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Variations in Patterns of Stolon Elongation and Ground Surface Covering of Zoysia japonica Steud.

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Abstract
In regard to the abilities of Zoysia japonica Steud. in elongating stolons and covering a ground surface, some investigations were made on the materials collected from various locations in Japan. The results indicate that there exist large variations in both abilities, which are also varied by environmental conditions. Total length of stolons were about twice in a year and 90 times in two years as compared with that at planting. However, there were great variations in stolon elongation among the populations collected from various parts of Japan. Those variations in total length were different each other between the following two practices: one was a whole-sod planting and the other was planting of pieces taken from stolons. In the year of planting, the stolons did not rapidly cover a ground surface. Each population showed its specific pattern of coverage of a ground surface in accordance with the distance from the center and with the growing seasons. The 10 populations studied were divided into three groups based on the degree of spreading of stolons and covering of a ground surface. The degree of covering was significantly affected by planting methods. On the basis of those patterns, the populations tasted were divided into four groups.

Discipline: Grassland
Additional key words: growth pattern, lawn grass, transplanting method, turf

Zoysia japonica Steud. is one of the native species in Japan, which has been used as forage for grazing cattle in native grasslands and lawns in parks and gardens. It distributes throughout the country except in northern Hokkaido. It is found that the northern boundary of habitats of this species is the central part of the Hokkaido island[1,8].

This species has various ecotypes in terms of its morphology. Kitamura[3] reviewed the information on genus *Zoysia* in Japan, concluding that the major species were *Z. japonica* Steud., *Z. matrella* (L.) Merr. and *Z. tenuifolia* Willd. On the basis of a comparative study on morphological aspects of those three species, Honda[2] identified some differences of *Z. japonica* from *Z. matrella* and *Z. tenuifolia* in morphology of limb, leaf sheath, erect stem, stolon and other tissues. Yamada[5] reported that there were variations in peroxidase isozyme contents in *Z. japonica*.

A series of experiments were undertaken to examine variations in morphology of *Z. japonica* collected from various locations of Japan. The results indicate that there exist wide variations in abilities of spreading stolons and covering a ground surface. This paper presents summarized results of those studies[4,6,7].

Variations in patterns of stolon elongation among the populations

1) Elongation of stolons in the first year of planting

One of the characteristics of *Z. japonica* is that it propagates by spreading its stolons rather than seeds. In order to examine patterns of initial elongation after planting, the following experiment was conducted: forty-four populations were made available for the study; they had been raised for lawns in enclosed plots (1 × 1 m each) for more than five

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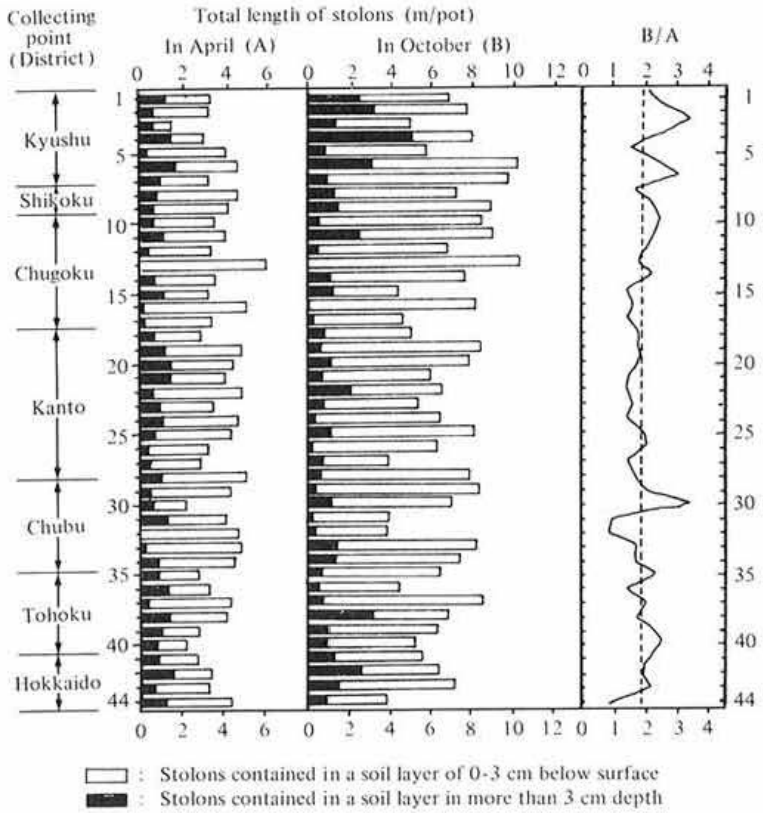

Fig. 1. Variations in total length of stolons of *Z. japonica* in April (A) and in October (B), and ratio of B to A
A: Total length of stolons contained in a sod (10 × 10 × 10 cm) before planting.
B: Total length of stolons contained in a sod in six months after planting.

years after planting. In April, before the plant growth became active, a sod (10 × 10 × 10 cm) of *Z. japonica* was cut out from the enclosed plot of each population and transplanted to the pot of 1/2000 a in size.

Total length of the stolons contained in the sod at the planting time was 3.84 m on an average of the 44 populations, ranging from 1.16 m to 6.13 m. This indicates that there is a potential for causing a fairly great variation in total length of stolons among the populations at the stage, in which a lawn has been established completely.

The experimental pots were located outside for six months until October, when *Z. japonica* stopped elongating stolons. The total length of stolons per pot in October reached 6.89 m on an average; the increment during the six-month period was 3.05 m, being 1.87 times as long as that in April. The greatest increase among the 44 populations was 6.52 m long per pot during that period. The least one was loss of 0.86 m long due to a serious damage caused by cutting in April. As shown in Fig. 1, there is a considerable variation in patterns of stolon elongation of *Z. japonica*. It was larger than variations in increases of weight of stolons and other tissues, which were also measured in the same period.

The length of stolons contained in a soil layer of 0–3 cm depth was measured separately from that in more than 3 cm depth. The ratio of stolon lengths in these two parts varied among the populations under study.

2) Elongation of stolons in the second year of planting

Another set of experiment was undertaken to examine patterns of stolon elongation in the second year. Ten populations were selected out of the 44 populations above. A *Zoysia* sod (10 × 10 × 15 cm) of each population was transplanted at the center of the experimental plot (2 × 2 m) in April. Measurements were taken in December in the following year after planting, when *Zoysia* grasses had already stopped growing up.

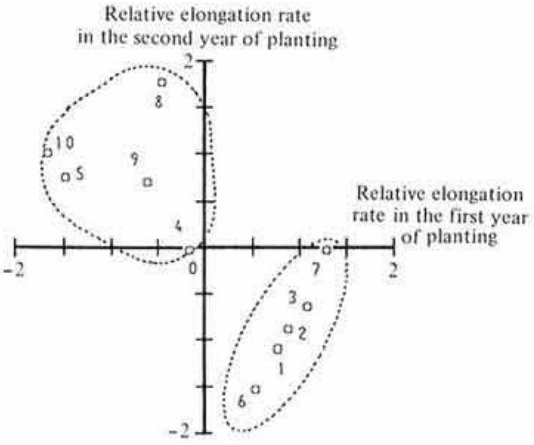

Fig. 2. Relative elongation rates of 10 populations of *Z. japonica* in the first and second years of planting
Numbers in the figure: Refer to the note in Table 1.

Table 1. Length and thickness of an internode of *Z. japonica* in September

No.	Collecting point (Prefecture)	Length (cm)	Thickness (mm)
1	Kagoshima	3.19	2.15
2	Kagawa	3.77	1.56
3	Hiroshima	4.06	1.68
4	Shimane	5.08	1.54
5	Nagano	3.94	1.89
6	Yamanashi	4.78	1.73
7	Aomori	4.10	1.64
8	Tochigi	4.45	1.65
9	Iwate	4.78	1.86
10	Hokkaido	4.21	1.73
	Mean	4.23	1.74
	S.D.	0.52	0.17

Total length of stolons per plot in December of the second year was 361.8 m on an average, ranging from 230.1 to 576.1 m. The average length of the 10 populations was 4.02 m at the planting time, the increment during the two-year period was about 90 times as long as that at the initial stage.

From the comparative analyses of the increments between the first and second years, the populations examined are divided into two groups as follows (Fig. 2): A; the stolon elongation was relatively good in the planting year, but not so good in the second year, and B; although the elongation was not so good in the first year, relatively good in the second year. Such a separation might have been caused by different responses of the respective populations to the damages given at the initial stage of growth.

3) Differences in stolon elongation between the two planting methods

In comparing abilities of stolon elongation among the populations, two planting methods were employed: one was to plant a sod of *Z. japonica* as a mass, and the other was to plant pieces of stolons separated from a sod.

The population collected in Hiroshima Prefecture showed a total length of stolons of 412.4 m per plot when planted by the former method, while it was 464.3 m in the latter method. There was a few other cases which indicated some differences in the total length between those two methods. In particular, a great difference took place in the population collected in Kagoshima Prefecture; i.e. 252.2 m and 500.9 m in the former and the latter method, respectively. On the contrary, the population collected in Tochigi Prefecture presented 576.7 and 392.6 m, respectively; this trend was opposite to the results obtained in the population collected in Kagoshima.

4) Length of internodes in Z. japonica

As shown in Table 1, the length of internodes on an average was 4.23 ± 0.52 cm. This character showed a relatively small variation as compared with those in total length of stolons. This implies that the variations in total length of stolons among the populations depend not on the length of internodes but on the increase in nodes.

Patterns of spreading stolons and covering a ground surface

1) Changes in patterns of covering a ground surface with Z. japonica

In the experiment extended to the second year, investigations on the coverage of a ground surface by the plants were made, by using experimental plots (2 × 2 m each), each of which was divided into 400 meshes. One mesh covered an area of 100 cm^2 (10 × 10 cm). State of the coverage in each mesh was classified into three, A, B and C, as follows: state A; complete lawn, state B; lawn (some bare parts could be identified), and state C; no lawn (the number of stolons could only be counted). The number of stolons in a mesh was counted in case of the state C.

Some results of those investigations are shown in Table 2 and Fig. 3, indicating an example of the population collected in Tochigi Prefecture. In April in the following year of planting, the longest stolon reached the point which was 1.4 m distant from

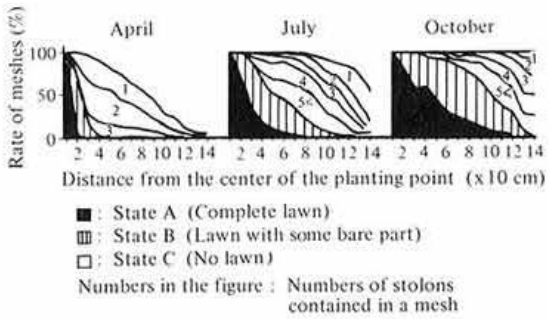

Fig. 3. Changes in growth patterns of *Z. japonica* expressed in percentage of meshes holding given number of stolons[a)]
a): Based on the data obtained in the second year of planting of *Z. japonica* population collected in Tochigi Prefecture.

Table 2. Changes in growth patterns of *Z. japonica* expressed in percentage or number of meshes covered by lawn or stolons[a)]

	Growth pattern[b)]	Distance from the center of the planting point (× 10 cm)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
April	Rate of meshes holding stolons (%)	100.0	100.0	95.8	89.9	80.6	74.5	63.0	54.2	43.5	28.1	22.6	8.3	5.0	4.2
	Rate of meshes of the states A and B (%)	100.0	72.9	15.3	1.2	–	–	–	–	–	–	–	–	–	–
	Rate of meshes of the state C (%)	–	27.1	80.6	88.7	80.6	74.5	63.0	54.2	43.5	28.1	22.6	8.3	5.0	4.2
	Number of stolons in a mesh	–	1.4	1.8	1.8	1.8	1.7	1.8	1.8	1.6	1.6	1.3	1.3	1.5	1.0
July	Rate of meshes holding stolons (%)	100.0	100.0	100.0	100.0	100.0	100.0	98.6	87.9	95.1	91.2	86.3	82.6	74.2	54.2
	Rate of meshes of the states A and B (%)	100.0	100.0	88.9	67.9	51.4	44.9	34.3	21.2	12.5	5.6	2.2	0.7	–	–
	Rate of meshes of the state C (%)	–	–	11.1	32.1	48.6	55.1	64.4	77.7	82.6	85.6	84.1	81.9	74.2	54.2
	Number of stolons in a mesh	–	–	3.6	4.0	4.1	4.3	4.3	4.2	4.0	3.4	3.3	2.7	2.1	1.8
October	Rate of meshes holding stolons (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Rate of meshes of the states A and B (%)	100.0	100.0	97.2	95.2	91.7	90.7	83.3	75.8	66.7	49.7	36.3	27.8	6.7	–
	Rate of meshes of the state C (%)	–	–	2.8	4.8	8.3	9.3	16.7	24.2	33.3	50.3	63.7	72.2	93.3	100.0
	Number of stolons in a mesh	–	–	4.0	3.3	5.3	4.6	5.1	5.3	5.4	5.3	5.2	4.7	4.3	3.3

a): Based on the data obtained in the second year of planting of *Z. japonica* population collected in Tochigi Prefecture.
b): States A, B and C: Complete lawn, lawn, and no lawn, respectively.

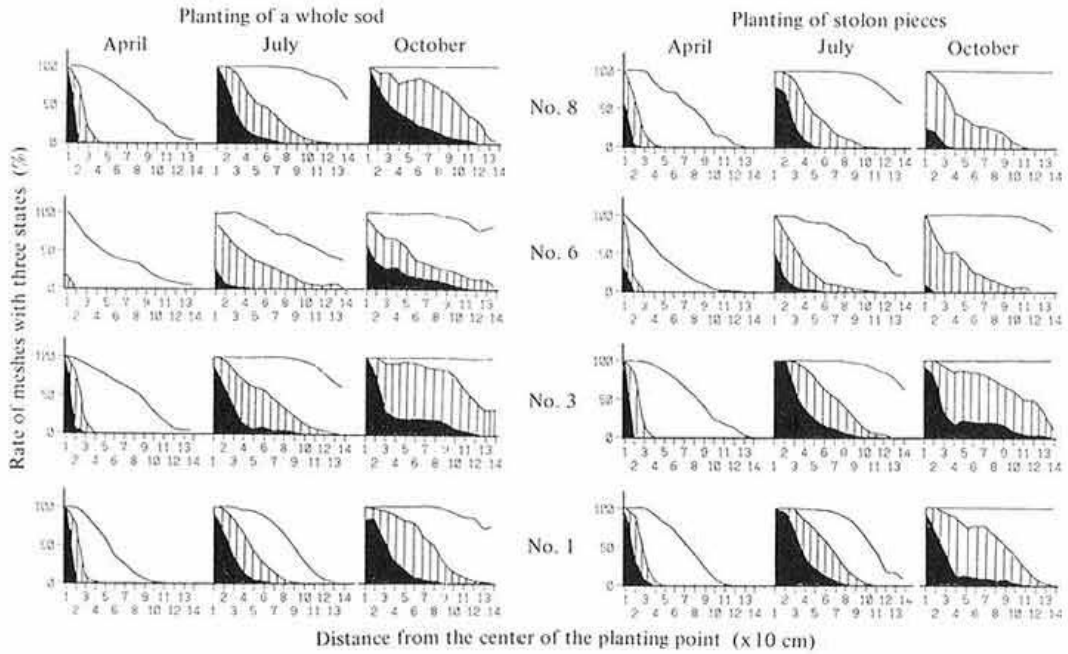

Fig. 4. Changes in growth patterns of *Z. japonica* under the two planting methods
Nos. 1, 3, 6 and 8: Populations collected in Kagoshima, Hiroshima, Yamanashi, and Tochigi Prefectures, respectively.
Markings: Refer to the note in Fig. 3.

the center of the experimental plot, whereas the numbers of stolons in each mesh were rather small. The furthest mesh which was classified in the state B existed in 40 cm distant from the center. This result shows that the stolons of *Z. japonica* did not rapidly cover the ground surface in the year of planting, accordingly.

In July of the second year, the stolons covered a half of the meshes 1.4 m distant from the center, and the states A and B spread in the meshes 70 and 120 cm distant from the center, respectively.

In October, every mesh within the radius of 1.4 m contained stolons: the average number of stolons in a mesh 1 m distant from the center was more than five. Approximately a half of the meshes 50 cm distant from the center were classified in the state A.

2) Differences among the populations in spreading stolons and covering a ground surface

In the same way as above, each mesh in the experimental plots of other 9 populations was classified on the basis of the degree of state of the ground coverage. The results of the 4 populations, including the material collecteld in Tochigi are shown in Fig. 4. Each population shows its specific pattern of proportions of the states A, B and C in accordance with the distance from the center and with the growing seasons.

Based on the degree of spreading stolons, expressed in the rates of the state C, and the degree of covering a ground surface, indicated in the rates of the states A and B, the 10 populations examined were divided into three groups as follows: I-1: spreading of stolons was good, and covering of the ground surface was also good; I-2: although spreading of stolons was poor, covering of the ground surface was medium; and I-3: spreading of stolons was medium, but covering of the ground surface was poor (Fig. 5).

It is noticeable that some populations did not cover a ground surface well in spite of their medium ability of spreading stolons. There was no geographical specificity in a relationship between the above groups and the origins of populations.

3) Differences in ground surface covering between the two planting methods

Ground surface coverings were examined on the 10 populations, which were propagated from pieces of stolons taken from the respective sods. There were differences in covering the ground surface of each population between the two methods: i.e. a whole-sod planting and a stolon-piece planting (Fig. 4). Larger differences were recognized in covering a ground surface than in spreading stolons. According to the degrees of difference in covering, the 10 populations studied were classified into the following four groups: II-1: better covering of the ground surface with stolon-piece planting than whole-sod planting; II-2: no differences between the two methods; II-3: poorer covering with the former than with the latter; and II-4: the poorest covering with the former than with the latter (Fig. 6).

The populations which showed vigorous elongation of stolons with a stolon-piece planting indicated a tendency to cover a ground surface with that planting method.

It seems that spreading of stolons and covering of the ground surface of a *Z. japonica* population are dependent on the combined effects of regrowth after planting and its own ability of spreading and covering.

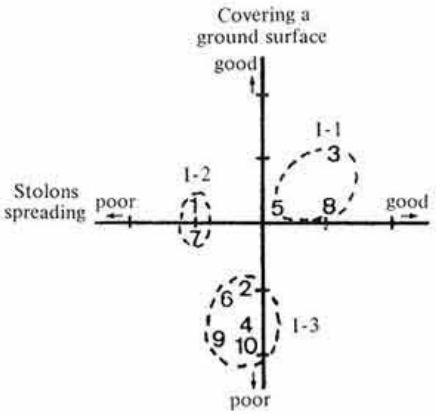

Fig. 5. Distribution of the selected 10 populations of *Z. japonica*
Groups I-1, -2 and -3: Classified on the basis of the degree of stolon spreading and ground surface covering (See text).
Numbers in the figure: Refer to the note in Table 1.

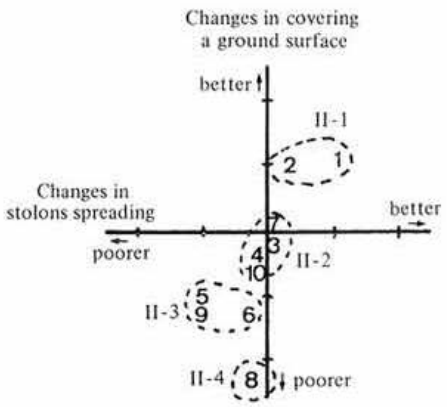

Fig. 6. Distribution of the selected 10 populations of *Z. japonica*
Groups II-1, -2, -3 and -4: Classified on the basis of differences in growth patterns between the two planting methods employed (See text).
Numbers in the figure: Refer to the note in Table 1.

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