Varietal Difference in Water Requirement and Water Economy in Oats

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I. Introduction

It has been observed that the most disastrous condition for plant growth prevails widely when the atmospheric drought and soil drought occur simultaneously (MAXIMOV 1929). Thus it seems important to investigate interspecific and especially intervarietal differences with special reference to drought resistance and wilting endurance. It has previously been shown that there are differences in the adaptation or adaptability to soil moisture among some oat varieties (KUMAGAI 1954). The adaptation to soil moisture is probably associated with the protoplasm of oat varieties (MAXIMOV 1929). However, so far as known, little work has been done on the adaptation capacity to soil moisture in oat varieties in our country.

The present work is a continuation and amplification of the studies on hygrotypes and xerotypes of oats started in 1953. The purpose of this work is to find out the varietal differences in water requirement by estimating the amount of water absorbed and water economy, using water culture. The relationship between the water requirements as seen in water culture and soil culture experiments has never been made clear. Although, in the latter, a maximal effort was made to unify the water condition among pots, the results were such that reliable data on transpiration could hardly be obtained because of the difficulty in maintaining uniform conditions.

II. Material and Methods

In the present investigation the following nine oat varieties were used as material.

(1) Victory No.1 was bred in 1923 at the Hokkaido Agricultural Experiment Station in Japan by pure line selection from a Svalöf Victory introduced from Sweden. The oats of this type have a high adaptability and are cultivated extensively, especially in Hokkaido, Japan.

(2) Marvellous was introduced from Sakhalin Central Agricultural Experiment Station in 1941. It is different from the variety which STANTON (1955) describes as late, midtall to tall having unilateral to semiunilateral panicles. The variety used in the present experiment is early and has shorter and equilateral panicles.

(3) Black President Oat is a variety from which "Black Mesdag" used in the previous work was selected. This variety was obtained from the Hokkaido University in 1925.

(4) Culberson is said to have been bred by a selection from Red Rustproof Oats. In an early stage of growth this variety is prostrate. It was introduced into Japan from the Department of Agriculture, U.S. A., 1933.

Received on Oct. 17, 1959.

(5) Kytö is said to have been introduced from Finland in 1938, but details regarding its origin and development are not quite clear. It is early, less tall with narrow leaf blade.

(6) Grocken Hafer was received from the Hokkaido University in 1932. Details regarding its origin and development are also not quite known. It has many spikelets and very broad leaf blades.

(7) Lee was bred by selection from a cross between Winter Turf and Aurora in U. S. A. and was introduced from the Tennessee Agriculture Experiment Station, U. S. A., in 1933. This variety is prostrate at an early stage of growth as in Culberson.

(8) Niagara was obtained from the Kōnōen Seed Company in Hokkaido in 1930. Its leaf blade is broad.

(9) Green Mountain is said to be similar to White Tartar and is unilateral in panicle attitude as described by STANTON (1955). But the Green Mountain which was used in the present investigation seems to be a little different from the above mentioned varieties. The latter variety is a naked oat and is prostrate.

The method to determine the water requirement consists of measuring the loss of water in a planted plot at intervals of 5 days and subtracting therefrom the amount of evaporated water in a nonplanted pot. The basic nutrient solution for water culture was composed of the following chemicals,

NO ₃ -N	40 p. p. m.	MgO	30 p. p. m.
P ₂ O ₅	40 p. p. m.	CaO	30 p. p. m.
K ₂ O	30 p. p. m.	FeCl ₃	2 %

The chemicals used were calcium nitrate, magnesium sulfate, potassium dehydrogen phosphate, potassium sulfate and ferrous chloride. Manganese sulfate was added to each pot so as to give a final concentration of 0.05% in July, 1955, since the author often observed manganese deficiency in many plants. As far as possible, an attempt was made to sustain pH of the nutrient solution at 5.2~5.6, by adjustment with sulfuric acid.

The experiments were carried out in duplicate. At first the oat seeds were planted in sand culture and after the seedling grew to a proper stage of growth, four healthy plants were transplanted to water culture. The culture solutions were added regularly to restore the loss due to transpiration and evaporation. The experiments were carried out in a green house at the Hokkaido National Agricultural Experiment Station during the spring and summer of both the years 1955 and 1956. The observations were taken until the oat plants attained full maturity.

III. Experimental Results

— Experiment in 1955 —

An experiment was conducted in order to determine water requirement. The amount of water absorbed by plant in each pot was measured at intervals of five days as mentioned previously.

The total amounts of water absorbed by each variety are given in Table 1. The experimental data presented in Table 1 are illustrated graphically in Figure 1. The varietal differences in the amount of water absorbed are indicated. Marvellous and Kytö showed lowest values in the amount of water absorbed during the growing season and the total sum with Marvellous ranking first and Kytö second. Following the above two varieties, Culberson, Black President Oat, Victory No. 1 are enumerated in the

Table 1 Total amount of water absorbed recorded at intervals of 5 days in 1955.

	Victory No. 1	Marvellous	Black President	Culber-son	Kytö	Glocken Hafer	Lee	Niagara	Green Mountain
May	cc	cc	cc	cc	cc	cc	cc	cc	cc
5	0	0	6	6	43	0	9	0	5
10	0	15	12	78	75	0	9	0	11
15	97	68	87	166	153	75	60	38	74
20	239	213	230	271	256	234	192	187	229
25	509	468	585	556	506	569	427	442	509
30	894	768	985	851	801	844	682	802	844
June									
4	1,209	1,143	1,520	1,271	1,156	1,319	1,007	1,272	1,239
9	2,704	2,638	3,485	3,111	2,331	2,889	2,727	2,952	2,784
14	3,854	3,728	4,955	4,461	3,216	4,189	4,097	4,327	3,974
19	5,316	5,059	6,642	6,148	4,403	5,751	5,953	6,002	5,567
24	6,187	5,659	7,600	7,043	5,013	6,646	6,982	7,048	6,529
29	7,532	6,520	9,020	8,418	6,113	8,131	8,747	8,765	8,269
July									
4	9,492	6,522	10,845	10,248	7,551	10,221	11,502	11,424	11,069
9	11,952	—	12,970	12,203	9,246	12,941	14,822	14,523	14,424
14	13,492	—	14,410	13,423	10,156	14,376	16,837	16,633	16,349
19	15,917	—	15,980	14,571	11,091	16,341	19,637	19,438	19,219
24	16,592	—	16,169	—	11,370	17,198	20,370	20,048	19,809

Fig 1. Diagrammatic illustration of the total amount of water absorbed during each growing stage in 1955.

1. Victory No.1 2. Marvellous 3. Block President Oat 4. Culberoson 5. Kytö
6. Glocken Hafer 7. Lee 8. Niagara
9. Green Mountain *Date headed.

of dry matter considerably small. Thus it is concluded that Marvellous and Victory No. 1 have a high water economy. Lee, Green Mountain and Niagara were high both in total amount of water absorbed during the whole growing season and in the amount

descending order of low water absorption. It was noted that the amount of water absorbed increased strikingly after heading, independent of variety. The green weight and dry weight per plant were also measured.

On the basis of these measurements the amount of water absorbed for the production of 1 gram dry matter was calculated i. e. water economy. The results are given in Table 2.

Table 2. Total amount of water absorbed and water economy in 9 oat varieties in 1955.

Name of variety	Total amount of absorption of water (cc)	Dry weight (grams)	Water economy (cc)
Victory No. 1	16,592	68.2	248.06
Marvellous	6,522	34.5	189.71
Black President Oat	16,169	55.3	282.29
Culberson	14,571	52.5	277.88
Kytö	11,370	39.0	292.36
Glocken Hafer	17,198	62.7	274.39
Lee	20,370	64.9	314.52
Niagara	20,048	65.8	304.46
Green Mountain	19,809	67.2	294.69

The Table 2, shows that Marvellous and Victory No.1 have the lowest value water economy. However, there are some varieties in which water absorption during growing season is high while the amount of water for producing 1 gram

Fig 2. Diagrammatic illustration of the total amount of water absorbed during each growing stage in 1956.

of water required for producing 1 gram of dry matter.

— Experiment in 1956 —

The results of the experiment conducted in the year 1956 as shown in Table 3 and Figure 2 indicate that the total amount of water absorption during the whole growing season of 1956 is higher than that of the 1955. Such differences may be due to the fact that the climatic conditions in 1956 were comparatively cooler and had considerable influence on water absorption by each plant. As regards the varietal differences the same tendency as seen in 1955 was found in 1956. Lee, Culberson and Green Mountain are among those which absorbed consistently a great amount of water. On the other hand, Marvellous absorbed the least amount of water following Grocken Hafer.

The amount of water necessary to produce 1 gram of dry matter, i.e. water economy was calculated for each variety studied. The results are illustrated in Table 4. It may be seen from Table 4 that Victory No. 1, Green Mountain and Marvellous showed relatively a high water economy and

Table 3. Total amount of water absorbed recorded at intervals of 5 days in 1956.

	Victory No. 1	Marvellous	Black President	Culberson	Kytö	Glocken Hafer	Lee	Niagara	Green Mountain
May	cc	cc	cc	cc	cc	cc	cc	cc	cc
24	0	0	15	40	0	0	15	0	15
29	30	0	55	90	75	50	55	0	50
June									
3	176	129	146	232	212	158	163	79	158
8	336	204	256	392	317	248	273	224	268
13	661	534	526	712	517	443	593	599	608
18	1,041	714	961	1,102	727	638	1,043	1,064	953
23	1,492	927	1,461	1,565	965	876	1,537	1,608	1,354
28	2,262	1,377	2,391	2,460	1,500	1,391	2,657	2,603	2,174
July									
3	3,352	2,022	3,666	3,940	2,160	2,081	4,467	4,018	3,469
8	4,215	2,460	4,660	4,803	3,267	2,519	5,849	4,794	4,632
13	5,550	3,205	6,235	6,183	4,112	3,319	8,124	6,019	6,597
18	7,240	4,045	8,115	8,773	5,102	4,504	10,749	7,489	9,532
23	8,878	4,620	9,896	11,373	6,021	5,467	13,774	8,821	12,226
28	10,218	5,130	11,256	13,573	6,751	6,172	16,179	9,826	14,551
Aug.									
2	12,268	5,860	13,146	17,248	7,836	7,207	19,989	11,381	17,791
7	14,443	6,516	15,165	21,136	9,199	8,507	24,214	14,156	21,123
12	16,778	7,476	17,285	26,066	10,469	9,412	29,694	16,851	25,448
17	18,558	7,838	19,031	30,234	11,540	9,922	33,812	18,578	29,106
22	19,403	7,931	19,621	32,699	11,874	—	36,112	19,408	30,991
27	20,720	—	—	36,314	—	—	39,303	20,379	33,974
Sep.									
1	21,522	—	—	40,049	—	—	42,953	—	37,106
6	—	—	—	42,137	—	—	44,807	—	38,046
11	—	—	—	44,045	—	—	46,932	—	—
16	—	—	—	47,578	—	—	47,995	—	—

Niagara being the lowest. On the other hand, Niagara consumed much water to produce gram of dry matter.

IV. Discussion

In the previous report the author discussed the adaptation and the adaptability regarding certain oat varieties, but no definite conclusion was reached on the water requirement by different varieties. Accordingly the present ex-

periments were designed and the varietal difference in water requirements has now become clear. The climatic conditions in 1955 were different from those in 1956. The interaction between varieties and years is statistically significant (Table 5), in as much as the values are largely derived from the interaction between Marvellous and others.

An analysis of variance regarding the amount of water absorbed for producing 1 gram of dry matter was done for both years in order to determine whether the varietal differences were statistically significant or not. The results obtained are given in Table 5. Mean squares in Table 5 show that the variation due to varieties is statistically significant.

In addition, statistical procedure was carried out by Tukey's method to determine the order of varieties. Thus, an examination of data with regards to water economy shows that there are four groups i.e. Marvellous belongs to the first group, which is the highest in water economy; Victory the second; Grocken Hafer, Green Mountain, Kytö, Culberson and Black President Oat the third; Lee and Niagara the fourth. It has been pointed out that Culberson was low in adaptability to water conditions. In the present experiment Culberson ranked sixth among the varieties studied and belongs to the second group in relation to the water economy. Culberson may be lower in adaptability to water condition since its water economy is lower. However, studies on the relation between water economy and adaptability to water condition still remains to be the most important subject to be studied in future.

Further-more, correlation coefficients were calculated in order to study the relations between the amount of water absorbed and some characteristics observed in nursery, and between water economy and some characteristics of each variety. Data for characters were taken from field tests of six varieties. The characters observed are culm height, panicle length, number of tillers, total weight, number of spikelet, culm weight, root weight, panicle weight, weight of grain, weight per 1,000 kernels, date of heading, ripening period, date of ripening, plant growth habit and lemma colors. Correlation coefficients are shown in Table 6. There were statistically significant differences

Table 4. Total amount of water absorbed and water economy in 9 oat varieties in 1956.

Name of variety	Total amount of water absorbed (cc)	Dry weight (grams)	Water economy (cc)
Victory No. 1	21,522	80.8	268.14
Marvellous	7,931	29.0	271.92
Black President Oat	19,621	64.5	305.13
Culberson	47,578	151.5	313.77
Kytö	11,874	39.1	287.07
Glocken Hafer	9,922	34.4	288.81
Lee	47,995	153.2	313.23
Niagara	20,379	67.8	341.54
Green Mountain	38,046	139.5	273.17

Table 5. Analysis of variance of water economy. i.e. the amount of water absorbed for producing 1 gram of dry matter.

Variation	D. F.	Sum of square	Mean square	F.
Among years	1	3,380.84	3,380.84	17.88**
Varieties	16	32,368.98		
Varieties	8	25,058.62	3,132.33	16.52**
Varieties×Years	8	7,310.36	913.80	4.82**
Marvellous : others	1	4,441.53	4,441.53	23.43**
Among others	7	2,868.83	409.83	2.16
Errors	18	3,412.73	189.60	

** Significant at the 0.01 level.

between the total amount of water absorbed and some growth habits. The water requirement is positively correlated with number of tillers, though it is not statistically significant.

V. Summary

Water requirement and water economy of oat varieties were studied accurately by water culture, in the years 1955 and 1956. The results of these experiments are summarized below :—

1. The total amount of water absorbed by each of the 9 varieties was determined at different growing stages. There was a considerable annual variation in water absorption among the varieties tested between 1955 and 1956.

2. The water economy of each variety was calculated, by dividing the total amount of water absorbed by the amount of dry weight produced. The order of varieties determined by the value of water economy did not coincide with that of calculated by the total amount of water absorbed.

3. As a whole, these oat varieties may be classified into several groups in accordance with the values of their water economy. By using Tukey's procedure, the varieties were statistically classified into four groups according to their respective water economies. The first group is higher in water economy, including two varieties, and the fourth group lower, including a single variety.

4. Correlation coefficients between the total amounts of water absorbed and some characteristics, were calculated. Correlation coefficients between total amount of water absorbed and forms of juvenile plant growth habits are significant. Number of tillers is positively correlated with water requirement, though it was not statistically significant. Thus it may be concluded that the varieties with more tillers and of prostrate type tend to absorb more water than those with fewer tillers and of erect type.

Acknowledgement

The author wishes to thank Mr. S. TABATA, Miss T. KOIKE and Mr. M. HAYASHI for their valuable assistance in carrying out the experiment. The author is also highly indebted to Dr. TAGAWA, Mr. T. HOSHINO, Mr. Y. SHIMAZAKI and Mr. N. TAKASE for their valuable advice and going through the present manuscript.

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Table 6. Correlation coefficients between the total amount of water absorbed and between water economy and some characters in field.

Characters	Total amount of absorption of water	Water economy
Culm Height	0.3705	0.2268
Panicle Length	0.2483	0.5337
No. of Tillers	0.6320	0.2311
Total Weight	0.4788	0.3012
No. of Spikelet	0.4297	0.4903
Culm Weight	0.5369	0.2574
Root Weight	0.3988	0.2059
Panicle Weight	0.3048	0.3394
Grain Weight	0.1469	0.3257
1000 Kernels	-0.5129	-0.1418
Date Headed	0.0281	0.2583
Date Ripe	0.4436	-0.0354
Ripening Periods	-0.0268	-0.3746
Lemma Color	0.0120	-0.1539
Plant Growth Habit	0.9131**	0.3136

** Significant at the 0.01 level.

えん麦における水分要求量と水分経済の品種間差異

熊 谷 健

形態的特性の異なるえん麦9品種の水分要求量と水分経済性の差異について1955年と1956年の両年にわたり水耕栽培法により調査し次の結果を得た。

全生育期間にわたって吸収した総吸水量、すなわち水分要求量について調査したところ、両供試年の気象条件の隔差がはなはだしいため両年の結果は著しい相違をきたしたにもかかわらず、水分要求量と水分経済の品種間差異は一貫して認められた。しかし、両者の品種順位は一致しなかつた。

供試品種の水分経済性を Tukey の統計的手続きを適用して四つの群に区分することができた。水分要求量または水分経済と諸形質との間の相関を求めたところ、水分要求量と稚苗期の草型（叢性）との間に有意な相関が認められ、ほふく型の多けつ性品種が直立型の茎数の少ない品種に比較して吸水量の多い傾向がうかがわれた。しかし、水分経済についてはこれと同様の関係は見出しがたかつた。(摘要)