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Genetical Variability of Excised-leaf Water Retention Capability in Wheat

Gnanasiri S. PREMACHANDRA* and Tohru SHIMADA**
(*Faculty of Applied Biological Science, Hiroshima University, Fukuyama 720, **Department of Grassland Science, Obihiro University of Agriculture, Obihiro 080, Japan)
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Abstract: Excised-leaf water retention capability of spring wheat and winter wheat were tested. Cultivar differences were well differentiated when the decrease in leaf water content % was between 11 and 30. An increase in excised-leaf water retention capability and a decrease in leaf water content were seen during winter compared to summer. Drought hardened plants showed higher water retention capability.

Excised-leaf water retention capability of the progenies from three crosses of winter wheat were evaluated. Frequency distribution patterns of the progenies showed the characteristic pattern of quantitative inheritance. Excised-leaf water retention capability of wheat seems to be a quantitative character governed by polygene action.
Key words: Drought tolerance, Excised-leaf water retention.

小麦切除葉の水分保持能の遺伝的差異：ニヤ-ナシリ．S. プレマチャンドラ*・嶋田　徹**（*広島大学生物生産学部・**帯広畜産大学畜産学部）

要　旨：小麦切除葉の水分保持能の遺伝的差異に関する知見を得るため春小麦と冬小麦それぞれ 12 品種，および Horoshiri × CI-14106 の F_5 の100 系統，Chihoku × Valujerskaja の F_4 の 70 系統と Chihoku × PI -173438 の F_4 の 70 系統を供試し，次の結果を得た．

(1) 切除葉の水分保持能の品種間差異は切除時の葉水分に対し 11% から 33% に低下する時点で明瞭に観察された．(2) 水分保持能は低水分含有葉で高く，冬期間生育した小麦は夏期間のものより高くなる傾向にあった．また対乾燥ハードニングにより葉水分保持能は強化される．(3) 3 栽培種の交配後世代系統の切除葉の水分保持能の変異分布から，水分保持能はポリジーンによる量的遺伝形質であることが明らかとなった．
キーワード：耐旱性，切除葉の水分保持．

Measurement of excised-leaf and excised-plant water retention capability has shown some promise of differentiating drought tolerance of plants. The rate of water loss of excised-plants in wheat and its relation to drought was first examined by Bayles et al.[1] Excised-plants of drought resistant winter wheat cultivars lost water more slowly than less resistant cultivars[1,8]. Later it was understood that drought hardy wheat cultivars had better water retention by excised-leaves than less hardy cultivars and it was well correlated with the order of hardiness observed in drought and heat tests.[2-7]

Measurement of excised-leaf water retention capability is normally done by drying the excised-leaves in a temperature and relative humidity controlled environment. Dedio[6] stated that no special care is required to control the drying conditions, particularly if all the samples are allowed to dry in the same chamber. Clarke and McCaig[2,3] and Clarke[4] noted differences in excised-leaf water retention capability in plants grown in different environments, *i. e.* of field and controlled environment materials. Clarke[4] found that the cultivar differences were clearly shown in stressed than in non-stressed environments and leaves from non-stressed environments lost water faster than leaves from stressed environments. Clarke[4] did not find differences in stomatal number in the field-grown and green house-grown materials.

Dedio[6] investigated the segregating populations for excised-leaf water retention capability using a cross between cultivars with high and low water retention and found that the higher retention parent seemed to be contributing dominant genes governing retention. He suggested that water retention was simply inherited and that the ability of retaining water was controlled by dominant gene action. Clarke and McCaig[3] and Clarke and Townley-Smith[5] found that the leaf water contents of the progeny lines of high and low water rentention parents were distributed between the parental values. They concluded that the excised-leaf water retention capability seemed to be somewhat heritable. However their results did not indicate that the high retention parent contributed one or few dominant genes governing retention, as reported by Dedio[6].

In this study the genetical variability of excised-leaf water retention capability in wheat was investigated. The environmental influence on excised-leaf water retention capability was also studied.

Materials and Methods

Twelve spring wheat and 12 winter wheat cultivars were grown in the field during June to August 1986 (summer) and in the green house during October to December 1986 (late autumn and early winter) in Obihiro University, Hokkaido. Field plots consisted of 3 m long rows spaced 0.4 m apart. In the green house, plants were grown in 42 cm × 30 cm × 12 cm plastic containers. Field and the green house experiments were replicated three times. When the plants were about 60 to 70 days old, uppermost fully expanded leaves were sampled, 3 to 4 hours after the sun rise. Soon after the sampling ten leaves were placed on 20 cm × 8 cm plastic trays and were weighed at various intervals as required in each experiment in the laboratory. Finally the oven dry weights of the leaf samples were recorded. Experiments consisted of 3 replications. Temperature and the relative humidity of the room were maintained at 23 ± 2°C and 60 ± 5% respectively.

The influence of drought hardening on excised-leaf water retention capability was investigated. Plants were stressed by withholding of watering for 12 days in the containers, when they were 40 days old. Stressed plants were re-watered for 12 days and the uppermost fully expanded leaves from the hardened and control plants were sampled and tested.

Seeds of the 3 winter wheat crosses : 1. 100 F_5 lines of Horoshiri × CI-14106, 2. 70 F_4 lines of Chihoku × Valujerskaja and 3. 70 F_4 lines of Chihoku × PI-173438 were obtained from the Kitami Agriculture Experimental Station, Hokkaido and were grown in the field during July to September 1986. Because of the limited and varied amounts of seeds, each line was not replicated in the field. When the plants were between 60 to 70 days old excised-leaf water retention capability was measured.

Results and Discussion

Table 1 illustrates the initial leaf water content % and decrease in leaf water content % at several time periods of 4 winter wheat cultivars grown in the field. Excised-leaf water retention capability (concerned to the decrease in leaf water content %) among cultivars could be differentiated and the relative differences among 4 cultivars remained constant when average weight loss of excised-leaves varied within a range of 11 to 32% (from 10 h to 24 h after excision). Clarke and McCaig[3] found greater differences between wheat genotypes when the average weight loss was between 10 to 40%.

Initial leaf water content % and decrease in leaf water content % of 12 spring wheat and 12 winter wheat cultivars during summer and winter are illustrated in Table 2 and Table 3 respectively. Water retention capability during winter was found to be high and therefore the decrease in leaf water content % was measured at 24 h after excision during winter, instead of 8 h after excision during summer. An increase in water retention capability and a decrease in initial leaf water content % was clearly seen in both spring wheat and winter wheat during winter as compared to results obtained in summer. This change could be attributed to the cold acclimation. Initial leaf water content % and decrease in leaf water content % were not correlated in both spring wheat and winter wheat. Dedio[6] found a high correlation between water retention and leaf water content of winter wheat. A correlation between both seasons for initial leaf water content % and decrease in leaf water content % was not found in both spring wheat and winter wheat.

Fig. 1 illustrates the effect of drought hardening on excised-leaf water retention capability of 4 winter wheat cultivars. Hardened plants showed higher water retention capability, but the difference between hardened and non-hardened treatments was not significant. This agrees with the results of Clarke and McCaig[2] and Clarke[4] who found higher water retention in leaves from rainfed than from irrigated wheat plants. Salim et al[7] also found improved water retention in hardened compared to non-hardened plants.

Clarke and Townley-Smith[5] did not find

Table 1. Initial leaf water content % and decrease in leaf water content % 2, 4, 8, 10, 12, 20 and 24 h after excision of four field grown winter wheat cultivars.

Cultivar	Initial leaf water content %	Decrease in leaf water content % at each time after excision						
		2h	4h	8h	10h	12h	20h	24h
Horoshiri	83.1	2.0	3.7	7.0	10.2	13.4	28.0	34.9
Chihoku	84.4	2.4	4.0	7.6	10.0	12.5	25.0	32.1
PI-173438	83.9	2.8	4.5	7.9	9.8	11.6	19.3	23.9
CI-14106	83.8	3.3	5.7	10.8	13.9	17.0	30.6	36.9
Mean	83.8	2.6	4.5	8.3	11.0	13.6	25.7	31.9
CV (%)	0.6	21.7	20.1	20.2	17.8	17.3	18.7	17.9
L.S.D (0.05)	0.5	0.2	0.7	0.8	1.3	1.7	4.4	5.5

Table 2. Initial leaf water content % and decrease in leaf water content % of spring wheat grown in the field (during summer) and in the green house (during winter).

Cultivar	Summer		Winter	
	Initial leaf water content %	Decrease in leaf water content % at 8 h after excision	Initial leaf water content %	Decrease in leaf water content % at 24 h after excision
Haruyutaka	81.4	17.9	77.0	13.3
R.L.4137	82.2	24.4	78.1	12.9
2-47-217	82.6	19.3	77.4	36.7
Moran	79.5	19.3	78.1	11.0
Tordo	81.0	27.8	78.2	16.3
Norin 35	—	—	73.1	14.6
Neepawa	81.0	13.8	77.7	8.1
Turbo	80.6	17.3	79.5	19.9
Veery-S	80.9	15.9	73.7	12.4
Haruhikari	80.5	30.8	78.8	22.0
Chikushi	—	—	74.5	12.0
Alandora	81.1	13.6	77.1	14.4
Mean	81.1	20.0	76.9	16.1
L.S.D. (0.05)	1.9	4.6	1.0	3.5

any correlation between crop yield and water retention capability in winter wheat. They stated that excised-leaf water retention capability is yield-negative in the high yielding environments but yield-positive under drought conditions, suggesting that the water retention trait is only of benefit under drought conditions. They suggested that the mechanisms governing water retention could be limiting gas exchange and photosynthetic productivity.

Figs. 2, 3 and 4 illustrate the frequency distribution of excised-leaf water retention capability of lines from winter wheat crosses. In Figs. 2 and 3, most of the lines were distributed between the parental values and the overall progeny means were located almost near the parental mean values. In Fig. 3, both parental values and the overall progeny mean were located in the middle of the frequency distribution. These frequency distributions show the characteristic pattern of quantitative (multiple gene) inheritance. However, the progenies tested in this study were F_4 and F_5 generations and therefore the frequency distribution patterns obtained were not identical to the characteristic pattern of quantitative inheritance. These results do not agree with the conclusion of Dedio[6] who stated that the high retention parent is contributing one or

Table 3. Initial leaf water content % and decrease in leaf water content % of winter wheat grown in the field (during summer) and in the green house (during winter).

Cultivar	Summer: Initial leaf water content %	Summer: Decrease in leaf water content % at 8 h after excision	Winter: Initial leaf water content %	Winter: Decrease in leaf water content % at 24 h after excision
Stephens	80.7	18.3	—	—
Kitakei	83.1	13.9	76.1	9.3
Norstar	—	—	73.8	13.1
Hokuei	83.5	13.4	75.4	7.2
Chihoku	82.8	13.2	76.6	7.7
Eiger	82.1	13.4	76.2	10.7
Valujerskaja	81.3	17.9	75.7	10.9
Horoshiri	82.6	12.0	76.0	10.0
Nanbu	83.0	10.1	—	—
Ibis	82.5	10.7	76.8	12.5
PI-173438	83.5	18.0	75.8	10.9
CI-14106	83.0	18.7	77.8	12.6
Mean	82.6	14.5	76.0	10.5
L.S.D.(0.05)	0.5	3.3	0.6	1.1

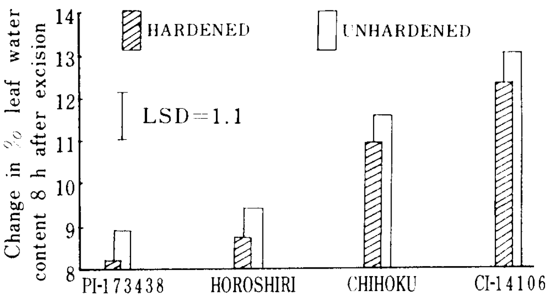

Fig. 1. The influence of drought hardening on excised-leaf water retention capability of four winter wheat cultivars.

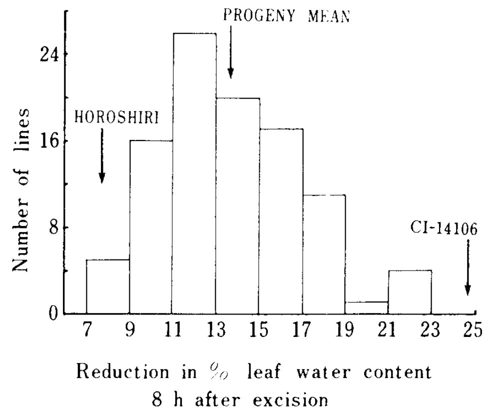

Fig. 2. Frequency distribution of excised-leaf water retention capability of 100 F_5 winter wheat lines from a cross of Horoshiri and CI-14106.

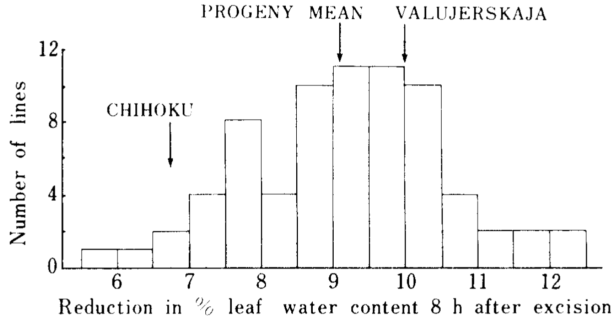

Fig. 3. Frequency distribution of excised-leaf water retention capability of 70 F_4 winter wheat lines from a cross of Chihoku and Valujerskaja.

few dominant genes governing retention and only a few genes are involved in controlling the water retention character. However, the results agree with the results of Clarke and McCaig[2] and Clarke and Townley-Smith[5] who illustrated the same pattern of segregating populations between the crosses of high and low retention parents of wheat. They concluded that excised-leaf water retention capability seems to be somewhat heritable. The results showed the characteristic pattern of multiple gene inheritance, which involves cumulative action of several or many genes. Therefore it is possible to conclude that the excised-leaf water retention capability of wheat seems to be a quantitative character which is determined by polygene action.

Screening for excised-leaf water retention capability can be easily done and needs no sophisticated technology. Weighing the leaf samples when the change in water content %

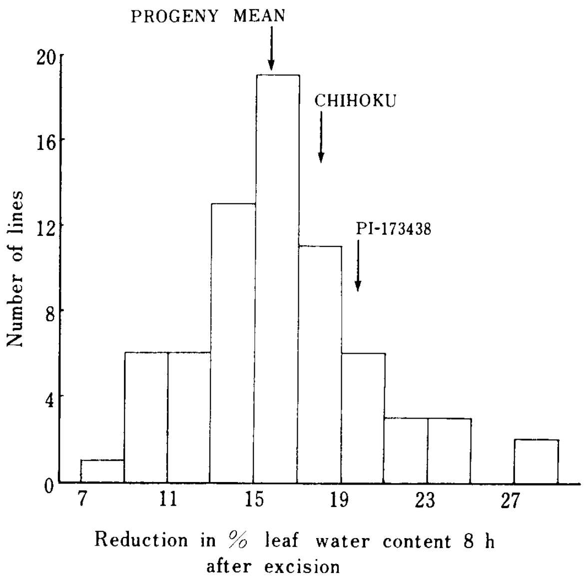

Fig. 4. Frequency distribution of excised-leaf water retention capability of 70 F_4 winter wheat lines from a cross of Chihoku and PI-173438.

is between 11 to 30, provides good cultivar differentiation. This can be used for screening drought tolerant genotypes and large number of lines in plant breeding programmes for drought tolerance. This character is unstable to some extent due to the different results obtained between seasons. Further studies are needed on excised-leaf water retention capability and its genetic variability.

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