培地の水ポテンシャルが日本コムギ品種の初生種子根の屈地性に及ぼす影響

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Effect of Water Potential of Culture Medium on Geotropic Response of Primary Seminal Root in Japanese Wheat Cultivars*

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Abstract : It has been observed that wheat has a shallow root system in wet soil and a deep root system in dry soil. However, the control mechanisms of root growth depending on soil water status remain unclear. Since root geotropic response seems to play an important role in the formation of the root system, the effect of water potential of culture medium on the geotropic response of the primary seminal root in Japanese wheat cultivars was examined. Agar medium with different concentrations of polyethylene glycol (PEG-6000) and vermiculite medium with different levels of water content were used. Growth angle of the primary seminal root in Minaminokomugi, which usually shows small root growth angle, became larger in low water potential media (−0.05 MPa) than in the control (0 MPa). Effects of low water potential on root geotropic responses in the agar medium were also examined in 133 Japanese wheat cultivars. Minaminokomugi and 50 other cultivars showed large responses in the low water potential medium. It is considered that low water potential of the culture medium stimulates positive root geotropic responses in certain Japanese wheat cultivars.
Key words : Geotropic response, Primary seminal root, *Triticum aestivum*, Water potential.

培地の水ポテンシャルが日本コムギ品種の初生種子根の屈地性に及ぼす影響 : 小柳敦史・佐藤暁子***・和田道宏（農業研究センター・***東北農業試験場）

要　旨 : コムギは湿潤土壌では浅い根系，乾燥土壌では深い根系を形成するといわれるが，このような生長制御の機構は不明である．そこで，根の屈地性に及ぼす培地の水ポテンシャルの影響を調べた．ポリエチレングリコール（PEG-6000）を添加して水ポテンシャルを低下させた寒天培地にミナミノコムギ（通常の根伸長角度 : 小）と農林 58 号（同 : 大）の発芽種子を初生種子根が水平になるような角度で置床した．20°C, 暗黒下で 2 日間培養した後に水平面からの伸長角度を測定したところ，−0.05 MPa 以下ではミナミノコムギの根の伸長角度が大きくなった．また，含水量を調節して pF 2.7（−0.05 MPa）としたバーミキュライト培地でもミナミノコムギの伸長角度は大きかった．そこで，農林登録 133 品種を用い，寒天培地で 0 及び −0.05 MPa における伸長角度を比較したところ，ミナミノコムギ他 50 品種で水ポテンシャルの低下に伴う伸長角度の増加が観察された．
キーワード : 屈地性，コムギ，初生種子根，水ポテンシャル．

In Japan, wheat has been grown both in upland and drained paddy fields. Thus, Japanese wheat cultivars have often been subjected to both types of water stresses, drought and excess soil moisture.

It has been observed that wheat has a shallow root system in wet fields and a deep root system in dry fields[10]. However, the control mechanisms of the root growth under different soil water status remain unclear.

This paper discusses the effects of water potential on the root geotropic response, which plays an important role in root distribution pattern, in Japanese wheat cultivars.

Materials and Methods

1. Plant materials

Minaminokomugi, which shows the smallest positive geotropic response of the root in Japanese cultivars, and Norin 58, which shows the largest positive response[6], were used in the experiments with agar and vermiculite media. Moreover, all 133 Japanese wheat cultivars including two cultivars mentioned above, were also used in the additional agar experiment.

2. Evaluation for geotropic responses

For selecting uniform materials, excess number of seeds, more than three times larger than actual use, were put in the plastic petri dishes with the embryo side facing upward. Seedlings, with primary seminal roots 3-mm long,

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were transplanted onto either agar or vermiculite medium. The direction of the root was adjusted horizontally in the medium at the time of transplanting. The measurement of the root growth angle was made with a protractor after incubation. Incubation was carried out for two days at 20°C and under dark condition except when the seedling was transplanted. The root growth angle was defined as the angle between the level surface and the line connecting the positions of the root tip at the time of transplanting and at the end of the incubation (Fig. 1). Root length was measured after taking the seedling out of the medium.

3. Agar experiment

Air was supplied into heated 0.2% agar solution by bubbling during the cooling process. The oxygen concentration of the agar solution became 6 mg/l. A 80 ml agar solution was put into each 100 ml beaker (Fig. 1). Water potential of the agar medium was adjusted by the use of polyethylene glycol (PEG-6000 : Nakarai Chemicals Ltd. and Ishizu Seiyaku Ltd.). Relationship between the concentration of PEG-6000 and water potential value was determined previously by a vapor pressure osmometer (Wescor Vapor Pressure Osmometer 5500). Examined water potential values were 0 (distilled water), −0.05 (4% solution of PEG-6000), −0.1 (8% solution of PEG-6000) and −0.2 (14% solution of PEG-6000) MPa in the experiment for the two cultivars Minaminokomugi and Norin 58. In additional experiment, 133 cultivars were examined in the media of 0 and −0.05 MPa. Ten plants were used for each treatment.

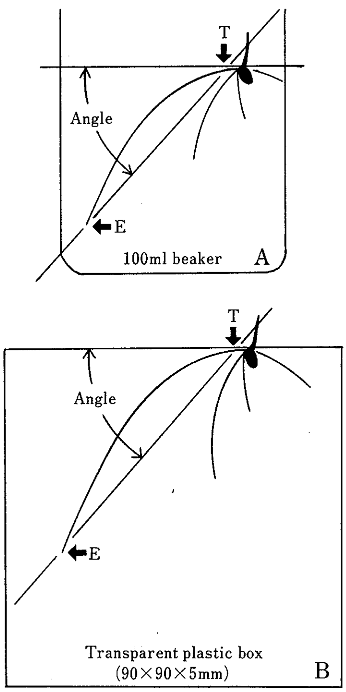

Fig. 1. Measurement of growth angle.
A : Agar experiment.
B : Vermiculite experiment.
T : Position of the root tip at the time of transplanting.
E : Position of the root tip at the end of incubation.

4. Vermiculite experiment

The effect of water potential on root growth angle of two cultivars Minaminokomugi and Norin 58 was also examined in vermiculite medium. A small transparent plastic box, 90 mm in width, 90 mm in height and 5 mm in thickness, was used as a root box (Fig. 1). Two treatments were carried out, one was flooding by distilled water (pF 0 : 0 MPa) and the other was pF 2.7 (−0.05 MPa). The latter was made by using the relationship between the pF value and the water content of the vermiculite, which was determined previously by a tensiometer. The oxygen concentration of the water was 9 mg/l. Twelve plants were used for each treatment.

Results

1. Agar experiment

As shown in Fig. 2, low water potential significantly increased the root growth angle of a cultivar Minaminokomugi. The average root growth angle of the cultivar was 11° in the control (0 MPa), however, it increased to 60° in the medium of −0.05 MPa. Stimulation of positive geotropic response was also observed in Norin 58 in the media of −0.05 and −0.1 MPa. It is considered that the changes in the angle were small because the growth angle in the control (0 MPa) was also large in the cultivar. Root elongation rates increased in the medium of −0.05 MPa and decreased in the media of −0.1 and −0.2 MPa in both cultivars (Table 1).

2. Vermiculite experiment

As shown in Fig. 3, the root growth angles were small (20°) in the flooding condition (pF

0 : 0 MPa) and large (64°) in pF 2.7 (−0.05 MPa) in Minaminokomugi. On the other hand, root growth angles of Norin 58 were large in both pF 0 (0 MPa) and pF 2.7 (−0.05 MPa). Root elongation rates of Minaminokomugi were 0.82 and 0.84 mm/h in pF 0 (0 MPa) and pF 2.7 (−0.05 MPa), respectively. The elongation rates of Norin 58 were 0.87 and 0.78 mm/h in pF 0 (0 MPa) and pF 2.7 (−0.05 MPa), respectively. Thus, the rate of root elongation was not significantly affected by low water potential in either variety (Table 2).

3. Experiment with 133 cultivars

As shown in Fig. 4, the root growth angles of most cultivars were larger in the agar medium with 4% solution of PEG-6000 (−0.05 MPa) than in the control (0 MPa), *i.e.*, most symbols exist above the line of equality (x=y). The root growth angles of a cultivar Minaminokomugi and 50 other cultivars were significantly larger in the medium of −0.05 MPa than in the control (0 MPa). On the other hand, no cultivar

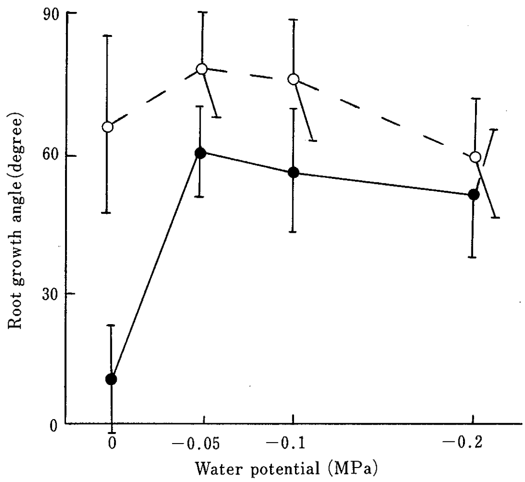

Fig. 2. Root growth angles in Minaminokomugi and Norin 58 in the agar medium with different water potential values.
●—● : Minaminokomugi.
○---○ : Norin 58.
Vertical bars indicate standard deviation.

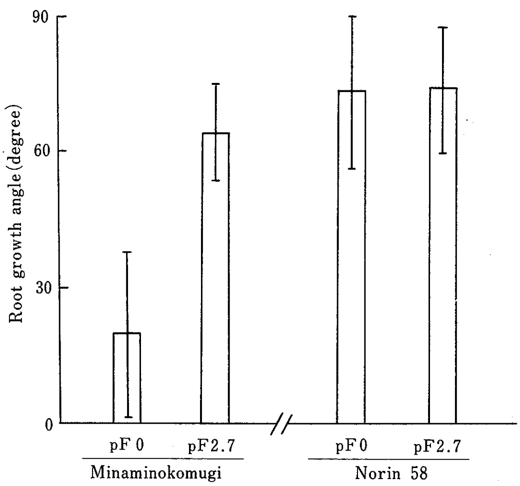

Fig. 3. Root growth angles in Minaminokomugi and Norin 58 in the vermiculite medium with different water potential values.
pF 0 : 0 MPa. pF 2.7 : −0.05 MPa.
Vertical bars indicate standard deviation.

Table 1. Root elongation rates in Minaminokomugi and Norin 58 in the agar medium of different water potential values.

Cultivar/MPa	0	−0.05	−0.1	−0.2
		(mm/h)		
Minaminokomugi	0.52±0.10	0.71±0.11	0.34±0.06	0.16±0.03
Norin 58	0.58±0.20	0.75±0.13	0.51±0.11	0.27±0.06

Means±standard deviations.

Table 2. Root elongation rates in Minaminokomugi and Norin 58 in the vermiculite medium of different water potential values.

Cultivar	pF 0 (0 MPa)	pF 2.7 (−0.05 MPa)
	(mm/h)	
Minaminokomugi	0.82±0.16	0.84±0.16
Norin 58	0.87±0.26	0.78±0.18

Means±standard deviations.

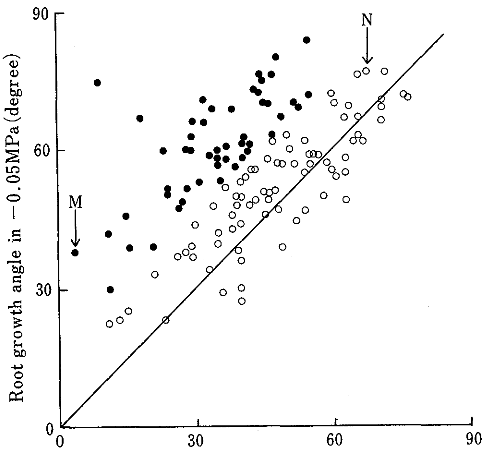

Fig. 4. Root growth angles in 133 cultivars in the agar medium of 0 and −0.05 MPa.
● : Cultivars ; the angles are significantly different at the 5% level between two water potential values.
○ : Cultivars ; the angles are not significantly different.
M : Minaminokomugi. N : Norin 58.
Line : x=y

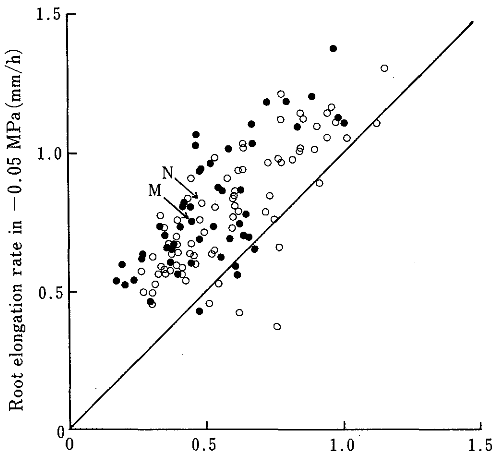

Fig. 5. Root elongation rates in 133 cultivars in the agar medium of 0 and −0.05 MPa.
● : Cultivars ; the angles in Fig. 4 are significantly different at the 5% level between two water potential values.
○ : Cultivars ; the angles in Fig. 4 are not significantly different.
M : Minaminokomugi. N : Norin 58.
Line : x=y

showed a smaller growth angle of the root in the medium of −0.05 MPa than in the control (0 MPa), significantly. Root elongation rates of the cultivars ranged from 0.18 to 1.16 mm/h with an average of 0.56 mm/h in the control (0 MPa) and from 0.37 to 1.38 mm/h with an average of 0.79 mm/h in the medium of −0.05 MPa (Fig. 5). Root elongation rates in the medium of −0.05 MPa were larger than in the control (0 MPa) in most cultivars.

Discussion

It has been reported that light[4,5,7,12], temperature[2,8], pH value[9] and oxygen concentration[9] of culture medium affect geotropic response of the root. However, our preliminary experiments suggested that light (450 μmol m^{-2} s^{-1}), temperature (10∼25°C), pH value (5∼11) and oxygen concentration (1∼30 mg/l) did not significantly affect the geotropic response of the primary seminal root in Minaminokomugi and Norin 58 in the agar medium. Then we examined the effect of water potential of the medium on root geotropic responses.

The change of root growth angle under different water potential values of culture medium had often been discussed as hydrotropism[1,9]. However, hydrotropism does not explain the change of root distribution pattern in the soil without water potential gradient. Recently, Takahashi and Suge[11] reported the relationship between root gravitropism and hydrotropism using a pea mutant. Moreover, Leopold and LaFavre[3] suggested that geotropic responses of the maize root were stimulated by a previous osmotic shock with polyethylene glycol (PEG-6000) in the humid air. We observed that roots in low water potential (−0.05 MPa) media showed larger positive geotropic responses than in the control (0 MPa) in a cultivar Minaminokomugi and 50 other Japanese wheat cultivars. Thus low water potential of culture medium is concluded to stimulate geotropic response of the root in certain Japanese wheat cultivars. There is a possibility that adaptive control of root morphogenesis depending on soil water status is explained by this low water potential-stimulated geotropic response.

Since stimulation of the positive geotropic response occurred with or without changes of the root elongation rate, the relationship between root elongation and geotropic response remains unclear in this experiment.

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** In Japanese with English title.