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FREEZING RESISTANCE OF JUVENILE PLANTS OF ASPARAGUS (*ASPARAGUS OFFICINALIS* L.)

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Introduction

In recent years, asparagus (*Asparagus officinalis* L.) has been grown in various areas in cold and tropical regions, especially in cold districts because of obtaining good quality, depending on its increasing demand. Asparagus plants, a perennial crop, are transplanted to field after about a year of raising seedlings, and enter into productive stage three years after the transplanting. In a cold region, such as Obihiro (in Hokkaido, Japan) where winter minimum temperature of about −30°C, little snow depth and nearly 30-cm soil freezing exist, asparagus juvenile plants sustain freezing injury and are occasionally killed. No study has been reported on freezing resistance of winter asparagus plants. In this paper, the authors describe an experimental study on freezing resistance of asparagus juvenile plants.

Materials and Methods

Plant materials used were juvenile (one-year-old) plants of asparagus (*Asparagus officinalis* L. cv. Mary Washington). The juvenile plants with scaly buds, roots, a small rhizome and no shoot were prepared by seeding (on 25 April), planting seedlings to field (on 24 june) and digging them up (on 13 December). The roots were cut into 10—12-cm lengths. Three to five plant materials were put into one plastic bag. Cooling procedures were as follows: the samples were kept at −5°C for two hours, and in that time, freezing was induced by touching the samples with small ice crystals, if no freezing occur. Then the samples were cooled stepwise to prescribed temperatures (in tables) at one-hour intervals according to the order of −5°, −10°, −15°, −20° and −25°C. Rewarming was carried out by letting them stand at 0-4°C for 24 hours. Survival and freezing injury were determined by water culture at temperatures varying from 17°C (in the night) to 28°C (in the day time). In the culture, 500-ml plastic pots containing 400-ml tap water were used, and scaly buds were close to the water surface.

Results and Discussion

In plants without freezing injury, shoots began to sprout five days after the beginning of water culture. In contrast, shoot emergence was delayed considerably in plants sustaining a little damage, while no emergence occurred in those with severe injury. Storage roots sustaining freezing injury were semitransparent and brittle immediately after the freezing treatments. Within a few days, water used for the culture became whitely cloudy in the freezing treatments at −10°, −15°, −20° and −25°C, slightly cloudy in the freezing at −5°C, and showed no change in the +4°C. As reported previously[1,3], it is considered that freezing destroys structure of cells to make semipermeability disappear and to extract the contents and electrolytes of the cells into the water. The results obtained are as follows.

Sprouting of the plants treated is shown in Table 1. In the unfreezing treatment at +4°C, all plants had more than one shoots, and the ratio of plants developing shoots was 100%. Sizable and mature scaly buds, which would develop shoots early in spring in field cultivation, showed no damage, and formed one to six shoots per plant. Small and immature shoots, requiring the longer than normal time in developing shoots in spring field, showed no freezing injury but induced no sprouting. In the treatment at −5°C, one to six shoots elongated on all plants. In this treatment, however, it was observed that some of the small scaly buds, which would sprout consecutively after the elongation of sizable buds, failed to sprout, and turned brittle due to freezing injury. In the treatment at −5°C, all of plants used had at least one shoot. In the freezing at −10°C, five of 15 plants sustained freezing injury, and failed to cause shoot growth, while the 10 other plants without injury had one to seven shoots. In this case, the shoots were fairly short, and no scaly bud sprouting was seen on the 10 plantlets due to freezing injury. On the other hand, in the treatment at −15°C,

TABLE 1. Sprouting of scaly buds on rhizomes of asparagus juvenile plants exposed to various low temperatures

Cooling temperature (°C)	No. of plants used	No. of plants sprouting shoots								Ratio to plants with shoots to plants used
		No. of shoots								
		0	1	2	3	4	5	6	7	
+ 4	15	0	1	6	1	6	0	1	0	15/15
− 5	9	0	1	2	0	3	1	2	0	9/ 9
−10	15	5	2	2	2	1	1	1	1	10/15
−15	15	13	1	0	1	0	0	0	0	2/15
−20	9	9	0	0	0	0	0	0	0	0/ 9
−25	7	7	0	0	0	0	0	0	0	0/ 7

a few scaly buds of two plants sprouted slightly to be very short shoots, whereas all scaly buds of the other plants were necrotized and putrified from freezing. In the treatments at −20° and −25°C, all buds of the plants were necrotized and deformed.

Freezing damage on storage roots are shown in Table 2. All storage roots in the treatment at +4°C were perfect. In the −5°C, roots of six plants were considerably injured, but those of three other plants had no damage. The freezing at −10°C gave considerable injury to storage roots of all plants. In the freezings at −15°, −20° and −25°C, severe injury were observed on all storage roots, and in water culture, the roots expelled their inner tissue into the solution to have only the cortical layer. In these treatments, all storage roots sustained the most severe damage.

Emergence of new storage roots on a rhizome is shown in Table 3. More than 90% of plants treated at +4°C developed new storage roots, excepting only one plant: two out of 15 plants had five new storage roots, the largest number per plant. In the −5°C and −10°C, new storage roots grew in five out of nine plants in the −5°C, and four out of 15 plants in the −10°C, though per-plant

TABLE 2. Freezing injury of roots of asparagus juvenile plants

Cooling temperature (°C)	No. of plants used	No. of plants classified according to degrees of damage of roots				Ratio of plants with roots damaged to plants used
		None	Slight	Fair	Heavily	
+ 4	15	15	0	0	0	0/15
− 5	9	3	6	0	0	6/ 9
−10	15	0	3	10	2	15/15
−15	15	0	0	0	15	15/15
−20	9	0	0	0	9	9/ 9
−25	7	0	0	0	7	7/ 7

TABLE 3. Emergence of new storage roots on asparagus juvenile plants exposed to various low temperatures

Cooling temperature (°C)	No. of plants used	No. of plants developing new storage roots							Ratio of plants with new storage roots to plants used
		No. of new storage roots							
		0	1	2	3	4	5	6	
+ 4	15	1	1	4	3	4	2	0	14/15
− 5	9	4	2	2	1	0	0	0	5/ 9
−10	15	11	2	1	0	1	0	0	4/15
−15	15	15	0	0	0	0	0	0	0/15
−20	9	9	0	0	0	0	0	0	0/ 9
−25	7	7	0	0	0	0	0	0	0/ 7

TABLE 4. Emergence of new absorbing roots on asparagus juvenile plants exposed to various low temperatures

Cooling temperature (°C)	No. of plants used	No. of plants classified according to degrees of new absorbing root emergence			Ratio of plants with new absorbing roots to plants used
		None	A few	Numerous	
+ 4	15	1	13	2	14/15
− 5	9	4	5	0	5/ 9
−10	15	13	2	0	2/15
−15	15	15	0	0	0/15
−20	9	9	0	0	0/ 9
−25	7	7	0	0	0/ 9

numbers (the largest: five) were less than those in the treatment at +4°C.

None of the new storage roots emerged in the treatments at −15°, −20° and −25°C. In addition, absorbing root formation on a storage root was observed in almost all plants in the +4°C, in more than harf the plants in the −5°C and in a few plants in the −10°C, while it was not recognized in the −15°, −20° and −25°C (Table 4).

From the results mentioned above, it is considered that asparagus juvenile plants slightly sustain freezing injury due to exposure to −5°C for one hour, and fairly, to −10°C for one hour. Concerning freezing resistance of subterranean parts of a plant, such as tubers and bulbs, SAKAI[2] investigated frost hardiness of various kinds of bulbs and tubers which were collected in the field in December, and described the following facts: anemone (*Anemone coronaria* L.) tubers could tolerate one-day freezing at −3° to −4°C and hyacinth (*Hyacinth orientalis* L.) bulbs could survive at −7°C, while ornithogalum (*Ornithogalum umbellatum* L.) bulbs showed a hardiness which allowed them to resist low temperatures of −12° to −13°C. In addition, regarding frost resistance of roots, SAKAI[2] reported that roots of Dutch iris (*Iris hollandica hort.*), hyacinth and crocus (*Crocus*) survived one-day freezing at −5°C, and ornithogalum tubers could tolerate the one-day freezing at −5°C.

In a cold district, an asparagus plant transfer substances produced in the aerial part to storage roots. TAGA *et al.*[6] described that sugars in the storage roots decreased from spring through late summer, and increased from August through October. On the other hand, SHIOMI *et al.*[4,5] clarified that asparagus plants contained various kinds of saccharides. From these facts, it is assumed that asparagus plants have a relatively high freezing resistance especially in winter, but unexpectedly, scaly buds and storage roots of asparagus did not show a high freezing resistance.

Summary

Freezing resistance of juvenile (one-year-old) asparagus (*Asparagus officinalis*

L.) plants sampled in early winter were tested by stepwise cooling down to −5°, −10°, −15°, −20° and −25°C. Shooting and rooting (storage and absorbing root emergence) were examined through water culture, and simultaneously, freezing injury of storage roots was observed. The results obtained are summarized as follows. 1. Shooting of scaly buds was observed on five out of 15 samples in the treatment at −5°C, two out of 15 at −10°C and all below −15°C. 2. Freezing injury of the storage roots was recognized in six out of nine samples at −5°C, and in all samples below −10°C. 3. Storage root emergence was obtained in treatments at −5°C and −10°C, and not in a treatment below −15°C. 4. Absorbing root development was observed in all plants in the treatment, at +4°C slightly in a few plants in the −5°C and −10°C, and completely negative in the treatments at −15°, −20° and −25°C.

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