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Effect of Growth Environment on the Root Development of Pasture Species

Ⅰ. Development of hydroponic technique for studies on the root characteristics

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생육환경이 주요 목초의 뿌리발육에 미치는 영향

Ⅰ. 뿌리의 특성 연구를 위한 수경재배법의 개발

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摘 要

수정된 Lincoln 용액을 사용하여 여러가지 목초의 상대생장율, 뿌리/지상부(R/S) 비율, 상대적 뿌리 용적 및 표면적 등을 동시에 비교하기 위하여 수경재배법을 개발하였다.

수정된 Lincoln 용액에서 19가지 초종이 모두 잘 자랐으며, 뿌리특성 연구에 긴요하게 이용될 수 있었다. 상대생장율은 조사기간 동안 이상적으로 일정 값을 유지하며 같은 식물체로 성공적으로 측정할 수 있었다. Group 간과 마찬가지로 group 내에서도 초종간 R/S율에 큰 차이가 있었다. 뿌리 조직밀도는 두과목초나 herb보다 화본과에서 낮았다. 뿌리 면적지수는 화본과 목초와 herb가 높았는데 이 면적지수는 각각 다른 초종의 상대적 根界 평가에 유용하게 이용될 수 있을 것으로 사료되었다.

Ⅰ. INTRODUCTION

Many kinds of nutrient solution have been used for physiological study of plants. Most of them have been developed for the growth of particular crops. Some solutions such as the Long Ashton and the Hoagland solution are widly used and are considered to be suitable for supporting growth of a range of different plant species (Hoagland and Arnon, 1950; Hewitt, 1966). However obtaining maximum growth of pasture or crop plants is difficult (Smith et al., 1983). Such a nutrient solution suitable for the physiological study of a range of grasses, legumes, and herbs is necessary.

Relative growth rate (RGR) is a useful tool studying differences is seedling vigor. This can be measured by weighing plants periodically in solution culture, and assess the seedlings vigor of many different species. Most quantitative studies of roots have used weight as the means of assessing the amount of root, but generally the capacity to take up water and

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nutrients is usually more closely related to surface area or volume of the root than to its weight.

The aim of this research was to develop hydroponic technique for pasture species so that we could produce plants and root systems without contamination by soil or other material, and so we could make repeated measurements on the same plants and return to the hydroponic system for further growth.

Developed hydroponic system was used to compare simultaneously a range of pasture species in terms of RGR, ratio of roots to shoots, and relative root volume and area.

Ⅱ. MATERIALS AND METHODS

The plant species used were:

Legumes; *Lotus corniculatus*
L. uliginosus
Lupinus polyphyllus
Medicago sativa
Trifolium ambiguum
T. medium
T. pratense
T. repens

Grasses; *Agrostis capillaris*
Dactylis glomerata
Festuca arundinacea
F. novae-zelandiae
F. rubra
Lolium perenne
Phleum pratense

Herbs; *Achillea millefolium*
Cichorum intybus
Hieracium pilosella
Plantago lancelata

Development of hydroponic technique

Seeds were initially sown in plastic tray (30×42×6 cm deep) filled with silt loam soil, and each type of nitrogen bacteria was inoculated to legumes. Twenty days after sowing seedling roots were washed free of soil and transplanted to a hydroponic unit. Plant roots were wrapt with germination paper and aluminum foil with the bottom in contact with the solution to make easy for plant to absorb nutrient and block sunlight. Hydroponic used nutrient film technique method with recirculating nutrient solution flowing in the bottom of 5cm deep×4m long units in glass house.

Lincoln solution subtracted $CaCl_2$ was used for plant growth trial. Nutrient solution was checked every other day with a conductivity meter ('Truncheon' Nutrient Salts Meter, NZ Hydroponics Ltd., NZ), and changed weekly. Evaporated water was replaced with distilled water every day.

Comparative root characteristics in hydroponics

Every three or four days plant fresh weights were measured after removing water on root surface with tissue paper to measure relative growth rate (Radford, 1967). Fresh weight was converted to dry weight using the percentage of dry matter measured with last harvested plants. RGR was expressed as the increase of plant weight per unit of weight present per unit of time following the formula of Radford (1967).

After seventeen days of solution culture the plants were harvested, and seperated into top and root, Root volume was determined with density bottle.

$x_1 = c + w_1$

$x_2 = c + w_2 + r$

$x_3 = r$

where c is container weight, w water weight full in bottle, and r fresh root weight.

$x_2 - x_1 = w_2 - w_1 + r$

As r is x_3,

$x_2 - x_1 - x_3 = w_2 - w_1$ = root volume

Gravimetric method (Carley and Watson, 1966) was used for estimating root-surface areas. A calcium nitrate solution consisting of 1 part water to 6 parts calcium nitrate was used in this method. A 200-ml beaker of calcium nitrate solution was placed on a laboratory scale and the weight of the beaker and solution recorded. Dried roots were dipped into this solution for 10 seconds and then lifted above the beaker and allowed to drain for 30 seconds. The weight of the solution was then recorded to determine the amount which had adhered to or been absorbed by the plant roots.

Root volume was devided by root dry weight to get root tissue density, and root area index was expressed as root surface area by root dry weight.

Ⅲ. RESULTS AND DISCUSSION

Development of hydroponic technique

Several methods of holding the plants above but in contact with the nutrient solution were tried. The requirement was that plants achieved good growth but that the plant could be removed for periodic weighing, and returned. Inserting roots in small plastic pots or wrapping in acrylic plastic was found not suitable for wrapping roots. Germination paper was good for absorbing nutrient solution, but did not have the strength for holding plants. Wrapping the root firstly in germination paper and then in aluminium foil was easy for handling, holding plant, and giving access to the nutrient solution.

Smith et al. (1983) reported that Ruakura solution achieved higher yields of ryegrass and white clover compared to other seven different nutrient solutions tried. The Lincoln solution used was a little higher in contents of macro nutrients and same in micro nutrients. But chlorine content is very high. Therefore calcium chloride was omitted from Lincoln solution and used as nutrient solution in this experiment. The composition, conductivity factor(CF) and pH of Ruakura, Lincoln, and the solution used in this experiment are given in Table 1.

Table 1. Initial concentration of major and minor elements (mg/l), pH and conductivity factor (CF) of high and low nutrient solutions used.

Nutrient level	pH	CF	NH_4-N	NH_3-N	P	S	K	Mg
Literature								
Ruakura	6.0	–	66	198	40	60	238	21
Lincoln	–	–	97	194	46	90	303	32
Used in this experiment								
	5.8	21	97	194	46	90	303	32

Nutrient level	Ca	Na	Cl	B	Cu	Fe	Mn	Mo	Zn
Literature									
Ruakura	127	15	9	0.5	0.04	3.0	0.5	0.01	0.25
Lincoln	274	0	333	0.5	0.04	3.0	0.5	0.01	0.25
Used in this experiment									
	138	0	93	0.5	0.04	3.0	0.5	0.01	0.25

About six litters of nutrient solution per gully was used, and every day the amount of water reduced by evaporation was refilled with distilled water. Total dry weight of plants at start, and after harvest per gully were 1.3, and 15.6g, respectively.

CF and pH decreased indication general decrease in solution nutrients (Table 2). Leaves of grasses began to turn yellow after seven days hydroponic culture.

In order to get the optimum growth of plants, it is necessary to test the strength of the solution daily, and add stock solution to maintain desired growing strength. Though further development for hydroponic technique was needed, the method developed to the stage of being able to handle sequential measurements on the same plant to determine the RGR of individual plants, and was proved to be a good method for studying plant root characteristics.

Table 2. Changes in pH and conductivity factor (CF) values of high and low nutrients solutions.

	Days in solution culture					
	0	4	7	11	14	17
pH	5.8	6.5	5.5	4.6	4.6	4.6
CF	21	19	17	16	12	11

Comparative root characteristics in hydroponics

Relative growth rate (RGR) was measured successfully showing reasonably consistant values over time as shown in Table 3. There was a much differences in RGR between species within groups, but not much differences between groups. *Trifolium medium, Festuca rubra* and *Hieracium pilosella* showed low RGR values. *Festuca novae-zelandiae* showed relatively higher RGR than expected. RGR of *Lupinus polyphyllus* and *Medicago sativa* were lower than expected, because there was some stress on those species when transplanted them from soil to hydroponics.

Root/shoot ratio of *Lotus corniculatus, Festuca novae-zelandiae,* and *Plantago lancelata* were low while *Trifolium ambiguum* and *Dactylis glomerata* showed high rates. There was a much differences between species within groups as between groups.

There was some differences in root tissue density between species, but not significant differences between groups. There were much differences among species and groups in root area index. This index was very high for grasses and herbs, because these group have fine roots. Root surface could be measured easily and quickly, and root area index should be useful for evaluating the comparative root system of different species.

IV. SUMMARY

Using modified Lincoln solution, hydroponic system was developed to compare simultaneously a range of pasture species in terms of relative growth rate(RGR), rate of roots to shoots, and relative root volume and root area.

Modified Lincoln solution achieved optimum growth of nineteen forage species tested, and was proved to be a good method for studying plant root characteristics.

RGR was measured sucessfully showing reasonably consistant values over time. There was a much

Table 3. Relative growth rate (RGR), root/shoot ratio, root area index, and root tissue density of plants grown in commercial nutrient solution.

Groups	Species	RGR (%/d)					Root/Shoot (%)	Root tissue density (cc/g)	Root area index (area/g)
		1st	2nd	3rd	4th	mean			
Legumes	*Trifolium pratense*	16.3	19.5	21.1	17.4	18.6	52	14	19
	Trifolium repens	19.7	20.2	24.1	22.9	21.7	53	14	24
	Trifolium medium	9.2	8.0	9.7	12.2	9.8	39	9	26
	Trifolium ambiguum	13.3	14.8	13.5	14.6	14.1	64	11	22
	Medicago sativa	13.6	13.5	13.7	16.5	14.3	47	10	17
	Lotus corniculatus	16.5	16.9	21.2	18.8	18.4	34	13	13
	Lotus uliginosus	19.2	18.6	21.8	21.6	20.3	47	12	27
	Lupinus polyphyllus	12.1	12.8	13.7	10.9	12.4	59	9	15
	Mean	15.0	15.5	17.4	16.9	16.2	49	11	20
	LSD 5%	4.25	4.85	6.23	5.01	4.92	12	2.6	5.9
	LSD 1%	6.29	7.17	9.22	7.41	7.28	18	3.8	8.7
Grasses	*Festuca arundinacea*	13.9	15.4	15.9	16.0	15.3	44	8	54
	Festuca rubra	14.0	13.3	13.2	11.3	13.0	41	8	66
	Lolium perenne	18.7	17.0	16.1	15.5	16.8	59	9	43
	Agrostis capillaris	19.5	22.4	20.3	19.8	20.5	45	9	41
	Phleum pratense	21.3	19.6	18.4	19.9	19.8	50	13	68
	Dactylis glomerata	19.4	20.7	18.9	19.1	19.5	66	11	54
	Mean	17.8	18.1	17.1	16.9	17.5	51	10	54
	LSD 5%	4.61	5.10	3.80	4.98	4.40	14	2.8	16.4
	LSD 1%	7.22	7.99	5.96	7.81	6.89	22	4.3	25.8
Herbs	*Cichorium intybus*	12.2	16.1	19.6	20.5	17.1	56	12	23
	Plantago lancelata	26.3	21.6	19.9	20.0	22.0	35	13	59
	Achillea millefolium	22.9	19.2	22.9	24.7	22.4	48	11	29
	Hieracium pilosella	6.9	6.0	9.2	11.5	8.4	46	9	36
	Festuca novae	14.7	17.3	18.5	19.7	17.6	33	13	69
	Mean	16.6	16.0	18.0	19.3	17.5	44	12	43
	LSD 5%	13.9	10.5	9.1	8.4	9.9	17	3.1	35
	LSD 1%	23.0	17.4	15.1	13.9	16.4	28	5.1	58

differences in root/shoot ratio between species within groups as between groups. Root tissue density was lower in grasses than legume or herb group. Root area index was very high for grasses and herbs, and this index should be useful for evaluating the comparative root system of different species.

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