Effects of Nitrogen, pH and Soil Factor on Seedling Growth of *Rumex obtusifolius* and *Rumex crispus*

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Abstract

The seedling growth of *Rumex obtusifolius* L. (broad-leaved dock) and *R. crispus* L. (curly dock) was investigated in a greenhouse in relation to soil factors, pH levels and nitrogen levels, and also investigated by the sand-cultured method in relation to pH and nitrogen levels during May to November in 1984.

1) There was little difference between the growth responses of both species to soil factors, pH levels and nitrogen levels.

2) Four treatments (higher pH, nitrogen application, sand mixture and a kind of soil) apparently stimulated dry matter production of both species and occupied the higher contribution rates of 13-28% to the total variance.

3) Dry matter production of both species was increased with increasing nitrogen application up to 20ka-N/10a. The increased rates of dry matter production per unit nitrogen applied were 0.14-0.17g in both species.

4) Both species produced almost the same dry matter at a nitrogen level of 0 ka/10a. At a nitrogen level of 20kg/10a, both species produced the same dry matter when pH was 6.5, whereas broad-leaved dock produced slightly higher dry matter than curly dock, when pH was 4.5 or 8.5.

Both broad-leaved dock and curly dock are to have been introduced into Japan in the Meiji era (about a hundred years ago)[6]. At present, broad-leaved dock is one of the most troublesome weeds in sown grasslands[5]. In most cases, its mature plants depress herbage production. In Europe, curly dock is a primary colonizer of cultivated land and is said to be the most weedy among *Rumex* species[1]. In Japan, however, it rarely colonized in sown grasslands. Its habitat is limited to the boundaries of sown grassland, roadside or abandoned field. These different behaviours of both species in sown grasslands may depend on different growth responses to environmental factors such as a kind of soil or climate.

The present study was designed to interpret the effects of nitrogen, pH, soil factor or growing season on their early growth and to assess the feature of broad-leaved dock as a grassland weed compared with that of curly dock.

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1. Materials and Methods

Five experiments using pots (20cm in diameter and 25cm height) were conducted in a greenhouse at Obihiro University in 1984. The seeds used were collected in September 1982 from an abandoned field where both species occurred together.

At first, the effects of 8 treatments (**Table 1**) were investigated twice: during May 24 to August 2 (high temperature and long-day photoperiod) and during August 6 to October 15 (low temperature and short-day photoperiod). Each treatment was arranged by the orthogonal table (1-a (2^{15}) of L_{16} type)[10]. Two types of soil were used: top soil (0-10cm) and deep soil (about 40cm depth) at the same sown grassland. Each soil was passed through 2mm sieve. Soil pH was controlled by the addition of peat moss (pH of 4.5 by 20% in weight) or $CaCO_3$ (pH of 6.5). On the commencement of each experiment, 16 seeds were sown in each pot: these were thinned to 8 per pot after 20 days. Shortly after emergence soil moisture was maintained to levels of 42 and 30% by the weighting method. Plants were sampled 70 days after the sowing of seeds.

The effect of nutrient solution with wide range of content (2nd experiment) and pH (3rd experiment) on growth of both species was examined by the sand culture method using HOAGLAND's solution[3]. Eight seeds were sown in a pot containing 3kg river sand previously washed. The plants were grown for 28 days with half-diluted HOAGLAND's solution (pH 6.5). These were thinned to 5 per pot. Pots were then grouped into two blocks: one for different nutrient levels (4-, 2-, 1-, 1/2-, 1/4-, 1/8- and 1/16- diluted HOAGLAND's solution) and the other for different pH levels (3.5, 4.5, 5.5, 6.5, 7.5, 8.5, and 9.5). Nutrient solution was given to pots at 2-day intervals and ionized water on alternate days. Each pot was leached at weekly intervals with one litre of ionized water to wash out residual nutrients. Plants were sampled 58 days after the sowing of seeds.

The following experiment was conducted

Table 1. Effects of eight treatments arranged by L_{16} (2^{15}) orthogonal table[10] on dry matter productions of broad-leaved dock and curly dock

Treatment	Level		Broad-leaved dock			Curly dock		
	1st	2nd	1st	2nd	Contribution[a)]	1st	2nd	Contribution[a)]
			(g/plant)		(%)	(g/plant)		(%)
Growing season	Spring-summer	Summer-autumn	0.79	0.61	0.6	0.89	0.45	7.6
Soil moisture	Wet	Dry	0.81	0.59	tr	0.57	0.77	tr
Soil pH	4.5	6.5	0.52	0.88	18.4	0.45	0.89	24.7
Nitrogen	0	10[b)]	0.26	1.14	17.6	0.26	1.08	22.7
Phosphorus	0	10[b)]	0.62	0.78	1.3	0.71	0.63	tr
Potassium	0	10[b)]	0.71	0.69	tr	0.53	0.81	tr
Kind of soil	Top soil	Deep soil	0.87	0.53	15.4	0.99	0.35	17.1
Sand	Blank	Mixture	0.23	1.17	28.0	0.43	0.91	13.2
Error					18.7			14.1

a) Contribution rate and significant test (*; $p<0.05$, **; $p<0.01$) were calculated after logarithm translation.
b) Application base was kg/10a.

during July 28 to October 26. Eight seeds were sown in a pot containing soil and these were thinned to 5 plants per pot 15 days after the sowing. The plants were grown at four nitrogen levels of 0, 10, 20, and 40kg/10a. The plants were sampled 30, 50, 70 and 90 days after the sowing of seeds.

Finally, the experiment was conducted during August 1 to November 9. Eight seeds were sown in pots containing soil; these were thinned to 5 plants per pot 15 days after the sowing. The treatments consisted of two nitrogen levels (0 and 20kg/10a) and three pH levels (4.5, 6.5 and 8.5). The plants were sampled 101 days after the sowing of seeds.

In each experiment, the plants sampled were washed and the following parameters were measured: length of primary shoot, and dry matter weight of root, leaf and stem (or petiole) after drying at 75°C for three days. In addition, all treatments were replicated three times.

2. Results

1) Effects of 8 treatments arranged by 2^{15} type

There was little difference between the growth responses of both species to 8 treatments examined. The following 4 treatments apparently affected both growth: higher pH, nitrogen application, surface soil and sand mixture.

Although there are many complex interactions between 8 treatments, the effects of main treatments were only taken up in this experiment and the result was shown in **Table 1**. At the first experiment, the meteorological condition was favorable for growth because of high temperature (mean daily temperature of 17.0 °C.) and long-day photoperiod (day length of 15 h.), whereas at the second experiment, less favorable for growth because of low temperature (10.9°C.) and short-day photoperiod (12 h.). Under these meteorological condition, the growth of curly dock was apparently depressed, but that of broad-leaved dock was little affected. As compared with potassium and phosphorus applied, nitrogen application apparently stimulated both growth. To the total variance of the mean value, the contribution rate of nitrogen application was 17.6% in broad-leaved dock and 22.7% in curly dock. Similarly, that of pH levels was 18.4 and 24.7%, respectively, of a kind of soil 15.4 and 17.1%, respectively, and of sand mixture 28.0 and 13.2%, respectively.

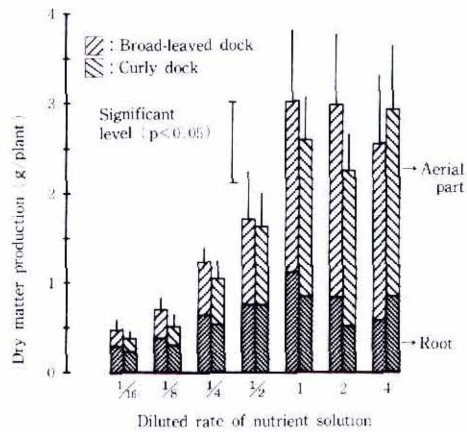

Fig. 1 Dry matter production of broad-leaved dock and curly dock at 7 levels of nutrient solution.
Vertical lines on the bars represent confident interval at p=0.05.

2) Effects of content and pH of nutrient solution

There was little difference between the growth responses of both species to wide range of content and pH of nutrient solution. Both dry matter production and aerial/root ratio were decreased with increasing diluted ratio of nutrient solution.

Standard HOAGLAND's solution contained 210 ppm nitrogen, 31 ppm phosphorus and 235 ppm potassium. Both species produced almost the same dry matter in 2- and 4-times concen-

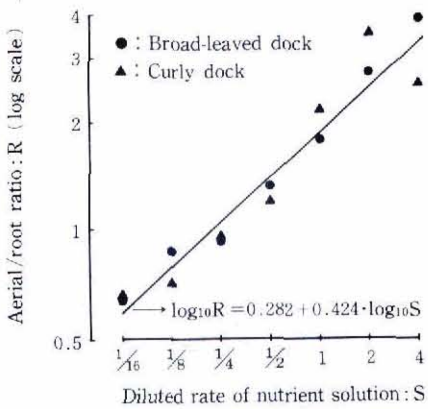

Fig. 2 Relatioship between diluted rate of nutrient solution and aerial/root ratio in broad-leaved dock and curly dock.

trated solution (**Fig. 1**). Mean dry matter production per plant in 1- to 4- times concentrated solution was 2.85g in broad-leaved dock and 2.59g in curly dock. As increasing diluted ratio of standard HOAGLAND's solution, dry matter production decreased at a constant rate (**Fig. 2**). Similarly, aerial/root ratio also decreased with increasing dilution ratio. That was 1.8 and 2.2, respectively, in standard solution, compared with 0.6 and 0.7, respectively, in 1/16-diluted solution.

Dry matter production per plant was little affected among a wide range of pH. That was 2.29-3.02g (mean of 2.53g) in broad-leaved dock and 2.01-3.18g (mean of 2.59g) in curly dock (**Table 2**).

3) Effects of nitrogen levels

There was no significant difference between the growth responses of both species to nitrogen levels (0-40 kg/10a).

An apparent increase in total dry matter production in both species was observed by nitrogen application 70 and 90 days after the sowing of seeds (**Fig. 3**). There was little increase in dry matter production at higher levels of nitrogen (more than 20 kg-N/10a). In the range of 0-20 kg-N/10a, increased dry

Table 2. Effects of pH levels of nutrient solution on total dry matter production (g/plant) of broad-leaved dock and curly dock

pH level	Broadleaved dock	Curly dock
3.5	2.43 ± 0.26*	2.89 ± 0.55*
4.5	2.55 ± 0.39	3.00 ± 0.64
5.5	2.51 ± 0.40	2.24 ± 0.38
6.5	3.02 ± 0.79	2.60 ± 0.47
7.5	2.34 ± 0.52	3.18 ± 0.57
8.5	2.60 ± 0.88	2.18 ± 0.51
9.5	2.29 ± 0.45	2.01 ± 0.47
Significant level ($p<0.05$)	1.14	1.04

*: confident interval at $p<0.05$.

matter production per 1 kg-N/10a was slightly higher in broad-leaved dock with mean value of 0.17g, compared with 0.14g in curly dock.

4) *Effects of nitrogen and pH levels*

Both species produced almost the same dry matter at 0 kg-N/10a. At 20 kg-N/10a, both species produced the same dry matter when pH was 6.5, whereas broad-leaved dock produced slighly higher dry matter than curly dock, when pH was 4.5 or 8.5.

When pH was 6.5, total dry matter production per plant was 1.01g in broad-leaved dock and 0.99g in curly dock at 0 kg-N/10a, whereas 2.76 and 2.68g, respectively, at 20 kg-N/10a

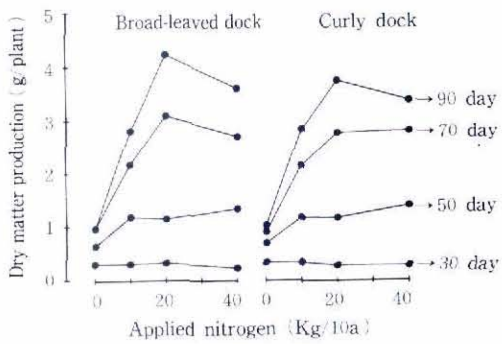

Fig. 3 Dry matter production of broad-leaved dock and curly dock at 4 levels of applied nitrogen.

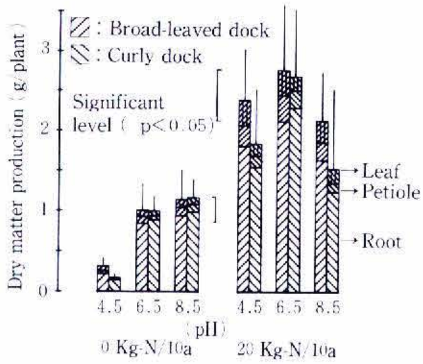

Fig. 4 Dry matter production of broad-leaved dock and curly dock at 2 nitrogen levels and 3 pH levels. Vertical lines on the bars represent confident interval at p=0.05.

(**Fig. 4**). As compared with dry matter production when pH was 6.5, lower pH (4.5) decreased by 31% in broad-leaved dock and by 16% in curly dock at 0 kg−N/10a, and by 86 and 68%, respectively, at 20 kg−N/10a. However, higher pH (8.5) increased by 114 and 118%, respectively, at 0 kg−N/10a, and decreased by 77 and 57%, respectively, at 20 kg−N/10a.

3. Discussion

The growth of both species was apparently affected by the following 4 factors among 8 treatments examined at the first experiment: pH, nitrogen, a kind of soil and sand mixture. At the next experiment, effects of pH and nitrogen were examined. When pH was 6.5, both species produced almost the same dry matter. At a lower pH level (4.5), broad-leaved dock produced more dry matter than curly dock. CAVERS & HARPER[1] pointed out the similar tendency that broad-leaved dock grew better on acid soil than did curly dock and that a reverse relationship was observed on calcareous soil. In addition, the mixture of sand stimulated the growth of both species. This was partially related to the soil type used (wettish volcanic-acid soil).

There was no effect of soil moisture levels on the growth of both species. On the study in England[1], broad-leaved dock grew well and was frequently present on wet soil. Since the region with wet soil was usually utilized as a permanent pasture, many grasslands were infested by broad-leaved dock. In contrast, a different result was reported in Japan[8]: broad-leaved dock grew more frequently on dry habitat and curly dock did on wet and fertile habitat in a river basin. Thus, a different result was reported in Japan and in England. Moreover, the result of this experiment was different even from these studies. It therefore seems that more research is needed on the effect of soil moisture levels on the growth of both species under many soil types.

According to the result in a sand culture using nutrient solution and in nitrogen application in soil, dry matter production of both species was increased with increasing nitrogen application up to 20kg−N/10a. Increased dry matter production per unit nitrogen applied was 0.17g in broad-leaved dock and 0.14g in curly dock. Thus, both species showed the same growth response to applied nitrogen. It is not supported, therefore, that broad-leaved dock is advantageous to curly dock in respect to the growth response to applied nitrogen[8,9].

In this study, each experiment was conducted in a greenhouse during a comparatively short term as pure culture of each species, so that there was little influence of interspecific or intraspecific competition. Under these conditions, there was not any apparent difference in the growth response of both species to fertilization and soil factors. It is considered, therefore, that the features of broad-leaved as a grassland weed is concerned with tolerance for disturbances or competitive ability with herbage plants as compared with those of curly dock[2,4,7].

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エゾノギシギシとナガバギシギシの稚苗の生長におよぼす窒素・pH・土壌要因の影響

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摘 要

1984年5—11月に温室において，エゾノギシギシ（*Rumex obtusifolius* L.）とナガバギシギシ（*R. crispus* L.）の稚苗の生長におよぼす土壌要因，pH，窒素の影響を調査し，また，砂耕栽培により pH，窒素の影響を調査した。

1）土壌要因，pH，窒素に対する両種の生長反応には明らかな差を認めなかった（**Table 1, 2; Fig. 1, 2**）。

2）両種の乾物生産量には4処理（高い pH，窒素施用，砂の添加，土壌の種類）の影響が大きく，これらの全体の分散に対する寄与率は13—28%を占めた（**Table 1**）。

3）両種の乾物生産量は窒素 20kg/10a までは施用量と共に増加した（**Fig. 3**）。単位窒素量あたりの乾物生産の増加量は両種において 0.14—0.17g であった。

4）両種の乾物生産量は窒素 0kg/10a のときは同様であった（**Fig. 4**）。窒素が 20kg/10a のときの乾物生産量は pH が 6.5 では両種の間に差はなかったが，pH が 4.5 または 8.5 ではエゾノギシギシの方がナガバギシギシより高い乾物生産量を示した。

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