Pod Dehiscence in Relation to Pod Position and Moisture Content in Soybean

Jutamas Romkaew¹, Teruhisa Umezaki¹, Kenya Suzuki² and Yuichi Nagaya¹

¹Graduate School of Bioresources, Mie University, 1577 Kurimamachiya-cho, Tsu, Mie 514-8507, Japan;
²Faculty of Bioresources, Mie University, 1577 Kurimamachiya-cho, Tsu, Mie 514-8507, Japan

Abstract: The relationship between pod dehiscence and the position and moisture content of pods was examined in two soybean cultivars, Fukuyutaka and Keito-daizu. The frequency of pod dehiscence at different parts of the stem was assessed by the strain-gauge method. Pods of the two cultivars were categorized into indehiscent, dehiscent (dehisced by the strain-gauge method) and naturally dehiscent pods. The moisture content of pods was measured after drying in a hot-air oven at 105±1°C for 24 hrs. In both Fukuyutaka and Keito-daizu, the pods at maturity were not dehisced at any part of the stem due to the high moisture content of pods. After maturity, the frequency of pod dehiscence at the upper part of the stem increased as the moisture content of pods decreased in both Fukuyutaka and Keito-daizu. A similar tendency was observed in both the field and the pot experiments. The frequency of pod dehiscence was higher at the upper part of the stem and increased as the moisture content of pods decreased.

Key words: Moisture content, Pod dehiscence, Pod position, Soybean, Strain gauge method.

The growth characteristics of soybean [Glycine max (L.) Merr.] were divided into two types: determinate and indeterminate. The vegetative activity decreases during the initiation of inflorescence in the determinate type but it continues in the indeterminate type. Although the determinate type performs shorter in flowering period than the indeterminate type (Yoshida et al., 1983; Gai et al., 1984; Foley et al., 1986; Kuroda et al., 1998; Zheng et al., 2005; Egli, 2005), its flowering period is longer than 20 days (Hansen and Shibles, 1978; Gai et al., 1984; Umezaki et al., 1988; Yokoyama et al., 1989; Dybing, 1994). The length of flowering period affects the variation in the pod maturity and moisture content in the plant.

Based on the stem characters, branching habit and pod setting, the determinate type soybean is classified into two subtypes, normal and fasciated. In the normal subtype, flowering occurs progressively upward along the main stem, flower development and stem growth occur simultaneously at different locations on the stem (Spaeth and Sinclair, 1984). The fasciation is characterized by abnormal growth, affecting to all parts of the plant, but is commonly exhibited in the stem. The fasciated stems become expanded or ribbon-like and tend to be wavy and linear (White, 1945; Lamotte et al., 1988). The flowers in the fasciated subtype are clustered at the top of the stem resulting in the formation of crowded pods (Wongyai et al., 1984; Leyser and Furner, 1992; Leffel et al., 1993). Seventy percent of the pods are located at the top of the main stem in fasciated soybean (Wongyai et al., 1984). The soybean fasciation trait is controlled by a single recessive gene (White, 1945; Albertsen et al., 1983; Wongyai et al., 1984; Leffel et al., 1993; Tang and Skorupska, 1997). In both normal and fasciated subtypes of determinate-type soybeans, the flowering duration is shorter than that in the indeterminate type (Yoshida et al., 1983; Foley et al., 1986; Saitoh et al., 1998). Wongyai et al. (1984) reported that in Fukuoka, Japan, the fasciated soybean ‘Keito-daizu’ showed flowering and maturity similar to those of a normal-type soybean ‘Fukuyutaka’.

In previous experiments, we clarified that pod dehiscence was determined by the moisture content of pod and categorized soybean cultivars into two groups as susceptible and resistant to dehiscence by the desiccator method (Romkaew and Umezaki, 2006). There are some differences in moisture content of pod among the pods set at different positions on the stem. Consequently, this experiment was conducted to clarify the relationship between pod position and moisture content of pod in relation to pod dehiscence in soybean.

Materials and Methods

Two determinate-type soybean cultivars, ‘Fukuyutaka’ and ‘Keito-daizu’ were planted in the field and pots. The field experiment was conducted at Mie University. Three seeds per hill were sown on July 8, 2005, at 20 cm spacing in a row of approximately 3 m long with 70 cm row spacing. The seedlings were thinned to one seedling per hill at two weeks after sowing.
fertilizer (N:P₂O₅:K₂O =3:10:10) at 100 g m⁻² and CaCO₃ at 100 g m⁻² were applied as basal dressing. This experiment was carried out under normal climatic conditions.

In the pot experiment, six seeds were sown per pot in a 1/2000 a Wagner pot on July 3, 2005, and the seedlings were thinned to one seedling per pot two weeks after sowing. Compound fertilizer (N:P₂O₅:K₂O =3:10:10) 8 g per pot and 5 g of CaCO₃ were applied as basal dressing.

In the field experiment, the pods of Fukuyutaka were sampled from 5 plants on Oct. 30, Nov. 13 and Dec. 12, in 2005. The pods of Keito-daizu were evaluated on Oct. 24, Nov. 2 and Dec. 12, in 2005. For the pot experiment, the pods of Fukuyutaka were sampled from 3 pots on Nov. 8 and on Nov. 20, in 2005. The pods of Keito-daizu were sampled from 3 pots on Nov. 10 and on Nov. 20, in 2005.

The emergence date was recorded to determine the number of days from sowing to 50% emergence. The flowering date was monitored measuring the number of days from sowing to 50% flowering and maturing date the day after sowing to maturity, when 95% of pods turning brown or black. The locations of the first flower and pod were observed in 15 plants from each cultivar grown in the field experiment and in all plants in the pot experiment. The first pod was defined as the pod that reached 10 mm in length first.

The pod dehiscence characters were assessed by the strain-gauge method. Thirty pods, each containing two seeds, were used. The force required to separate the valves of pod at the septum was considered to be less than 1 kg weight. A single pod was set on the fixed base, pressed with a bar connected to the strain gauge and cracked at less than 1 kg pressure, by which some pods indehiscent. Then the numbers of dehiscent (dehisced by the strain-gauge method), indehiscent and naturally dehiscent pods were counted. The moisture content of pods was measured after drying in a hot air oven at 105±1°C for 24 hrs. The percentage of dehiscent pods and moisture content of pods were investigated after dividing the main stem of Fukuyutaka into three parts; lower (from cotyledonary node to the 6th node), middle (from the 7th node to 12th node) and upper (above the 12th node) parts. In Keito-daizu, the cluster at the top of the stem was divided into two parts; lower and upper part. The top of the stem in Keito-daizu usually bended in various angles. The top of the cluster on the stem which bended perpendicular to ground, less than 45°, was regarded as the upper part, whereas the top of cluster on the stem which bended more than 135° was regarded as the lower part. The cluster on the stem which bended to 90±45° divided into two parts with the axis.

Results and Discussion

Fig. 1 shows the average temperature, relative humidity and the amount of rainfall during the experiment from July to December 2005 conducted at Tsu in Mie Prefecture. The average temperature, relative humidity and weekly rainfall during the vegetative stage were 27.3°C, 70.9% and 21.1 mm, respectively. Fukuyutaka and Keito-daizu grown in the field flowered on Aug. 17 and Aug. 23, respectively, and those grown in pots on Aug. 13 and Aug. 15, respectively. The pods of two cultivars were harvested from late-October to mid-December. The average temperature, relative humidity and weekly rainfall from maturity to harvesting were 11.8°C, 59.6% and 5.1 mm, respectively. It was assumed that the low relative humidity during harvesting decreased the moisture content of pod. The pods of the two cultivars were harvested from late-October to mid-December. The average temperature, relative humidity and weekly rainfall from maturity to harvesting were 11.8°C, 59.6% and 5.1 mm, respectively. It was assumed that the low relative humidity during harvesting decreased the moisture content of pod. The pods of the two cultivars were harvested from late-October to mid-December. The average temperature, relative humidity and weekly rainfall from maturity to harvesting were 11.8°C, 59.6% and 5.1 mm, respectively.

Fig. 2 shows the morphological characteristics and growth habits of Fukuyutaka and Keito-daizu. Fukuyutaka had few if any branches, and a flattened stem but Fukuyutaka produced 3 to 5 heavy branches. The pods of Fukuyutaka were distributed evenly along the
main stem and its branches, but more than 70% were concentrated at the top of the stem in Keito-daizu pods (Wongyai et al., 1984). Table 1 shows the date of emergence, flowering, maturing, the position of the first flower, the position of the first pod and the number of nodes on the main stem in Fukuyutaka and Keito-daizu grown in the field. Fukuyutaka and Keito-daizu were slightly different in emergence, flowering and maturing dates.

Table 1. Dates of emergence, flowering, maturing, the position of the first flower, the position of the first pod and number of nodes on the main stem in Fukuyutaka and Keito-daizu grown in the field.

| Cultivars   | Emergence date | Flowering date | Maturing date | Position of the first flower | Position of the first pod | Number of nodes on the main stem |
|-------------|----------------|----------------|---------------|-----------------------------|----------------------------|----------------------------------|
| Fukuyutaka | July 13 (5)    | Aug. 17 (40)   | Oct. 28 (112) | The 9th, 10th or 11th node on the main stem | The 9th, 10th or 11th node on the main stem | 15-17                           |
| Keito-daizu | July 12 (4)    | Aug. 23 (46)   | Oct. 24 (108) | The bottom of cluster at the top of the main stem | The bottom of cluster at the top of the main stem | —                               |

Sowing date: July 8, 2005. Values in parentheses indicate the number of days after sowing.

Table 2. Total number of pods, degree of pod dehiscence and moisture content of pod in Fukuyutaka and Keito-daizu grown in the field.

| Cultivars   | Time of observation | Parts of stem or cluster | Number of pods | Percentage of pod | Moisture content of pod (%) |
|-------------|---------------------|--------------------------|---------------|------------------|----------------------------|
|             |                     | Indehiscent Dehiscent Naturally dehiscent | Indehiscent Dehiscent Naturally dehiscent | Indehiscent Dehiscent Naturally dehiscent |
| Fukuyutaka | Maturity            | Lower 32 0 0             | 22.1 0 0      | 15.9             | *                          |
|             |                     | Middle 44 0 0            | 30.3 0 0      | 13.3             | *                          |
|             |                     | Upper 59 10 0            | 40.7 6.9 0    | 12.1             | 10.5 *                      |
|             |                     | Total 135 10 0           | 93.1 6.9 0    | 12.9             | 10.5 *                      |
|             | 16DAM               | Lower 46 0 0             | 33.1 0 0      | 12.7             | *                          |
|             |                     | Middle 45 0 0            | 32.5 0 0      | 13.2             | *                          |
|             |                     | Upper 45 3 0             | 32.4 2.0 0    | 13.5             | 11.6 *                      |
|             |                     | Total 136 3 0            | 98.0 2.0 0    | 13.1             | 11.6 *                      |
|             | 45DAM               | Lower 9 22 0             | 6.2 15.1 0    | 10.3             | 10.2 *                      |
|             |                     | Middle 24 24 0           | 16.6 16.6 0   | 10.5             | 9.4 *                       |
|             |                     | Upper 17 47 2            | 11.7 32.4 1.4 | 10.9             | 10.4 10.0                   |
|             |                     | Total 50 93 2            | 34.5 64.1 1.4 | 10.6             | 10.1 10.0                   |
| Keito-daizu | Maturity            | Lower 15 5 0             | 38.5 12.8 0   | 10.7             | 8.4 *                       |
|             |                     | Upper 14 5 0             | 35.9 12.8 0   | 12.0             | 10.9 *                      |
|             |                     | Total 29 10 0            | 74.4 25.6 0   | 11.3             | 9.7 *                       |
|             | 9DAM                | Lower 39 3 0             | 50.6 3.9 0    | 12.2             | 8.7 *                       |
|             |                     | Upper 23 7 5             | 29.9 9.1 6.5  | 10.9             | 9.2 8.0                     |
|             |                     | Total 62 10 5            | 80.5 13.0 6.5 | 11.7             | 9.0 8.0                     |
|             | 49DAM               | Lower 1 24 6             | 1.2 28.9 7.2  | 10.5             | 8.7 8.6                     |
|             |                     | Upper 0 31 21            | 0 37.3 25.4   | *                | 8.5 8.3                     |
|             |                     | Total 1 55 27            | 1.2 66.2 32.6 | 10.5             | 8.6 8.4                     |

*no indehiscent, dehiscent and naturally dehiscent pods.
DAM, days after maturity.
and 109 days after sowing, respectively.

The first flower appeared at the 9th, 10th or 11th node on the main stem in Fukuyutaka, which had 15 to 17 nodes on the main stem. The flowering nodes expanded from the first flowering node. The first pod was observed at the position of the first flower. In contrast, the first flower and the first pod on the fasciated plant Keito-daizu were at the bottom of the cluster (Table 1). In other words, the flowering position expanded from the bottom to the top of the cluster. Flowering of cultivated and wild-type plants proceeded from the basal order racemes to the upper order racemes (Saitoh, et al., 2004). Torigoe et al. (1982) reported that there was a regularity in the developing pattern of primary raceme from the bottom to the top of the main stem in normal determinate soybean 'Tachisuzunari'. The first flower opened at the lowest node without a primary branch on the main stem.

Table 2 shows the total number of sample pods, the frequency of pod dehiscence and moisture content of pods in Fukuyutaka and Keito-daizu grown in the field. The pods counted in this experiment were flawless each containing two seeds, and were classified into three types, indehiscent, dehiscent (dehisced by the strain-gauge method) and naturally dehiscent pods. They were also divided into three or two groups depending on the position on the main stem, lower, middle and upper parts in Fukuyutaka and lower and upper parts in Keito-daizu.

In Fukuyutaka, most of the pods were indehiscent and only a few of them in the upper part were dehiscent at maturity and 16 days after maturity (Table 2). Naturally dehiscent pods were not observed within 16 days after maturity. At 45 days after maturity, however, 64.1% of the pods were dehiscent and 1.4% were naturally dehiscent. The percentage of dehiscent pods was higher at the upper part than the lower part of the stem. On the other hand, the moisture content of dehiscent pods was lower than that of indehiscent pods and higher than that of naturally dehiscent pods, irrespective of the position of the pods on the stem and the date of observation (Table 2).

In Keito-daizu also, 25% of the pods were dehiscent at maturity, and 6.5 and 32.6% of the pods were naturally dehiscent at 9 and 49 days after maturity, respectively. The values are clearly higher than those in Fukuyutaka. However, the moisture content of dehiscent pods was lower than that of indehiscent pods and higher than that of naturally dehiscent pods and the pattern of pod dehiscence and moisture content of pods were similar to those in Fukuyutaka, at any date observed.

Table 3 shows the dates of emergence, flowering, maturing, the position of the first flower, the position of the first pod and number of nodes on the main stem in Fukuyutaka and Keito-daizu grown in the pot.

| Cultivars      | Emergence date | Flowering date | Maturing date | Position of the first flower | Position of the first pod | Number of nodes on the main stem |
|----------------|----------------|----------------|---------------|-------------------------------|----------------------------|----------------------------------|
| Fukuyutaka    | July 7 (4)     | Aug. 13 (41)   | Nov. 8 (128)  | The 10th or 11th node on the main stem | 10th or 11th node on the main stem and 1st or 2nd node on the branch from 8th node | 14-16 |
| Keito-daizu    | July 7 (4)     | Aug. 15 (44)   | Nov. 9 (129)  | The bottom of cluster at the top of the main stem | The bottom of cluster at the top of the main stem | — |

Sowing date: July 3, 2005, Values in parentheses indicate the number of days after sowing.

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Table 4. Total number of pods, degree of pod dehiscence and moisture content of pod in Fukuyutaka and Keito-daizu grown in the pot.

| Cultivars | Time of observation | Parts of stem or cluster | Number of pods | Percentage of pod | Moisture content of pod (%) |
|-----------|---------------------|--------------------------|----------------|------------------|-----------------------------|
|           |                     |                          | Indehiscent     | Dehiscent        | Naturally dehiscent          | Indehiscent | Dehiscent | Naturally dehiscent | Indehiscent | Dehiscent | Naturally dehiscent |
| Fukuyutaka Maturity | Lower                | 16                       | 0              | 0                | 22.2                        | 0           | 0         | 21.7              | *           | *         | *                   |
|           | Middle              | 26                       | 1              | 0                | 36.1                        | 1.4         | 0         | 15.7              | 10.8        | *         | *                   |
|           | Upper               | 21                       | 8              | 0                | 29.2                        | 11.1        | 0         | 12.5              | 13.2        | *         | *                   |
|           | Total               | 63                       | 9              | 0                | 87.5                        | 12.5        | 0         | 16.2              | 12.9        | *         | *                   |
|           | 11DAM               | Lower                | 8              | 10               | 9.8                         | 12.2        | 0         | 11.1              | 9.9         | *         | *                   |
|           | Middle              | 7                       | 7              | 0                | 8.5                         | 8.5         | 0         | 11.1              | 10.3        | *         | *                   |
|           | Upper               | 16                      | 31             | 3                | 19.5                        | 37.8        | 3.7       | 10.9              | 9.8         | 8.6       |                     |
|           | Total               | 31                      | 48             | 3                | 37.8                        | 58.9        | 3.7       | 11.0              | 9.9         | 8.6       |                     |
| Keito-daizu Maturity | Lower               | 17                       | 2              | 0                | 35.4                        | 4.2         | 0         | 11.9              | 9.5         | *         | *                   |
|           | Upper               | 25                      | 4              | 0                | 52.1                        | 8.3         | 0         | 10.1              | 10.5        | *         | *                   |
|           | Total               | 42                      | 6              | 0                | 87.5                        | 12.5        | 0         | 10.8              | 10.2        | *         | *                   |
|           | 12DAM               | Lower                | 18                       | 4                | 1                           | 36.0        | 8.0       | 2.0               | 9.4         | 9.3       | 8.5                   |
|           | Upper               | 12                      | 14             | 1                | 24.0                        | 28.0        | 2.0       | 8.9               | 8.8         | 9.7       |                     |
|           | Total               | 30                      | 18             | 2                | 60.0                        | 36.0        | 4.0       | 9.2               | 8.9         | 9.1       |                     |

*no indehiscent, dehiscent and naturally dehiscent pods.

DAM, days after maturity.

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