of the Vegetable and Tea Research Institute, Oita Prefectural Agriculture, Forestry and Fisheries Research Center (Kuju) (540m above sea level, gray lowland soil). At Kurume, three-month-old ‘Grande’ asparagus seedlings were planted 0.4m apart in single rows spaced 1.5m from the bed center (167 plants/a) on 20 April, 2006. The rows were covered by black polyethylene mulch, and the growing ferns were supported by steel pipes and double-layer nets. At Kuju, the four-month-old seedlings were planted in the same arrangement on 22 May, 2006 and grown as at Kurume. At Kurume and Kuju, compound fertilizer at the rate of 3kg/a of N, 3kg/a of P₂O₅ and 3kg/a of K₂O were applied as basal fertilizer, and pest control was performed adequately. Rootstocks were dug up on 20 November and 20 December, 2006 at Kurume and on 29 November, 2006 at Kuju, respectively, and transplanted in culture beds set in a PO greenhouse with an air-inflated double-layer curtain with PO film at Kurume. The rootstocks were filled tight in the bed and covered with soil and conifer bark mixture (soil: bark = 1:1). When the soil temperature in the bed 5 cm below the ground level decreased below



Fig. 2. Setting of heat-storage mulches on the ground in the double-layer PO curtain (left) and a compartment of mulch (right) (Expt. 3)

The black arrows in the left picture show the positions of the heat-storage mulch, which is divided into compartments 100cm long, each of which contains approximately 28L of water as a thermal storage medium.

16 °C, the beds were heated by electric heat lines set at the bottom of the beds. The double-layer curtain was worked every night and, if needed for thermal retention, in daytime on rainy or cloudy days. When the air temperature became excessive in the house on fine days, both sides of the house and the curtain were opened appropriately. During growing rootstocks in open fields, air temperatures were recorded at 10- and 60-minute intervals at Kurume and Kuju, respectively, while the daily mean air temperatures were calculated from recorded data.

3. Spear productivity in FFC without heating (Expt. 3)

On 1 June, 2007, three-month-old seedlings of the ‘UC157’ asparagus were planted in the same arrangement in an open field at Nagasaki (yellow soil dressed by andosol) and grown as with Expt. 2. Rootstocks were dug up on 18 December, 2007 and transplanted into the culture beds set in the PO greenhouse at Kurume, as described in Expt. 2. In this experiment, the beds were not heated. The management of the greenhouse was the same as in Expt. 2. On 11 January, 2008, heat-storage mulches (“Hot mulch”, Takii & Co., Ltd., Kyoto, Japan) were set on the ground in the greenhouse (Fig. 2) and the air temperatures inside and outside the greenhouse and the soil temperatures in the bed 5 and 15cm below ground level were recorded.

4. Spear measurement

In all experiments, spears more than 25 cm long were harvested every day. The harvested spears were cut to 25cm in length and weighed. Spears exceeding 5g in weight and which met the standards of JA (Japan Agricultural Cooperatives) ZEN-NOH Nagasaki were considered marketable.

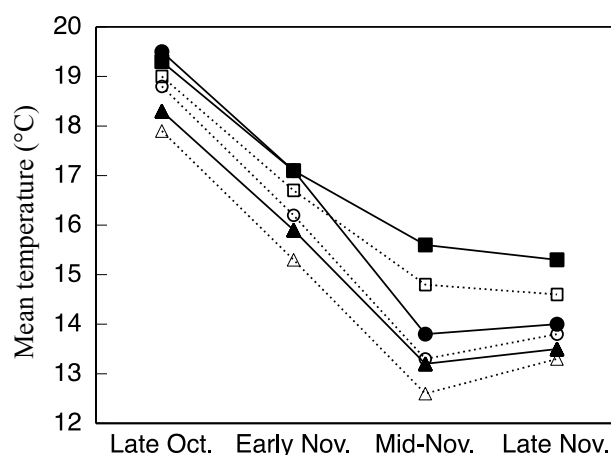


Fig. 3. Effect of thermal retention (TR) treatment on air and soil temperatures in the greenhouse in PMC in 2006 (Expt. 1).

···□·· Soil in Cont., —■— Soil in TR,
 ···△·· Air 10cm above the ground in Cont.,
 —▲— Air 10cm above the ground in TR,
 ···○·· Air 100cm above the ground in Cont.,
 —●— Air 100cm above the ground in TR.

Results

1. Effect of combining treatment of BA foliage spraying with thermal retention on extending the harvest period in PMC (Expt. 1)

The mean air and soil temperatures tended to be higher in the TR treatment than in the control (Fig. 3). In both years, no marketable spears were harvested in November in the control, whereas the combined treatment of BA foli-

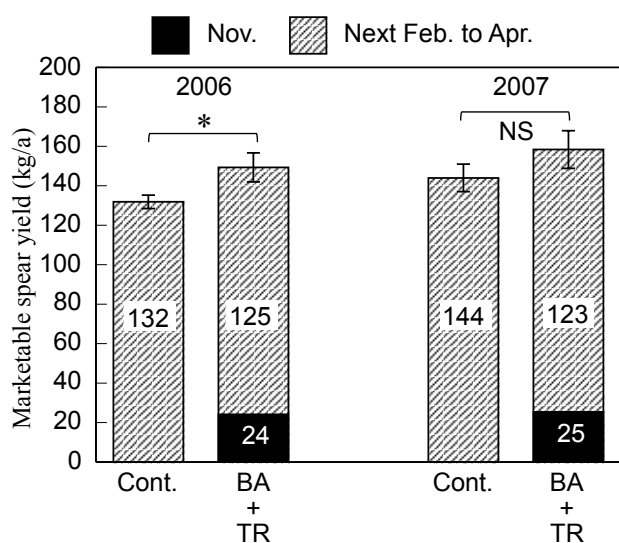


Fig. 4. Effect of benzyladenine (BA) spraying with thermal retention (TR) treatment on the marketable spear yield in November and the following spring in PMC (Expt. 1)

Columns and numerals in the columns indicate mean values in six repetitions of 40 plants. * and NS indicates mean separation of the total marketable spear yield by t-test, a 5% level of significance and non-significance, respectively. Vertical bars indicate SE of total marketable spear yield (n=6).

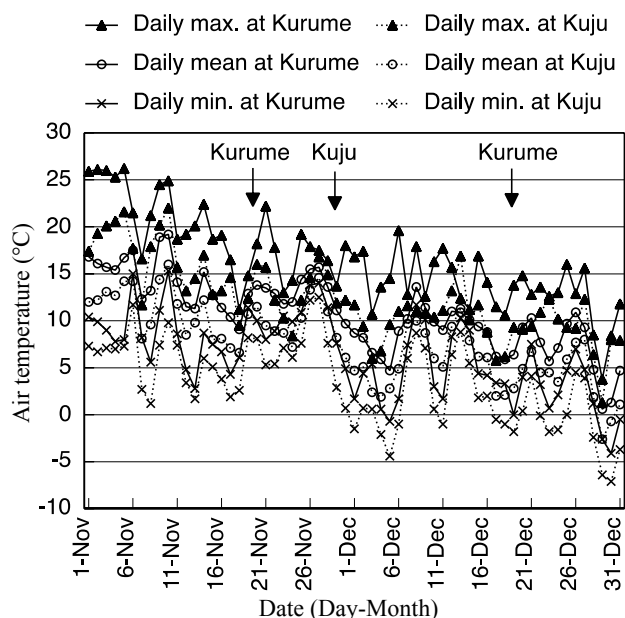


Fig. 5. Change in air temperature at Kurume and Kuju (Expt. 2)

Arrows in the graph indicate the digging dates of rootstocks at the sites.

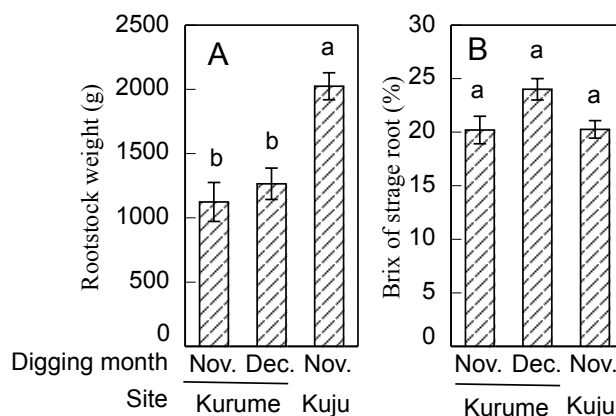


Fig. 6. Effect of rootstock digging month and growing site on (A) rootstock weight and (B) Brix of storage roots (Expt. 2)

Columns indicate the mean values of 10 plants in Kurume, 9 plants in Kuju in A and 5 plants in Kuju in B. Different letters indicate mean separation by the Tukey-Kramer test, 5% level of significance. Vertical bars indicate SE (n=5-10).

age spraying with TR enabled the harvesting of spears in November (Fig. 4). The total marketable spear yield for November and the following spring tended to be greater in the combined treatment than the control, although the spring yield declined slightly in the combined treatment (Fig. 4).

2. Effect of transplanting time to a greenhouse and growing site of rootstocks on FFC spear yield (Expt. 2)

The air temperature until all the rootstocks had been dug up was lower at Kuju than Kurume (Fig. 5), while the rootstock weight at Kuju exceeded that at Kurume, although no difference was observed between the digging months at Kurume (Fig. 6A), nor any in the brix of storage roots (Fig. 6B). The marketable spear yield and mean spear weight were primarily greater in the rootstocks grown at Kuju and secondarily in those dug up in December at Kurume, followed by those dug up in November at Kurume (Figs. 7A, B). The proportion of marketable yield to rootstock weight was similarly higher in the rootstocks grown at Kuju and in those dug up in December at Kurume than in those dug up in November at Kurume (Fig. 7C).

3. Spear productivity in FFC without heating (Expt. 3)

An example of changes of air and soil temperatures in the greenhouse is presented in Fig. 8. Before the setting of heat-storage mulches, the mean night air temperature and minimum air temperature in the double-layer curtain were 3 to 5°C higher than those outdoors, while the mean soil temperatures were maintained above 15°C (Table 1). When setting the heat-storage mulches, the differences between the

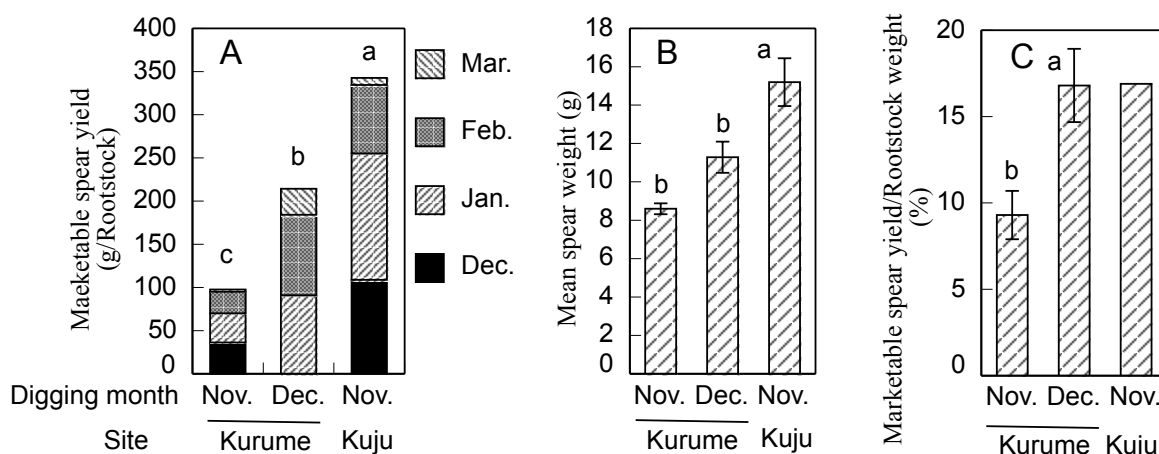


Fig. 7. Effect of rootstock digging month and growing site on (A) marketable spear yield, (B) mean spear weight, and (C) proportion of marketable yield to rootstock weight (Expt. 2)

Columns indicate the mean values of 10 plants. Different letters indicate the mean separation of the total marketable spear yield by the Tukey-Kramer test, 5% level of significance in A, and mean separation in B and C. Vertical bars in B and C indicate SE (n=10). Kuju in C has no statistical test letter and a vertical bar because the value was estimated using mean values in (A) marketable spear yield and rootstock weight in Fig. 6A.

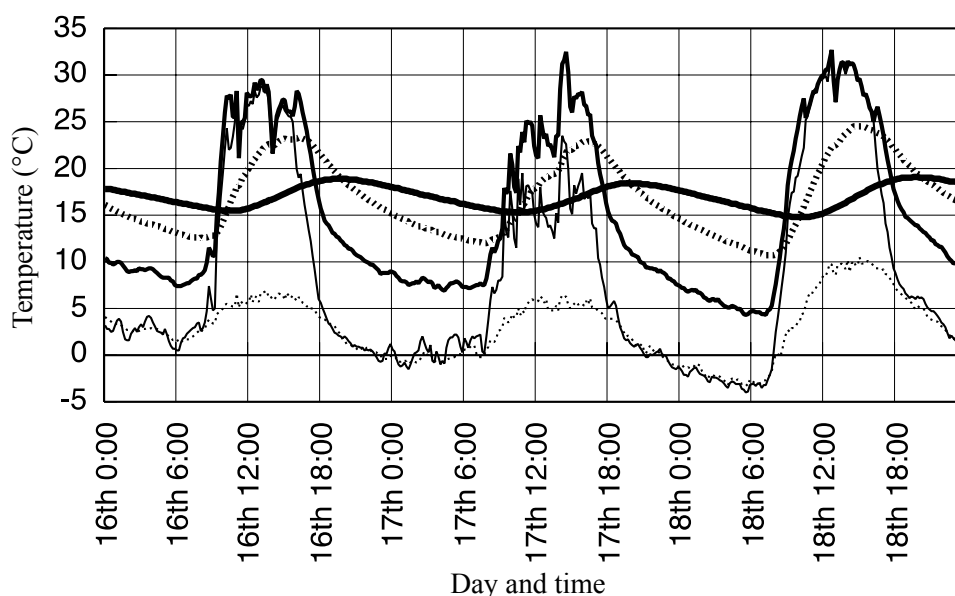


Fig. 8. Change of temperatures inside and outside the greenhouse equipped with an air-inflated double-layer curtain and heat-storage mulch (16 to 18 February, 2008) (Expt. 3)

..... Air outdoors, — Air in greenhouse (Outside curtains), — Air in greenhouse (Inside curtains),
 - - - - Soil in greenhouse (5cm below the ground), — Soil in greenhouse (15cm below the ground).

mean night air temperature and minimum air temperature inside the curtain and those outdoors were 1 to 2°C greater than those before setting the mulches, although no difference in soil temperature was observed before and after setting the mulches (Table 1). Rootstocks with mean weight of 2400 g produced marketable spears with a total of 470 g/rootstock and an average of 14 g/spear (Table 2). The proportion of marketable spear yield to rootstock weight was approximately 20% (19.4%), as high as that of December-dug rootstocks cultured in the bed with heating in Expt. 2 (Table 2).

Discussion

The results in Expt. 1 indicated the potential to extend the harvest period of older (more than 10 years old) asparagus plants as well as younger (one to two years old) plants (Mouri et al. 1995, Ikeuchi & Kobayakawa 2000) by the combined treatment of BA foliage spraying with thermal retention in PMC in Kyushu. In Expt. 2, the spear productivity of rootstocks grown in lowlands (i.e. Kurume) was less

Table 1. Night air temperature, minimum air temperature and soil temperature in the plastic greenhouse equipped with an air-inflated double-layer curtain

Term	Heat storage mulch	Mean night air temperature (°C) ^z			Minimum air temperature (°C)			Mean soil temperature (°C) ^y	
		Outdoor (A)	In curtain (B)	Difference (B-A)	Outdoor (a)	In curtain (b)	Difference (b-a)	5cm deep	15cm deep
Early Dec.	No	5.8	9.4	3.7	3.4	7.2	3.9	15.5	17.1
Mid-Dec.	No	6.2	9.6	3.4	4.3	7.8	3.5	15.6	16.9
Late Dec.	No	7.9	11.3	3.4	5.8	9.5	3.7	16.1	17.0
Early Jan.	No	4.3	9.0	4.7	1.3	6.1	4.8	15.9	16.6
	Mean	6.1	10.0	3.8	3.8	7.8	4.0	15.8	16.9
Mid-Jan.	With	6.2	11.3	5.1	3.8	8.9	5.2	16.7	17.4
Late Jan.	With	4.2	9.0	4.8	2.9	7.6	4.6	14.0	15.0
Early Feb.	With	3.2	9.5	6.3	0.8	6.3	5.5	15.7	15.9
Mid-Feb.	With	2.0	9.5	7.5	-0.6	6.6	7.2	16.7	16.8
Late Feb.	With	5.1	11.7	6.6	1.4	8.0	6.6	17.9	17.9
	Mean	4.3	10.3	6.1	1.8	7.6	5.8	16.3	16.7

^z Mean temperature from 19:00 on the previous day to 6:00.

^y Mean temperature for a whole day.

Numerals are the mean diurnal values for each term.

Measurement was carried out from 6 December, 2007 to 29 February, 2008.

Table 2. Spear productivity in FFC without heating

At digging up time		Marketable spear yield (B) (g/rootstock)	Mean spear weight (g)	B/A (%)
Rootstock weight (A) (g)	Brix of storage root (%)			
2414 ± 111 ^z	33.0 ± 0.7	467.6 ± 17.8	13.8 ± 0.4	19.4

^z Mean value ± SE (n=55 and 10 in rootstock weight and brix of storage root at digging up time, respectively, and n=2 of 15 plants in marketable spear yield and mean spear weight).

in November digging than December digging in FFC in Kyushu; perhaps due to insufficient exposure to low temperature for breaking dormancy (Koizumi et al. 2002). Spear productivity for the November digging of rootstocks was increased by growing rootstocks in the highlands (i.e. Kuju), where rootstocks were more exposed to low temperatures than in the lowlands. Therefore, the profitable FFC of asparagus from December would be possible by growing rootstocks in the Kyushu highlands. Furthermore, the results in Expt. 3 indicated that in FFC, profitable spear yield seemed to be obtained in the greenhouse without heating and with thermal retention treatment, such as the inner double-layer curtain (triple coverings) in the experiment, in the Kyushu lowlands during the earlier period than the previous report (Uchida & Takahashi 1991).

Based on the results obtained in these experiments, we could show the potential for the profitable year-round production of green asparagus without heating in Kyushu by extending the harvest period to November in PMC and

applying FCC production from December by growing rootstocks in the highlands and producing spears in a thermal-retained greenhouse in the lowlands. For asparagus, dormancy is considered induced by a certain chilling temperature in autumn in temperate regions, whereupon poor sprouting of spear is caused (Hayashi & Hiraoka 1978). It was reported that the release of the bud dormancy of asparagus depended not only on the growing temperature but also on the duration and temperature of chilling (Ku et al. 2007), while it was also reported that spears could sprout more than 23°C; regardless of the degree of dormancy of asparagus plants (Hayashi & Hiraoka 1978). Recently, environmental conditions such as autumn and winter temperatures, in which we attempted experiments to produce asparagus spears in the paper, varied by the year, so that the degree of dormancy of asparagus plants would be unstable in the seasons, particularly autumn. Therefore, further thermal retaining techniques to maintain a higher temperature should be investigated to make the production system more stable.

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