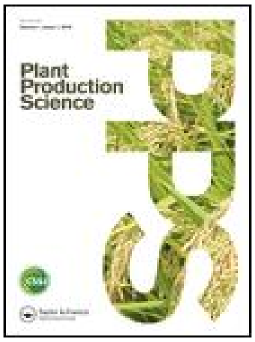

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Varietal difference of soybean plant type focus on petiole

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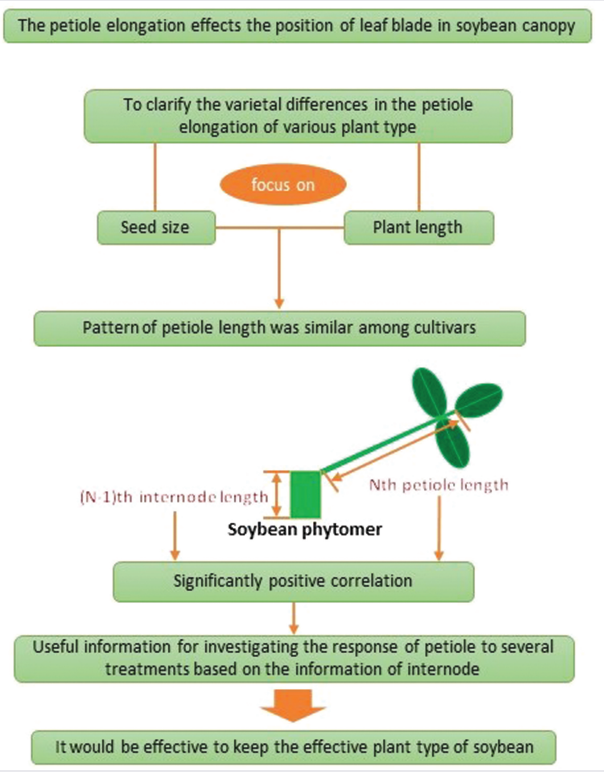
ABSTRACT

It is very important to keep the effective canopy structure in soybean from flowering to seed developing period. The petiole elongation effects the position of leaf blade in canopy. In order to clarify the varietal differences in the petiole elongation characteristics in soybean, the eleven determinate growth type soybean cultivars were used. The first trifoliolate leaf on the main stem was the shortest and longer at upper position, while uppermost 2nd–4th petiole was the longest among all the petioles. The number of leaves on the main stem and the position of the longest petiole varied among cultivars with different seed size and stem length, but there was no difference in the pattern of petiole length. The pattern of petiole length and that of internode length on the main stem appear to be similar. So, the relationship between the *N*th petiole length and the (*N*-1)th internode length belong to the same phytomer were investigated. Each cultivar showed significantly positive correlation between the *N*th petiole length and the (*N*-1)th internode length. This result indicated that the elongation pattern of petiole is similar to that of internode irrespective of cultivar. By investigating the response of petioles to physical and chemical treatments based on the information of internode, the positioning of leaf blade could be controlled more efficiently. It would be possible to modify plant type of soybean with these informations.



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Soybean is one of the most important crops in Japan like rice but soybean seed yield is lower than rice. Average rice yield is 529 t ha^{-1} and soybean yield is 144 t ha^{-1} in Japan in 2018 (MAFF, 2018). One of the limiting factors of soybean yield is poor light interception by canopy. Leaf blades of rice are erect and long and narrow, light penetrate to the lower layer of the canopy (Tsunoda, 1959). But soybean leaflets grow densely in the upper layers of the canopy, and these restricts light penetration into the lower layers. In general, leaf erectness is regarded as an important agronomic trait for high yield because there is a liner relationship between the inclination angle of the leaf blade and the canopy light extinction coefficient (Soda et al., 2010). Kokubun and Watanabe (1981) reported that the improvement of light-intercepting characteristics by making the upper leaves erect, yield up to about 10% under high density in a narrow row spacing condition. On the other hand, Sagawa (1983) indicated the unimportance of inclination angle of petiole, which affect that of leaflets strongly in soybean plants, because the effect of artificial control of petiole angle on seed yield was small. It is necessary for the improvement of light-intercepting characteristics not only to control inclination angle of petiole and leaflet but also to arrange place leaflet position in the various layers of the canopy.

The leaflet position in the soybean canopy would be associated with the lengths of internodes and petioles in each layer mainly. In the main stem, the synchronization of internode elongation and leaf emergence, the effects of plant hormones and environmental factors on internode elongation have been reported (Torigoe et al., 1980; T. Umezaki, 1991; T. Umezaki & Matsumoto, 1989a, 1990; T. Umezaki et al., 1991a, 1991b; T. Umezaki & Yoshida, 1992). In the branch, the factors affecting the elongation and regularity of emergence are reported (Oizumi, 1962; Torigoe et al., 1980). In the petiole, synchronization of petiole elongation and leaf emergence, elongation process, and pattern of final length have been reported (Nakaseko et al., 1979; Ohashi et al., 2019; Oizumi, 1962; Torigoe et al., 1980; T. Umezaki, 1990).

There are varietal differences in the plant type (Isoda et al., 1996; Nagasuga et al., 2011; Nakaseko et al., 1979; Ookawa et al., 1999), and it is also classified by the main stem length, the number of branches, the ratio of seed number to seed size (100 seeds weight) (Matsumoto & Umezaki, 1987; Watanabe et al., 1975). On the other T. Umezaki and Matsumoto (1989a, 1989b)) reported that there was no difference among varieties regarding the synchronization of internode elongation and the pattern of the final length on the main stem. It is important for the arrangements of leaflet positions in the canopy to clarify both the mechanism of petiole elongation and the varietal differences. However, there is no report on the varietal difference in the elongation characteristics of the petiole involved in the final determination of the plant type. This study was conducted to clarify the varietal differences in the petiole elongation characteristics in soybean.

Materials and methods

Plant cultivation

The eleven determinate growth type soybean cultivars, Fukuyutaka, Yahagi, Yahagi-dwarf line, Hyuga, Hyuga-dwarf line, Misato-zairai No.14, Nattoshoryu, Kosuzu, Suzuotome, Kosamame, and Tamahomare were used to evaluate the varietal difference of soybean plant type. Hyuga-dwarf line is a dwarf mutant induced from cultivar Hyuga by the ethylene-imine treatment (T. Umezaki, Matsuo et al., 1988). Misato-zairai No. 14 is a line selected by pure line separation from Misato-zairai local variety in Mie Prefecture, and has a large 100 seeds weight and a relatively small amount of vegetative growth compared to Misato-zairai (Nose et al., 2013). This experiments were conducted at the Experimental Field of Mie University from 2013 to 2018. Four seeds per hill were sown on 3 July in 2013, 2014, 2016, 2017, 2018, and 14 July in 2015 with 70 cm between rows and 20 cm spacing between plants within a row. The plot for each cultivar consisted of four rows with 3 m long in each row. Seedlings were thinned to two plants per hill on seven days after sowing, and to one plant per hill on 14 days after sowing. Chemical fertilizer was applied at a rate of 3:10:10 g m^{-2} of N:P_2O_5:K_2O before sowing, and 100 g m^{-2} of calcium carbonate was also applied at the same time.

Measurement of growth

Seven plants of each cultivar were selected and all petioles on the main stem were marked. The final length of petiole was measured after defoliation. After the harvested plants had been air-dried, the final length of internode on the main stem was measured. The internode order, expressed 1, 2, and the number (N) more than 3, indicates the internode between cotyledon and primary leaf nodes, primary leaf and the first trifoliolate leaf nodes, and (N-2)th and (N-1)th trifoliolate leaf nodes, respectively.

Results and discussion

The final length of petiole on the main stem are shown in Figure 1. The petiole length of Yahagi-dwarf line was

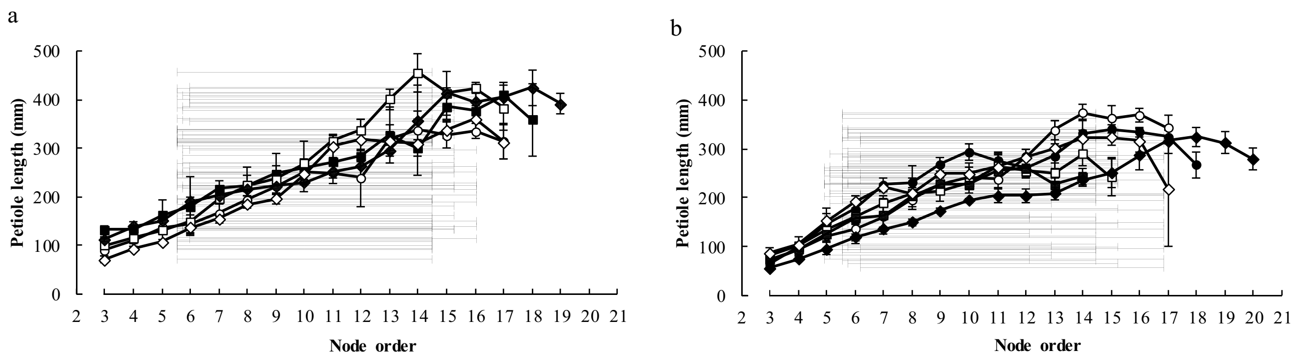

Figure 1. (a) Final petiole length on 2017. (b) Final petiole length on 2016.

smaller than Yahagi in the leaves on lower position and larger than Yahagi in middle and upper leaves. The petiole length of Hyuga-dwarf line was smaller than Hyuga except middle leaves (Figure 1a). The number of leaves on the main stem and the position of the longest petiole varied among cultivars with different 100-seed weight, but there was no difference in the pattern of the final length of petiole (Figure 1b). Figure 2 shows the final length of petiole on the main stem in each year. The number of leaves on the main stem and the position of the longest petiole varied with year, but there was no difference in the pattern of the final length of petiole. The first trifoliolate leaf petiole was the shortest and longer at upper position, while uppermost 2nd–4th petiole was the longest among all the petioles in each cultivar. The same tendency was reported (Nakaseko et al., 1979; Ohashi et al., 2019; Torigoe et al., 1980; T. Umezaki, 1990). Although the number of node on the main stem and the position of the longest petiole varied with cultivar and year, the pattern of final length of petiole on the main stem was similar.

The final length of internode on the main stem are shown in Figure 3. In both Yahagi and Hyuga, the internode length of the dwarf line was smaller than that of the normal line respectively (Figure 3a). The number of leaves on the main stem and the position of the longest internode varied among cultivars with different 100-seed weight, but there was no difference in the pattern of the final length of internode (Figure 3b). Figure 4 shows the final length of internode on the main stem in each year. The third internode was the shortest and longer at upper position, while uppermost 2nd–4th internode was the longest among all the internodes in each year. The same tendency was reported (Ohashi et al., 2019; Torigoe et al., 1980; T. Umezaki & Matsumoto, 1989a). The number of nodes on the main stem and the position of the longest internode varied with year, but there was no difference in the pattern of the final length of internode. The similar results were reported by T. Umezaki and Matsumoto (1989b).

The pattern of final length of petiole and that of internode on the main stem appear to be similar. The Nth petiole and the (*N*-1)th internode belong to the same phytomer, and the growth of both is thought to be closely related. So, the relationship between the *N*th petiole length and the (*N*-1)th internode length are shown in Figure 5. The phytomer with large petiole length had large internode length and positive correlation was observed between the *N*th petiole length and

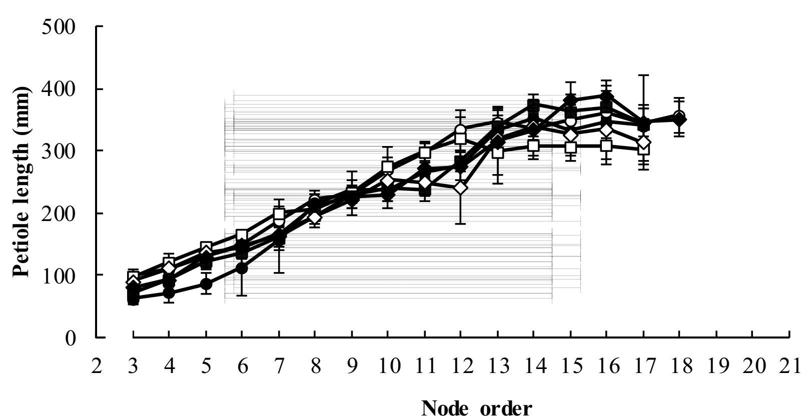

Figure 2. Final petiole length of Fukuyutaka.

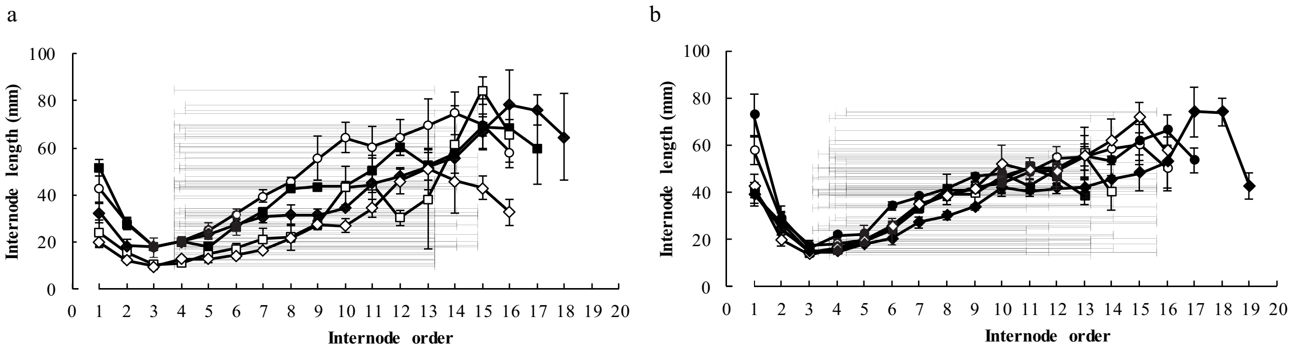

Figure 3. (a) Final internode length on 2017. (b) Final internode length on 2016.

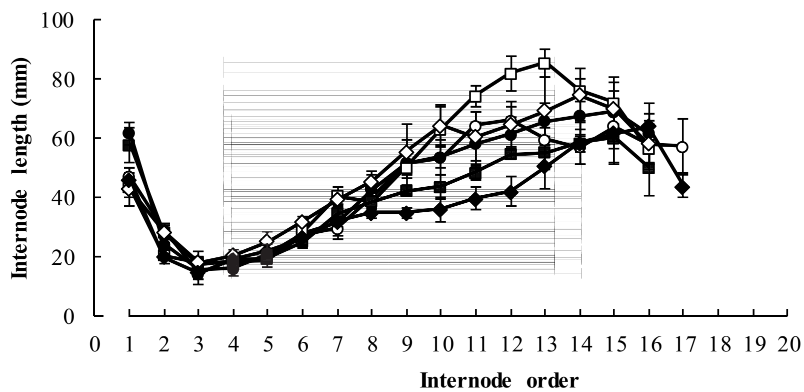

Figure 4. Final internode length of Fukuyutaka.

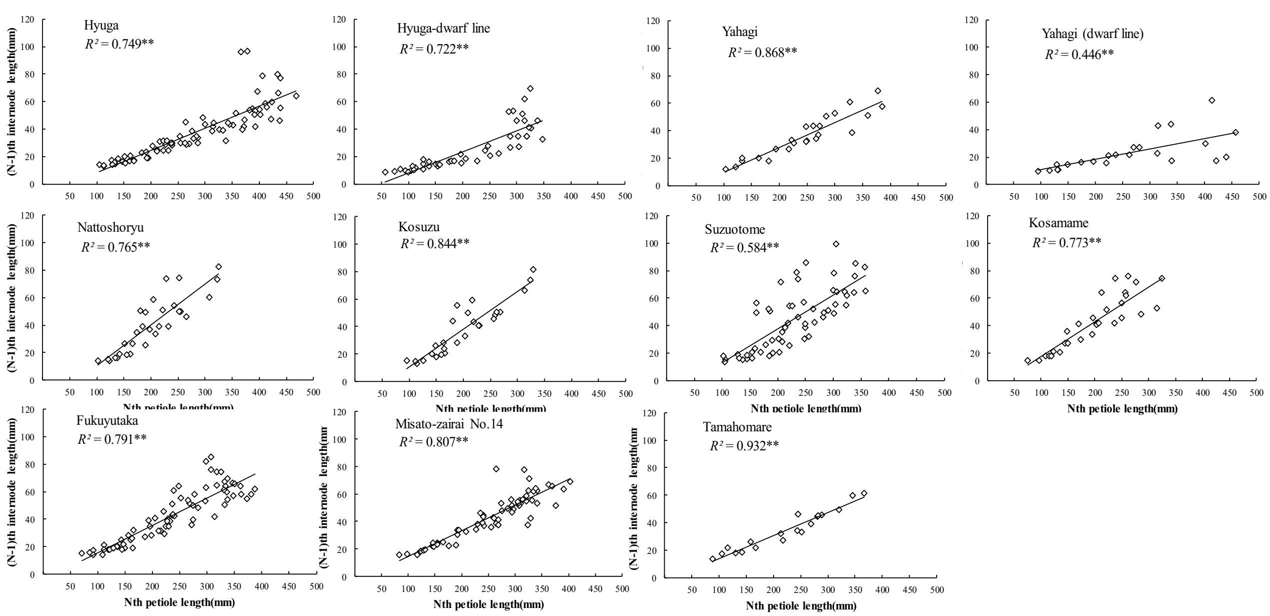

Figure 5. Relationship between the *N*th petiole length and the (*N*-1)th internode length.

the (*N*-1)th internode length (Ohashi et al., 2019). In this study, it was also showed significantly positive correlation between the *N*th petiole length and the (*N*-1)th internode length in each cultivar. This result indicated that the pattern of final length of petiole are similar to that of internode irrespective of cultivar.

In this study, it was clarified that there is no varietal difference in the elongation characteristics of petioles on the main stem and the relation between the *N*th petiole length and the (*N*-1)th internode length belonging to the same phytomer. The internodes on the main stem in soybean have been investigated in detail for elongation characteristics, response to physical and chemical treatments, and varietal differences (Torigoe et al., 1980; T. Umezaki, 1991; T. Umezaki & Matsumoto, 1989a, 1989b, 1990; T. Umezaki et al., 1991a, 1991b; T. Umezaki & Yoshida, 1992). It is the most important result of this study that the same petiole elongation patterns which we reported in previous paper (Ohashi et al., 2019), were observed in many soybean varieties widely. In order to modify the plant type practically, it is important to control the petiole length and the petiole direction that the angle between petiole and stem. One of the authors reported the relationship between water condition and inclination angles of leaflets and petioles (Nagasuga et al., 2013) and further research is planned in the future.

On the other hand, Katayama (1951) reported the synchronization between leaf emergence of main calm and branching in rice plant and wheat. This information is important for controlling ear number through fertilizer dressing methods, and improved grain yield effectively. On pulse crops, nodules work to cover the effect of fertilizer dressing, but increasing phytomers per unit area by fertilization, increase the yields as same as other crops. In addition, one of the authors tried to increase soybean yield by using dwarf lines that are composed of small phytomers, and reported early sowing with/by high density were effective on the yield of soybean dwarf lines (T. Umezaki, Matsumoto et al., 1988; T. Umezaki et al., 1987). So it is important to arrange phytomers effectively not only as the source but also as the sink. By investigating the response of petioles to physical and chemical treatments based on the information of internode, the light-intercepting characteristics can be controlled more efficiently through improving phytomer arrangement. It would be possible to modify plant type of soybean with these informations.

Disclosure statement

No potential conflict of interest was reported by the authors.

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