Simultaneous growth of pods and seeds set on different racemes in soybean

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Abstract

Soybean flowers continue to open for a long period but the pods mature simultaneously. The developmental differences of pods and seeds between early- and late-opened flowers are not well known. We investigated the timing of growth beginning of pods and seeds set on different raceme orders with different flowering time in soybean. Soybean plants were grown in a greenhouse in 2001 and in the field in 2003 in Kyushu University, Fukuoka of Japan. Soybean pods grew very slowly after flower opened whereas the pods of other three legumes (common bean, azuki bean and mung bean) started to elongate immediately after flower opened. In soybean, the pods that opened earlier started to elongate later, leading to uniform development of the pods that opened at different dates. The similar phenomenon was observed in seed growth but it seemed to be more pronounced in pod elongation than seed growth.

Media summary

The earlier a flower opens, the slower the pod develops. This regulation leads to the uniform pod maturation in whole plant of soybean.

Key words

Flowering, Pod growth, Raceme order, Seed growth, Soybean, Uniform maturation.

Introduction

The period of reproductive growth (from the start of flowering to maturation) in soybean is very long compared with that in cereals. The pod shells in soybean develop after flowering, whereas the husks in rice or wheat, those function is the same as that of pod shell in soybean, are formed before flowering. Therefore, the seed filling begins about four weeks after flowering in soybean (Konno, 1976), but about one week after flowering in rice or wheat (Sofield et al., 1977; Chowdhury and Wardlaw, 1978). However, in some legumes, such as mung bean, cowpea and common bean, the period from flowering to maturation is also shorter than that in soybean (Egli, 1998).

Several studies documented that the pod growth is very slow after flowering in soybean. Zheng et al. (2003) found that the lag period of pod growth is much longer in the flowers that opened early. On the other hand, Saitoh et al. (1998) indicated that the delay of pod growth is much longer in the low order racemes (early opening flowers) and is reduced in high order racemes (late opening flowers). These results suggest that the timing of pod growth plays a role in the regulation of synchronous pod maturation in soybean. However, there are no further observations focused on it. The understanding of this function may be helpful to improve the production of other legumes, such as cowpea, mung bean and common bean.

In this study, we investigated the timing of pod and seed growth on individual raceme order that opened the flower at different time.

Materials and Methods

Experiment 1. Soybean (cv. Fukuyutaka, determinate type) and the other three legumes (common bean, mung bean and azuki bean) were grown in a greenhouse (pot experiment) in 2001 at Kyushu University, Fukuoka of Japan. Paddy soil mixed with 5 g compound fertilizer (N:P2O5:K2O = 3:10:10) and 3 g lime were compacted in a plastic pot (4 L in volume) before sowing. After emergence, one plant per pot was allowed to grow. When the flower began opening, 20 – 50 flowers opened on the same day and same raceme order were labeled with a tag of 8 X 12 mm in size. In order to get high possibility of pod set, only one or two flowers per raceme were used. According to Torigoe et al (1982), we divided the raceme order as primary raceme, terminal raceme, secondary raceme, sub-branch raceme and tertiary raceme by the order of flower opening. The lengths of pods developed from labeled flowers were measured every other day.

Experiment 2. A soybean cultivar Fukuyutaka was grown in the field of Kyushu University in 2003 with 60cm X 15cm spacing. After the plants began flowering, about 200 flowers opened on the same day and same raceme order were labeled with a paper tag of 8 X 12 mm in size. After the pods reached full size, 10 pods (two seeds pod only) from each raceme order were sampled and dried in an oven at 90 ^{o}C for 2 days and then the seeds were weighed.

Results

Fig. 1 shows the changes with the lapse of time of pod length after flower opening in four legumes. The pod growth was obviously slow in soybean compared with that in the other three crops. Soybean pods reached the maximum length about 25 days after flower opening against 7 days in mung bean, and 10 days in azuki bean and common bean.

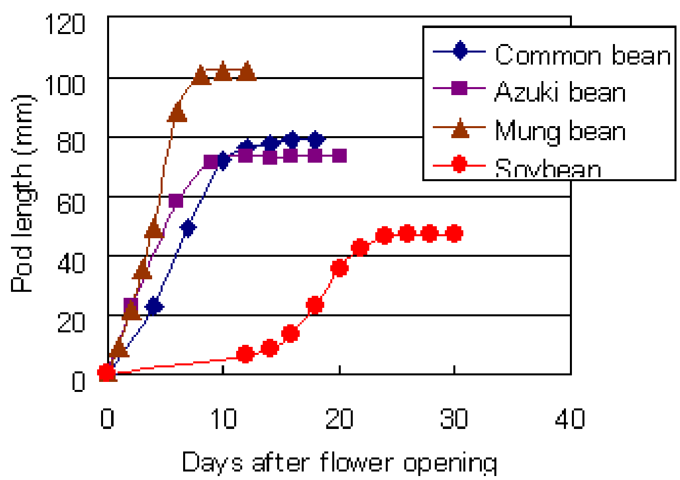

Fig. 1. Comparison of pod growth among four crops.

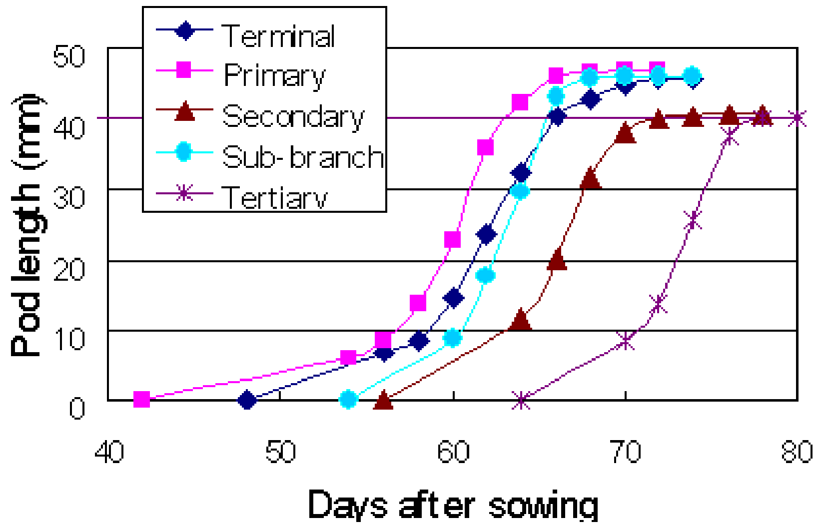

Fig. 2. Changes in the pod length among different raceme orders in soybean. The plots on the horizontal axis show the day after sowing.

Fig. 2 shows the pod growth after flowering on individual raceme. The flowers opened first on primary raceme on 42 DAS (days after sowing), then followed by terminal raceme (5 days late), sub-branch raceme (12 days late), secondary raceme (14 days late) and tertiary raceme (22 days late). However, the delay observed at flowering time seemed to be shortened at the phase of pod elongation.

In order to evaluate the developmental difference in pod growth among the raceme orders, in Table 1, we described a linear equation on individual raceme between the pod length and DAS during the linear phase of pod elongation based on Fig.2. As a result, the DAS for the pod reached at 20 cm in length was 59.2 on primary raceme, but was 72.7 on tertiary raceme. The difference between two raceme orders was 13.5 days and it was shorter than the difference at flowering time (22 days). Same results were also observed on terminal, sub-branch and secondary racemes.

Table 1. Linear equation between pod length (Y) and days after sowing (X) on the individual raceme.

Raceme	Equation	R2	X(Y=20)	Delay(days)
Primary	Y = 4.9633X- 274.05	0.985	59.2	0.0
Terminal	Y = 4.3177X- 244.31	0.999	61.2	2.0
Sub-branch	Y = 5.7542X- 337.66	0.991	62.2	3.0
Secondary	Y = 4.5563X- 279.80	0.988	65.8	6.6
Tertiary	Y = 4.9500X- 340.10	0.971	72.7	13.5

By the same procedure, the seed growth on individual raceme is shown in Fig. 3 and the linear equation between seed weight and DAS is shown in Table 2. The seed growth on individual raceme, especially on primary, terminal, sub-branch and secondary racemes became to be proceeded almost at same time, but is a little late on tertiary raceme. Therefore, the delay of seed growth on the racemes opened the flower late was shorter than those of pod growth, such as it was reduced to 3.1 against 6.6 in the pod growth on secondary raceme and was reduced to 12.0 against 13.5 in the pod growth on tertiary raceme. However, the overtaking of pod and seed growth in late opening flower was more dramatic during pod elongation more than seed growth.

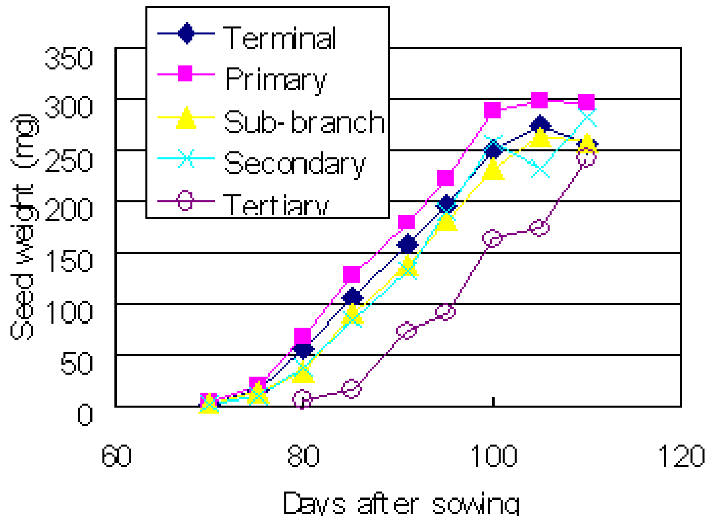

Fig. 3. Changes in the seed weight among different raceme orders in soybean.

Discussion

Since more than 2/3 of vegetative organs develop after the start of flowering in soybean (Shimada et al., 1990; Asanuma et al., 1991; Baba et al., 2003), slow development in the pods set on the flowers that opened early is considered to be caused by the competition for assimilate between reproductive and vegetative organs after the start of flowering (Brun and Betts, 1984). It also indicates that the vegetative growth is more preceded than reproductive growth at that stage. Zheng et al (2003) have found that the pod growth is stimulated by short photoperiod after flower opened but is not by sink removal (removing all flowers and stem tops except the target flowers) and benzyl adenine application. However, what factors limit the assimilate proportion between vegetative and reproductive organs is unknown.

Table 2. Linear equation between seed weight (Y) and days after sowing (X) on the individual raceme.

Raceme	Equation	R2	X (Y=100)	Delay (days)
Primary	Y = 10.545X - 773.8	0.995	82.7	0.0
Terminal	Y = 9.3753X - 691.63	0.998	84.4	1.7
Sub-branch	Y = 8.9927X - 673.22	0.989	86.0	3.3
Secondary	Y = 9.8645X - 745.91	0.977	85.8	3.1
Tertiary	Y = 8.7954X - 732.92	0.976	94.7	12.0

Conclusion

In soybean , the earlier a flower opens, the slower the pod and seed develop. This regulation could cause the uniform pod maturation in whole plants. The elucidation of its mechanism would be very helpful for the improvement of other leguminous crops production.

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