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## STUDIES ON FLOWER BUD FORMATION OF *ASPARAGUS OFFICINALIS* L.

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### Introduction

It is known that the sex of asparagus (*Asparagus officinalis* L.), is genetically determined by a pair of sex chromosomes<sup>1,2)</sup>. A female is homozygous (mm), a male is heterozygous (Mm) and a supermale, artificially bred, is found homozygous (MM)<sup>3,4,5)</sup>. The female flower consists of a well-developed pistil and vestigial stamens, and the male flower has six developed stamens<sup>6)</sup>. In addition, male flowers can be classified into five types by the size and developmental limit of a pistil<sup>7,8,9)</sup>. At an extremely low frequency, hermaphrodite flowers, which genotypically are males with a matured ovule, can be found out in male plants growing in the field.

Various trials of obtaining a group including male plants alone have been carried out using the male plants with a hermaphrodite flowers, because in asparagus cultivation a male plant has higher productivity than a female plant<sup>4,10,11,12)</sup>.

Morphologically or genetically, little attention has been given to flower bud formation because *Asparagus officinalis* L. is not a fruit vegetable.

However, detailed works on the onset and process of flower bud formation should be required to establish breeding systems of cultivation methods.

In this study, the authors intended to classify morphologically the flower bud formation process and to examine the relationship between vegetative growth (spear growth) and reproductive growth (flower bud formation).

### Materials and Methods

*Flower bud development at various growth stages of spears.* Spears were collected from Experimental Farm of Hokkaido University and microscopically dissected to observe the development of flower buds. Developmental stages of flower buds were classified into 5 categories, which had indices corresponding to the categories. An average growth index of flower bud in a spear was calculated. The length of spears were measured and the total number of flower buds on a spear were counted.

*Onset of flower bud formation.* On 11 November 1988 and 30 March and 13 April 1989, an asparagus subterranean part was dug up and the buds which were dormant or grew 1-1.5 cm in length, were collected from the crown. For the observation of the onset of flower bud formation, those buds were fixed with formalin-acetate alcohol (FAA), dehydrated, and embedded in paraplast. Sections were stained with hematoxylin.

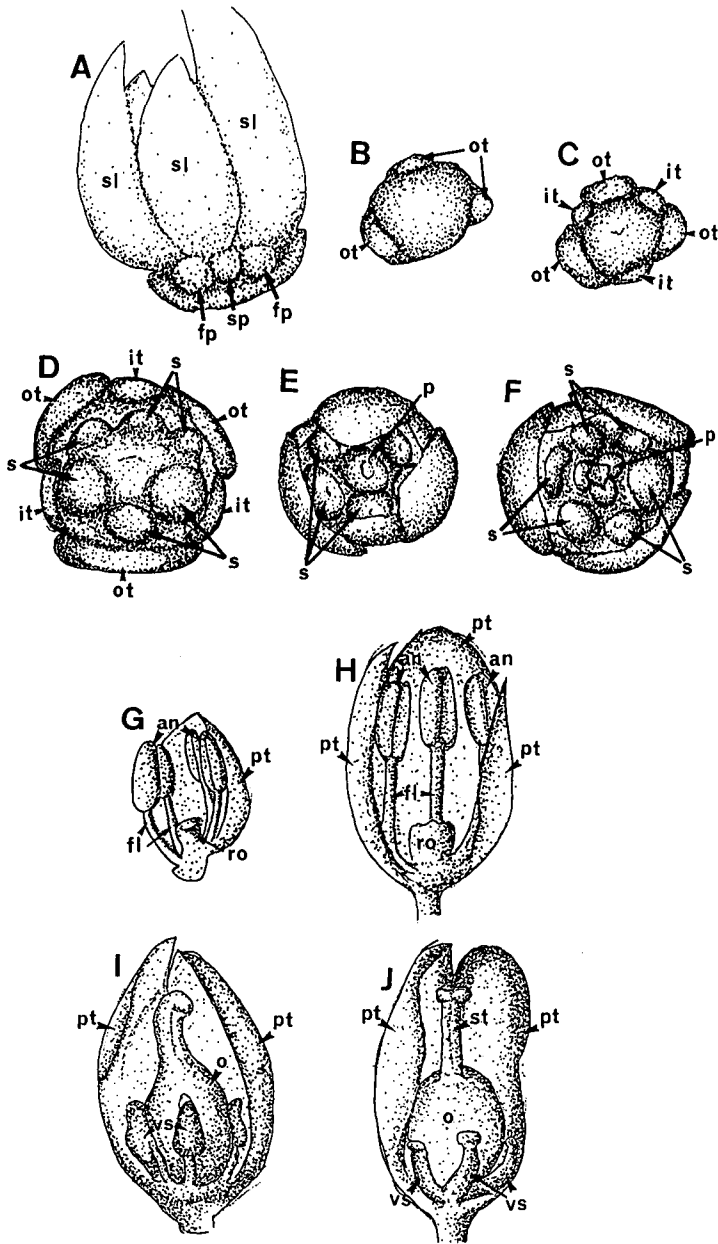
### Results

*Flower bud development at various growth stages of spears.* Formations of both male and female flowers of asparagus could be classified into 5 developmental stages through microscopical observation. (1) Domed primordium stage : three domed primordia were formed in a line between the bases of scale leaves. At the stage, it could not be distinguished that the center primordium would develop into lateral shoot and the other primordia into a flower bud (Fig. 1-A). (2) Outer tepal-forming stage : top of the flower bud became slightly flat, and three portions of stage of the primordium remain upheaved, forming outer tepals (Fig. 1-B). (3) Inner tepal-forming stage : Inner tepals appeared slightly inside between outer tepals (Fig. 1-C), and an inner stamen was formed inside an outer tepal, and an outer stamen was formed inside the outer tepals. At this stage, a flower bud had 6 tepals and 6 stamen primordia (Fig. 1-D). (4) Pistil-forming stage : a domed pistil primordium arose in the central part of the flowers (Fig. 1-E). Three parts were divided on a pistil, resulting in three grooves that generated on surface of the pistil (Fig. 1-F). A definite difference between anatomical structures of male and female flowers were not recognized before this stage. (5) Flower bud-developing stage : Characteristics of male and female flower began to appear at this stage. At the early developmental stage of flower bud (approximately 1 cm in length), in male flower, anthers and filaments started to differentiate from the stamen primordium, whereas a pistil developed extremely slowly and stopped growth at primary stage of its developmental process (Fig. 1-G, H). On the other hand, in female flowers, a pistil grew vigorously, and then a style elongated, while the stamen development was inhibited (Fig. 1-I, J). When the flower bud length reached more than 2 mm, morphological differences between male and female flowers became clear. The pistil in the male flower and the stamens in the female flower remained at the primary stage of their developmental process.

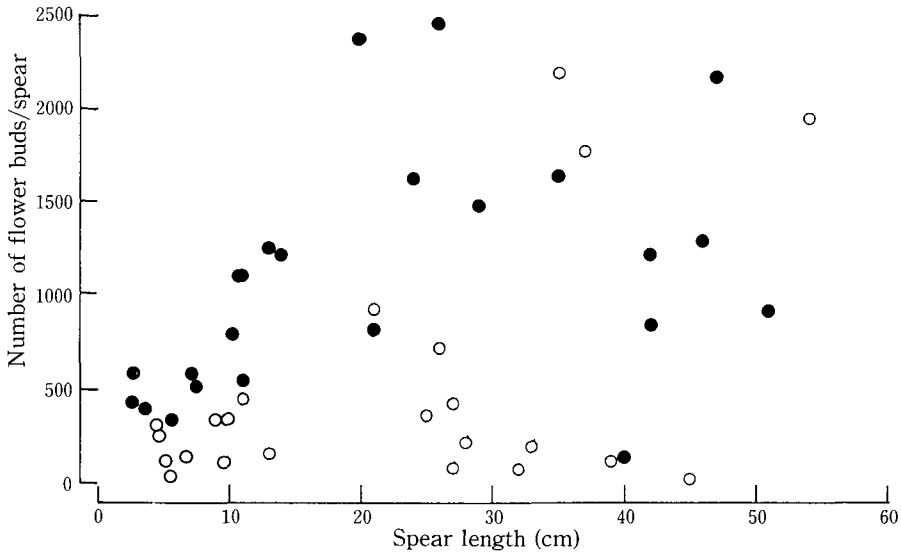
The total number of flower buds in a spear of male plants were more than those in the female, regardless of the spear length (Fig. 2.).

The average value of flower bud growth index increased with the increase of the spear length. An average of flower bud growth indices in the female plant was a little higher than that in the male (Fig. 3.).

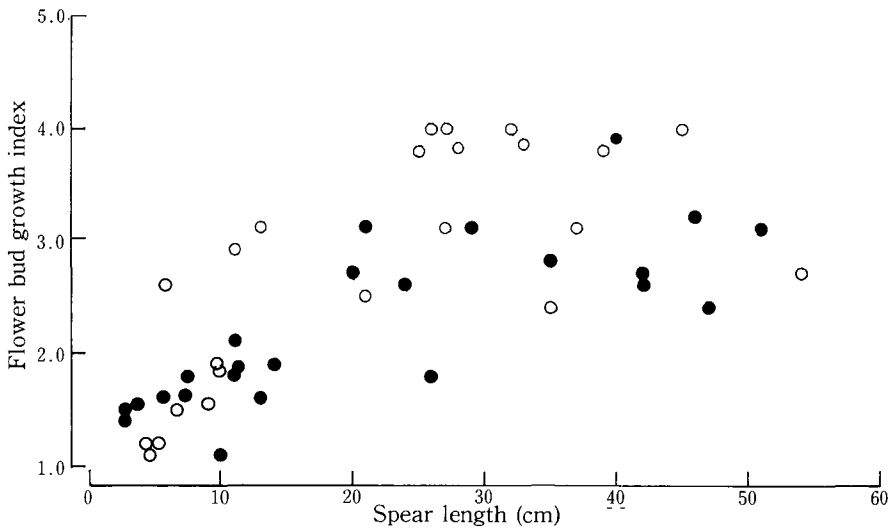
*Onset of flower bud formation.* No flower bud were formed in the new buds which had not elongated (Fig. 4-A). The new buds were obtained from 11 November through 30 March. Flower bud initiation was observed at the base of



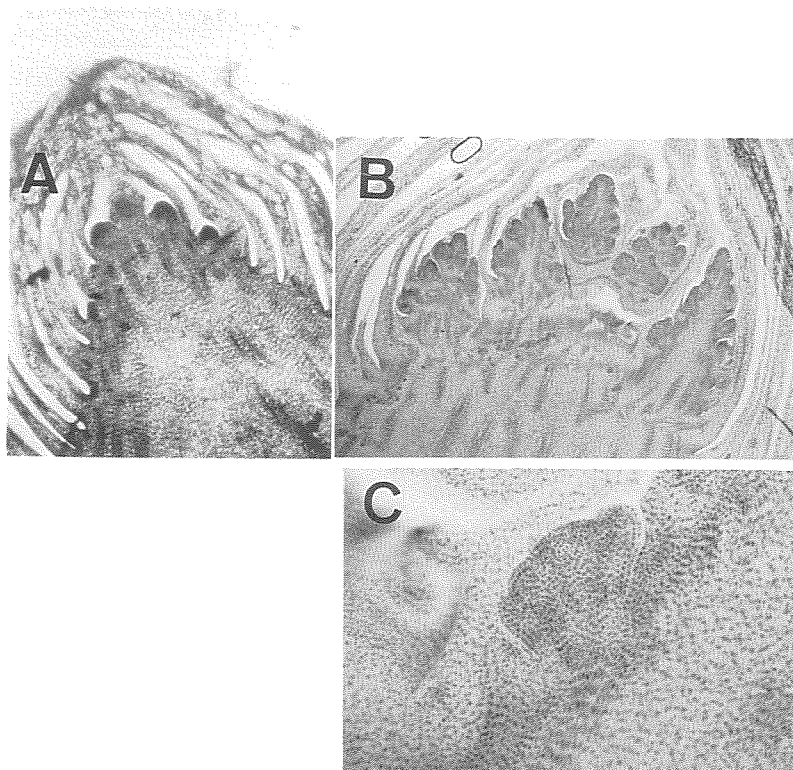
**Fig. 1.** Illustrations of the flower bud formation in *Asparagus officinalis* L. A-F, developmental stages of asparagus flower; G, H, subsequent stages of male flower; I, J, subsequent stages of female flower; sl, scale leaf; fp, flower primordium; sp, stem primordium; ot, outer tepal; it, inner tepal; s, stamen; p, pistil; an, anther; fl, filament; ro, rudimentary ovary; pt, petal; vs, vestigial stamen; st, style; o, ovary.



**Fig. 2.** Relationship between flower bud number and spear length in asparagus (cv. Mary Washington 500W).  
 ○, female flower bud ; ●, male flower bud.



**Fig. 3.** Relationship between flower bud growth index and spear length in asparagus (cv. Mary Washington 500W).  
 ○, female flower bud ; ●, male flower bud.  
 1, domed primordium stage ; 2, outer tepal-forming stage;  
 3, inner tepal-forming stage ; 4, pistil-forming stage ;  
 5, flower bud-developing stage.



**Fig. 4.** Longitudinal sections of crown-formed bud derived from the rhizome.  
A : crown-formed bud before growing.  
B : crown-formed bud immediately after onset of growth.  
C : magnification of flower buds formed.

lateral bud inside new buds whose length reached 1 to 1.5 cm (Fig. 4-B, C).

### Discussion

In the present experiments the flower induction process from flower bud initiation to flowering was observed microscopically, and the original of flower organ formation was clarified.

The fact that the morphological differences between male and female have not been recognized before the onset of pistil formation agreed with that of Lenitsky<sup>13)</sup>. After that, the differences between male and female flowers became microscopically observable. Lazarte et al. obtained the same results and explained that the result was due to the difference in vascular bundle formation of the male and female plants<sup>14)</sup>.

In this study, it was also revealed that flower bud formation started nearly at the time of lateral shoot primordium formation. But the physiological mechanism of the flower bud initiation has not been clarified.

It is known that average number of female flowers per female plant were less than that of the male. The phenomenon may indicate that the difference between number of the female flowers and that of the male flowers can be recognized at earlier stage of the spear growth (less than 10 cm in length).

Flower bud growth index in the female plant was higher than that in the male plant before flowering (less than 60 cm in spear length.) However, in the whole plant, male flowers appear on the stalk and the branches earlier than female flowers. To explain these phenomena consistently, it may be possible to predict that flower bud growth indices of the male plant scatter wider than those of the female. Further researches on the scatter of the flower growth indices in both the male plants and the female plants per spear should be required.

It was revealed that the flower bud formation started at the same time of the onset of crown-formed bud growth and that it was synchronized. This is clarified by recognizing the flower bud formations in the juvenile crown-formed bud (1–1.5 cm in length) and not in the new crown-formed bud (small dormant bud). Some juvenile crown-formed buds which contain young flower buds may overwinter and grow in next spring.

### Summary

Histological observation of the flower bud formation process in asparagus (*Asparagus officinalis* L.) was carried out microscopically. Developmental process of the flower bud formation were classified into 5 stages : domed primordium stage, outer tepal-forming stage, inner tepal-forming stage, pistil-forming stage and flower bud-developing stage. Before pistil-forming stage, no morphological difference in flower bud structure existed between male and female flowers.

Flower bud formation started approximately at the time of the onset of lateral shoot primordium formation, and subsequently was synchronized. The number of flower buds in one spear of a male plant was more than that of the female. It is already known that total number of flowers per adult stalk in the male plant is more than that in the female. From the results of the present research, the difference was recognized between the younger spears (less than 10 cm in length) of the male and female. On a spear before flowering, flower bud growth index in the male plant was a little higher than that in the female. Further researches on the scatter of the flower bud growth index per spear in the male plant and the female plant should be attempted.

It was clarified that the differentiation of flower buds did not occur before the growth onset of the bud on rhizome, but began at the same time of the bud growth onset and was gradually synchronized. It is suggested that the flower buds in the spear bud (especially in spear) that has stopped its growth before winter may overwinter and start to grow in the next season.

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