Clonal Variation in the Effects of Nitrogen Applied to Mother Plant on the Sprouting Behavior of Tubers of Arrowhead, *Sagittaria trifolia* L.

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Introduction

Edaphic ecotypes in nitrogen response have been shown in some species^{1,3,13,14}. A number of annual plants have been found to display variation in seed germination^{10,11,12,16,22}. Environmental differences, such as temperature, photoperiod and air humidity, during seed maturation reportedly affect germinating habits in some annual plants^{4,6,9,21}. Drainage of paddy field and the presence or absence of rice plants during growth of the mother plants of *Sagittaria trifolia* L. influenced tuber dormancy⁷. Difference in nitrogen level applied to the mother plants also affected the tuber sprouting behavior of this species¹⁷.

S. trifolia has wide clonal variation in plant growth habits and propagule production¹⁹, and also in the patterns of these characteristics in response to nitrogen²⁰.

The present study was conducted to clarify the effects of nitrogen applied to the mother plant of *S. trifolia* on the sprouting of tubers and clonal variation in response to nitrogen.

Materials and Methods

Nineteen clones from six locations in the southern part of Kyoto Prefecture and the growing method used in this study were the same as those described in a previous study²⁰. Twenty ramets from one clone were divided into four experimental lots containing different amounts of nitrogen fertilizer. Four levels

of nitrogen were obtained by varying the amount of sodium-nitrate mixed in 860 ml soil : 0 mg (0 N), 68.8 mg (8 N), 137.6 mg (16 N) and 275.2 mg (32 N).

Fifteen to thirty-five tubers in each experimental lot of the 19 clones were randomly selected after the ramets were dug up at the beginning of December, 1981, when their aerial parts had withered completely. These tubers were stored in a wet condition at 5°C for about 70 days. Their fresh weights were measured, and then the tubers were placed in individual cells (1.7×1.7×2.7 cm) on February 19, 1982. All cells were placed in a single tub and the water depth was kept at about 3 cm until the end of the cultivation. This tub was placed in a greenhouse at Aburahi Laboratories ; water temperature was 16–27°C at the beginning of the experiment and increased progressively to 25–38°C at the beginning of August.

Tubers which had just sprouted were dried at 80°C in an air-drafted oven and weighed. Sprouting of the tubers was observed for about 250 days.

Results

Nitrogen applied to the mother plant influenced the number of days to tuber sprouting. Among the four nitrogen levels used, 32 N caused the fastest sprouting, as shown in Fig. 1. The relationship in days to sprouting between 8 N and the other three nitrogen levels, 0, 16 and 32 N, are represented by the

Fig. 1. Relationship in the days to sprouting of tubers produced in 8 N and the other three nitrogen levels, 0 (●), 16 (▲) and 32 N (▽).

Each mark shows the mean value of tubers produced by a clone.

α : $Y = 5.597 + 0.720 X$, $r = 0.882$ ($n = 19$, $p < 0.01$) : the relationship between 8 N and 0 N.

β : $Y = 2.383 + 0.828 X$, $r = 0.866$ ($n = 19$, $p < 0.01$) : the relationship between 8 N and 16 N.

γ : $Y = 7.051 + 0.330 X$, $r = 0.737$ ($n = 19$, $p < 0.01$) : the relationship between 8 N and 32 N.

estimated regression lines α , β and γ , respectively. These regression lines were significantly different from the theoretical line $Y = X$. Line γ was significantly different from the two other lines, α and β , which were not significantly different from each other.

According to the nitrogen response in tuber sprouting, the 19 clones were divided into groups A, B, C and D of nine, two, five and three clones, respectively (Fig. 2) : A : those in which the days to sprouting of tubers grown only at 32 N was significantly shorter than that at 8 N ; B : those in which the days to sprouting of tubers grown at 0 N and 32 N was significantly shorter than that at 8 N ; C : those in which the days to sprouting of tubers grown at 8 N was the longest ; D : the remain-

ing three clones, Nos. 3, 6 and 13.

The days to sprouting of tubers of No. 3 grown at 8 and 32 N were shorter than those at 0 and 16 N. Clone No. 3 belonging to group D showed a lower value at 8 N than that at 0 and 16 N, but the value at 8 N in this experiment was especially shorter than that at 8 N in other years. The days to sprouting of No. 6 grown at both 16 and 32 N were significantly shorter than those at both 0 and 8 N. The days to sprouting of No. 13 grown at 16 N were the shortest among the four nitrogen levels.

The effects of nitrogen applied to the mother plants on the relative frequency of days to tuber sprouting in clone Nos. 1, 6, 12, 15 and 18, which exhibited different representative patterns, are shown in Fig. 3. Clone Nos. 1 and 12 belonged to group A, and Nos. 15, 18 and 6 to groups B, C and D, respectively. Tubers of No. 1 grown at 8 N sprouted gradually over a long period, and sprouting behavior did not differ from that at 0 and 16 N ; however, the tubers of 32 N sprouted quickly and simultaneously. The sprouting pattern of No. 12 grown at 8 N did not resemble that at 0 and 16 N levels, decreasing at 32 N. The tubers of No. 12 at 8 N sprouted simultaneously and more quickly than that of No. 1 at the same nitrogen level, but the changing pattern of sprouting behavior of this clone among the four nitrogen levels most resembled that of No. 1. The period to sprouting of No. 15 at 0 N was shorter than those at 8 and 16 N, and that at 32 N was the shortest and was simultaneous among the four nitrogen levels. The tubers of No. 18 at 8 N sprouted gradually over a long period, while tubers of the other three nitrogen levels sprouted simultaneously and more quickly. The tubers of clone No. 6 at 16 and 32 N sprouted more quickly than those at 0 and 8 N.

The relationship between the tuber characteristics of percent dry matter and dry weight and the days to tuber sprouting displayed marked variation as shown in Fig. 4. The days to sprouting of tubers of No. 1 increased

Fig. 2. Clonal variation of nitrogen response in tuber sprouting.

○ : no difference to the value of 8 N at 5 % level.

● : shorter than the value of 8 N at 5 % level.

△ : longer than the value of 8 N at 5 % level.

Figure at the right of the symbol indicates clone Number.

Fig. 3. Clonal variation of nitrogen response in the relative frequency of days to sprouting of tubers.

The representative clones of the sprouting pattern are shown, with the group in parenthesis.

Fig. 4. Clonal variation in effect of nitrogen application on the relationship between dry weight or percent dry matter and days to sprouting of tubers.
● : 0 N, ○ : 8 N, ▲ : 16 N, ▼ : 32 N.

with the increase of the percent dry matter and dry weight of tubers, and this tendency did not correlate to the amount of nitrogen applied. This relationship was not recognized in the remaining four clones, Nos. 5, 10, 12 and 16.

Discussion

Differences in nitrogen applied to mother plants of *Sagittaria trifolia* influenced plant growth, the amount of propagule production, percent dry matter of tubers and the relationship between tuber size and the number produced^{17,18)}. Wide clonal variation of the nitrogen response of these characteristics was also observed²⁰⁾.

ITO and MIYAHARA⁷⁾ reported that differences in the environment of the mother plant, such as drainage of the paddy field and the presence or absence of rice plants, affected tuber dormancy of this species. The number of days to tuber sprouting increased as the amount of nitrogen applied to the mother plant increased¹⁷⁾.

In this study, the difference in the amount of nitrogen level applied to the mother plants influenced tuber sprouting behavior: tubers at 32 N sprouted more quickly than those at 0, 8 and 16 N (Figs. 1, 2 and 3). With all 19 clones, except No. 3, the days to tuber sprouting increased from 0 N to 8 N but decreased from 8 N to 32 N. Consequently, the nitrogen level applied to mother plant strongly affects tuber sprouting behavior. As numerous environmental factors affect seed or tuber dormancy in plants^{4,6,9,15,21)}, many factors other than nitrogen, paddy drainage and the presence or absence of rice plants probably also affect tuber sprouting behavior of this species. Differences in the amount of nitrogen applied hardly altered individual tuber weight and percent dry matter, except for the tubers produced by poorly growing individuals²⁰⁾. Changes of the tuber sprouting pattern among nitrogen levels probably is not due to the differences in the

degree of tuber maturation but to other factors.

KOBAYASHI *et al.*⁸⁾ found that the period to tuber sprouting of 18 among 40 clones of *Eleocharis kuroguwai* were related positively or negatively to the fresh or dry weight and the percentage dry matter or tuber shape, although the remaining 20 clones did not show such a tendency. *S. trifolia*, like *E. kuroguwai*, shows wide clonal variation in the relationship between the days to sprouting and percent dry matter or dry weight. The period to sprouting of one clone, No. 1, of the five clones in Fig. 4, significantly increased with the increase in percent dry matter and also the dry weight of tubers. However, such relationship was not found in the remaining four clones, Nos. 5, 10, 12 and 16.

As discussed above, nitrogen applied to the mother plant strongly affected the tuber sprouting habit of all 19 clones. *S. trifolia* varies widely in this characteristic; moreover, both the pattern and degree of nitrogen response of tuber sprouting differed among the clones. *Eleocharis kuroguwai* was divided into three groups on the basis of its tuber sprouting patterns, which were related to the adaptive characteristic of individual habitats⁹⁾. CAVERS and HARPER²⁾ identified factors which affect seed germination polymorphisms: some of which could be ascribed to seed ripeness or its position on the plant, but most of the variation occurred among plants within a small habitat sample; the variation was greater among plants than among habitats. HARPER⁵⁾ concluded that this phenomenon is a general tendency in plants. However, in the present study, the relationship between sprouting behavior and the habitat characteristic was not clarified because of the small number of clones used and the locations sampled. This species must grow under many kinds of nitrogen environments and compete with other weeds together with rice plants. This species displays a broad variation of nitrogen response in its plant growth and propagule production in

relation to its location²⁰⁾. Thus, the nitrogen response of the tuber sprouting pattern must differ among locations.

Summary

Clonal variation in the influence of different levels of nitrogen applied (0, 8, 16 and 32 kg/10a) to mother plants on tuber sprouting behavior was investigated for 19 clones of *Sagittaria trifolia* L., which were collected from six locations in the southern part of Kyoto prefecture.

Differences in the nitrogen levels affected the days to tuber sprouting; the period to sprouting at 32 N were shorter than those at the other three nitrogen levels. There was wide clonal variation not only in the days to sprouting at each nitrogen level, but also in the nitrogen response of this characteristic. Based on the nitrogen response of the days to sprouting, the 19 clones were divided into four groups, A, B, C and D, of nine, two, five and three clones, respectively: A: those in which the days to sprouting only at 32 N was significantly shorter than at 8 N; B: those in which the days to sprouting at 0 and 32 N were significantly shorter than at 8 N; C: those in which the days to sprouting at 0, 16 and 32 N were significantly shorter than at 8 N; D: the remaining clones.

The effects of the nitrogen levels applied to the mother plants on the relative frequency of the days to tuber sprouting also differed among clones. The sprouting pattern of group A was not so different among 0, 8 and 16 N, while the tubers of 32 N sprouted more quickly and synchronously. The tubers of group B of 0 N sprouted more quickly than those of 8 and 16 N, and those of 32 N sprouted the most quickly and simultaneously among four nitrogen levels. The tubers of group C at 8 N sprouted gradually over a long period, while tubers at the other three nitrogen levels sprouted more quickly and simultaneously.

The relationship between percent dry mat-

ter or dry weight of tubers and the period to sprouting displayed remarkable variations. The days to sprouting of tubers of clone No. 1 increased with the increase of percent dry matter or dry weight in comparison with the other clones, and this tendency differed with the nitrogen dosage. This relationship was not recognized in clone Nos. 5, 10, 12 and 16.

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(Received November 28, 1986)

親植物に対する窒素施用量の差異がオモダカ塊茎の 萌芽に及ぼす影響のクローン間差異について

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摘 要

本研究は、京都府南部の6地域の水田から採取した19クローンのオモダカを0, 8, 16 および 32 kg/10 a (それぞれ 0 N, 8 N, 16 N, および 32 N 区と略記する) の4窒素施用条件下で栽培し、得られた塊茎の萌芽性をクローン別に調査したものである。1981年12月上旬に掘り上げた塊茎を約70日間5°C 湿潤状態で保存し、1982年2月19日に1クローンの1窒素施用区につき15から30塊茎をガラス温室内の小さく区画されたバット (1.7×1.7×2.7 cm) に個体

別に置床し、実験終了まで3 cm の水深とした。萌芽までの日数は各塊茎毎に調査し、萌芽後塊茎は直ちに 80°C で乾燥させ、重量を測定した。

親植物に対する窒素施用量の差異は、いずれのクローン由来の塊茎の萌芽日数にも大きな影響を及ぼした。特に、32 N 区では 8 N 区に比べて著しく萌芽日数が短縮した。窒素に対する反応に基づいて19クローンは次の4群に分けられた。A 群：32 N 区の塊茎のみが 8 N 区の塊茎より早く萌芽した。B 群：0 N 区および 32 N 区の塊茎萌芽日数が 8 N 区より短くなった。C 群：0 N 区、16 N 区および 32 N 区の塊茎の萌芽が 8 N 区より早くなった。D 群：その他。

また、親植物に対する窒素施用量が塊茎の萌芽日数の頻度分布に及ぼす影響にも大きなクローン間差異が認められた。A 群では 32 N 区の塊茎萌芽が他の3つの区に比べ早くかつ萌芽まで日数の変異が小さかった。B 群の 0 N 区の塊茎萌芽は 8 N 区および 16 N 区に比べ早く、また、32 N 区の塊茎萌芽が4区中最も早くかつ萌芽まで日数の変異が小さかった。C 群の 8 N 区における塊茎萌芽は長期間にわたっていたが、他の3区では 8 N 区に比べより早くかつ変異が小さかった。

塊茎の乾物重や乾物率と萌芽日数との関係もクローン間で差異があり、この関係における窒素反応もクローン間で異なっていた。クローン No. 1 の塊茎萌芽日数は塊茎の乾物重および乾物率の増加にともない増加した。そして、この関係は窒素施用量の差異により影響を受けた。このような関係はクローン No. 5, 10, 12 および 16 では認められなかった。