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THE WATER REQUIREMENT OF PLANTS AT AKRON, COLO.

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(Contribution from Bureau of Plant Industry)

Reprinted from **JOURNAL OF AGRICULTURAL RESEARCH**

Vol. 34, No. 12 : : : Washington, D. C., June 15, 1927

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE, WITH THE COOPERATION OF THE ASSOCIATION OF LAND-GRANT COLLEGES

U. S. GOVERNMENT PRINTING OFFICE : 1927

THE WATER REQUIREMENT OF PLANTS AT AKRON, COLO.[1]

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INTRODUCTION

The term "water requirement" indicates the ratio of weight of water absorbed by the plant during its growth period to the weight of dry matter harvested. Only in the case of root crops is the weight of the underground parts included. Previous measurements at Akron, Colo., have been reported by Briggs and Shantz.[4] Their results include two crops grown in 1910, 31 in 1911, 44 in 1912, and 55 in 1913.[5]

The experiments were enlarged in 1914, 1915, and 1916 to include 68 sets of plants, but in 1917 this number was reduced to 29 sets. A few additional sets were grown each year as late-season crops or in specially constructed pots. The published data covered 132 sets of 6 pots each, while the data here presented comprise an additional 147 sets of 6 pots each. The total experiment represents 288 sets of more than 1,800 pots, covering the period 1911 to 1917. There are here included only those experiments which give relative values and are directly comparable, and these are combined in a final summary (Tables 33, 34, and 35). A weighted summary, which represents the mean value for a period of years for each crop and the relative water requirement for the different crops, as closely as they can be expressed from the measurements at hand, is also given. Estimates are made of the probable highest and lowest values which would have been recorded had each crop been grown continuously from 1908 to 1925. These estimates are based on evaporation and transpiration data. The experiments at Akron, Colo., were discontinued at the end of 1917.

[1] Received for publication Dec. 7, 1926; issued July, 1927.

[2] Formerly Physiologist in Charge, Plant Geography and Physiology, Bureau of Plant Industry.

[3] The results here recorded are part of an extensive experiment begun by L. J. Briggs, while in charge of the Office of Biophysical Investigations, and the senior author, then of the Office of Alkali and Drought Resistant Plant Investigations. At the beginning of the World War Doctor Briggs was transferred to the United States Bureau of Standards, and the senior author carried on the work until 1919, having personal supervision of the work at Akron from 1910 to 1916, inclusive. The writers are indebted to each of the following men, who, between 1910 and 1917, assisted in this project for periods ranging from 1 to 5 years: A. P. Kidder, Homer Martin, Auguste Bonequet, A McG. Peter, R. D. Rands, G. Crawford, A. F. Cajori, N. Peter, H. W. Marquard, J. D. Hird, R. L. Piemeisel, H. Shattyn, T. R. Henault, F. M. Eaton, and Clyde Griswold. On them rested most of the responsibility of daily attention to the work in the field and of keeping the experiments and records in good condition. The writers are also indebted to A. McG. Peter, F. A. Cajori, N. Peter, J. D. Hird, H. Shattyn, F. M. Eaton, Clyde Griswold, Homer Martin, and W. H. Heald for work with the records and on crops in Washington; to O. J. Grace, farm superintendent at the Akron field station, for assistance and farm labor in connection with the experiments; to the Office of Dry-Land Agriculture for making available the facilities of its field station for this work; to T. H. Kearney, physiologist in charge of alkali and drought-resistant plant investigations, under whose direction the work was undertaken by the senior author, for sympathetic support and advice; and to L. J. Briggs, with whom the senior author collaborated, and who, had he not been transferred to another field of work, would have been joint author of this publication. The responsibility of collecting this material and preparing it for publication has fallen entirely upon the senior author and his assistant, Lydia N. Piemeisel.

[4] BRIGGS, L. J., and SHANTZ, H. L. THE WATER REQUIREMENT OF PLANTS. I.—INVESTIGATIONS IN THE GREAT PLAINS IN 1910 AND 1911. U. S. Dept. Agr., Bur. Plant Indus. Bul. 284, 49 p., illus. 1913.

[5] BRIGGS, L. J., and SHANTZ, H. L. RELATIVE WATER REQUIREMENT OF PLANTS. Jour. Agr. Research 3: 1-64, illus. 1914.

METHODS

The methods used in conducting these experiments have been fully described in the publications already cited. Plants were grown in a screened inclosure to protect them from hail and birds (fig. 1), and the results thus obtained were compared with those obtained with plants freely exposed, and also with plants grown in fields of grain.

The pots used contained about 115 kilograms of soil. Each pot was provided with a tight-fitting cover and sealed. A capillary tube was inserted through the corks to prevent the carrying in of rain water by suction resulting from rapid cooling during showers. The pots were weighed daily, or as often as necessary to insure their maintenance at the proper water content. The initial weight was taken as soon as the pots were planted and waxed. The pots were weighed with a spring balance. This balance was checked against a platform balance several times during each weighing, for temperature

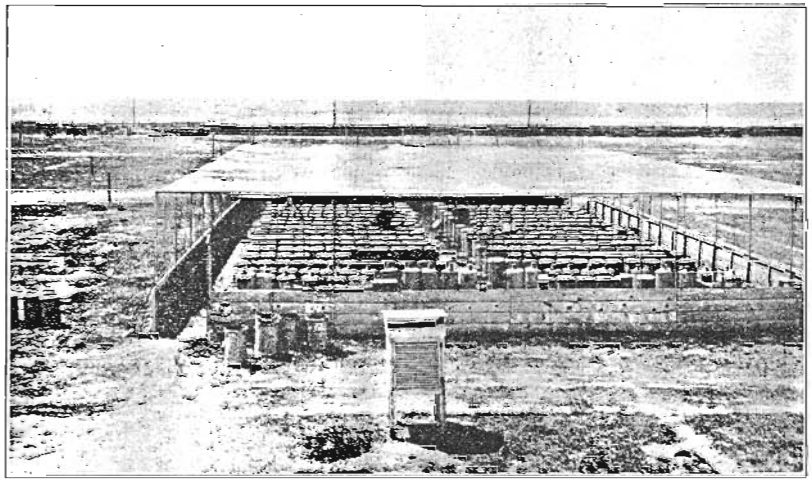

FIG. 1.—A general view at planting time of the shelter in which water requirement measurements at Akron were made. Photographed May 8, 1914

and other changes, so that the results obtained were accurate to within one-fifth of a kilogram. Water was added from calibrated flasks with the neck cut to deliver 2 liters.

Fertilizer composed of 25 parts per million of PO_4, 50 parts per million of NO_3, and 33 parts per million of K was added to each pot four times during the growth period. In 1911 and 1914 twice this amount was added. One-fourth of the fertilizer was added in 2 liters of water and was followed immediately by an additional 2 liters of water. Check determinations showed no difference in the water requirement of fertilized and unfertilized pots.

Akron, Colo., is located on the high plains, and the national vegetation consists of a relatively pure short grass cover. (See fig. 2.)

Complete records of weather factors were taken, including solar radiation, depression of wet bulb thermometer, air temperature, wind velocity, and evaporation from a free water surface.[6] [7]

[6] BRIGGS, L. J., and SHANTZ, H. L. HOURLY TRANSPIRATION RATE ON CLEAR DAYS AS DETERMINED BY CYCLIC ENVIRONMENTAL FACTORS. Jour. Agr. Research 5: 583-650, illus. 1915.

[7] BRIGGS, L. J., and SHANTZ, H. L. DAILY TRANSPIRATION DURING THE NORMAL GROWTH PERIOD AND ITS CORRELATION WITH THE WEATHER. Jour. Agr. Research 7: 155-212. illus. 1916.

EFFECT OF THE SHELTER

The results presented in this paper were obtained in a screened inclosure covered with No. 21 galvanized wire netting of 3/8-inch mesh. The previous measurements [8] show that the light was reduced about 20 per cent by the inclosure. The water-requirement measurements have led to the conclusion that pots sunk in trenches, surrounded by a field of grain, have a water requirement of about 10 per cent above wheat grown in an inclosure, and 10 per cent below that of wheat grown outside the inclosure in a freely exposed position.

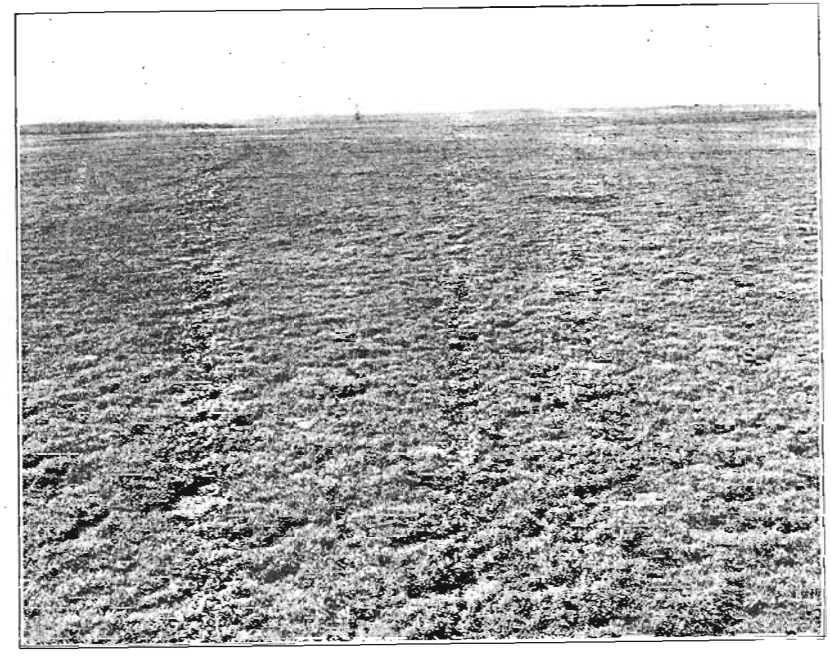

FIG. 2.—General view of the natural vegetation at Akron, Colo. A relatively pure cover of grama grass (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). Photographed April 18, 1910

As the result of a long series of observations, measurements for 1911, 1913, 1914, 1915, 1916, and 1917 are now available (Table 1). These measurements show a wide variation, and many factors must be taken into account in their interpretation. The conditions in the field were probably more favorable at times than those in the shelter, especially for such warm weather crops as sorghums and millets. Observations in the shelter were made under most favorable conditions, since the plants were protected from excessively high winds and from damage by hail, wind, or birds (fig. 3). In the field, on the other hand, plants were subject to all the variable and inclement conditions of the weather, so that the measurements show a much wider variation and a much greater probable error than those grown in the shelter.

While the plants grown in the open were also exposed they were watched much more closely and were protected to some extent against excessive storms. The values here presented are more extensive than those cited by Briggs and Shantz in the 1913 measurements. The measurements presented in Table 1 show that the water

[8] BRIGGS, L. J., and SHANTZ, H. L. Op. cit. 1914. p. 3.

requirement in the field was 10 per cent higher than that in the screened inclosure, which is in exact accord with the results previously obtained. For the freely exposed plants, however, the water requirement was only 3 per cent above that in the field or 13 per cent above the crops in the shelter. It seems safe to assume that had these experiments been carried on in the open, unprotected, and with the same exposure as field plots, the water requirement would have been about 10 per cent higher than at present recorded. Table 1 gives the results obtained under the three locations.

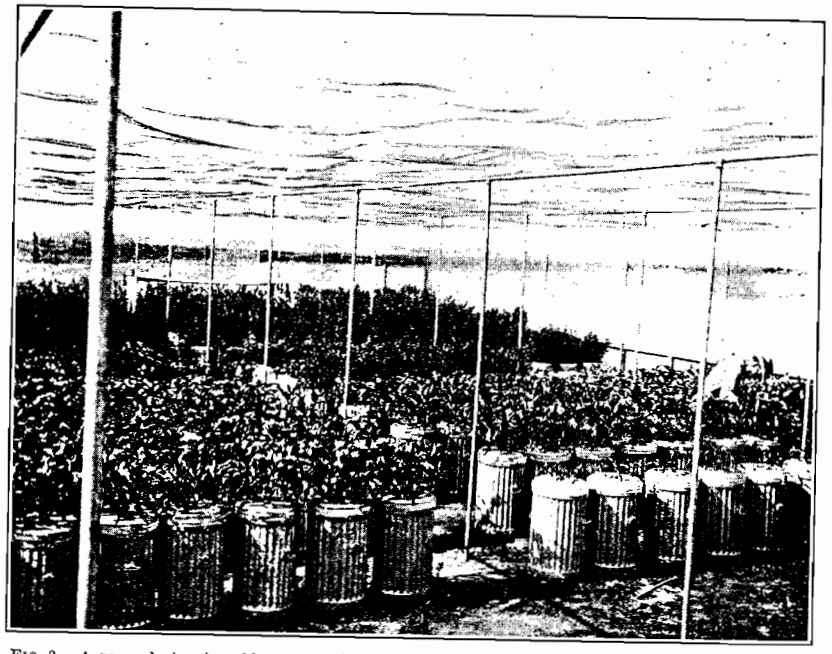

FIG. 3.—A general view in midseason of the shelter in which the water requirement measurements at Akron were made. Photographed July 13, 1912

TABLE 1.—*Effect of exposure on water requirement, as shown by experiments with plants grown in the open but slightly protected, in the field, and under shelter, at Akron, Colo., field station*

Year	Crop	Water requirement of plants—					
		In open		In field		In shelter	
		Actual	*Per cent*	*Actual*	*Per cent*	*Actual*	*Per cent*
1911	Tumbleweed	275±7	99			277±4	100
1913	Wheat, Kubanka, C. I. 1440	627±5	126	562±6	113	496±5	100
	Alfalfa, Grimm, E-23	1030±12	124			834±8	100
1914	Wheat, Kubanka, C. I. 1440			625±20	121	518±6	100
	Sudan grass	455±9	115	402±6	102	394±4	100
	Alfalfa, Grimm, E-23	1039±19	117			890±6	100
	Millet, Kursk			287±6	97	295±2	100
1915	Wheat, Kubanka, C. I. 1440			361±3	89	405±3	100
	Sudan grass	287±8	110	290±5	112	260±3	100
	Alfalfa, Grimm, E-23	795±20	114			695±9	100
	Millet, Kursk			218±3	108	202±1	100
1916	Wheat, Kubanka C. I. 1440			908±50	143	636±14	100
	Sudan grass			377±10	88	426±3	100
	Alfalfa, Grimm, E-23	1095±25	105			1047±9	100
	Millet, Kursk			460±16	125	367±4	100
1917	Sudan grass	409±9	108			378±3	100
	Average		113		110		100

WATER-REQUIREMENT EXPERIMENTS, 1910 TO 1917

As already mentioned, the results of experiments from 1910 to 1913 have been published, only the final results being included in the summary in Tables 33, 34, and 35 of this discussion.

Many of the experiments from 1914 to 1916, which included 68 sets of plants used each year, covered special measurements not included in this paper. Only those which are comparable and which have a bearing on the relative water requirement of plants are here presented. To obtain the data presented in each table six determinations usually were made for each crop. These have been combined into an average for which a probable error has been calculated.

WATER-REQUIREMENT EXPERIMENTS, 1914

Sixty-one sets of plants were grown in 1914, which was an average year, the water requirement being approximately the same as the mean for the series of plants grown each year from 1911 to 1917. (Tables 27 and 28.) The evaporation also was practically the same as for the mean of the period 1911–1917 (Tables 31 and 32) and for the longer period 1908–1924 (Table 32). During this year special attention was given to alfalfas which were being tried out in the dry land regions, and to corn and wheat varieties. The results of the water-requirement measurements of the corn hybrids grown have already been presented.[9]

WATER REQUIREMENT OF WHEAT VARIETIES, 1914

Fourteen varieties of wheat were grown in the experiments in 1914 (Table 2) 5 of which were durums, and 8 were common varieties and 1 was a hybrid. The results, based on dry matter, are as follows:

Durum wheats:	
Beloturka	458±10
Jumillo	496±10
C. I. 4131	507±8
Kubanka, C. I. 1440	518±6
C. I. 4082	538±5
Average	503±8
Common wheats:	
Marquis, C. I. 3641	498±5
Preston, C. I. 3328	510±3
C. I. 4090	567±6
Common wheats—Continued.	
Galgalos, C. I. 2398	624±5
C. I. 4087	638±2
Pacific Bluestem	679±3
C. I. 4103	689±8
C. I. 4127	[a]916±15
Average	601±5
Hybrids:	
Jumillo×Preston	574±2
Average for series	560±6

[a] Omitted from average.

The water requirement of the durum wheats in 1914 was 16 per cent lower than the water-requirement measurements for the common wheats. The Beloturka variety gave the lowest water-requirement value, 458±10. The next most efficient of the durum wheats was Jumillo. The standard variety, Kubanka, grown throughout the series of experiments, ranked above all the other varieties of durums, with the exception of an introduction from Peru, C. I. 4082, which had a value approximately 4 per cent higher than Kubanka. The value of Kubanka was 518±6. The variation of the different varieties of durum wheats based on the lowest water-requirement value amounted to only 17 per cent.

[9] BRIGGS, L. J., and SHANTZ, H. L. INFLUENCE OF HYBRIDIZATION AND CROSS-POLLINATION ON THE WATER REQUIREMENT OF PLANTS. Jour. Agr. Research 4: 391–402, illus. 1915.

TABLE 2.—*Water requirement based on grain and dry matter, of varieties of wheat at Akron, Colo., 1914*

Variety of wheat	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on—	
							Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Kubanka, C. I. 1440 (*T. durum*)	May 9 to Aug. 6	1	340.6	126.3	171.0	37	1354	502
		2	245.2	95.3	123.2	39	1293	502
		3	287.3	108.1	155.5	38	1438	541
		4	329.0	123.9	173.6	38	1401	528
		5	318.8	119.2	161.7	37	1357	507
		6	313.1	121.7	165.8	39	1362	530
Mean							1367±13	518±6
Galgalos, C. I. 2398 (*T. aestivum*)	May 9 to Aug. 11	7	292.5	91.9	189.3	31	2060	647
		8	305.2	98.9	192.5	32	1946	631
		9	283.9	96.1	172.9	34	1799	609
		10	278.8	94.3	166.3	34	1764	596
		11	311.8	101.3	195.5	32	1930	627
		12	318.1	105.8	201.1	33	1901	632
Mean							1900±30	624±5
Pacific Bluestem C. I. 4067 (*T. aestivum*)	May 9 to Aug. 12	13	352.3	76.4	236.4	22	3094	671
		14	315.6	56.0	220.5	18	3938	699
		15	328.4	66.9	225.4	20	3369	686
		16	335.4	61.4	223.3	18	3637	666
		17	312.4	61.1	210.7	20	3448	674
		18	326.6	56.9	221.7	17	3896	679
Mean							3564±98	679±3
C. I. 4087 (*T. aestivum*)	May 9 to Aug. 4	19	312.4	88.7	196.2	28	2212	628
		20	272.6	75.8	175.6	28	2317	644
		21	294.5	95.0	189.2	32	1992	642
		22	296.2	95.9	189.5	32	1976	640
		23	291.1	94.1	185.1	32	1967	636
		24	267.9	81.8	171.3	31	2094	639
Mean							2093±43	638±2
C. I. 4090, S. P. I. 36502 (*T. aestivum*)	May 9 to Aug. 4	25	272.5	101.7	157.3	37	1547	577
		26	260.1	91.6	146.9	35	1604	565
		27	258.0	90.9	150.0	35	1650	581
		28	271.3	91.7	154.0	34	1679	568
		29	279.5	94.0	166.1	34	1767	594
		30	324.4	109.7	168.5	34	1536	519
Mean							1631±26	567±6
C. I. 4103 (*T. aestivum*)	May 9 to Aug. 4	31	220.7	.....	157.7	.....	.....	715
		32	218.4	.....	146.7	.....	.....	672
		33	239.5	.....	158.9	.....	.....	663
		34	242.0	.....	167.1	.....	.....	690
		35	247.3	.....	165.0	.....	.....	667
		36	214.9	.....	155.7	.....	.....	725
Mean								689±8
C. I. 4127 (*T. aestivum*)	May 9 to Aug. 4	37	193.8	.....	168.0	.....	.....	867
		38	174.9	.....	157.4	.....	.....	900
		39	173.3	.....	149.7	.....	.....	864
		40	157.8	.....	152.4	.....	.....	966
		41	139.1	.....	134.4	.....	.....	966
		42	156.8	.....	145.8	.....	.....	930
Mean								916±15
Beloturka, C. I. 3705, S. P. I. 35480 (*T. durum*)	May 9 to Aug. 11	43	279.0	102.0	127.3	37	1248	456
		44	301.1	109.9	152.1	36	1384	505
		45	269.5	96.5	131.9	36	1367	489
		46	232.8	85.2	94.2	37	1106	405
		47	269.3	103.0	116.1	38	1127	431
		48	306.6	116.7	141.0	38	1208	460
Mean							1240±35	458±10
C. I. 4131 (from Siberia) (*T. durum*)	May 9 to Aug. 6	49	158.4	61.2	71.6	39	1170	452
		50	224.9	92.1	125.2	41	1359	557
		51	221.5	86.4	114.6	39	1326	517
		52	246.6	98.9	125.8	40	1272	510
		53	236.6	95.2	117.8	40	1237	498
		54	253.8	95.1	128.7	37	1353	507
Mean							1286±23	507±8
C. I. 4082 (from Peru) (*T. durum*)	May 9 to Aug. 11	55	252.0	105.0	144.9	42	1380	575
		56	326.4	123.2	173.9	38	1412	533
		57	313.2	112.4	168.8	36	1502	539
		58	315.2	125.2	164.2	40	1312	521
		59	295.4	89.8	154.6	30	1722	523
		60	299.4	112.3	161.1	38	1435	538
Mean							1461±38	538±5

TABLE 2.—*Water requirement based on grain and dry matter, of varieties of wheat at Akron, Colo., 1914*—Continued

Variety of wheat	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on—	
							Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Marquis, C. I. 3641 (*T. aestivum*)	May 9 to Aug. 3	61	242.6	84.6	120.6	35	1426	497
		62	226.8	76.3	111.3	34	1459	491
		63	195.0	64.6	102.3	33	1584	525
		64	225.4	72.3	105.3	32	1456	467
		65	194.4	68.1	98.4	35	1445	506
		66	187.9	65.1	94.1	35	1445	501
Mean							1469±14	498±5
Jumillo, C. I. 1736 (*T. durum*)	May 9 to Aug. 11	67	209.7	83.0	110.4	40	1330	526
		68	240.7	91.7	129.0	38	1407	536
		69	252.5	92.7	120.5	37	1300	477
		70	265.7	98.6	134.8	37	1367	507
		71	262.3	95.5	125.0	36	1309	477
		72	334.8	132.1	151.8	39	1149	453
Mean							1310±22	496±10
Jumillo×Preston (*T. durum*×*T. aestivum*)	May 9 to Aug. 1	73	283.6	75.0	162.3	26	2164	572
		74	302.2	91.2	172.6	30	1893	571
		75	253.6	72.1	147.6	28	2047	582
		76	225.8	65.6	127.9	29	1950	566
		77	226.6	67.5	129.6	30	1920	572
		78	235.9	70.2	136.6	30	1946	579
Mean							1987±30	574±2
Preston, C. I. 3328 (*T. aestivum*)	May 9 to Aug. 3	79	237.4	78.4	118.0	33	1505	497
		80	261.3	81.1	132.9	31	1639	509
		81	281.4	94.7	147.8	34	1561	525
		82	215.8	75.5	110.8	35	1468	513
		83	249.2	87.0	129.6	35	1490	520
		84	224.3	79.4	111.7	35	1407	498
Mean							1512±22	510±3

Of the common wheats, the lowest water-requirement value, 498 ± 5, was obtained from Marquis; this was 8 per cent higher than the value obtained from the most efficient durum. The other varieties ranged in value up to 38 per cent above Marquis. In this discussion C. I. 4127, which is a fall variety and produced only rosettes in the experiments, has been eliminated from consideration and its value has been omitted in computing the average. One hybrid between a durum and a common wheat was included. This hybrid showed a water requirement 14 per cent above the mean water requirement of the two parents, 16 per cent above the durum parent and 13 per cent above the common parent.[10]

The water requirement of wheats, based on grain production, is as follows:

Durum:	
Beloturka	1240 ± 35
C. I. 4131	1286 ± 23
Jumillo	1310 ± 22
Kubanka, C. I. 1440	1367 ± 13
C. I. 4082	1461 ± 38
Average	1333 ± 28
Common:	
Marquis, C. I. 3641	1469 ± 14
Preston, C. I. 3328	1512 ± 22
Common—Continued.	
C. I. 4090	1631 ± 26
Galgalos, C. I. 2398	1900 ± 30
C. I. 4087	2093 ± 43
Pacific Bluestem	3564 ± 98
Average	2028 ± 48
Hybrids:	
Jumillo×Preston	1987 ± 30
Average for series	1735 ± 39

[10] BRIGGS, L. J., and SHANTZ, H. L. Op. cit. 1915.

Arranged in order of increasing water requirement the order of common wheat varieties is about the same, whether the results are based on total dry matter or grain only. The durum wheats show decided superiority over the common wheats, the lowest of the latter series exceeding in water requirement the highest durum. The durums have a water requirement only 66 per cent of the average of the common wheats. In other words, the grain yield is proportionately higher in the durum wheats than in the common wheats.

The water requirement of the hybrid based on grain was far above either parent, and about 41 per cent above the mean of the two parents.

WATER REQUIREMENT OF OATS, BARLEY, AND RYE, 1914

Two varieties of oats were grown in 1914, Swedish Select having a water requirement of 599 ± 2, Burt 615 ± 6. These two varieties showed less than 3 per cent difference in water requirement. Oats has a water requirement 8 per cent higher than wheat. On the basis of grain produced, Swedish Select had a water requirement of 1421 ± 8 and Burt of 1483 ± 31, or about the same as the better common wheats.

Barley gave a water requirement of 501 ± 5 and rye of 622 ± 7. Rye, therefore, shows a higher water requirement than any of the groups of small grains, and is followed in turn by oats, the common varieties of wheat, and the durums. On the basis of grain production, barley had a water requirement of 1179 ± 28 and rye of 2291 ± 54. With the exception of Pacific Bluestem, one of the common wheats, barley is the most efficient and rye the least efficient of any of the small grains in the use of water. The water-requirement measurements of oats, barley, and rye as obtained in the Akron measurements are shown in Table 3.

TABLE 3.—*Water requirement, based on grain and dry matter, of oats, barley, and rye at Akron, Colo., 1914*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on—	
							Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Barley, Hannchen, C. I. 531 (*Hordeum distichon*).	May 9 to July 25	85	186.8	81.4	89.6	44	1107	480
		86	187.5	80.8	91.6	43	1134	489
		87	187.0	79.1	95.9	42	1212	513
		88	184.4	78.6	91.4	43	1163	496
		89	177.3	80.7	88.1	46	1092	497
		90	168.3	65.4	89.4	39	1367	531
Mean							1179±28	501±5
Oats, Swedish Select, C. I. 134 (*Avena sativa*).	May 9 to Aug. 1	91	234.0	97.1	138.8	41	1429	593
		92	254.2	108.2	152.9	43	1413	601
		93	269.2	110.8	161.7	41	1459	601
		94	255.9	107.4	154.8	42	1441	605
		95	288.2	119.7	170.0	42	1420	590
		96	285.3	126.3	172.5	44	1366	605
Mean							1421±8	599±2
Oats, Burt, C. I. 293 (*A. sativa*).	May 9 to July 25	97	246.8	109.1	155.0	44	1421	628
		98	241.0	97.5	153.2	40	1571	636
		99	251.2	102.3	158.0	41	1545	629
		100	256.8	99.6	157.2	39	1578	612
		101	265.0	112.6	157.5	42	1399	594
		102	244.7	104.8	144.8	43	1382	592
Mean							1483±31	615±6
Rye, spring, C. I. 73 (*Secale cereale*).	May 9 to July 25	103	182.1	53.7	116.4	29	2168	639
		104	193.5	56.5	121.6	29	2152	628
		105	203.2	56.0	119.1	28	2127	586
		106	173.1	42.6	110.9	25	2603	641
		107	206.8	57.0	131.5	28	2307	636
		108	212.4	53.5	127.9	25	2391	602
Mean							2291±54	622±7

Nine varieties and five hybrids of corn were grown in 1914: The water requirements based on dry matter production, was:

Corn:		Hybrids:	
Tom Thumb	315 ± 8	Algeria × China	347 ± 5
Algeria	330 ± 4	Joaquin × Budapest	365 ± 5
Budapest	345 ± 3	German C24–1 × German C24–2	372 ± 1
China White	344 ± 7	Budapest × Pima	388 ± 5
Pima	365 ± 7	Joaquin × Pima	389 ± 9
Northwestern Dent	368 ± 6		
Joaquin	368 ± 9	Average	372 ± 5
German C24–2	372 ± 3		
German C24–1	385 ± 5	Average for series	361 ± 6
Average	355 ± 6		

Of the corn varieties, Tom Thumb is the lowest in water-requirement value. It was grown during the late season (Table 7). The highest water-requirement value is shown by a German sweet corn, C24–1. A comparison of the hybrids and their parents shows that the hybrids range in water requirement from 10 per cent below to 10 per cent above the parental mean. The chances are even also that a maize hybrid will not depart in its water requirement more than ± 6 per cent from the parental mean.[10]

The water requirement of the hybrids was 3 per cent higher than that of the corn group as a whole, which was considerably lowered by the inclusion of Tom Thumb, a variety not used in hybridization. It is interesting to compare these corn varieties on the basis of their water requirement. Tom Thumb, which stands first in the line of efficiency, is a very diminutive corn, so small that is has little or no practical value. Next in efficiency are Algeria, Budapest, China White, Pima, and Northwestern Dent, the latter a short season crop grown in the northern Plains region.

Only two sorghum varieties were grown in 1914, Dakota Amber and Minnesota Amber. Minnesota Amber has a slightly lower water requirement than Dakota Amber, their values being 284 ± 3 and 296 ± 1, respectively (Table 4). The probable error in the determination of water requirement of sorghum is usually about 1 per cent. The difference in water requirement of these two varieties is approximately 4 per cent. Sorghum was 19 per cent more efficient in the use of water than the corn varieties. Even in grain production these forage sorghums have a low water requirement, the value being 893 ± 26 for Minnesota Amber and 898 ± 50 for Dakota Amber, or 76 per cent of the water requirement for barley, the most efficient of the small grains.

Kursk millet, with a water requirement of 295 ± 2, is much more efficient than Siberian millet, with a water requirement of 316 ± 5. The millets in this case, have a water requirement 5 per cent higher than the sorghums, but 15 per cent lower than corn. On the basis of grain production, Kursk has a water requirement of 1075 ± 38 and Siberian of 1162 ± 51. In other words it is about as efficient as barley. Kursk millet which was also grown as a late season crop (see Table 7), gave a value 4 per cent lower than when grown in the spring.

[10] BRIGGS, L. J., and SHANTZ, H. L. Op. cit. 1915. p. 401.

WATER REQUIREMENT OF LEGUMES, 1914

Fourteen varieties of legumes were grown in the water requirement experiments in 1914. The water requirements of these varieties, based on dry matter, was:

Crimson clover	517±19	Alfalfa, A. D. I. 162–98	904±12
Hairy vetch	531±3	Alfalfa, A. D. I. E–23–20–52	906±12
Guar	544±8	Alfalfa, A. D. I. 162–98–B	906±12
Vetch, black bitter	584±12	Alfalfa, A. D. I. E–5–30	933±11
Cowpea	659±5	Alfalfa, Grimm, A. D. I. H–4–60	957±8
Alfalfa, A. D. I. 162–98–A	810±5		
Alfalfa, Hansen	846±27	Average	776±15
Lupinus albus	870±34		
Alfalfa, Grimm, A. D. I. E–23	890±6		

TABLE 4.—*Water requirement based on dry matter, of corn, sorghum, millet, and sudan grass, at Akron, Colo., 1914*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
CORN (*Zea mays*)			*Grams*	*Grams*	*Kgms.*	*P. ct*		
Algeria×China	June 3 to Aug. 31	243	515.0		176.3			342
		244	474.2		175.0			369
		245	524.4		178.3			340
		246	573.0		187.6			327
		247	477.5		170.9			358
Mean								347±5
China White	June 3 to Aug. 31	248	401.3		149.2			372
		249	313.9		104.2			332
		250	394.7		141.1			357
		251	406.7		130.1			320
		252	419.3		143.1			341
Mean								344±7
Joaquin	June 3 to Aug. 31	253	343.3		140.7			410
		254	287.0		91.3			318
		255	96.3		35.1			364
		256	201.7		74.7			370
		257	301.0		113.6			377
Mean								368±9
Joaquin×Budapest	June 3 to Aug. 31	258	410.3		142.4			347
		259	453.5		159.4			351
		260	382.7		148.9			389
		261	358.0		131.8			368
		262	388.4		143.4			369
Mean								365±5
Budapest	June 3 to Sept. 1	263	427.5		150.2			351
		264	398.3		134.4			337
		265	451.7		150.8			334
		266	379.7		133.2			351
		267	396.7		139.3			351
Mean								345±3
Budapest×Pima	June 3 to Sept. 1	268	368.4		137.4			373
		269	364.8		149.8			411
		270	362.6		144.1			397
		271	364.2		138.4			380
		272	348.5		132.8			381
Mean								388±5

TABLE 4.—*Water requirement based on dry matter, of corn, sorghum, millet, and sudan grass, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
CORN—continued (*Zea Mays*)			*Grams*	*Grams*	*Kgms.*	*P. ct*		
Pima	June 3 to Sept. 1	273	350.7		134.0			382
		274	343.0		132.0			385
		275	375.3		123.2			328
		276	335.2		120.5			359
		277	402.3		149.6			372
Mean								365±7
Joaquin×Pima	June 3 to Sept. 1	278	365.5		151.4			414
		279	388.9		161.2			415
		280	352.3		126.8			360
		281	324.9		121.3			373
		282	433.3		165.2			381
Mean								389±9
Northwestern Dent	June 3 to Aug. 31	217	308.3		119.2			387
		218	281.2		108.1			384
		219	298.1		109.1			366
		220	269.2		102.0			379
		221	300.1		109.0			363
		222	369.2		121.8			330
Mean								368±6
German C24–1	June 3 to Sept. 1	223	354.4		135.4			382
		224	296.7		107.5			362
		225	333.2		129.8			390
		226	306.4		122.4			399
		227	317.4		125.1			394
Mean								385±5
German C24–1 and C24–2	June 3 to Sept. 1	228	419.0		155.6			371
		229	432.4		158.2			366
		230	362.2		136.3			376
		231	357.0		133.7			375
		232	379.5		140.4			370
Mean								372±1
German C24–2	June 3 to Aug. 31	233	374.6		143.8			384
		234	407.5		148.2			364
		235	399.8		150.0			375
		236	379.7		139.9			368
		237	335.0		123.2			368
Mean								372±3
Algeria	June 3 to Aug. 31	238	354.7		117.8			332
		239	521.2		161.1			309
		240	431.3		149.0			345
		241	392.0		131.4			335
		242	386.7		127.8			330
Mean								330±4
SORGHUM (*Andropogon sorghum*)								
Minnesota, Black Amber, A. D. I. 341–13.	June 9 to Sept. 1	205	538.7	191.9	161.3	36	841	299
		206	434.8	132.8	128.2	31	965	295
		207	443.4	141.9	123.9	32	873	279
		208	478.5	172.5	133.7	36	775	279
		209	403.0	110.1	113.0	27	1026	280
		210	444.2	136.8	119.7	31	875	269
Mean							893±26	284±3

TABLE 4.—*Water requirement based on dry matter, of corn, sorghum, millet, and sudan grass, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
SORGHUM—continued								
(*Andropogon sorghum*)								
Dakota Amber, A. D. I. 341-10-4.	June 9 to Sept. 1		*Grams*	*Grams*	*Kgms.*	*P. ct*		
		211	476.0	139.6	137.5	29	985	289
		212	430.0	170.8	128.8	40	754	300
		213	399.6	147.1	117.9	37	801	295
		214	401.1	139.5	120.6	35	865	301
		215	433.6	167.0	128.7	39	771	297
		216	419.7	101.4	122.5	24	1208	292
Mean							898±50	296±1
SUDAN GRASS, S. P. I. 25017								
(*Andropogon sorghum aethiopicus*)								
First crop	June 10 to Aug. 12	410	353.5		129.2			365
		411	244.9		88.1			360
		412	363.0		127.6			352
		413	270.1		102.1			378
		414	275.9		103.0			373
Mean								366±3
Second crop	Aug. 13 to Oct. 15	410	64.5		35.0			543
		411	58.2		29.2			502
		412	63.3		34.6			547
		413	55.9		30.9			553
		414	51.0		28.2			553
Mean								540±6
Combined crops	June 10 to Oct. 15	410	418.0		164.2			393
		411	303.1		117.3			387
		412	426.3		162.2			380
		413	326.0		133.0			408
		414	326.9		131.2			401
Mean								394±4
MILLET								
(*Chaetochloa italica*)								
Kursk, S. P. I. 34771	June 9 to Aug. 12	181	322.1	80.2	92.8	25	1157	288
		182	274.8	88.6	81.6	32	921	297
		183	276.8	82.1	80.2	30	977	290
		184	303.6	70.4	91.3	23	1297	301
		185	311.2	85.9	91.4	28	1064	294
		186	318.7	92.4	95.4	29	1032	299
Mean							1075±38	295±2
Siberian, A. D. I. 3-4	June 9 to Aug. 12	187	325.2	104.2	98.7	32	947	304
		188	321.1	91.2	106.4	28	1167	331
		189	323.2	91.6	92.3	28	1008	286
		190	295.1	66.8	92.7	23	1388	314
		191	293.6	88.4	99.2	30	1122	338
		192	348.6	83.4	111.6	24	1338	320
Mean							1162±51	316±5

The first four legume crops were grown during the late season and are therefore not strictly comparable. However, this is true of all crops that do not have the same length of growth period. The results obtained with these four crops are therefore included with the other measurements in the summary tables. The legumes at Akron range in their water requirement from crimson clover at 517 ± 19, the

lowest, to a Grimm alfalfa at 957 ± 8, the highest, a difference of 85 per cent. Legumes usually have a high water requirement but some of the varieties, crimson clover, hairy vetch, guar, and bitter vetch each have a water requirement of less than 600, while the Grimm alfalfas average about 900. Of the alfalfas, *Medicago falcata* has a water requirement 7 per cent lower than the average of the Grimm varieties, but not lower than the range of the latter, since one of the Grimm varieties, A. D. I. 162-98-A, showed a water requirement 4 per cent lower than *M. falcata*. (See Table 5.)

TABLE 5.—*Water requirement, based on dry matter, of legumes, at Akron, Colo., 1914*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
ALFALFA								
(*Medicago sativa*)								
Grimm, A. D. I. E23-20-52, first crop.	June 5 to July 11		*Grams*	*Grams*	*Kgms.*	*P. ct*		
		109	70.3		43.4			617
		110	77.9		49.3			633
		111	78.6		47.6			606
		112	79.3		51.1			644
		113	54.5		33.5			615
		114	72.0		43.1			599
Mean								619±5
Grimm, second crop	July 12 to Aug. 16	109	56.4		57.0			1011
		110	69.9		65.7			940
		111	77.5		68.3			881
		112	83.4		72.8			873
		113	50.5		39.5			782
		114	60.2		55.0			914
Mean								900±21
Grimm, third crop	Aug. 16 to Oct. 26	109	137.8		146.2			1061
		110	120.0		136.9			1141
		111	142.7		144.1			1010
		112	132.0		137.1			1039
		113	86.0		93.4			1086
		114	101.3		120.6			1191
Mean								1088±20
Grimm, combined crop	June 5 to Oct. 26	109	264.5		246.6			932
		110	267.8		251.9			941
		111	298.8		260.0			870
		112	294.7		261.0			886
		113	191.0		166.4			871
		114	233.5		218.7			937
Mean								906±12
Grimm, A. D. I. E23, first crop.	June 5 to July 11	115	61.6		38.9			631
		116	94.7		56.7			599
		117	87.3		53.0			607
		118	94.1		57.2			608
		119	87.7		53.6			611
		120	98.2		59.2			603
Mean								610±3
Grimm, second crop	July 12 to Aug. 15	115	68.6		60.3			879
		116	85.7		75.1			876
		117	70.6		67.7			959
		118	74.1		66.3			895
		119	71.0		68.3			962
		120	91.7		79.5			867
Mean								906±14

TABLE 5.—*Water requirement, based on dry matter, of legumes, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
ALFALFA—continued (*Medicago sativa*)			*Grams*	*Grams*	*Kgms.*	*P. ct*		
Grimm, third crop	Aug. 16 to Oct. 26	115	111.5		126.4			1134
		116	154.0		159.3			1034
		117	130.6		137.4			1052
		118	139.0		148.6			1069
		119	142.3		142.9			1004
		120	172.5		179.3			1039
Mean								1055±12
Grimm, combined crop	June 5 to Oct. 26	115	241.7		225.6			933
		116	334.4		291.1			871
		117	288.5		258.1			895
		118	307.2		272.1			886
		119	301.0		264.8			880
		120	362.4		318.0			877
Mean								890±6
Grimm, A. D. I. E-5-30, first crop.	June 5 to July 11	121	87.0		59.1			679
		122	83.8		52.4			625
		123	86.2		53.8			624
		124	79.0		52.8			668
		125	94.0		59.4			632
		126	81.4		54.0			663
Mean								649±8
Grimm, second crop	July 12 to Aug. 15	121	73.9		72.0			974
		122	75.3		68.9			915
		123	74.5		70.2			942
		124	73.1		68.2			933
		125	83.8		71.7			856
		126	71.5		67.6			945
Mean								928±11
Grimm, third crop	Aug. 16 to Oct. 26	121	126.6		158.9			1255
		122	127.6		139.4			1092
		123	122.5		131.4			1073
		124	121.7		137.8			1132
		125	128.4		143.7			1119
		126	117.6		130.7			1111
Mean								1136±16
Grimm, combined crop	June 5 to Oct. 26	121	287.5		290.0			1009
		122	286.7		260.7			909
		123	283.2		255.4			902
		124	273.8		258.8			945
		125	306.2		274.8			897
		126	270.5		252.3			933
Mean								933±11
A. D. I. 162-98-A, first crop	May 9 to July 11	127	229.0		159.6			697
		128	203.1		147.1			724
		129	202.6		142.9			705
		130	172.7		127.0			735
		131	208.4		150.7			723
		132	201.9		148.7			737
Mean								720±5
A. D. I. 162-98-A, second crop	July 12 to Aug. 15	127	146.3		124.6			852
		128	139.1		118.7			853
		129	135.9		103.0			758
		130	135.4		106.3			785
		131	142.9		110.7			775
		132	175.4		145.5			830
Mean								809±14

TABLE 5.—*Water requirement, based on dry matter, of legumes, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
ALFALFA—continued (*Medicago sativa*)			*Grams*	*Grams*	*Kgms.*	*P. ct*		
A. D. I. 162-98-A, third crop	Aug. 16 to Oct. 26	127	208.5		187.2			898
		128	205.6		186.5			907
		129	206.4		183.9			891
		130	200.7		182.2			908
		131	214.3		188.9			881
		132	216.5		196.1			906
Mean								899±3
A. D. I. 162-98-A, combined crop	May 9 to Oct. 26	127	583.8		471.4			807
		128	547.8		452.3			828
		129	544.9		429.8			789
		130	508.8		415.5			817
		131	565.6		450.3			796
		132	593.8		490.3			826
Mean								810±5
A. D. I. 162-98, first crop	June 5 to July 11	133	91.5		60.7			663
		134	90.0		56.2			624
		135	73.2		42.6			582
		136	74.8		42.6			570
		137	81.3		49.7			611
		138	69.0		39.7			575
Mean								604±11
A. D. I. 162-98, second crop	July 12 to Aug. 15	133	65.3		62.6			959
		134	72.3		61.6			852
		135	61.3		57.0			930
		136	67.9		58.2			857
		137	69.0		61.3			888
		138	66.8		56.8			850
Mean								859±14
A. D. I. 162-98, third crop	Aug. 16 to Oct. 26	133	119.6		147.2			1231
		134	139.4		146.8			1053
		135	87.6		101.3			1156
		136	119.4		131.5			1101
		137	110.0		130.1			1183
		138	99.8		103.8			1040
Mean								1127±24
A. D. I. 162-98, combined crop	June 5 to Oct. 26	133	276.4		270.5			979
		134	301.7		264.6			877
		135	222.1		200.9			905
		136	262.1		232.3			886
		137	260.3		241.1			926
		138	235.6		200.3			850
Mean								904±12
A. D. I. 162-98-B, first crop	May 9 to July 11	139	178.9		126.2			705
		140	166.2		128.4			773
		141	153.2		114.0			744
		142	155.8		123.0			789
		143	167.7		127.7			761
		144	175.2		138.3			789
Mean								760±9
A. D. I. 162-98-B, second crop	July 12 to Aug. 15	139	125.0		101.1			809
		140	116.6		97.7			838
		141	107.8		90.0			835
		142	112.5		97.6			868
		143	122.4		102.8			840
		144	134.7		114.1			847
Mean								840±5

TABLE 5.—*Water requirement, based on dry matter, of legumes, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
ALFALFA—continued								
(*Medicago sativa*)			*Grams*	*Grams*	*Kgms.*	*P. ct*		
A. D. I. 162-98-B, third crop	Aug. 16 to Oct. 26	139	183.5		184.4			1005
		140	143.3		173.6			1211
		141	182.2		185.3			1017
		142	196.3		198.0			1009
		143	146.0		174.9			1198
		144	206.8		233.9			1131
Mean								1095±32
A. D. I. 162-98-B, combined crop	May 9 to Oct. 26	139	487.4		411.7			845
		140	426.1		399.7			938
		141	443.2		389.3			878
		142	464.6		418.6			901
		143	436.1		405.4			930
		144	516.7		486.3			941
Mean								906±12
Grimm A. D. I. H-4-60, first crop	June 5 to July 11	151	95.0		62.4			657
		152	96.9		62.1			641
		153	96.3		63.4			658
		154	99.2		68.6			692
		155	97.2		65.5			674
		156	88.4		55.5			628
Mean								658±6
A. D. I. H-4-60, second crop	July 12 to Aug. 15	151	86.0		79.0			919
		152	84.4		75.5			895
		153	78.1		73.0			935
		154	86.0		78.1			908
		155	70.6		67.9			962
		156	73.2		67.6			923
Mean								924±6
A. D. I. H-4-60, third crop	Aug. 16 to Oct. 26	151	107.9		147.5			1367
		152	119.8		140.9			1176
		153	113.6		141.6			1246
		154	108.6		138.0			1271
		155	116.0		132.8			1145
		156	105.8		128.9			1218
Mean								1237±22
A. D. I. H-4-60, combined crop	June 5 to Oct. 26	151	288.9		288.9			1000
		152	301.1		278.5			925
		153	288.0		278.0			965
		154	293.8		284.7			969
		155	283.8		266.2			938
		156	267.4		252.0			942
Mean								957±8
(*Medicago falcata*)								
Hansen seed, first crop	June 9 to July 11	145	25.2		16.6			659
		146	23.9		16.9			707
		147	21.9		12.0			548
		148	16.0		11.4			713
		149	28.0		18.0			643
		150	19.5		12.5			641
Mean								652±16
Hansen seed, second crop	July 12 to Aug. 15	145	52.9		42.4			802
		146	49.0		38.5			786
		147	15.2		10.6			697
		148	46.8		34.2			731
		149	41.0		32.2			785
		150	33.3		23.6			709
Mean								752±15

TABLE 5.—*Water requirement, based on dry matter, of legumes, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
ALFALFA—continued								
(*Medicago falcata*)			*Grams*	*Grams*	*Kgms.*	*P. ct.*		
Hansen seed, third crop	Aug. 16 to Oct. 26	145	29.9		36.4			1217
		146	22.4		31.6			1411
		147	39.4		29.4			746
		148	25.0		33.3			1332
		149	22.4		32.3			1442
		150	23.8		25.2			1059
Mean								1201±75
Hansen seed, combined crop	June 9 to Oct. 26	145	108.0		95.4			883
		146	95.3		87.0			913
		147	76.5		52.0			680
		148	87.8		78.9			899
		149	91.4		82.5			903
		150	76.6		61.3			800
Mean								846±27
COWPEA								
(*Vigna sinensis*)								
S. P. I. 29282	May 28 to Aug. 12	169	179.6	63.4	117.5	35	1853	654
		170	169.7	52.7	108.6	31	2061	640
		171	161.7	56.2	106.9	35	1902	661
		172	163.3	55.8	110.6	34	1982	677
		173	171.9	57.8	110.5	34	1912	643
		174	175.4	57.9	119.3	33	2060	680
Mean							1962±27	659±5
Lupinus albus								
S. P. I. 35477	May 28 to Aug. 12	175	84.1	11.6	82.2	14	7086	977
		176	64.6	10.5	58.7	16	5590	909
		177	116.9	24.0	95.0	21	3958	813
		178	100.4	19.1	82.1	19	4298	818
		179	117.7	22.6	83.2	19	3681	707
		180	54.7	1.4	54.4	(a)	(a)	995
Mean							4923±478	870±34

[a] Omitted in computing mean.

Cowpeas, an important field crop, require 659 ± 5, or 28 per cent, less water than the Grimm varieties of alfalfa, but more than twice as much as sorghum. *Lupinus albus* requires 870 ± 34, or almost as much as alfalfa. On the basis of seed production, cowpeas gave a water requirement of 1962 ± 27 and *L. albus* 4923 ± 478.

WATER REQUIREMENT OF COTTON, PIGWEED, AND GRAMA GRASS, 1914

Cotton was included in the experiments each year at Akron. Notwithstanding the fact that cotton was far from its natural range the water requirement of that crop, 574 ± 9, was as low as for oats and almost as low as for wheat (Table 6).

Pigweed produced three crops, the combined crop having a water requirement of 306 ± 1, and was exceeded only by millet and sorghum in the efficient use of water. Pigweed was about three times as efficient as alfalfa and twice as efficient as oats and some of the wheats.

TABLE 6.—*Water requirement, based on dry matter, of cotton, pigweed, and grama grass, at Akron, Colo., 1914*

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
COTTON (*Gossypium hirsutum*)			*Grams*	*Kgms.*	
Triumph	June 17 to Oct. 15	193	363.8	194.6	535
		194	345.1	194.1	562
		195	360.8	199.1	552
		196	328.5	190.2	579
		197	311.7	187.5	602
		198	370.7	226.6	611
Mean					574±9
PIGWEED (*Amaranthus retroflexus*)					
First crop	June 3 to July 14	163	124.0	39.9	322
		164	115.8	38.2	330
		165	127.0	37.9	298
		166	118.7	36.3	306
		167	126.7	40.5	320
		168	131.0	39.8	304
Mean					313±4
Second crop	July 15 to Aug. 13	163	57.8	17.6	304
		164	55.2	15.9	288
		165	54.1	16.2	299
		166	49.4	15.8	320
		167	48.6	14.5	298
		168	57.8	18.0	311
Mean					303±3
Third crop	Aug. 14 to Oct. 17	163	44.7	12.0	268
		164	44.0	12.3	280
		165	44.1	13.7	311
		166	36.8	10.8	293
		167	41.6	11.9	286
		168	42.3	12.0	284
Mean					287±4
Combined crop	June 3 to Oct. 17	163	226.5	69.5	307
		164	215.0	66.4	309
		165	225.2	67.8	301
		166	204.9	62.9	307
		167	216.9	66.9	308
		168	231.1	69.8	302
Mean					306±1
GRAMA GRASS (*Bouteloua gracilis*)					
First crop	June 3 to July 14	157	26.6	9.8	368
		158	23.1	7.9	342
		159	28.1	9.1	324
		160	28.5	9.6	337
		161	27.9	8.8	315
		162	24.7	7.1	287
Mean					329±8
Second crop	July 15 to Aug. 12	157	36.2	11.7	323
		158	28.4	9.9	349
		159	29.7	10.4	350
		160	35.6	10.8	303
		161	24.9	8.9	357
		162	28.0	9.4	336
Mean					336±6

TABLE 6.—*Water requirement, based on dry matter, of cotton, pigweed, and grama grass, at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
GRAMA GRASS—continued (*Bouteloua gracilis*)			*Grams*	*Kgms.*	
Third crop	Aug. 13 to Oct. 16	157	11.6	10.7	922
		158	13.7	8.3	606
		159	19.5	10.2	523
		160	19.8	9.6	485
		161	14.9	8.4	564
		162	13.0	7.8	600
Mean					617±39
Combined crop	June 3 to Oct. 16	157	74.4	32.2	433
		158	65.2	26.1	400
		159	77.3	29.7	384
		160	83.9	30.0	358
		161	67.7	26.1	386
		162	65.7	24.3	370
Mean					389±7

Three crops of grama grass gave a combined water requirement, based on dry matter, of 389 ± 7. This is the most important of the native grasses. It is somewhat less efficient than corn in the use of water, and requires 34 per cent more water than the sorghum varieties tested.

WATER REQUIREMENT OF PLANTS GROWN DURING LATE SUMMER AND AUTUMN, 1914

Thirteen late-season crops were grown, the time of planting ranging from August 28 to September 4. Grouped in the order of their efficiency in the use of water for dry matter production these crops are as follows:

Tumbleweed	272±4	Guar	544±8
Kursk millet	284±4	Buffalo bur	557±7
Tom Thumb corn	315±8	Bitter vetch	584±12
Clammyweed	502±11	Polygonum	705±50
Nightshade	506±14	Verbena	730±20
Crimson clover	517±19	Franseria	1176±47
Hairy vetch	531±3		

It will be seen that the same variety of millet, Kursk, S. P. I. 34771, was approximately 4 per cent more efficient when grown as a late-season crop than when grown during the regular season.

The results obtained in these measurements as shown in Table 7 are included in the records obtained from those made earlier in the season, since there is a close agreement between the water requirement values of plants grown late in the season and those of the same plants grown early in the season. Many of the plants are weeds and thrive naturally during the late summer and autumn. There is a surprisingly wide range in water requirement among the common weeds. Tumbleweed is more efficient than millet or Tom Thumb corn. The legumes have a relatively low water requirement. The

water requirement values of crimson clover, hairy vetch, guar, and bitter vetch are aproximately the same as the wheats, while polygonum and verbena, roadside weeds, require more water than any crop group except alfalfa. Franseria, a native plant of wet bottoms, showed a water requirement higher than any of the series.

TABLE 7.—*Water requirement, based on dry matter, of plants grown during late summer and autumn at Akron, Colo., 1914*

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
			Grams	*Kgms.*	
Clammyweed (*Polanisia*) following Baluchistan wheat.	Aug. 29 to Oct. 17	37	4.8	2.5	521
		38	6.1	3.2	525
		39	6.3	3.3	524
		40	6.8	3.2	471
		42	4.5	2.1	467
Mean					502±11
Millet, Kursk (*Chaetochloa italica*), following Siberia wheat.	Aug. 28 to Oct. 15	49	31.2	8.2	263
		50	50.1	15.0	299
		51	69.5	20.5	295
		52	61.7	17.6	285
		53	69.0	18.9	274
		54	44.8	12.8	286
Mean					284±4
Tumbleweed (*Amaranthus graecizans*), following Peru wheat.	Aug. 28 to Oct. 13	55	49.9	12.4	248
		56	46.5	13.1	282
		57	45.1	12.5	277
		58	47.0	13.3	283
		59	36.2	9.5	262
		60	56.4	15.9	282
Mean					272±4
Corn, Tom Thumb (*Zea mays*), following Canada (Marquis) wheat.	Aug. 28 to Oct. 13	61	51.1	16.0	313
		62	63.2	16.7	264
		63	61.2	19.3	315
		64	42.1	15.5	368
		65	65.0	19.6	302
		66	64.5	21.3	330
Mean					315±8
Guar, following Jumillo wheat	Aug. 28 to Oct. 12	67	6.9	3.6	522
		68	6.7	3.7	552
		69	7.2	4.3	597
		70	3.7	2.0	541
		71	9.6	5.2	542
		72	8.4	4.3	512
Mean					544±8
Crimson clover, following Jumillo wheat × Velvet chaff wheat (*Trifolium incarnatum*).	Sept. 4 to Oct. 27	73	22.4	10.5	469
		74	16.7	7.8	467
		75	17.1	7.9	462
		76	14.8	7.7	520
		77	23.7	13.2	557
		78	26.4	16.6	629
Mean					517±19
Black bitter vetch (*Vicia ervillea*) following Velvet chaff wheat.	Sept. 4 to Oct. 27	79	17.9	9.9	553
		80	39.3	21.7	552
		81	40.7	26.3	646
		82	32.0	19.3	603
		83	26.6	14.8	556
		84	24.2	14.4	595
Mean					584±12

TABLE 7.—*Water requirement, based on dry matter, of plants grown during late summer and autumn at Akron, Colo., 1914*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
			Grams	*Kgms.*	
Polygonum aviculare, following Hannchen barley.	Aug. 28 to Oct. 27	85	10.3	7.7	748
		86	3.2	1.6	500
		87	5.1	4.0	784
		88	7.6	6.0	789
Mean					705±50
Buffalo bur (*Solanum rostratum*), following Swedish Select oats.	Aug. 28 to Oct. 15	91	51.3	29.7	579
		92	51.9	29.0	559
		93	51.8	29.3	566
		94	56.0	29.5	527
		95	49.5	28.5	576
		96	55.3	29.6	535
Mean					557±7
Nighshade (*Solanum triflorum*), following Burt oats.	Aug. 29 to Oct. 27	97	73.3	41.2	562
		98	68.6	38.7	564
		99	59.6	29.5	495
		100	57.5	28.1	489
		101	62.8	27.3	435
		102	62.7	30.9	493
Mean					506±14
Verbena (*Verbena bractiosa*), following Vern rye.	Aug. 29 to Oct. 27	103	20.3	14.4	709
		104	24.0	15.4	642
		105	20.9	14.5	694
		106	20.7	14.9	720
		107	13.9	10.3	741
		108	13.5	11.8	874
Mean					730±20
Franseria tenuifolia, following cowpea	Aug. 29 to Oct. 27	169	4.8	4.7	979
		170	7.7	8.2	1065
		171	11.3	15.1	1336
		172	14.6	19.9	1363
		173	11.5	12.2	1061
		174	13.6	17.0	1250
Mean					1176±53
Hairy vetch (*Vicia villosa*), following *Lupinus albus*.	Sept. 4 to Oct. 27	175	36.4	19.2	527
		176	43.5	22.5	517
		177	26.5	14.3	540
		178	27.9	15.2	545
		179	31.0	16.5	532
		180	27.3	14.3	524
Mean					531±3

SUMMARY OF WATER-REQUIREMENT MEASUREMENTS MADE IN 1914

In order to compare rapidly the water requirement of the various crops for the different years and to eliminate errors due to averaging plants of low and high water requirement, which would be equivalent to weighting those of high-water requirement, the yearly values have been expressed as proportions of the average for the period of years during which the crop was grown, which value was fixed at 100. This gives a truer value for each year than could be obtained by averaging actual values. In the discussion the values thus obtained have been treated as index numbers and the expression "points above" or "points below" have been used to express the relative positions. To express these differences in percentages would lead to confusion.

It is the opinion of the writers that the facts are well shown by this simple method of treatment which is here followed in order to avoid the use of logarithms in the discussion of the data. The procedure will be clearly understood by comparing Table 27, the actual values, with Table 28, the index values.

The climatic conditions controlling the use of water in the 1914 experiments were near the average for the period 1911–1917. (See Tables 27 and 28.) As compared with the previous years the water requirement was about the same as in 1913, apparently a little less than 1911, and about 25 points higher than in 1912. The latter year was unusually favorable. On the whole the weather was cool and relatively damp and the sun's intensity was about 20 per cent below normal.[11]

The water requirement in 1914 was 26 points higher than the water requirement in the cool, damp year, 1915; 2 points higher than in 1917, which was nearly an average year; and 28 points lower than in the dry year, 1916.

During 1914 tumbleweed showed the greatest efficiency in the use of water, its water-requirement value being 272 ± 4. It was followed closely by Minnesota Amber and Dakota Amber sorghum, with values of 284 ± 3 and 296 ± 1, respectively, and Kursk millet with a value of 295 ± 2. The corn varieties ranged in water-requirement value from 315 ± 8 to 389 ± 9. The range in values of other crops were as follows: Wheats, from 458 ± 10 to 689 ± 8; barley, 501 ± 5; oats from 599 ± 2 to 615 ± 6; rye, 622 ± 7; legumes from 517 ± 19 for crimson clover to 957 ± 8 for a Grimm alfalfa; while weeds ranged from 272 ± 4 for tumbleweed to 1176 ± 53 for Franseria. As a general statement, the sorghums, millets, and corns were the most efficient of the crop plants in the use of water, small grains were intermediate, and legumes were least efficient.

On the basis of grain production, sorghums ranging from 893 ± 26 to 898 ± 50 were most efficient in the use of water; millets ranging from 1075 ± 38 to 1162 ± 51 were next; followed by the small grains, ranging from 1179 ± 28 for Hannchen barley, to 3564 ± 98 for Pacific Bluestem wheat.

Based on seed production the legumes showed very high water requirement. Cowpeas gave a value of 1962 ± 27 and *Lupinus albus* of 4923 ± 478.

WATER-REQUIREMENT EXPERIMENTS, 1915

In 1915, 67 sets of plants were grown, the results from 39 of which are included in the relative water-requirement figures here presented. The year was unusually cool and damp, and the water requirement, the evaporation, and the temperature were lower than during any other year of the experimental period under discussion. (See Tables 27, 28, 31, and 32.) Special attention was given during 1915 to wheat and flax.

WATER REQUIREMENT OF VARIETIES OF WHEAT, 1915

Eighteen varieties of wheat were grown at Akron in 1915. Eight of these were durum wheats, 9 were common varieties, and 1 was a hybrid. The results, based on dry matter, are as follows:

[11] BRIGGS, L. J., and SHANTZ, H. L. Op. cit. 1914. p. 54.

Durum wheats:	
C. I. 4131 (old seed)	357 ± 4
C. I. 4131	364 ± 6
Beloturka, C. I. 3705 (old seed)	387 ± 3
Beloturka, C. I. 3705	390 ± 2
Jumillo, C. I. 1736	396 ± 6
Kubanka, C. I. 1440	405 ± 3
C. I. 4082 (old seed)	413 ± 6
C. I. 4082	431 ± 3
Average	393 ± 4
Common wheats:	
Marquis, C. I. 3641 (old seed)	412 ± 3
Marquis, C. I. 3641	424 ± 3
Common wheat—Continued.	
Preston, C. I. 3328	452 ± 6
C. I. 4090 (old seed)	461 ± 5
C. I. 4090	469 ± 4
Galgalos, C. I. 2398	481 ± 4
Pacific Bluestem, C. I. 4067	491 ± 4
C. I. 4087	501 ± 4
C. I. 4087 (old seed)	505 ± 3
Average	466 ± 4
Hybrid wheat:	
Jumillo × Preston	417 ± 2
Average for series	431 ± 4

The water-requirement measurements for the durum wheats were 16 per cent lower than the water-requirement measurements for the common wheats. One of the durum wheats, C. I. 4131, an introduction from Siberia, showed the lowest water requirement, 357 ± 4. As in 1914, Kubanka, C. I. 1440, with a water-requirement value of 405 ± 3, ranked above all other varieties of durums except an introduction from Peru, which had a value 6 per cent higher than Kubanka. The variation of the different varieties of durum wheats based on the lowest value amounted to only 21 per cent.

Of the common wheats, the lowest water-requirement value, as in 1914, was shown by Marquis. Its value, 412 ± 3, was 15 per cent higher than the most efficient durum. The other varieties of common wheat ranged as high as 23 per cent above Marquis.

One hybrid of a durum and a common wheat was included in the test. The hybrid gave a water requirement 2 per cent lower than the mean water requirement of the two parents, 5 per cent above that of the durum parent, and 8 per cent below that of the common parent. This result does not agree with the result in 1914 when the hybrid gave a water requirement 14 per cent above the mean of the parents. Based on grain production the durum parent had a water requirement 34 per cent below that of the common wheat parent. The water requirement of the hybrid was 25 per cent above the parental mean, 4 per cent above the water requirement of the common parent, and 58 per cent above that of the durum parent. Since no explanation can be given of the result, it seems unsafe to conclude that the water requirement of wheat hybrids, based on total dry matter, would fall above that of the mean of the parents. The results obtained are more nearly in accord with those obtained with corn in 1914.

The water requirement of wheats in 1915, based on grain production, was as follows:

Durum:	
C. I. 4131 (old seed)	944 ± 15
C. I. 4131	1042 ± 28
Beloturka	1122 ± 11
Beloturka (old seed)	1129 ± 11
Jumillo	1179 ± 15
Kubanka, C. I. 1440	1232 ± 13
C. I. 4082 (old seed)	1299 ± 38
C. I. 4082	1315 ± 28
Average	1158 ± 22
Common:	
Marquis (old seed)	1190 ± 15
Marquis	1279 ± 22
Common—Continued.	
C. I. 4090 (old seed)	1451 ± 39
Galgalos	1551 ± 65
C. I. 4090	1617 ± 20
C. I. 4087 (old seed)	1725 ± 25
C. I. 4087	1766 ± 39
Preston	1788 ± 71
Pacific Bluestem	3343 ± 119
Average	1746 ± 56
Hybrid:	
Jumillo × Preston	1859 ± 103
Average for series	1491 ± 49

The water requirement of durum wheats based on grain production was 1158±22, or 66 per cent of that of the common wheats, 1746±56. The order of increasing water requirement for the varieties is almost the same as in 1914, and with a few exceptions is approximately the same as when based on total dry matter. As in 1914, Pacific Bluestem gave the highest water requirement among the common wheats and C. I. 4082 among the durums. Among the common wheats Marquis gave the lowest value during both years. It is interesting to observe that the different varieties of the group stand in almost the same relation to each other as they did in 1914, and that, with one exception, the original importation gave a slightly lower value for the water requirement, based on dry matter, than the seed grown at the station. Except in one set, C. I. 4090, the differences are not significant. The water requirement of the wheat hybrid, based on grain yield, was equal to the mean of the parents. Detailed results of the experiments with wheat varieties are shown in Table 8.

TABLE 8.—*Water requirement, based on dry matter and grain, of varieties of whea at Akron, Colo., 1915*

Variety	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Kubanka, C. I. 1440 (*T. durum*).	May 22 to Aug. 21	1	192.4	66.2	81.2	34	1227	422
		2	220.0	69.7	92.7	32	1330	421
		3	194.1	61.1	82.0	31	1342	422
		4	222.5	72.2	86.8	32	1202	390
		5	202.1	58.8	77.5	29	1318	383
		6	225.3	72.9	87.8	32	1204	390
Mean							1271±22	405±6
Kubanka, C. I. 1440 (*T. durum*).	May 24 to Aug. 24	109	261.7	93.3	103.5	36	1109	395
		110	268.7	91.8	112.0	34	1220	417
		111	246.9	85.8	102.2	35	1191	414
		112	260.2	83.5	104.0	32	1246	400
		113	279.1	94.8	111.8	34	1179	401
		114	279.7	93.1	113.4	33	1218	405
Mean							1194±13	405±3
Mean of pots 1 to 6 and 109 to 114.							1232±13	405±3
Galgalos, C. I. 2398 (*T. aestivum*).	May 22 to Aug. 16	7	167.4	56.2	80.4	34	1431	480
		8	159.5	47.7	75.7	30	1587	475
		9	169.1	60.4	77.4	36	1281	458
		10	177.4	60.7	87.6	34	1443	494
		11	176.1	55.4	85.0	31	1534	483
		12	155.6	38.1	77.4	24	2031	497
Mean							1551±65	481±4
Pacific Bluestem, C. I. 4067 (*T. aestivum*).	May 22 to Aug. 26	13	196.7	34.7	95.7	18	2758	487
		14	200.3	30.9	101.6	15	3288	507
		15	190.0	29.9	94.2	16	3151	496
		16	208.1	32.3	104.7	16	3241	503
		17	206.7	29.2	97.2	14	3329	470
		18	286.5	32.3	138.5	11	4288	483
Mean							3343±119	491±4

TABLE 8.—*Water requirement, based on dry matter and grain, of varieties of wheat at Akron, Colo., 1915*—Continued

Variety	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
C. I. 4087, S. P. I. 36499 (*T. aestivum*), old seed.	May 22 to Aug. 18	19	225.9	67.1	113.9	30	1697	504
		20	208.9	60.0	104.8	29	1747	502
		21	214.5	65.7	104.0	31	1583	485
		22	219.1	65.4	110.9	30	1696	506
		23	221.3	61.8	116.7	28	1888	527
		24	225.5	65.8	114.3	29	1737	507
Mean							1725±25	505±3
C. I. 4087, S. P. I. 36499 (*T. aestivum*), Akron seed.	May 22 to Aug. 18	25	219.2	61.7	110.3	28	1788	503
		26	224.9	62.6	117.6	28	1879	523
		27	219.4	63.1	110.5	29	1751	504
		28	216.0	62.1	107.1	29	1725	496
		29	216.2	56.3	109.2	26	1940	505
		30	244.2	76.2	115.2	31	1512	472
Mean							1766±39	501±4
C. I. 4090, S. P. I. 36502 (*T. aestivum*), old seed.	May 22 to Aug. 16	37	219.7	74.8	97.0	34	1297	442
		38	228.8	70.8	110.3	31	1558	482
		39	214.0	66.7	98.1	31	1471	458
		40	226.1	66.0	107.8	29	1633	477
		41	231.0	74.7	107.8	32	1443	467
		42	206.1	69.4	90.5	34	1304	439
Mean							1451±39	461±5
C. I. 4090, S. P. I. 36502 (*T. aestivum*), Akron seed.	May 22 to Aug. 16	43	206.4	62.5	98.6	30	1578	478
		44	190.8	58.1	93.0	30	1601	487
		45	207.1	61.3	95.1	30	1551	459
		46	212.8	61.8	97.6	29	1579	459
		47	206.5	59.0	98.0	29	1661	475
		48	220.3	58.0	100.5	26	1733	456
Mean							1617±20	469±4
Beloturka, C. I. 3705, S. P. I. 35480 (*T. durum*), old seed.	May 22 to Aug. 21	49	313.4	105.8	119.6	34	1130	382
		50	293.4	100.0	109.5	34	1095	373
		51	273.0	96.8	107.3	35	1108	393
		52	287.1	99.5	114.6	35	1152	399
		53	313.6	108.8	119.6	35	1099	381
		54	322.3	107.1	127.4	33	1190	395
Mean							1129±11	387±3
Beloturka, C. I. 3705, S. P. I. 35480 (*T. durum*), Akron seed.	May 22 to Aug. 21	55	244.6	84.2	98.6	34	1171	403
		56	260.7	91.2	101.9	35	1117	391
		57	284.7	97.1	110.4	34	1137	388
		58	269.8	93.0	106.5	34	1145	395
		59	322.9	110.9	122.1	34	1101	378
		60	313.4	113.6	120.3	36	1059	384
Mean							1122±11	390±2
C. I. 4131, S. P. I. 37159 (*T. durum*), from Siberia, old seed.	May 28 to Aug. 24	67	336.8	132.2	119.5	39	904	355
		68	319.0	118.2	118.4	37	1002	371
		69	274.3	96.3	94.2	35	978	343
		70	312.2	123.3	111.8	39	907	358
		71	309.2	117.5	114.3	38	973	370
		72	247.4	94.4	84.9	38	899	343
Mean							944±15	357±4
C. I. 4131, S. P. I. 37159 (*T. durum*), Akron seed.	May 28 to Aug. 24	73	363.0	137.0	131.2	38	958	361
		74	355.3	124.2	138.6	35	1116	390
		75	288.1	104.5	103.8	36	993	360
		76	330.2	116.3	111.2	35	956	337
		77	322.0	112.8	124.8	35	1106	388
		78	337.6	103.7	116.4	31	1122	345
Mean							1042±28	364±6

TABLE 8.—*Water requirement, based on dry matter and grain, of varieties of wheat at Akron, Colo., 1915*—Continued

Variety	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on—	
							Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
C. I. 4082, S. P. I. 36388 (*T. durum*), from Peru, old seed.	May 22 to Aug. 25.	85	281.1	97.3	104.8	35	1077	373
		86	285.1	96.8	122.6	34	1267	430
		87	275.7	84.9	115.3	31	1358	418
		88	285.0	86.6	116.1	30	1341	407
		89	292.8	83.0	124.8	28	1504	426
		90	311.1	104.9	130.9	34	1248	421
Mean							1299±38	413±6
C. I. 4082, S. P. I. 36388 (*T. durum*), Akron seed.	May 22 to Aug. 25.	91	291.2	102.1	128.4	35	1258	441
		92	324.2	109.4	141.3	34	1292	436
		93	322.1	95.3	139.4	30	1463	433
		94	306.6	100.0	124.0	33	1240	404
		95	270.2	85.6	118.9	32	1389	440
		96	243.3	84.4	105.4	35	1249	433
Mean							1315±28	431±3
Marquis, C. I. 3641 (*T. aestivum*), old seed.	May 22 to Aug. 16.	97	198.9	71.3	82.6	36	1158	415
		98	212.4	74.4	86.2	35	1159	406
		99	219.8	76.6	86.5	35	1129	394
		100	205.9	71.2	86.2	35	1211	419
		101	211.8	69.2	87.2	33	1260	412
		102	199.7	69.4	84.7	35	1220	424
Mean							1190±15	412±3
Marquis, C. I. 3641 (*T. aestivum*), Akron seed.	May 22 to Aug. 16.	103	220.6	71.7	95.4	33	1331	432
		104	200.0	64.3	83.9	32	1305	420
		105	199.5	66.1	87.9	33	1330	441
		106	196.2	62.5	82.9	32	1326	423
		107	203.1	68.5	81.6	34	1191	402
		108	227.4	81.3	96.6	36	1188	425
Mean							1279±22	424±3
Jumillo, C. I. 1736 (*T. durum*)	May 28 to Aug. 24.	115	269.2	91.4	112.9	34	1235	419
		116	271.0	90.7	102.7	33	1132	379
		117	292.9	89.7	108.1	31	1205	369
		118	265.4	89.4	109.1	34	1220	411
		119	255.1	88.8	100.3	35	1130	393
		120	269.8	94.7	109.2	35	1153	405
Mean							1179±15	396±6
Jumillo × Preston	May 28 to Aug. 26.	121	249.1	69.7	107.2	28	1538	430
		122	243.0	65.5	101.8	27	1554	419
		123	257.4	62.3	106.4	24	1708	413
		124	254.3	57.6	104.7	23	1818	412
		125	278.0	50.3	116.0	18	2306	417
		126	303.1	55.9	124.6	18	2229	411
Mean							1859±103	417±2
Preston, C. I. 3328 (*T. aestivum*).	May 28 to Aug. 26.	127	294.2	73.3	126.0	25	1719	428
		128	290.0	77.7	127.1	27	1636	438
		129	239.2	60.0	112.4	25	1873	470
		130	257.2	58.4	119.6	23	2048	465
		131	283.4	66.3	133.2	23	2009	470
		132	308.9	94.5	136.4	31	1443	442
Mean							1788±71	452±6

EFFECT OF OLD SEED ON WATER REQUIREMENT

Since the results are so slight as not to affect the general average of these varieties and since they serve really only as duplicate determinations the measurements covering the effect of old seed on water requirement are included here. The new seed was produced in 1914 and the old seed was part of the original importation or was produced earlier than 1914.

A comparison of the water-requirement values of durum and common wheats from both new and old seed, on the basis of both dry matter and grain production, in 1915, shows the following results:

Variety	Water requirement based on total dry matter with—		Water requirement based on total grain with—	
	Old seed	New seed	Old seed	New seed
Durum wheats:				
C. I. 4131	357±4	364±6	944±15	1042±28
Beloturka, C. I. 3705	387±3	390±2	1122±11	1129±11
C. I. 4082	413±6	431±3	1315±28	1299±38
Common wheats:				
Marquis, C. I. 3641	412±3	424±3	1190±15	1279±22
C. I. 4090	461±5	469±4	1451±39	1617±20
C. I. 4087	505±3	501±4	1725±25	1766±39
Mean	423±4	430±4	1291±24	1355±28

The differences are very slight but except in one case are all in one direction, the old seed giving the lower water requirement.

A similar experiment was conducted in 1916 except that old seed was used, and was compared with "first generation" seed produced in 1914, and with "second generation" seed produced in 1915. The water-requirement measurements were as follows:

Variety	Water requirement based on total dry matter with—			Water requirement based on grain with—		
	Old seed	First generation seed	Second generation seed	Old seed	First generation seed	Second generation seed
Durum wheats:						
C. I. 4082	666±24	710±9	683±18	2291±172	1903±80	1821±60
C. I. 4131	719±15	717±30	712±10	2126±104	2640±170	2095±104
Common wheats:						
Marquis, C. I. 3641	680±12	726±5	713±19	2395±230	2339±126	2008±43
Mean	688±18	718±18	703±16	2271±176	2294±131	1975±74

WATER REQUIREMENT OF BARLEY, OATS, AND RYE, 1915

Barley gave a water requirement of 404 ± 11 and rye of 469 ± 8. Barley has a water requirement, when based on grain production, of 949 ± 50, equal to the best of the wheats.

Two varieties of oats were grown in 1915, Burt with a water requirement of 445 ± 5, and Swedish Select with a water requirement of 448 ± 10, a difference of less than 1 per cent (Table 9). As compared with wheat, oats had a water requirement 4 per cent higher. On the basis of grain produced, the water requirement of Burt oats was 1150 ± 27 and of Swedish Select 1102 ± 34, both somewhat lower than in 1914 but about the same as the durum wheats.

TABLE 9.—*Water requirement, based on grain and dry matter, of barley, oats, and rye at Akron, Colo., 1915*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Barley, Hannchen, C. I. 531 (*Hordeum distichon*).	May 28 to Aug. 11.	133	204.8	88.5	72.8	43	823	355
		134	283.7	131.5	107.4	46	817	379
		135	271.9	131.0	105.8	48	808	389
		136	274.1	106.6	121.9	39	1144	445
		137	285.2	116.0	114.9	41	991	403
		138	250.4	102.0	113.4	41	1112	453
Mean							949±50	404±11
Oats, Swedish Select, C. I. 134 (*Avena sativa*).	May 28 to Aug. 21.	139	317.5	128.8	136.9	41	1063	431
		140	349.1	149.0	144.6	43	970	414
		141	307.2	128.1	147.4	42	1151	480
		142	284.0	107.3	139.3	38	1298	490
		143	363.2	144.8	163.2	40	1127	449
		144	373.5	158.4	158.5	42	1001	424
Mean							1102±34	448±10
Oats, Burt, C. I. 293 (*A. sativa*).	May 28 to Aug. 11.	145	274.5	98.8	122.7	36	1242	447
		146	222.3	82.9	99.5	37	1200	448
		147	203.4	80.1	97.7	39	1220	480
		148	213.2	88.9	95.0	42	1069	446
		149	209.3	82.8	90.1	40	1088	430
		150	273.8	106.7	115.3	39	1081	421
Mean							1150±27	445±5.
Rye, Vern, C. I. 73 (*Secale cereale*).	May 28 to Aug. 17.	151	222.0	71.8	101.9	32	1419	459
		152	205.8	71.6	92.8	35	1296	451
		153	178.7	54.2	88.7	30	1637	496
		154	207.8	80.9	89.5	39	1106	431
		155	206.1	62.7	98.5	30	1571	478
		156	196.8	51.9	97.6	26	1881	496
Mean							1485±80	469±8

As in previous experiments rye was the least efficient in the use of water of any of the small grains. It was followed by the common wheats, oats, barley, and durum wheats in the order of their increased efficiency. On the basis of grain production barley is the lowest, followed by durum wheat, oats, rye, and common wheats. It is possible that the relatively high water requirement of barley and the durum wheats is due to the cool, damp season, which was less favorable for their growth than for some of the other varieties.

WATER REQUIREMENT OF FLAX, 1915

Six varieties of flax were grown in 1915. (See fig. 4 and Table 10.) The water requirement of each variety, based on the production of dry matter, is as follows:

Kashgar	569±4	Smyrna	663±16
North Dakota Resistant	579±10	Jalaun	682±14
Reserve	615±7		
Soddo White	625±4	Average	622±10

Flax has a high water requirement, about equivalent to alfalfa, and higher than any of the small grains. The range in water requirement of the varieties here tested, based on the lowest value, is 20 per cent.

TABLE 10.—*Water requirement, based on grain and dry matter, of flax varieties, at Akron, Colo., 1915*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
FLAX (*Linum usitatissimum*)			*Grams*	*Grams*	*Kgms.*	*P. ct.*		
North Dakota Resistant, No. 114, C. I. 13.	June 1 to Aug. 17.	157	140.0	40.4	75.5	29	1869	539
		158	150.5	30.4	82.2	20	2704	546
		159	142.3	43.7	91.4	31	2092	642
		160	166.5	55.2	97.8	33	1772	587
		161	141.3	40.0	81.1	28	2028	574
		162	152.5	48.1	89.4	32	1859	586
Mean							2054±87	579±10
Smyrna, S. P. I. 36949 (Turkey), C. I. 30.	June 1 to Aug. 26.	163	169.1	42.1	114.3	25	2715	676
		164	195.9	52.3	147.9	27	2828	755
		165	166.8	36.7	103.0	22	2807	618
		166	175.0	32.4	109.1	19	3367	623
		167	178.3	45.9	111.1	26	2420	623
		168	203.7	53.9	138.7	26	2573	681
Mean							2785±82	663±16
Soddo White, S. P. I. 37086 (Abyssinia), C. I. 36.	June 1 to Aug. 17.	169	169.1	66.4	107.2	39	1614	634
		170	139.4	56.6	87.5	41	1546	628
		171	167.8	72.2	107.3	43	1486	639
		172	162.2	64.5	100.8	40	1563	621
		173	169.8	67.3	107.5	40	1597	633
		174	163.0	65.3	96.6	40	1479	593
Mean							1548±17	625±4
Jalaun, S. P. I. 36566 (India), C. I. 21.	June 1 to Aug. 17.	175	119.4	38.2	83.8	32	2194	702
		176	104.1	27.4	70.2	26	2562	674
		177	89.5	24.2	62.6	27	2587	699
		178	116.6	39.7	81.4	34	2050	698
		179	34.4	.8	19.9			578
		180	94.6	25.8	69.8	27	2705	738
Mean							2420±101	682±14
Kashgar, S. P. I. 37719, C. I. 50-1.	June 1 to Sept. 2.	181	168.3	25.2	99.2	15	3937	589
		182	175.8	25.6	102.7	15	4012	584
		183	170.0	10.6	96.1	6	*9066	565
		184	141.7	1.7	80.7			570
		185	179.4	14.3	99.3	8	*6944	554
		186	185.7	16.2	102.9	9	*6352	554
Mean							3975±32	569±4
Reserve, C. I. 19	June 1 to Aug. 26.	187	172.1	45.0	99.9	26	2220	580
		188	180.3	49.6	113.9	28	2296	632
		189	189.1	45.3	121.1	24	2673	640
		190	177.2	46.0	110.3	26	2398	622
		191	195.3	53.2	116.7	27	2194	598
		192	200.6	48.8	124.2	24	2545	619
Mean							2388±57	615±7

* Omitted in computing mean.

Based on grain production the water requirement of flax was as follows:

Soddo White	1548±17	Smyrna	2785±82
North Dakota Resistant	2054±87	Kashgar	3975±32
Reserve	2388±57		
Jalaun	2420±101	Average	2528±70

The range is very great, the most efficient requiring less than two-fifths as much water as the least efficient, and ranking in grain production with some of the better common wheats.

FIG. 4.—Flax grown in the water requirement experiments at Akron, Colo., in 1915. Photographed July 13, 1915

WATER REQUIREMENT OF CORN, SORGHUM, SUDAN GRASS, AND MILLET, 1915

The values obtained for these crops in 1915 were as follows:

Millet	202±1	Corn, Northwestern Dent	253±7
Sorghum, Minnesota Amber	203±3	Sudan grass	260±3

Millet and sorghum gave about the same result while corn required 25 per cent, and Sudan grass 28 per cent more water than millet and sorghum. Millet and sorghum have the lowest water requirement of any of the crops grown. The water requirement based on grain produced was lowest in millet, 665±24, highest in corn, 2060±108, and intermediate for sorghum, 1116±105. The value for millet was the lowest recorded, while the water requirement of sorghum was about as low as for the durum wheats. Table 11 summarizes the results of this experiment.

TABLE 11.—*Water requirement, based on grain and dry matter, of millet, sorghum, sudan grass, and corn, at Akron, Colo., 1915*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Millet, Kursk, S. P. I. 34771 (*Chaetochloa italica*).	June 26 to Sept. 2	223	248.1	89.1	49.4	36	554	199
		224	271.1	92.8	54.4	34	586	201
		225	271.0	78.3	54.8	29	700	202
		226	304.1	73.4	59.5	24	811	196
		227	241.5	73.3	48.9	30	667	202
		228	200.0	63.2	42.4	32	671	212
Mean							665±24	202±1
Sorghum, Minnesota Amber, A. D. I. 341–13 (*Andropogon sorghum*).	June 26 to Sept. 14	235	182.4	47.5	36.0	26	758	197
		236	202.0	33.1	44.5	16	1344	220
		237	244.5	56.0	49.8	23	889	204
		238	153.9	20.6	32.0	13	1553	208
		239	177.3	40.5	35.2	23	869	199
		240	258.8	38.7	49.7	15	1284	192
Mean							1116±105	203±3
Sudan grass (*Andropogon sorghum aethiopicus*): S. P. I. 25017 (in the shelter) (first crop).	June 26 to Aug. 28	253	156.2		39.8			255
		254	150.8		36.4			241
		255	156.9		39.1			249
		256	163.1		41.9			257
		257	203.6		48.8			240
		258	222.6		52.4			235
Mean								246±3
S. P. I. 25017 (second crop).	Aug. 29 to Sept. 24	253	16.3		6.8			417
		254	17.9		6.9			385
		255	15.8		6.2			392
		256	12.5		6.0			480
		257	16.6		6.7			404
		258	10.3		4.8			466
Mean								424±12
S. P. I. 25017 (combined crop).	June 26 to Sept. 24	253	172.5		46.6			270
		254	168.7		43.3			257
		255	172.7		45.3			262
		256	175.6		47.9			273
		257	220.2		55.5			252
		258	232.9		57.2			246
Mean								260±3
Corn, Northwestern Dent (*Zea mays*).	June 26 to Sept. 14	241	71.9	8.5	18.6	12	2188	259
		242	76.8		16.1			210
		243	67.0		18.2			272
		244	159.5	20.5	39.6	13	1932	248
		245	173.7	7.0	43.3	4		249
		246	123.2		34.8			282
Mean							2060±108	253±7

WATER REQUIREMENT OF LEGUMES, 1915

Of two closely related varieties of alfalfa grown, one gave a value of 695±9 and the other a value about 1 per cent less, 685±13 (Table 12). Cowpeas required only 413±5 or 60 per cent of that of alfalfa. The water requirement of cowpeas, based on seed production, was 1257±39, almost as low as the durum wheats. A second set of cowpeas planted later required 17 per cent more water than the regular crop and produced little seed.

TABLE 12.—*Water requirement, based on dry matter, of legumes at Akron, Colo., 1915*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
ALFALFA (*Medicago sativa*)			*Grams*	*Grams*	*Kgms.*	*P. ct.*		
A. D. I. E-23, first crop	June 17 to Aug. 6	193	163.7		113.0			690
		194	126.8		79.2			625
		195	133.7		95.2			712
		196	119.7		73.3			612
		197	117.2		74.7			637
		198	138.0		83.0			601
Mean								646±14
A. D. I. E-23, second crop	Aug. 7 to Sept. 21	193	88.9		69.6			783
		194	98.1		74.9			764
		195	80.9		64.3			795
		196	74.3		54.8			738
		197	79.6		61.9			778
		198	78.3		61.2			782
Mean								773±6
A. D. I. E-23 combined crop.	June 17 to Sept. 21	193	252.6		182.6			723
		194	224.9		154.1			685
		195	214.6		159.5			743
		196	194.0		128.1			660
		197	196.8		136.6			694
		198	216.3		144.2			667
Mean								695±9
A. D. I. 162-98-A1, first crop.	June 17 to Aug. 6	199	93.3		53.8			577
		200	138.5		78.5			567
		201	133.3		82.8			621
		202	120.1		74.0			616
		203	77.9		55.8			716
		204	124.6		76.8			616
Mean								619±13
A. D. I. 162-98-A1, second crop.	Aug. 7 to Sept. 21	199	66.2		53.1			802
		200	86.7		61.9			714
		201	82.7		64.3			778
		202	73.1		58.6			802
		203	69.6		60.5			869
		204	88.2		63.9			724
Mean								782±16
A. D. I. 162-98-A1, combined crop.	June 17 to Sept. 21	199	159.5		106.9			670
		200	225.2		140.4			623
		201	216.0		147.1			681
		202	193.2		132.6			686
		203	147.5		116.3			788
		204	212.8		140.7			661
Mean								685±13
COWPEA (*Vigna sinensis*)								
S. P. I. 29282	June 4 to Sept. 9	217	126.3	39.2	51.1	31	1304	405
		218	119.8	40.8	51.0	34	1250	426
		219	105.9	41.2	41.5	39	1007	392
		220	152.5	42.8	64.7	28	1512	424
		221	128.3	43.0	51.7	34	1202	403
		222	133.8	44.9	57.0	34	1269	426
Mean							1257±39	413±5
S. P. I. 29282	July 21 to Sept. 21	259	73.4	3.4	39.2	5	[a]11529	534
		260	79.8	2.9	39.0	4	[a]13448	489
		261	96.6	9.1	45.2	9	4967	468
		262	65.8	5.0	32.2	8	6440	489
		263	101.6	7.3	46.8	7	6411	461
		264	76.9	2.6	35.1	3	[a]13500	456
Mean							5939±3882	483±8

[a] Omitted in calculating the mean.

WATER REQUIREMENT OF POTATOES, COTTON, GRAMA GRASS, AND PIGWEED, 1915

Potatoes had a water requirement of 329±4, between oats and wheat (Table 13). On the basis of tuber production the value was 945±134, and on the basis of green weight it would be about 192±29. During 1915 cotton had a very high water requirement, 443±8, or 35 per cent above that of potatoes, due largely to the cool, damp year, which was almost ideal for potato, but very unfavorable for cotton.

TABLE 13.—*Water requirement, based on tuber and dry matter, of potatoes, and on dry matter in cotton, grama grass, and pigweed, at Akron, Colo., 1915*

Kind of plant	Period of growth	Pot No.	Dry matter	Tubers	Water	Tubers	Water requirements based on— Grain	Dry matter
POTATO (*Solanum tuberosum*)			*Grams*	*Grams*	*Kgms.*	*Per cent*		
Irish Cobbler	July to Sept. 25	307	56.3	25.1	19.2	45	765	341
		308	60.6	27.1	20.5	45	756	338
		309	67.2	16.1	22.3	24	1385	332
		310	66.9	10.6	22.8	16	[a]2151	341
		311	85.6	48.8	25.5	57	523	298
		312	63.4	15.9	20.6	25	1296	325
Mean							945±134	329±4
COTTON (*Gossypium hirsutum*)								
Triumph	June 26 to Sept. 25	229	82.0		38.7			472
		230	74.4		35.2			473
		231	122.0		51.9			425
		232	141.5		63.3			447
		233	127.5		52.2			409
		234	104.6		45.0			430
Mean								443±8
GRAMA GRASS (*Bouteloua gracilis*)								
First crop	June 4 to Aug. 6	205	23.2		6.9			297
		206	18.2		5.2			286
		207	28.9		8.0			277
		208	38.1		10.2			268
		209	44.7		12.4			277
		210	22.4		6.0			268
Mean								279±3
Second crop	Aug. 6 to Sept. 21	205	11.3		5.9			522
		206	8.8		4.1			466
		207	11.1		5.3			477
		208	23.9		5.7			238
		209	26.0		7.2			277
		210	13.3		4.4			331
Mean								385±39
Combined crop	June 4 to Sept. 21	205	34.5		12.8			371
		206	27.0		9.3			344
		207	40.0		13.3			333
		208	62.0		15.9			256
		209	70.7		19.6			277
		210	35.7		10.4			291
Mean								312±14

[a] Not included in the mean.

TABLE 13.—*Water requirement, based on tuber and dry matter, of potatoes, and on dry matter in cotton, grama grass, and pigweed, at Akron, Colo., 1915*—Contd.

Kind of plant	Period of growth	Pot No.	Dry matter	Tubers	Water	Tubers	Water requirements based on—	
							Grain	Dry matter
PIGWEED (*Amaranthus retroflexus*)			*Grams*	*Grams*	*Kgms.*	*P. ct.*		
First crop	June 26 to Aug. 6	211	116.2		28.1			242
		212	128.0		32.0			250
		213	160.3		36.2			226
		214	112.8		28.3			251
		215	113.1		27.1			240
		216	145.5		32.6			224
Mean								239±3
Second crop	Aug. 6 to Sept. 21	211	29.0		5.5			190
		212	28.7		5.9			206
		213	19.7		4.0			203
		214	37.1		6.8			183
		215	39.6		7.2			182
		216	24.3		4.0			165
Mean								188±4
Combined crop	June 26 to Sept. 21	211	145.2		33.6			231
		212	156.7		37.9			242
		213	180.0		40.2			223
		214	149.9		35.1			234
		215	152.7		34.3			225
		216	169.8		36.6			216
Mean								229±3

Pigweed produced only two crops with a water requirement of 229±3, while grama grass also produced two crops and had a water requirement of 312±14. During 1914 pigweed was 21 per cent and during 1915 27 per cent more efficient than grama grass. As compared with sorghum and millet, pigweed required 13 per cent and grama grass 54 per cent more water.

SUMMARY OF WATER REQUIREMENT MEASUREMENTS MADE IN 1915

The climatic conditions in 1915 were unusually cool and damp as compared with average years. (See Tables 27, 28, 31, and 32.) The evaporation, 33.40 inches for the growing period, was lower than for any year from 1908 to 1924, and the precipitation was unusually heavy, 19.44 inches for the six months' growing period. The water-requirement value in 1915 (see Table 28) was 27 points lower than 1914, 45 points lower than 1916, and 20 points lower than 1917. A comparison of the water requirements of the 1915 crops with those of 1914, shows that cowpeas was the outstanding crop of 1915, with a water requirement 43 points lower than in 1914, while the 15 crops grown for the period, 1914 to 1917, ranged from 19 to 43 points lower in their water requirement in 1915 than in 1914.

Of the crops grown during the period 1914 to 1917, the lowest proportionate values in 1915 were for corn, 8 points below the mean of all crops, followed by Kursk millet, Swedish Select and Burt oats, cowpeas, and Sudan grass. The highest relative value was for grama grass, 17 points above the mean for all crops, followed by Galgalos wheat, cotton, alfalfa, and Kubanka wheat.

On the basis of grain production the water requirement was lower in 1915 than in any other year except 1912. (See Table 29.) In general, the plants which have a low water requirement on the basis of dry matter, also have a low water requirement when based on grain yield. Oats was proportionately low and sorghum proportionately high in 1915.

WATER REQUIREMENT OF PLANTS, 1916

Of the plants grown at Akron in 1916 35 sets are included in these tables. The year was unusually dry, the precipitation for the growing period being 10.77 inches, the lowest for any year of the period, 1911 to 1917, with the exception of 1911. Evaporation, 47.18 inches for the growing period, was correspondingly high. Although the evaporation for the season was as high in 1911 as in 1916, the monthly evaporation was more evenly distributed in 1911. In July, 1916, the evaporation was higher than in any month during the period 1908 to 1924, inclusive. (See Tables 27, 28, 31, and 32.) This unusually dry month is reflected in the high water requirement, since practically all crops were actively growing during this period.

WATER REQUIREMENT OF VARIETIES OF WHEAT, 1916

Fifteen sets of wheat were grown in 1916, including 8 durum, 6 of common, and 1 of a hybrid wheat. The water-requirement results, based on dry matter, are as follows:

Durum:	
Kubanka, C. I. 1440	636±14
C. I. 4082 (old seed)	666±24
C. I. 4082 (second generation seed)	683±18
Kubanka, C. I. 2094	696±30
C. I. 4082 (first generation seed)	710±9
C. I. 4131 (second generation seed	712±10
C. I. 4131 (first generation seed)	717±30
C. I. 4131 (old seed)	719±15
Average	692±20
Common:	
Galgalos, C. I. 2398	652±8
Marquis, C. I. 3641 (old seed)	680±12
Common—Continued.	
Pacific Bluestem, C. I. 4067	690±7
Marquis, C. I. 3641 (second generation seed)	713±19
Marquis, C. I. 3641 (first generation seed)	726±5
Haynes Bluestem	743±11
Average	701±11
Hybrid:	
Kubanka, C. I. 2094× Haynes Bluestem	636±21
Average for series	692±17

The water requirement for the durum wheats was 1 per cent lower than the water requirement for the common wheats. In contrast to 1914 and 1915, Kubanka had the lowest water requirement of any of the varieties of wheat grown. The variation between the lowest and highest water-requirement measurements of the durums was 13 per cent. The lowest value among the common wheats was obtained from Galgalos, 652±8, which was 2 per cent higher than the most efficient durum. The varieties of common wheat showed a range of 14 per cent in water-requirement measurements.

The hybrid wheat had a water requirement 14 per cent lower than that of the common parent, 9 per cent lower than that of the durum parent, and 12 per cent lower than the mean of the parents. These results show a marked improvement on the part of the hybrid, an improvement equal to that shown by corn hybrids. Among the

corn hybrids the water-requirement range was from 10 per cent above to 10 per cent below the parental mean. The water-requirement measurements for the wheat hybrids recorded in this paper range from 14 per cent below to 14 per cent above the parental mean. On the basis of grain production the hybrid requirement is 16 per cent more than the parental mean.

The water requirement measurements of the wheats, based on grain production, are as follows:

Durum wheats	
Kubanka, C. I. 1440	1779 ± 108
C. I. 4082 (second generation seed)	1821 ± 60
Kubanka, C. I. 2094	1857 ± 142
C. I. 4082 (first generation seed)	1903 ± 80
C. I. 4131 (second generation seed)	2095 ± 104
C. I. 4131 (old seed)	2125 ± 104
C. I. 4082 (old seed)	2291 ± 172
C. I. 4131 (first generation seed)	2640 ± 170
Average	2064 ± 123
Common wheats:	
Marquis (second generation seed)	2008 ± 43
Common wheats—Contd.	
Haynes Bluestem	2338 ± 78
Marquis (first generation seed)	2339 ± 126
Marquis (old seed)	2395 ± 232
Galgalos, C. I. 2398	2445 ± 155
Pacific Bluestem, C. I. 4067	2959 ± 346
Average	2414 ± 192
Hybrid:	
Kubanka, C. I. 2094 × Haynes Bluestem	2434 ± 103
Average for series	2229 ± 152

The water requirement of the durum wheats in 1916 was 2064 ± 123, or 85 per cent of the common wheats. Kubanka, C. I. 1440, gave the lowest water requirement of any of the varieties grown, while Pacific Bluestem had the highest value. One of the sets of Marquis wheat again gave the lowest water requirement of the common wheats. The range in water requirement was about the same in both groups, the lowest value being about 68 per cent of the highest. On the basis of total dry matter the water-requirement range in the durum group was also the same as in the common group. Based on grain production, however, the water requirement of the durums was much less, the lowest value being 88 per cent of the highest. Table 14 gives the water-requirement results for the wheat varieties in 1916.

TABLE 14.—*Water requirement, based on grain and dry matter, of wheat varieties at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Kubanka, C. I. 1440 (*Triticum durum*).	June 3 to Aug. 12	1	89.6	29.2	62.3	33	2134	695
		2	104.3	38.7	64.0	37	1654	614
		3	85.8	28.9	48.8	34	1689	569
		4	95.7	35.8	62.5	37	1746	653
		5	102.1	39.7	68.2	39	1718	668
		6	72.8	26.0	45.0	36	1731	618
Mean							1779±108	636±14
Galgalos, C. I. 2398 (*T. durum*).	June 3 to Aug. 12	7	59.9	17.2	40.6	29	2360	678
		8	44.5	9.5	27.9	21	2937	627
		9	45.6	9.4	28.0	21	2979	614
		10	27.8	6.9	18.3	25	2652	658
		11	90.3	30.0	58.9	33	1963	652
		12	70.2	27.0	48.1	38	1781	685
Mean							2445±155	652±8

TABLE 14.—*Water requirement, based on grain and dry matter, of wheat varieties at Akron, Colo., 1916*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Water requirements based on— Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Pacific Bluestem, C. I. 4067 (*T. acstivum*).	June 3 to Aug. 21	13	131.0	40.7	91.3	31	2243	697
		14	47.1	4.4	30.8			654
		15	116.4	28.5	80.0	24	2807	687
		16	90.0	16.9	64.7	19	3828	719
		18	54.5	1.5	37.7			692
Mean							2959±346	690±7
C. I. 4131 (from Siberia) (*T. durum*), old seed.	June 3 to Aug. 16	19	97.5	36.4	65.3	37	1794	670
		20	86.5	25.9	59.5	30	2297	688
		21	39.8	11.1	27.6	28	2486	693
		22	76.2	30.4	56.0	40	1842	735
		23	70.8	22.8	50.3	32	2206	710
		24	27.2	6.5	22.3	24	*3431	820
Mean							2125±104	719±15
C. I. 4131 (from Siberia), first generation seed.	June 3 to Aug. 16	25	14.1	3.7	12.6	26	*3405	894
		26	70.3	22.6	49.7	32	2199	707
		27	33.9	7.3	23.9	22	3274	705
		28	30.2	7.8	18.6	26	2385	616
		29	39.4	9.7	26.2	25	2701	665
Mean							2640±170	717±30
C. I. 4131 (from Siberia), second generation seed.	June 3 to Aug. 16	32	32.5	9.4	23.0	29	2447	708
		33	78.8	30.4	58.9	39	1938	747
		34	89.7	36.6	66.0	41	1803	736
		35	77.3	26.7	51.5	35	1929	666
		36	44.1	13.2	31.1	30	2356	705
Mean							2095±104	712±10
C. I. 4082 (from Peru) (*T. durum*), old seed.	June 3 to Aug. 21	43	36.4	11.5	23.5	32	2043	646
		44	22.7	6.7	17.3	30	2582	762
		45	18.2	3.9	11.4	21	2923	626
		46	25.9	10.0	15.2	39	1520	587
		47	49.4	14.7	35.1	30	2388	711
Mean							2291±172	666±24
C. I. 4082 (from Peru), first generation seed.	June 3 to Aug. 21	49	53.8	21.5	39.1	40	1819	727
		50	27.1	2.8	19.3	10	*6893	712
		51	96.2	40.3	67.1	42	1665	698
		52	37.5	11.4	26.1	30	2289	696
		53	62.3	20.8	41.4	33	1990	665
		54	100.0	43.5	76.3	44	1754	763
Mean							1903±80	710±9
C. I. 4082 (from Peru), second generation seed.	June 3 to Aug. 21	55	24.5	7.2	15.9	29	2208	649
		56	88.7	37.4	58.9	42	1575	664
		57	26.7	11.4	20.6	43	1807	772
		58	26.7	9.5	16.9	36	1779	633
		59	50.9	17.2	32.8	34	1907	644
		60	101.5	45.2	74.5	45	1648	734
Mean							1821±60	683±18
Marquis, C. I. 3641 (*T. durum*), old seed.	June 3 to Aug. 9	67	38.4	8.2	24.4	21	2976	635
		68	86.8	30.2	60.1	35	1990	692
		70	77.9	25.1	55.7	32	2219	715
		72	49.1	9.8	33.2	20	*3388	676
Mean							2395±232	680±12

* Omitted in the mean

TABLE 14.—*Water requirement, based on grain and dry matter, of wheat varieties at Akron, Colo., 1916*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Marquis, C. I. 3641, first generation seed.	June 3 to Aug. 9	73	78.5	26.5	56.3	34	2125	717
		74	92.3	36.0	66.3	39	1842	718
		75	56.5	17.7	39.8	31	2249	704
		76	86.1	29.0	62.7	34	2162	728
		77	35.2	11.2	25.9	32	2313	736
		78	32.4	7.3	24.4	23	3342	753
Mean							2339±126	726±5
Marquis, C. I. 3641, second generation seed.	June 3 to Aug. 9	79	19.5	4.0	15.7	21	[a]3925	805
		80	22.3	8.2	17.2	37	2098	771
		81	78.5	27.1	54.9	35	2026	699
		82	54.7	17.1	36.8	31	2152	673
		83	70.1	24.2	45.9	35	1897	655
		84	77.6	28.0	52.3	36	1868	674
Mean							2008±43	713±19
Kubanka, C. I. 2094 (*T. durum*).	June 3 to Aug. 16	91	32.3	9.5	23.4	29	[a]2463	724
		92	54.5	15.8	31.3	29	1981	574
		94	13.5	5.0	10.2	37	2040	756
		96	8.5	4.0	6.2	47	1550	729
Mean							1857±142	696±30
Kubanka, C. I. 2094×Haynes Bluestem, C. I. 2874.	June 3 to Aug. 16	97	65.4	18.0	39.0	28	2167	596
		98	94.8	29.5	61.7	31	2092	651
		99	92.7	25.4	56.5	27	2224	609
		100	77.8	19.5	48.7	25	2497	626
		101	36.7	7.1	20.1	19	2831	548
		102	78.9	22.2	62.0	28	2793	786
Mean							2434±103	636±21
Haynes Bluestem, Minnesota 169, C. I. 2874 (*T. aestivum*).	June 3 to Aug. 9	115	97.5	32.3	74.1	33	2294	760
		116	96.6	33.1	68.8	34	2079	712
		117	96.5	32.0	71.1	33	2222	737
		118	99.1	32.0	68.5	32	2141	691
		119	95.8	30.4	76.3	32	2510	796
		120	68.9	18.9	52.6	27	2783	763
Mean							2338±78	743±11

[a] Omitted in the mean.

WATER REQUIREMENT OF BARLEY, OATS, AND RYE, 1916

Barley gave a water requirement of 664 ± 9 and rye of 800 ± 11, or 64 and 71 per cent higher, respectively, than in 1915. Based on grain weight, the water requirement of barley was 1425 ± 27 and of rye 2871 ± 99, or 50 and 93 per cent higher, respectively, than in 1915.

Two varieties of oats were grown in 1916, Burt, with a water requirement of 809 ± 5, and Swedish Select, with a water requirement of 876 ± 21. Oats had a water requirement in 1916, 88 per cent higher than in 1915. As compared with wheat, oats had a water requirement 22 per cent higher. On the basis of grain production, Burt oats had a water requirement of 1975 ± 49, or 72 per cent higher than in 1915, while Swedish Select required 2288 ± 39, more than twice as much as in 1915 (Table 15).

TABLE 15.—*Water requirement, based on grain and dry matter, of barley, oats, and rye at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Barley, Hannchen, C. I. 531 (*Hordeum distichon*).	June 3 to July 29	139	82.2	40.7	58.1	50	1428	707
		140	103.2	45.2	71.0	44	1571	688
		141	113.5	55.2	74.3	49	1346	655
		142	108.5	52.0	68.2	48	1312	629
		143	112.2	52.5	73.8	47	1406	658
		144	102.5	44.5	66.2	43	1488	646
Mean							1425±27	664±9
Oats, Swedish Select, C. I. 134 (*Avena sativa*).	June 3 to Aug. 9	127	104.0	42.2	95.5	40	2263	918
		128	97.7	40.2	93.6	41	2328	958
		129	108.1	38.8	98.4	36	2536	910
		130	98.3	34.6	79.0	35	2283	804
		131	106.7	40.7	93.9	38	2307	880
		132	104.6	40.7	81.9	39	2012	783
Mean							2288±39	876±21
Oats, Burt, C. I. 293 (*A. sativa*).	June 3 to July 26	133	90.4	39.8	71.9	44	1807	795
		134	86.0	38.3	67.4	45	1760	784
		135	80.0	33.0	64.9	41	1967	811
		136	85.4	35.2	70.7	41	2009	828
		137	82.3	33.3	68.1	40	2045	827
		138	88.7	31.6	71.5	36	2263	806
Mean							1975±49	809±5
Rye, Vern, C. I. 73 (*Secale cereale*).	June 3 to Aug. 5	145	84.5	22.3	70.4	26	3157	833
		146	91.7	27.2	78.1	30	2871	852
		147	89.1	20.8	69.9	23	3361	785
		148	94.4	34.1	71.6	36	2100	758
		149	56.9	16.0	45.7	28	2856	803
		150	85.5	22.9	65.9	27	2878	771
Mean							2871±99	800±11

Swedish Select oats had the highest water requirement based on total dry matter of any of the small grains, and was followed by Burt oats, rye, the common and durum wheats, and barley. Kubanka and Galgalos wheat and barley had the lowest water requirements of any of the small grains. Oats and rye seem to have been affected more than any other crop by the extremely dry season.

WATER REQUIREMENT OF CORN, SORGHUM, SUDAN GRASS, AND MILLET, 1916

Only one variety of each of these crops was grown in 1916 at Akron. The water-requirement results obtained from this test were as follows:

Sorghum, Minnesota Amber	296 ± 4	Sudan Grass	426 ± 3
Millett, Kursk	367 ± 4	Corn, Northwestern Dent	495 ± 13

This year of high water requirement did not greatly affect sorghum. (See Table 16.) Although 46 per cent higher than in 1915, its water requirement was relatively low. A similiar response has been noted for sorghum on several occasions, which during hot weather compensates in growth for the increased rate of transpiration. Sudan grass behaved much as did sorghum but showed a slightly greater reaction to the dry season, the water requirement being 64 per cent higher than in 1915. Millet, with a water requirement 82 per cent and corn and Swedish Select oats with a water requirement 96 per cent above that in 1915, responded to the dry season to a greater extent than any other crops.

TABLE 16.—*Water requirement, based on grain, of corn, sorghum, and millet, and on dry matter for sudan grass, at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Corn, Northwestern Dent (*Zea mays*).	June 16 to Aug. 23.	271	152.9	19.6	70.8	13	3612	463
		272	193.4	Trace.	100.0			517
		273	206.7	Trace.	99.1			479
		274	148.4	18.0	65.8	12	3656	443
		275	186.0	8.9	97.5	5	[a]10955	524
		276	196.0	2.5	106.8		[a]4272	545
Mean							3634±19	495±13
Sorghum, Minnesota Amber, A. D. I. 341–13 (*Andropogon sorghum*).	June 17 to Aug. 23.	259	228.6	77.5	70.6	34	911	309
		260	202.1	73.6	61.4	36	834	304
		261	268.5	92.0	80.1	34	871	298
		262	238.5	94.5	67.8	40	717	284
		263	218.8	67.4	62.7	31	939	287
Mean							853±26	296±4
Sudan grass (*Andropogon sorghum aethiopicus*), first crop.	June 30 to July 26.	337	108.1		49.4			457
		338	92.3		42.7			463
		339	90.2		42.5			471
		340	92.3		42.4			459
		341	106.6		41.0			385
		342	105.0		43.5			414
Mean								442±11
Sudan grass, second crop	July 26 to Sept. 2.	337	67.6		27.7			410
		338	68.9		25.9			376
		339	59.0		22.3			378
		340	62.8		25.6			408
		341	54.2		23.2			428
		342	62.5		27.0			432
Mean								405±7
Sudan grass, combined crop	June 30 to Sept. 2.	337	175.7		77.1			439
		338	161.2		68.6			426
		339	149.2		64.8			434
		340	155.1		68.0			438
		341	160.8		64.2			399
		342	167.5		70.5			421
Mean								426±3
Millet, Kursk, S. P. I. 34771 (*Chaetochloa italica*).	June 17 to Aug. 12.	253	238.2	72.2	89.7	30	1242	377
		254	179.0	48.4	68.0	27	1405	380
		255	174.9	46.0	64.6	26	1404	369
		256	155.1	39.4	53.2	25	1359	343
		257	145.0	45.9	54.2	32	1181	374
		258	133.6	46.9	47.8	35	1019	358
Mean							1267±45	367±4

[a] Not included in the mean.

The grain production of corn was very uncertain and is not especially significant. The water requirement, based on grain, was 3634 ± 19, or 76 per cent above that in 1915. The water requirement for sorghum based on grain production, was 853 ± 26, or 24 per cent less than in 1915. This result is remarkable and shows strikingly the ability of sorghum to maintain a low water requirement even during an exceptionally dry and hot season.

The water requirement of millet was 1267 ± 45, or 91 per cent higher than in 1915. With the exception of sorghum the water requirement based on grain yield, of the crops included in this experiment, shows about the same response as does that based on total dry matter.

WATER REQUIREMENT OF VARIETIES OF FLAX, 1916

The experiments with flax were very unsatisfactory (Table 17). The hot dry season was very unfavorable and only a few pots survived. The Jalaun variety gave a water requirement of 1098 = 10, or 61 per cent higher than in 1915, and Kashgar a water requirement

of 812 = 0, or 43 per cent higher than in 1915. Flax did not respond to the dry, hot year to any greater extent than the other crops grown. These values, therefore, fall within the range of expectation.

TABLE 17.—*Water requirement of varieties of flax at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
FLAX (*Linum usitatissimum*)			*Grams*	*Grams*	*Kgms.*	*P. ct.*		
Jalaun, S. P. I. 36566, Indian, C. I. 21.	June 26 to Aug. 9.	172	7.2	1.4	7.9	19		1097
		173	13.7	1.6	15.4	12	963	1124
		174	8.2		8.8			1073
Mean								1098±10
Kashgar, S. P. I. 37719, C. I. 50–1.	June 26 to Sept. 2.	175	62.8	7.5	51.0	12		812
		178	84.5	16.9	68.6	20		812
Mean								812±0

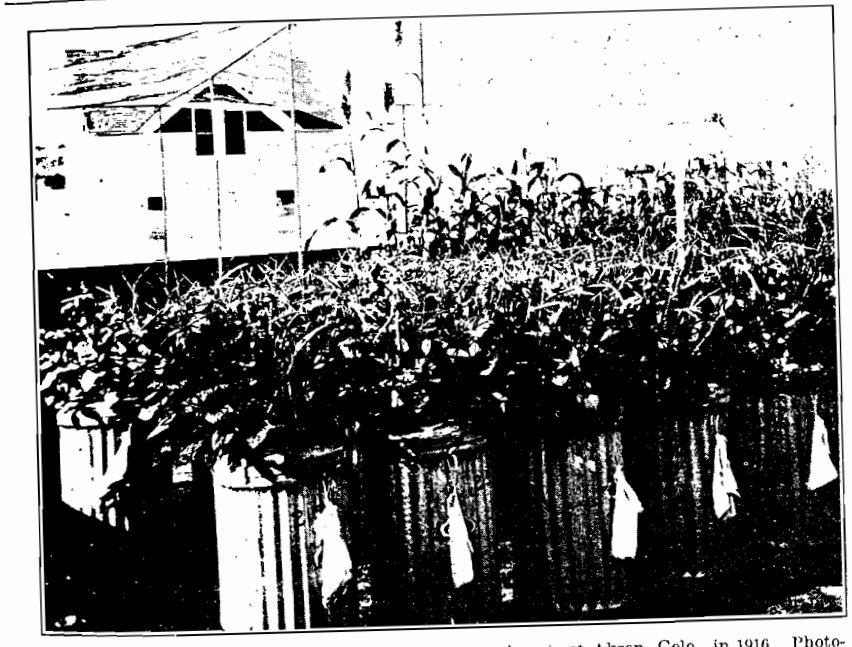

FIG. 5.—Cowpeas grown in the water requirement experiments at Akron, Colo., in 1916. Photographed August 2, 1916

WATER REQUIREMENT OF LEGUMES, 1916

The water requirement of alfalfa in 1916, 1047 ± 9, was higher than for any year with the exception of 1911. Alfalfa responds to dry and hot weather and the high water-requirement value in 1916 is due partly to the first or spring crop which gave a value almost as high as the second or midsummer crop. In 1916 the yield of three crops was less than the yield of two crops in 1915. The water requirement of alfalfa for 1916 was 51 per cent greater than for 1915.

Cowpeas (see fig. 5), although a southern crop, responded in a greater degree to the hot, dry season than any crop, excepting corn and oats. On the basis of total dry matter the water requirement was 767 ± 8, or 86 per cent higher than in 1915, and on the basis of seed production, 2373 ± 77, or 89 per cent above the 1915 results. Table 18 shows complete results for the 1916 water-requirement measurements of legumes.

TABLE 18.—*Water requirement, based on dry matter, of legumes and grain, Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
ALFALFA								
(*Medicago sativa*)								
Grimm, A. D. I. E-23, first crop	June 24 to July 25	199	*Grams* 18.2	*Grams*	*Kgms.* 19.7	*P ct.*		1082
		200	20.1		19.1			950
		201	26.5		30.5			1151
		202	28.0		30.2			1079
		203	34.0		45.1			1326
		204	40.5		48.5			1198
Mean								1131±5
Grimm, A. D. I. E-23, second crop	July 25 to Aug. 30	199	43.8		52.7			1203
		200	42.2		55.4			1313
		201	50.0		57.8			1156
		202	47.1		56.5			1200
		203	53.1		61.8			1164
		204	55.9		66.5			1190
Mean								1204±1
Grimm, A. D. I. E-23, third crop	Aug. 30 to Oct. 2	199	41.5		34.7			836
		200	41.1		34.0			827
		201	42.0		32.0			762
		202	47.4		38.1			804
		203	50.8		41.0			807
		204	58.0		53.6			924
Mean								827±1
Grimm, A. D. I. E-23, combined crop	June 24 to Oct. 2	199	103.5		107.1			1035
		200	103.4		108.5			1049
		201	118.5		120.3			1015
		202	122.5		124.8			1019
		203	137.9		147.9			1073
		204	154.4		168.6			1092
Mean								1047±9
COWPEA								
(*Vigna sinensis*)								
S. P. I. 29282	June 16 to Aug. 15	211	145.4	47.9	106.9	33	2232	735
		212	107.9	32.8	86.6	30	2640	803
		213	107.8	44.8	85.3	42	1904	791
		214	114.5	34.0	87.9	30	2585	768
		215	115.8	36.1	86.5	31	2396	747
		216	125.2	38.1	94.5	30	2480	755
Mean							2373±77	767±8

WATER REQUIREMENT OF COTTON AND POTATOES, 1916

The water requirement of cotton was 612 ± 9 (Table 19), or 38 per cent above that of 1915. The hot, dry year was favorable for this crop, which was relatively as efficient in the use of water as sorghum, and was exceeded only by grama grass and Galgalos wheat.

TABLE 19.—*Water requirement of cotton, based on dry matter, and of potatoes, based on dry matter and tubers at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
Cotton, Triumph (*Gossypium hirsutum*).	June 27 to Sept. 29	247	*Grams* 133.8	*Grams*	*Kgms.* 78.7	*P. ct.*		588
		248	136.3		81.7			599
		249	121.5		81.1			667
		250	134.2		80.8			602
		251	187.3		118.3			632
		252	194.3		113.6			585
Mean								612±9
POTATO								
(*Solanum tuberosum*)							*Tubers*	
McCormick	June 22 to Sept. 13	187	120.7	27.6	90.2	23	3268	747
		188	98.3	14.3	82.9	15	5797	843
		189	108.1	26.9	92.7	25	3446	858
		190	110.5	2.4	68.1	22	2838	616
		191	74.1	.1	48.1	13	4810	649
		192	114.2	9.5	85.6	8	901	750
Mean							3510±452	744±28
Irish Cobbler	June 26 to Sept. 13	193	109.8	55.3	61.4	50	1110	559
		195	127.4	90.9	82.5	71	908	648
		196	119.0	88.7	75.0	75	846	630
		197	133.7	100.4	79.9	75	796	598
		198	91.9	54.2	65.6	59	1210	714
Mean							974±63	630±17

Potatoes required about the same amount of water as in 1913. The McCormick variety was grown only in 1913 and 1916, both of which were dry and hot. Based on dry matter this variety required 744 ± 28, or 18 per cent more water than Irish Cobbler and on tuber production more than 3½ times as much. Irish Cobbler was relatively less efficient during the hot year, 1916, than the cool year, 1915, the water requirement being 630 ± 17 or 91 per cent above that of 1915. On the basis of tuber production, however, Irish Cobbler required only 974 ± 63, or 3 per cent more water than in 1915.

WATER REQUIREMENT OF NATIVE PLANTS, 1916

The most efficient plant was grama grass with a water requirement of 336 ± 8, the average for two crops, followed closely by pigweed with a water requirement for two crops of 340 ± 13 (Table 20). These values are low and were exceeded in 1916 by sorghum only. During the unusually hot, dry year grama grass showed an exceptional ability to efficiently utilize the water supply. Its relative water-requirement value, 21 points below the average of all crops (Table 28), was the lowest of any of the plants measured. Sorghum, the second best crop in relative water requirement, was 11 points above grama grass. Both plants showed unusually low values as compared with the results of other years. The water requirement of lamb's-quarters was 666 ± 27, of sunflower, 579 ± 10, and of Iva, 652 ± 6, or about equal to such crops as the small grains, but much higher than sorghum, corn, and millet.

TABLE 20.—*Water requirement, based on dry matter, of native plants, at Akron, Colo., 1916*

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
GRAMA GRASS					
(*Bouteloua gracilis*)					
			Grams	*Kgms.*	
First crop	June 16 to July 26	223	15.0	6.1	407
		225	15.7	6.8	433
		226	12.6	5.1	405
		227	27.6	11.8	428
		228	16.7	8.0	479
Mean					430±8
Second crop	July 26 to Sept. 1	223	7.9	1.3	165
		225	17.8	3.9	219
		226	14.7	3.6	245
		227	31.4	9.2	293
		228	11.8	2.4	203
Mean					225±8
Combined crop	June 16 to Sept. 1	223	22.9	7.4	323
		225	33.5	10.7	319
		226	27.3	8.7	319
		227	59.0	21.0	356
		228	28.5	10.4	365
Mean					336±8
PIGWEED					
(*Amaranthus retroflexus*)					
First crop	June 27 to July 26	205	67.9	28.0	412
		206	62.2	28.5	458
		207	58.3	26.4	453
		208	65.0	30.3	466
		209	58.1	26.5	456
		210	17.6	6.9	392
Mean					440±9
Second crop	July 26 to Sept. 1	205	62.6	14.4	230
		206	56.2	14.9	265
		207	49.5	13.5	273
		208	57.6	14.1	245
		209	57.9	16.1	278
		210	52.8	10.8	205
Mean					249±9
Combined crop	June 27 to Sept. 1	205	130.5	42.4	325
		206	118.4	43.4	367
		207	107.8	39.9	370
		208	122.6	44.4	362
		209	116.0	42.6	367
		210	70.4	17.7	251
Mean					340±13
MISCELLANEOUS					
Lamb's-quarters (*Chenopodium album*)	July 13 to Sept. 1	37	97.7	84.2	862
		38	131.1	84.9	648
		39	135.9	84.4	621
		40	118.8	81.1	683
		41	139.0	87.5	629
		42	146.9	81.5	555
Mean					666±27
Sunflower (*Helianthus annuus*)	July 13 to Sept. 4	229	256.9	140.0	545
		230	235.2	132.5	563
		231	218.9	126.8	579
		232	229.4	140.4	612
		233	216.7	119.7	552
		234	203.7	127.4	625
Mean					579±10
Iva xanthifolia	July 13 to Sept. 4	235	185.7	119.9	646
		236	202.9	129.1	636
		237	173.6	110.9	639
		238	115.7	80.2	693
		239	100.9	64.7	641
		240	214.6	141.4	659
Mean					652±6

SUMMARY OF WATER-REQUIREMENT MEASUREMENTS MADE IN 1916

It is especially interesting to note the relative behavior of different crops during this year of extreme climatic conditions. (See Tables 27, 28, 31, and 32.) The weather during the year was very hot and dry. The evaporation for the six-months' growing period, 47.18 inches, was the highest for any year from 1911 to 1917, with the exception of 1911. The precipitation, 10.77 inches, was also low.

As compared with 1911, the water-requirement values in 1916 are higher. This is probably due partly to the very high evaporation during July, 1916, the evaporation for that month being over 11 inches, or higher than the monthly record for the period 1908 to 1925, inclusive. This high value is reflected in the water-requirement measurements, since all crops were active during this period.

In Table 28 the relative values, based on actual values given in Table 27, afford a means of judging the relative efficiency or inefficiency in the use of water of any one of the crops grown for the different periods. The longest series of experiments were conducted during the years 1914–1917. The water requirement in 1916 was 22 points above the average for the period. Seven of the crops gave relative values less than 22 points above the average while eight gave values more than 22 points above. The highest value for the period was 37 points above the average and the lowest 21 points below.

Grama grass, with a water requirement 21 points below the average of the crops shown in Table 28, made the best individual crop record. Its remarkable adjustment to the hot, dry weather conditions during the year stamps grama grass as relatively efficient in its use of water. On the basis of grain production sorghum, with a water requirement 51 points below the average of crops shown in Table 29, made an exceptionally good showing. Cotton has a value 8 points below and Galgalos wheat 9 points below the mean for all crops. The hot year reacted most unfavorably on Swedish Select oats which was 15 points above the average, followed by Northwestern Dent corn, cowpeas, Burt oats, and Kursk millet, 13, 10, 7, and 6 points, respectively, above the average.

The water requirement on the basis of grain production was higher in 1916 than in any other year. Sorghum showed the lowest relative water requirement while Northwestern Dent corn showed the highest.

WATER REQUIREMENT OF PLANTS, 1917

Only 16 sets of plants were used in the regular water-requirement experiments during 1917. These included crops previously grown. The climatic conditions during the year were about normal; and the evaporation was about the average for the entire observation period. The water requirement of the seven crops grown during the period, 1911–1917, averaged about the same as for the entire period. The season was similar to 1913 and 1914, although the rainfall was greater.

WATER REQUIREMENT OF WHEAT, OATS, BARLEY, AND RYE, 1917

Only two varieties of wheat were grown in the regular series in 1917. Kubanka had a water requirement of 471 ± 4 and Galgalos of 543 ± 6 (Table 21). The oats varieties, Swedish Select and Burt, had practically the same values, 635 ± 5 and 636 ± 5, respectively.

The water requirement of rye, 625 ± 5, was a little less than for oat and barley, 522 ± 4, and a little lower than Galgalos wheat. Base on index values, Kubanka and Galgalos wheat had a water require ment in 1917 considerably below the mean of the series. The oat varieties, as well as those of barley and rye, on the other hand required proportionately more water than wheat.

TABLE 21.—*Water requirement, on the basis of grain and dry matter, of wheat, oats, barley, and rye, at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Wheat, Kubanka, C. I. 1440 (*Triticum durum*).	June 11 to Aug. 21	1	145.7	51.2	71.3	35	1393	489
		2	161.7	52.0	77.5	32	1490	479
		3	149.4	51.3	71.0	34	1384	475
		4	165.1	58.5	75.9	35	1297	460
		5	131.9	46.1	61.1	35	1325	463
		6	164.6	57.4	75.3	35	1312	457
Mean							1367±21	471±
Wheat, Galgalos, C. I. 2398 (*T. aestivum*).	June 11 to Aug. 17	7	159.3	55.5	87.6	35	1578	550
		8	156.9	57.0	85.9	36	1507	547
		9	150.9	53.3	80.0	35	1501	530
		10	164.4	61.4	88.1	37	1435	536
		11	169.0	59.8	87.7	35	1467	519
		12	158.1	56.7	91.0	36	1605	576
Mean							1516±19	543±
Oats, Swedish Select, C. I. 134 (*Avena sativa*).	June 11 to Aug. 17	13	185.6	53.9	115.0	29	2134	620
		14	169.4	54.5	105.0	32	1927	620
		15	161.3	48.3	105.1	30	2176	652
		16	161.6	49.3	102.4	31	2077	634
		17	194.9	57.2	128.7	29	2250	660
		18	152.7	48.3	94.9	32	1965	621
Mean							2088±37	635±
Oats, Burt, C. I. 293 (*A. sativa*).	June 11 to Aug. 6	19	150.0	42.5	99.3	28	2336	662
		20	146.3	53.8	94.5	37	1757	646
		21	151.5	46.2	96.7	31	2093	638
		22	162.2	59.9	103.4	37	1726	637
		23	164.5	71.7	102.1	44	1424	621
		24	148.3	50.7	90.6	34	1787	611
Mean							1854±91	636±
Barley, Hannchen, C. I. 531 (*Hordeum distichon*).	June 11 to Aug. 15	25	114.7	49.8	58.6	43	1177	511
		26	136.0	63.1	68.9	46	1092	507
		27	152.3	68.0	81.1	45	1193	533
		28	143.1	66.8	75.3	47	1127	526
		29	148.8	70.7	79.7	48	1127	536
		30	142.9	63.3	74.1	44	1171	519
Mean							1148±12	522±
Rye, Vern, C. I. 73 (*Secale cereale*).	June 11 to Aug. 22	31	123.2	35.7	78.0	29	2185	633
		32	133.8	50.6	84.3	38	1666	630
		33	101.7	34.7	61.2	34	1764	602
		34	104.7	33.3	64.7	32	1943	618
		35	131.9	42.6	80.5	32	1890	610
		36	131.8	35.3	86.2	27	2442	654
Mean							1982±84	625±

A number of wheats were grown in the field in pots 6 feet long, holding the same amount of soil as the standard pots. These crops grew on the stored soil moisture. The results of this test are given in Table 22. The values of the wheats grown in the field should be

reduced by 10 per cent, to compare with those in the shelter. This reduced value has been used in the discussion and in the summary table. The water requirements of the wheat crops are as follows:

Durum wheats:	
Kubanka, C. I. 1440	471 ± 4
C. I. 4082	465 ± 11
Average	468 ± 8
Common:	
Power, C. I. 3697	459 ± 8
Glyndon, C. I. 2873	472 ± 4
Ghirka	473 ± 57
Common—Continued.	
Prelude	482 ± 25
Pioneer	[a] 490
Haynes Bluestem	515 ± 6
Galgalos	543 ± 6
Average	491 ± 26
Average for the series	486 ± 23

The durum wheats are a little more efficient than the common wheats. The most efficient is Kubanka, with a water requirement of 471 ± 4, and the least efficient is Galgalos with a water requirement of 543 ± 6, 15 per cent above Kubanka.

TABLE 22.—*Water requirement, based on grain and dry matter, of wheat varieties in 6-foot cans, at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Haynes' Bluestem (*Triticum aestivum*).	June 9 to Sept. 12	5	32.6	11.4	18.4	35	1614	564
		6	21.9	4.1	12.7	19	3098	580
Mean								572±7
C. I. 4082, from Peru (*T. durum*).	June 9 to Sept. 12	7	20.0	.....	9.8	.....	.....	490
		8	15.4	2.8	7.9	18	2821	513
		9	16.8	3.4	9.2	20	2706	548
Mean								517±12
Glyndon, C. I. 2873 (*T. aestivum*).	June 9 to Sept. 12	13	10.8	3.2	5.7	30	1781	528
		14	23.8	6.1	12.2	26	2000	513
		15	14.7	3.6	7.8	24	2167	531
Mean								524±4
Power, C. I. 3697 (*T. aestivum*).	June 9 to Sept. 12	16	17.8	.....	8.7	.....	.....	489
		17	17.3	2.8	8.9	16	3179	514
		18	19.5	.....	10.3	.....	.....	528
Mean								510±9
Ghirka (*T. aestivum*)	June 9 to Sept. 12	19	15.8	2.9	9.5	18	3276	601
		20	12.2	.....	5.5	.....	.....	451
Mean								526±63
Prelude, C. I. 4323 (*T. aestivum*).	June 9 to Aug. 22	25	14.7	.....	7.9	.....	.....	537
		26	7.6	3.1	4.6	41	1484	605
		27	8.6	.....	4.0	.....	.....	465
Mean								536±28
Pioneer (*T. aestivum*)	June 9 to Aug. 28	28	9.0	.....	4.9	.....	.....	544

[a] Omitted in estimating probable error of means.

WATER REQUIREMENT OF CORN, SORGHUM, SUDAN GRASS, AND MILLET, 1917

One variety of each of the crops was grown in 1917, the water-requirement values being as follows:

Sorghum, Minnesota Amber	272 ± 5	Corn, Northwestern Dent	346 ± 3
Millet, Kursk	284 ± 5	Sudan grass	378 ± 3

Although it had the lowest actual water requirement, sorghum was 6 points above the average for all crops on the basis of the index values, and of the crops here considered was exceeded only by Sudan grass, which was 7 points above the average of all crops for the year. Millet and corn departed only two points from the average. Climatically, 1917 was about an average year. Table 23 gives the results of the measurements of these four crops in detail.

TABLE 23.—*Water requirement, based on grain and dry matter, of corn, sorghum, sudan grass, and millet, at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct*		
Corn, Northwestern Dent, (*Zea mays*).	June 14 to Sept. 1	67	363.3	59.2	120.0	16	2027	330
		68	330.7	66.6	116.2	20	1745	351
		69	333.8	13.4	115.6	4	[a] 8627	346
		70	343.5	11.6	124.5	3	[a] 10733	362
		71	350.6	59.7	120.3	17	2015	343
		72	299.0	6.5	126.1	2	[a] 19400	[a] 422
Mean							1929±73	346±3
Sorghum, Black Amber, Minnesota 341–13 (*Andropogon sorghum*).	June 20 to Sept. 4	61	320.8	56.6	81.2	18	1435	253
		62	285.1	22.1	82.9	8	[a] 3751	291
		63	262.1	31.9	72.6	12	2276	277
		64	224.5	12.9	68.7	6	[a] 5326	[a] 306
		65	269.4	34.7	70.9	13	2043	263
		66	295.1	77.7	81.1	26	1044	275
Mean							1700±224	272±5
Millet, Kursk, S. P. I. 34771 (*Chaetochloa italica*).	June 20 to July 30	37	199.1	------	59.3	------	------	298
		38	235.6	------	65.5	------	------	278
		39	231.9	------	62.9	------	------	271
		40	203.8	------	61.8	------	------	303
		41	277.5	------	72.1	------	------	260
		42	227.1	------	66.9	------	------	295
Mean								284±5
SUDAN GRASS (*Andropogon sorghum aethiopicus*)								
S. P. I. 25017, first crop	June 20 to Aug. 2	79	145.9	------	55.5	------	------	380
		80	139.6	------	57.0	------	------	408
		81	141.7	------	58.2	------	------	411
		82	143.6	------	56.8	------	------	396
		83	134.9	------	56.7	------	------	420
		84	138.8	------	59.3	------	------	427
Mean								407±5
S. P. I. 25017, second crop	Aug. 2 to Sept. 10	79	108.3	------	36.5	------	------	337
		80	95.7	------	32.5	------	------	340
		81	106.8	------	36.1	------	------	338
		82	104.1	------	34.6	------	------	332
		83	104.5	------	37.0	------	------	354
		84	113.8	------	37.7	------	------	331
Mean								339±2
S. P. I. 25017, combined crop.	June 20 to Sept. 10	79	254.2	------	92.0	------	------	362
		80	235.3	------	89.5	------	------	380
		81	248.5	------	94.3	------	------	379
		82	247.7	------	91.4	------	------	369
		83	239.4	------	93.7	------	------	391
		84	252.6	------	97.0	------	------	384
Mean								378±3

[a] Omitted in the mean.

WATER REQUIREMENT OF ALFALFA, 1917

The water requirement for three crops of alfalfa 822±8 (Table 24) was the lowest value for the entire period except the damp cool years 1912 and 1915. Alfalfa seems to have been a little more efficient in its use of water during 1917 than during the period, 1911–1917.

TABLE 24.—*Water requirement, on the basis of dry matter, of alfalfa, at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
ALFALFA (*Medicago satira*)			*Grams*	*Kgms.*	
Dillman, E-23, first crop	June 22 to Aug. 3	55	60.3	59.8	992
		56	59.0	56.5	958
		57	54.6	40.3	738
		58	54.6	44.4	813
		59	59.3	54.4	917
		60	52.8	47.7	903
Mean					887±28
Dillman, E-23, second crop	Aug. 3 to Sept. 3	55	71.3	47.0	659
		56	63.3	47.4	749
		57	46.8	43.4	927
		58	50.5	45.3	897
		59	57.7	47.1	816
		60	49.8	45.9	922
Mean					828±33
Dillman, E-23, third crop	Sept. 3 to Oct. 9	55	79.1	57.2	723
		56	72.9	54.6	749
		57	52.6	47.9	911
		58	70.2	53.2	758
		59	75.4	57.0	756
		60	70.8	53.5	756
Mean					776±17
Dillman, E-23, combined crop	June 22 to Oct. 9	55	210.7	164.0	778
		56	195.2	158.5	812
		57	154.0	131.6	855
		58	175.3	142.9	815
		59	192.4	158.5	824
		60	173.4	147.1	848
Mean					822±8

WATER REQUIREMENT OF COTTON, FLAX, AND COWPEAS, 1917

On the basis of index values, cowpeas, with a water requirement of 481±4 (Table 25), was 14 points below the average. Cotton responded about as would be expected in view of the weather conditions, giving a water requirement value near the mean of all crops for the year.

TABLE 25.—*Water requirement, based on dry matter, of cotton, flax, and cowpeas, at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Grain	Water	Grain	Water requirements based on— Grain	Dry matter
			Grams	*Grams*	*Kgms.*	*P. ct.*		
Cotton, Triumph (*Gossypium hirsutum*).	June 29 to Oct. 8	73	294.5		149.0			506
		74	300.5		156.9			522
		75	300.7		151.7			504
		76	229.6		119.4			520
		77	287.8		154.1			535
		78	237.4		128.8			543
Mean								522±4
Flax, Damont, C. I. 3 (*Linum usitatissimum*).	June 22 to Sept. 7	97	34.7	6.9	20.1			579
		99	35.1	5.0	21.0			598
		100	26.5	2.6	15.0			566
		101	20.5	2.6	12.3			600
		102	19.2	2.4	13.1			682
Mean								605±18
Cowpea, S. P. I. 29282 (*Vigna sinensis*).	June 20 to Aug. 30	43	161.1	70.4	75.9	44	1078	471
		44	169.3	71.1	84.5	42	1188	499
		45	170.1	70.9	78.8	42	1111	463
		46	161.8	69.6	77.0	43	1106	476
		47	174.9	73.2	84.7	42	1157	484
		48	183.3	73.6	89.9	40	1221	490
Mean							1144±17	481±4

WATER REQUIREMENT OF GRAMA GRASS AND PIGWEED, 1917

Grama grass, whose water requirement was 290±9 (Table 26) had a relative value 10 points below the average of all crops in 1917 and a lower actual value than for any particular year of the entire period of the experiments. Pigweed, with a water requirement of 307±6, however, was 7 points above the average of all crops on the basis of index figures.

TABLE 26.—*Water requirement, based on dry matter, of grama grass and pigweed at Akron, Colo., 1917*

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
GRAMA GRASS (*Bouteloua gracilis*)			*Grams*	*Kgms.*	
First crop	June 22 to Aug. 20	91	41.0	10.5	256
		92	48.3	13.0	269
		93	28.7	6.8	237
		94	43.3	12.8	296
		95	13.3	4.6	346
		96	11.4	3.6	316
Mean					287±12
Second crop	Aug. 20 to Oct. 12	91	9.8	3.5	357
		92	9.4	2.2	234
		93	9.4	3.0	319
		94	11.3	3.1	274
		95	6.3	2.5	397
		96	7.0	1.7	243
Mean					304±20
Combined crop	June 22 to Oct. 12	91	50.8	14.0	276
		92	57.7	15.2	263
		93	38.1	9.8	257
		94	54.6	15.9	291
		95	19.6	7.1	362
		96	18.4	5.3	288
Mean					290±9

TABLE 26.—*Water requirement, based on dry matter, of grama grass and pigweed, at Akron, Colo., 1917*—Continued

Kind of plant	Period of growth	Pot No.	Dry matter	Water	Water requirements based on dry matter
PIGWEED (*Amaranthus retroflexus*)			*Grams*	*Kgms.*	
First crop	June 20 to Aug. 3	49	119.5	40.4	338
		50	24.2	10.2	421
		51	42.4	15.4	363
		52	120.0	40.8	340
		53	111.4	37.3	335
		54	128.5	42.2	328
Mean					354±10
Second crop	Aug. 3 to Sept. 1	49	30.3	6.5	215
		50	11.3	2.1	186
		51	50.3	9.5	189
		52	35.9	7.2	201
		53	36.3	7.3	201
		54	30.8	5.7	185
Mean					196±4
Combined crop	June 20 to Sept. 1	49	149.8	46.9	313
		50	35.5	12.3	346
		51	92.7	24.9	269
		52	155.9	48.0	308
		53	147.7	44.6	302
		54	159.3	47.9	301
Mean					307±6

SUMMARY OF WATER-REQUIREMENT MEASUREMENTS MADE IN 1917

Although the evaporation in 1917 was slightly above normal, the water requirement of all crops was slightly below normal. (See Table 28.) The only crops to show a water requirement above the average for all years were: Pigweed, Sudan grass, sorghum, and Burt oats, with water requirements, 7, 7, 6, and 5 points, respectively, above the average for the year.

Cowpeas, grama grass, Kubanka wheat, Galgalos wheat, alfalfa, and corn, with water requirements 14, 10, 4, 3, 2, and 2 points, respectively, below the average for the year, were also below the average for the entire experimental period. Cowpeas and grama grass were especially efficient, while pigweed and sorghum, crops of about the same temperature requirements, were relatively inefficient.

GENERAL SUMMARY OF WATER-REQUIREMENT MEASUREMENTS MADE AT AKRON, COLO.

For the purpose of comparing the water requirement of the series for different years the results with those crops grown continuously during the period (see Table 27) have been reduced to a percentage basis (Table 28). In this way the over-emphasis which would otherwise be placed on plants with a high water requirement is avoided. If the water requirement results for 1911 are compared with those of the average of the series (see Table 27), a mean result 8 per cent above the average of the series if based on actual values, and 7 per cent above if based on percentages is obtained (see Table 28). This difference is the result of averaging such divergent values as 1,068 for alfalfa and 298 for sorghum. The use of the actual averages in this case would be equivalent to weighting the results in proportion to their values.

TABLE 27.—*The water requirement, based on dry matter, of crops grown at Akron, Colo., for the periods 1911–1917, 1912–1917, 1913–1917, and 1914–1917, inclusive, and the evaporation in inches for the period, April to September, inclusive, of each year*

Crop	Seasonal water requirement and evaporation							Average
	1911	1912	1913	1914	1915	1916	1917	
PERIOD 1911–1917								
Alfalfa, A. D. I. E–23	1058±16	657±11	834±8	890±6	695±9	1047±9	822±8	859±10
Oats, Swedish Select, C. I. 134	615±7	423±5	617±9	599±2	448±10	876±21	635±5	602±11
Oats, Burt, C. I. 293	639±7	449±3	617±5	615±6	445±5	809±5	636±5	601±5
Barley, Hannchen, C. I. 531	527±8	443±3	[a] 513±12	501±5	404±11	664±9	522±4	511±8
Wheat, Kubanka, C. I. 1440	468±8	394±7	496±5	518±6	405±3	636±14	471±4	484±7
Corn, Northwestern Dent	368±10	280±10	399±12	368±6	253±7	495±13	346±3	358±9
Millet, Kursk, S. P. I. 34771	[b] 287±2	187±2	286±4	295±2	202±1	367±4	284±5	273±3
Sorghum, Minnesota Amber, A. D. I. 341–13	[c] 298±4	239±2	298±2	284±3	203±3	296±4	272±5	270±3
Average	534±9	384±6	508±8	509±5	382±7	649±11	499±5	495±8
Evaporation in inches, April to September	48. 80	37. 75	43. 06	41. 86	33. 40	47. 17	42. 70	42. 11
PERIOD 1912–1917								
Alfalfa, A. D. I. E–23		657±11	834±8	890±6	695±9	1047±9	822±8	824±9
Oats, Swedish Select, C. I. 134		423±5	617±9	599±2	448±10	876±21	635±5	600±11
Oats, Burt, C. I. 293		449±3	617±5	615±6	445±5	809±5	636±5	595±5
Barley, Hannchen, C. I. 531		443±3	[a] 513±12	501±5	404±11	664±9	522±4	508±8
Wheat, Kubanka, C. I. 1440		394±7	496±5	518±6	405±3	636±14	471±4	487±7
Corn, Northwestern Dent		280±10	399±12	368±6	253±7	495±13	346±3	357±9
Millet, Kursk, S. P. I. 34771		187±2	286±4	295±2	202±1	367±4	284±5	270±3
Sorghum, Minnesota Amber, A. D. I. 341–13		239±2	298±2	284±3	203±3	296±4	272±5	265±3
Cotton, Triumph		488±14	657±11	574±9	443±8	612±9	522±4	549±10
Average		396±8	524±8	516±5	389±7	645±11	501±5	495±8
Evaporation in inches, April to September		37. 75	43. 06	41. 86	33. 40	47. 17	42. 70	
PERIOD 1913–1917								
Alfalfa, A. D. I. E–23			834±8	890±6	695±9	1047±9	822±8	858±8
Oats, Swedish Select, C. I. 134			617±9	599±2	448±10	876±21	635±5	635±11
Oats, Burt, C. I. 293			617±5	615±6	445±5	809±5	636±5	624±5
Barley, Hannchen, C. I. 531			[a] 513±12	501±5	404±11	664±9	522±4	521±9
Wheat, Kubanka, C. I. 1440			496±5	518±6	405±3	636±14	471±4	505±7
Corn, Northwestern Dent			399±12	368±6	253±7	495±13	346±3	372±9
Millet, Kursk, S. P. I. 34771			286±4	295±2	202±1	367±4	284±5	287±3
Sorghum, Minnesota Amber, A. D. I. 341–13			298±2	284±3	203±3	296±4	272±5	271±4
Cotton, Triumph			657±11	574±9	443±8	612±9	522±4	562±9
Cowpea, S. P. I. 29282			571±3	659±5	413±5	767±8	481±4	578±5
Pigweed			320±7	306±1	229±3	340±13	307±6	300±7
Grama grass			[d] 389±12	389±7	312±14	336±8	290±9	343±10
Average			500±8	500±5	371±8	604±11	466±5	488±8
Evaporation in inches, April to September			43. 06	41. 86	33. 40	47. 17	42. 70	
PERIOD 1914–1917								
Alfalfa, A. D. I. E–23				890±6	695±9	1047±9	822±8	864±8
Oats, Swedish Select, C. I. 134				599±2	448±10	876±21	635±5	640±12
Oats, Burt, C. I. 293				615±6	445±5	809±5	636±5	626±5
Barley, Hannchen, C. I. 531				501±5	404±11	664±9	522±4	523±8
Wheat, Kubanka, C. I. 1440				518±6	405±3	636±14	471±4	508±8
Corn, Northwestern Dent				368±6	253±7	495±13	346±3	366±8
Millet, Kursk, S. P. I. 34771				295±2	202±1	367±4	284±5	287±3
Sorghum, Minnesota Amber, A. D. I. 341–13				284±3	203±3	296±4	272±5	264±4
Cotton, Triumph				574±9	443±8	612±9	522±4	538±8
Cowpea, S. P. I. 29282				659±5	413±5	767±8	481±4	580±6
Pigweed				306±1	229±3	340±13	307±6	296±7
Grama grass				389±7	312±14	336±8	290±9	332±10
Rye, Vern, C. I. 73				622±7	469±8	800±11	625±5	629±8
Wheat, Galgalos, C. I. 2398				624±5	481±4	652±8	543±6	575±6
Sudan Grass, S. P. I. 25017				394±4	260±3	426±3	378±3	365±3
Average				509±5	377±7	608±10	476±5	493±7
Evaporation in inches, April to September				41. 86	33. 40	47. 17	42. 70	

[a] Interpolated value.
[b] S. P. I. 22420.
[c] Red Amber Sorghum.
[d] Bouteloua gracilis and B. dactyloides mixed.

TABLE 28.—*Water requirement and evaporation results shown in Table 27 expressed in index numbers of the mean value for each crop, taken as 100; and the ratio of the water requirement index to the evaporation index*

Crop	Index numbers of water requirement and evaporation, and water requirement-evaporation ratio index numbers of different crops.							Mean
	1911	1912	1913	1914	1915	1916	1917	
PERIOD 1911–1917								
Alfalfa, A. D. I. E–23	124	76	97	104	81	122	96	100
Oats, Swedish Select	102	70	102	100	74	146	105	100
Oats, Burt	106	75	103	102	74	135	106	100
Barley, Hannchen	103	87	100	98	79	130	102	100
Wheat, Kubanka, C. I. 1440	97	81	102	107	84	131	97	100
Corn, Northwestern Dent	103	78	111	103	71	138	97	100
Millet, Kursk	105	68	105	108	74	134	104	100
Sorghum, Minnesota Amber	110	89	110	105	75	110	101	100
Water requirement average	107	78	104	103	77	131	101	100
Evaporation average	116	90	102	99	79	112	101	100
W/E	92	87	102	104	97	117	100	100
PERIOD 1912–1917								
Alfalfa, A. D. I. E–23		80	101	108	84	127	100	100
Oats, Swedish Select		71	103	100	75	146	106	100
Oats, Burt, C. I. 293		75	104	103	75	136	107	100
Barley, Hannchen		87	101	99	80	131	103	100
Wheat, Kubanka, C. I. 1440		81	102	106	83	131	97	100
Corn, Northwestern Dent		78	112	103	71	139	97	100
Millet, Kursk		69	106	109	75	136	105	100
Sorghum, Minnesota Amber		90	112	107	77	112	103	100
Cotton, Triumph		89	120	105	81	111	95	100
Water requirement average		80	107	104	78	130	101	100
Evaporation average		93	105	102	81	115	104	100
W/E		86	102	102	96	113	97	
PERIOD 1913–1917								
Alfalfa, A. D. I. E–23			97	104	81	122	96	100
Oats, Swedish Select			97	94	71	138	100	100
Oats, Burt, C. I. 293			99	99	71	130	102	100
Barley, Hannchen			98	96	78	127	100	100
Wheat, Kubanka, C. I. 1440			98	103	80	126	93	100
Corn, Northwestern Dent			107	99	68	133	93	100
Millet, Kursk			100	103	70	128	99	100
Sorghum, Minnesota Amber			110	105	75	109	100	100
Cotton, Triumph			117	102	79	109	93	100
Cowpea, S. P. I. 29282			99	114	71	133	83	100
Pigweed			107	102	76	113	102	100
Grama grass			113	113	91	98	85	100
Water requirement average			104	103	76	122	96	100
Evaporation average			103	101	80	113	103	100
W/E			101	102	95	108	93	
PERIOD 1914–1917								
Alfalfa, A. D. I. E–23				103	81	121	95	100
Oats, Swedish Select				94	70	137	99	100
Oats, Burt				98	71	129	102	100
Barley, Hannchen				96	77	127	100	100
Wheat, Kubanka, C. I. 1440				102	80	125	93	100
Corn, Northwestern Dent				101	69	135	95	100
Millet, Kursk				103	70	128	99	100
Sorghum, Minnesota Amber				108	77	112	103	100
Cotton, Triumph				107	82	114	97	100
Cowpea				114	71	132	83	100
Pigweed				103	77	115	104	100
Grama grass				117	94	101	87	100
Rye, Vern				99	75	127	99	100
Wheat, Galgalos				109	84	113	94	100
Sudan grass				108	71	117	104	100
Water requirement average				104	77	122	97	100
Evaporation average				101	81	114	103	100
W/E				103	95	107	94	
Index averages used	107	80	104	104	77	122	97	

TABLE 29.—*Water-requirement values (actual and index) based on grain of all crops grown at Akron, Colo., for the periods 1911–1917, inclusive*

WATER REQUIREMENT (ACTUAL VALUES) FOR CROPS

Crop	1911	1912	1913	1914	1915	1916	1917	Average
Oats, Swedish Select	1632±35	1103±18	1876±55	1421±8	1102±34	2288±39	2088±37	1641±35
Oats, Burt	1500±57	1224±55	1641±33	1483±31	1150±27	1975±49	1854±91	1547±53
Wheat, Kubanka, C. I. 1440	1191±14	1111±37	1322±16	1367±13	1232±13	1779±108	1367±21	1338±45
Corn, Northwestern Dent	2040±342	954±106	1241±77	[a]1846±159	2060±108	3634±19	1929±73	1958±159
Millet, Kursk	[b] 923±40	483±11	985±99	1075±38	665±24	1267±45	[a]1085±74	926±55
Sorghum, Minnesota Amber	[c]1494±202	607±15	765±12	893±26	1116±105	853±26	1700±224	1061±122
Average	1463±165	914±52	1305±58	1348±69	1221±65	1966±56	1671±109	1412±91
Average for first 3 crops	1441±39	1146±40	1613±38	1424±20	1161±26	2014±72	1770±58	1510±45

WATER REQUIREMENT (INDEX VALUES) FOR CROPS

Oats, Swedish Select	99	67	114	86	67	139	127	100
Oats, Burt	97	79	106	96	74	128	120	100
Wheat, Kubanka, C. I. 1440	89	83	99	102	92	133	102	100
Corn, Northwestern Dent	104	49	63	94	105	186	99	100
Millet, Kursk	100	52	106	116	72	137	117	100
Sorghum, Minnesota Amber	141	57	72	84	105	80	160	100
Average	105	65	93	96	86	134	121	100
Average for first 3 crops	95	76	106	95	78	133	116	100

WATER REQUIREMENT (ACTUAL VALUES) FOR CROPS

Oats, Swedish Select				1421±8	1102±34	2288±39	2088±37	1725±32
Oats, Burt				1483±31	1150±27	1975±49	1854±91	1616±56
Wheat, Kubanka, C. I. 1440				1367±13	1232±13	1779±108	1367±21	1436±56
Wheat, Galgalos				1900±30	1551±65	2445±155	1516±19	1853±86
Rye, Vern				2291±54	1485±80	2871±99	1982±84	2157±81
Barley, Hannchen				1179±28	949±50	1425±27	1148±12	1175±32
Corn, Northwestern Dent				1846±159	2060±108	3634±19	1929±73	2367±103
Sorghum, Minnesota Amber				893±26	1116±105	853±26	1700±224	1141±125
Millet, Kursk				1075±38	665±24	1267±45	1085±74	1023±49
Cowpea				1962±27	1257±39	2373±77	1144±17	1684±46
Average				1542±58	1257±63	2091±77	1581±89	1618±73

WATER REQUIREMENT (INDEX VALUES) FOR CROPS

Oats, Swedish Select				82	64	133	121	100
Oats, Burt				92	71	122	115	100
Wheat, Kubanka, C. I. 1440				95	86	124	95	100
Wheat, Galgalos				103	84	132	82	100
Rye, Vern				106	69	133	92	100
Barley, Hannchen				100	81	121	98	100
Corn, Northwestern Dent				78	87	154	81	100
Sorghum, Minnesota Amber				78	98	75	149	100
Millet, Kursk				105	65	124	106	100
Cowpea				117	75	141	68	100
Average				96	78	126	101	100

[a] Interpolated on the basis of the ratio of the averages of the first three crops for the years 1911–1913 and 1915–1917 to the average for corn for the same years and the average of the first three crops to the interpolated values for corn for the year 1914. Interpolation for millet by the same method.

[b] S. P. I. 22420 used in 1911 instead of S. P. I. 34771.

[c] Red Amber used in 1911 instead of Minnesota Amber.

While the results are presented in percentages of the average, the basis is in each case 100, and the values may be regarded as index numbers. It is possible, then, to express the relative water requirement of crops in terms of positions, of points above or points below the average. To express these relative positions as percentages above or below would lead to confusion. By the use of these simple index numbers, logarithms, which would have made the results more difficult for the general reader, have been dispensed with. The index averages at the bottom of Table 28 represent as nearly as possible the response of crop plants to the different seasons. Accepting these values, the actual values summarized in Table 34 have been weighted and averaged to give a column of weighted values, which represents the probable values if each crop had been grown each year of the experiment. This value assumes that the mean values of average index numbers hold for all crops. The greatest observed error in this assumption for the crops grown continuously for four or more years is 20 per cent. In Table 29 the water requirement based on grain production has been treated in the same way as the water requirement based on total dry matter in Tables 27 and 28. The index numbers based on grain production are also given in Table 29. The water requirement based on grain production is much more variable than when based on dry matter. The same index figures have been used, therefore, in computing the values in Table 34 as were used in computing those in Table 33.

EFFECT OF SEASON ON WATER REQUIREMENT

The values in Table 27 have been reduced in Table 28, to index numbers having a mean value of 100, and may be compared directly to determine the effect of the different years. While the values are high or low in proportion to the favorable or unfavorable season there are minor crop differences of great physiological significance. The variation in water requirement from year to year is greater proportionately than the variation in evaporation. The evaporation index numbers for the period 1911 to 1917, inclusive, varied from 79 points for 1915, to 116 points for 1911, a range of only 37 points, while the mean water requirement index numbers varied from 77 points for 1915, to 131 points for 1916, a range of 54 points. The greatest water requirement range for any single crop was from 70 to 146, or 76 points, for Swedish Select oats; and the smallest range was from 75 to 110, or 35 points, for sorghum.

Evaporation does not vary as much from year to year as does the water requirement. (See Tables 27 and 28.) This is to be expected, for during years of exceedingly unfavorable conditions when the evaporation is unusually high, plants respond by evaporating freely to the dry air and may even be injured by the high evaporation and temperature to the extent that the rate of growth is retarded. A disproportionately great effect on the water requirement would therefore be expected.

THE RESPONSE OF PLANTS TO DIFFERENT SEASONS

The effect of the seasons was much the same on all crops. (See figs. 6 and 7.) They responded in varying degrees, however, corn and oats being most responsive, and sorghum and grama grass least responsive. (See Table 28.)

On the basis of the behavior of all crops grown from 1911 to 1917, inclusive (see Table 28), the values for 1911 have two outstanding results—the water requirement of alfalfa was 17 points too high and

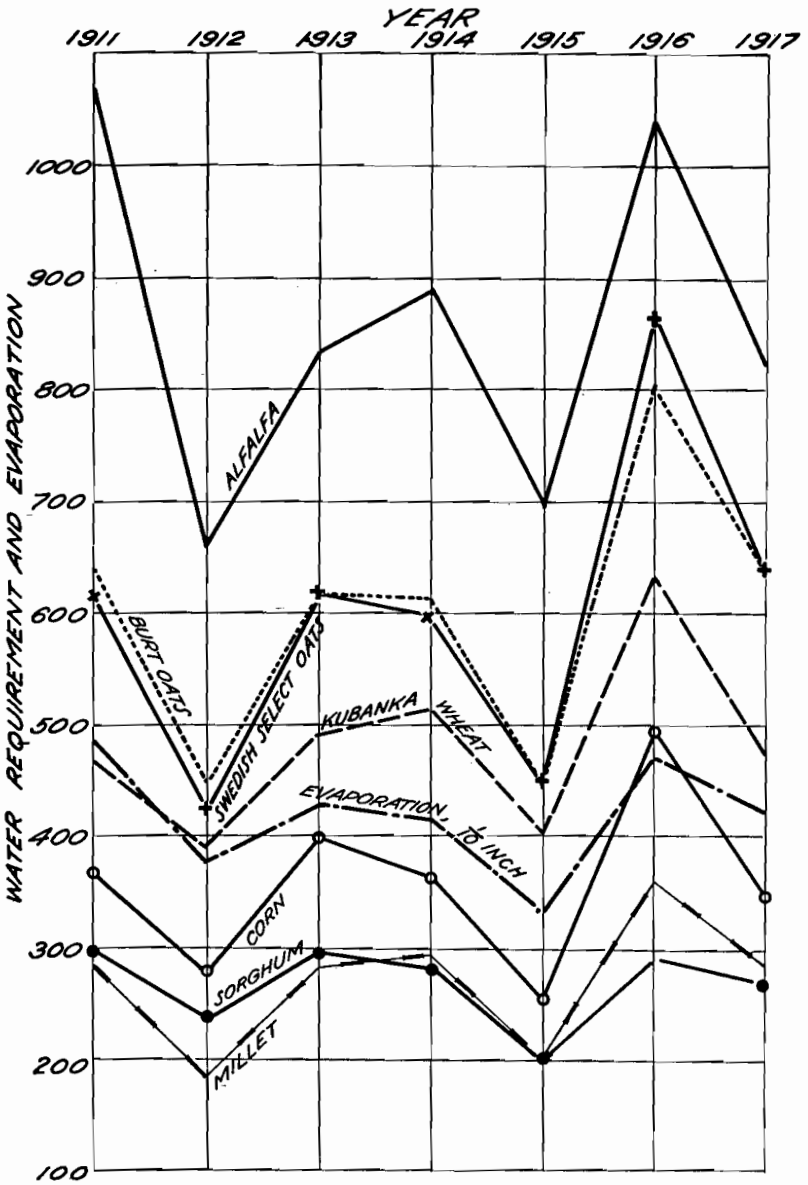

FIG. 6.—The water requirement of different crops and evaporation in tenths of an inch for the years 1911–1917

Kubanka wheat 10 points too low. No thoroughly satisfactory explanation can be made of these results. On the basis of total amount of growth, alfalfa was high and Kubanka wheat low. (See Table 30.) The year 1911 was hot and dry (see Tables 31 and 32),

and Kubanka wheat is not affected by such conditions to the same extent as are many of the other crops. In 1912 the water requirement of Kubanka wheat was relatively high, but the year was cool and damp and conditions seemed not to be as nearly optimum for this crop as during the hot, dry years. This is especially noticeable

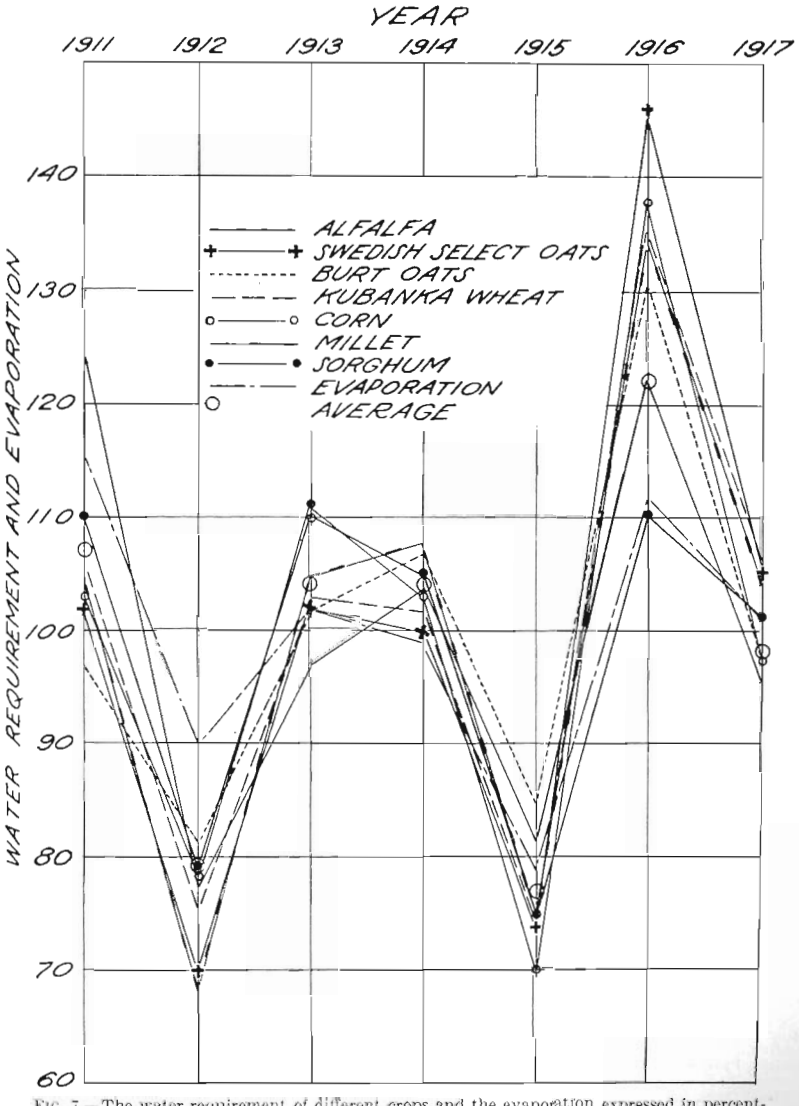

FIG. 7.—The water requirement of different crops and the evaporation expressed in percentages of the mean for the years 1911–1917

in the 1915 results, when Kubanka wheat had a higher relative water requirement value than any other crop. During 1916 the water requirement value of Kubanka wheat was as high as the mean water requirement of all crops for the year. The alfalfa results are likely to be influenced by a factor that does not enter to the same degree in the

case of wheat, which has only a single crop, as compared with from two to four crops in the case of alfalfa. For instance, the water requirement of alfalfa, on the basis of season's growth, for a hot month of one year, when the crop is at its maximum growth, as compared with the water requirement of alfalfa during the same month of another year, when the crop has just been cut and the plants are small, may be quite different. In general terms, the results with alfalfa are in accordance with the mean of the eight crops grown. In 1911 the value was 17 points too high; in 1914, 1 point too high; and in 1915, 4 points too high, although the latter was an unusually cold and damp year. The water requirement of alfalfa for all other years was low, especially in 1917, 1916, 1913, and 1912, when the values were 5, 9, 7, and 2 points, respectively, below the mean of the eight crops grown in the experiment.

TABLE 30.—*Dry matter per pot expressed in grams and in index numbers of the mean value for each crop taken as 100, of all crops grown at Akron, Colo., for the periods 1911–1917, inclusive*

DRY MATTER PER POT (IN GRAMS)

Crop	1911	1912	1913	1914	1915	1916	1917	Average
Alfalfa, A. D. I. E-23	196.4	337.8	292.2	305.9	216.5	123.4	183.5	236.5
Oats, Swedish Select, C. I. 134	173.7	396.0	275.5	264.5	332.4	103.2	170.9	245.1
Oats, Burt, C. I. 293	143.1	342.0	248.4	250.8	232.8	85.5	153.8	208.1
Barley, Hannchen, C. I. 531	136.3	297.3	(a)	181.9	261.7	103.7	139.6	186.8
Wheat, Kubanka, C. I. 1440	94.2	274.1	280.4	305.7	237.7	91.7	153.1	205.3
Corn, Northwestern Dent	160.7	432.0	356.3	304.4	112.0	180.6	336.8	269.0
Millet, Kursk, S. P. I. 34771	202.0	242.7	211.3	301.2	256.0	171.0	229.2	230.5
Sorghum, Minnesota Amber, A. D. I. 341-13	307.6	487.2	605.5	457.1	203.2	192.8	276.2	361.4
Average	176.8	351.1	324.2	296.4	231.5	131.5	205.4	[b] 244.0

DRY MATTER PER POT EXPRESSED IN INDEX VALUES OF THE MEAN VALUE

Alfalfa, A. D. I. E-23	83	143	124	129	92	52	78	100
Oats, Swedish Select, C. I. 134	71	162	112	108	136	42	70	100
Oats, Burt, C. I. 293	69	164	119	121	112	41	74	100
Barley, Hannchen, C. I. 531	73	159	------	97	140	56	75	100
Wheat, Kubanka, C. I. 1440	46	134	137	149	116	45	75	100
Corn, Northwestern Dent	60	161	132	113	42	67	125	100
Millet, Kursk, S. P. I. 34771	88	105	92	131	111	74	99	100
Sorghum, Minnesota Amber, A. D. I. 341-13	85	135	168	126	56	53	76	100
Average	72	145	126	122	101	54	84	100

DRY MATTER PER POT (IN GRAMS)

Alfalfa, A. D. I. E-23	------	------	------	305.9	216.5	123.4	183.5	207.3
Oats, Swedish Select, C. I. 134	------	------	------	264.5	332.4	103.2	170.9	217.8
Oats, Burt, C. I. 293	------	------	------	250.8	232.8	85.5	153.8	180.7
Barley, Hannchen, C. I. 531	------	------	------	181.9	261.7	103.7	139.6	171.7
Wheat, Kubanka, C. I. 1440	------	------	------	305.7	237.7	91.7	153.1	197.1
Corn, Northwestern Dent	------	------	------	304.4	112.0	180.6	336.8	233.4
Millet, Kursk, S. P. I. 34771	------	------	------	301.2	256.0	171.0	229.2	239.4
Sorghum, Minnesota Amber, A. D. I. 341-13	------	------	------	457.1	203.2	192.8	276.2	282.3
Cotton, Triumph	------	------	------	346.8	108.7	151.2	275.1	220.5
Cowpea, S. P. I. 29282	------	------	------	170.3	127.8	119.4	170.1	146.9
Pigweed	------	------	------	219.9	159.1	110.0	123.5	153.1
Grama grass	------	------	------	72.4	45.0	34.2	40.0	47.9
Rye, Vern, C. I. 73	------	------	------	195.2	202.9	83.7	121.2	150.8
Wheat, Galgalos, C. I. 2398	------	------	------	298.4	167.5	56.4	159.8	170.5
Sudan Grass, S. P. I. 25017	------	------	------	360.1	190.4	161.4	246.3	239.6
Average	------	------	------	268.7	190.2	117.9	185.3	190.5

[a] No correction made for the absence of this value.

[b] True average.

TABLE 30.—*Dry matter per pot expressed in grams and in index numbers of the mean value for each crop taken as 100, of all crops grown at Akron, Colo., for the periods 1911–1917, inclusive*—Continued.

DRY MATTER PER POT EXPRESSED IN INDEX VALUES OF THE MEAN VALUE

Crop	1911	1912	1913	1914	1915	1916	1917	Average
Alfalfa, A. D. I. E-23	------	------	------	148	104	60	89	100
Oats, Swedish Select, C. I. 134	------	------	------	121	153	47	78	100
Oats, Burt, C. I. 293	------	------	------	139	129	47	85	100
Barley, Hannchen, C. I. 531	------	------	------	106	152	60	81	100
Wheat, Kubanka, C. I. 1440	------	------	------	155	121	47	78	100
Corn, Northwestern Dent	------	------	------	130	48	77	144	100
Millet, Kursk, S. P. I. 34771	------	------	------	126	107	71	96	100
Sorghum, Minnesota Amber, A. D. I. 341-13	------	------	------	162	72	68	98	100
Cotton, Triumph	------	------	------	157	49	69	125	100
Cowpea, S. P. I. 29282	------	------	------	116	87	81	116	100
Pigweed	------	------	------	144	104	72	81	100
Grama grass	------	------	------	151	94	71	84	100
Rye, Vern, C. I. 73	------	------	------	129	135	56	80	100
Wheat, Galgalos, C. I. 2398	------	------	------	175	98	33	94	100
Sudan Grass, S. P. I. 25017	------	------	------	151	79	67	103	100
Average	------	------	------	141	102	62	95	100

The two varieties of oats agree in water-requirement value fairly well, but diverge 11 points in 1916. Their values were remarkably low during the cool, damp years 1912 and 1915, but during the hot, dry year 1916 they were higher than for any other crops except corn. During the three years 1913, 1914, and 1917, when the evaporation rate was approximately the mean of the period, the water requirement of oats did not depart more than 6 points from its mean for the total period.

The water requirement of barley approximates the mean of all crops during the hot, dry years, but during the cool, damp years its water-requirement values were relatively high, 9 points in 1912 and 2 points in 1915. It resembles Kubanka wheat closely and is in contrast with oats varieties in its response to various years.

PROBABLE RANGE IN WATER REQUIREMENT OF CROPS

Tables 27 and 28 and Figures 6 and 7 indicate that crops react differently in different seasons. If in the seven-year period, 1911–1917, the average index value of the longest series of crops available is used, the highest water-requirement values, considering the results of experiments as a whole, were obtained in 1916, when the index value was 22 points above the average. This was an exceptionally dry year and the evaporation during July, when the crops were growing actively, was higher than for any month recorded at Akron during the period 1908–1925. (See Tables 31 and 32.) The lowest water-requirement values for the period were obtained in 1915, when the values dropped to 23 points below the average. The year was characterized by a low mean temperature, 50° F., and by a very low seasonal evaporation, lower than for any year during the period 1908 to 1924, inclusive. The year 1912 was almost as low and was characterized by low rates of evaporation, a low mean temperature, 59° F., and by reduced light intensity.[12] Of the remaining years,

[12] BRIGGS, L. J., and SHANTZ, H. L. RELATIVE WATER REQUIREMENT OF PLANTS. Jour. Agr. Research 3: 6. 1914.

1917 was almost the average for the series, while 1911, 1913, and 1914 were somewhat above the average. The variation in water requirement from year to year at Akron is very great, the range, during the period of the experiments here discussed, based on the mean, being about 45 points. The extreme range for a single crop was about 67 points for oats, and the lowest about 30 points for grama grass. The range in evaporation was about 37 points.

TABLE 31.—*Climatic conditions at Akron, Colo., from April to September, inclusive, for the years 1911–1917*

Month	Air temperature (°F.)					Precipitation	Evaporation	Wind velocity per hour
	Average of—			Absolute				
	Mean	Maximum	Minimum	Maximum	Minimum			
						Inches	*Inches*	*Miles*
1911:								
April	47	62	31	77	16	2.63	5.84	9.1
May	58	73	43	91	28	1.15	7.32	9.7
June	70	87	53	98	43	1.48	9.75	7.4
July	70	86	55	95	46	1.34	9.77	7.1
August	69	86	54	99	41	1.30	8.94	8.1
September	64	80	50	95	39	2.40	7.18	7.0
1912:								
April	45	58	32	73	23	2.49	4.58	9.9
May	55	70	42	92	28	2.86	7.10	8.5
June	63	75	49	89	37	3.39	6.75	6.1
July	70	84	55	96	46	3.58	7.62	5.4
August	69	83	55	96	48	1.58	7.05	4.7
September	54	68	41	91	22	1.88	4.65	6.0
1913:								
April	47	63	33	84	10	2.19	4.44	8.1
May	57	72	44	91	31	1.44	5.84	6.9
June	67	82	53	97	37	1.35	8.18	8.1
July	72	88	55	103	43	1.85	9.26	6.1
August	75	91	59	98	53	1.14	9.30	5.6
September	58	70	45	92	27	2.08	6.04	6.4
1914:								
April	45	58	34	79	15	4.01	4.29	8.7
May	57	70	44	85	32	1.46	5.61	7.4
June	68	83	50	93	38	3.54	7.51	5.8
July	72	87	58	96	49	1.66	8.65	5.8
August	71	88	55	101	40	1.05	8.36	6.5
September	64	83	47	92	31	.23	7.44	6.9
1915:								
April	50	62	38	78	29	5.19	4.22	7.5
May	52	64	41	88	27	4.13	5.03	7.7
June	60	72	49	82	35	3.75	5.88	6.8
July	67	81	54	95	40	1.10	6.66	6.2
August	64	79	52	94	39	3.51	5.82	4.3
September	60	76	47	92	35	1.76	5.79	6.4
1916:								
April	44	59	30	84	11	1.59	6.21	8.1
May	55	70	41	92	27	2.24	7.81	9.3
June	64	80	49	99	33	2.09	7.98	7.4
July	75	93	60	98	54	1.77	11.12	7.3
August	69	83	56	95	45	2.82	7.22	5.4
September	61	77	45	91	30	.26	6.84	6.2
1917:								
April	44	58	29	88	15	.96	4.08	6.8
May	50	64	36	82	21	7.79	4.93	8.5
June	64	80	48	97	32	.56	8.42	7.4
July	73	90	57	99	47	1.52	10.19	5.5
August	67	82	52	97	42	1.78	8.46	5.8
September	64	79	48	95	39	2.19	6.62	6.0
Average or total:								
1911	63	79	48	99	16	10.30	48.80	8.1
1912	59	73	46	96	22	15.78	37.75	6.8
1913	63	78	48	103	10	10.05	43.06	6.9
1914	63	78	48	101	15	11.95	41.86	6.9
1915	59	72	47	95	27	19.44	33.40	6.5
1916	61	77	47	99	11	10.77	47.18	7.3
1917	60	76	45	99	15	14.80	42.70	6.7

TABLE 32.—*Precipitation and evaporation at Akron, Colo., from April to September, inclusive, for the years 1908–1925*

Year	April	May	June	July	August	September	Total
Precipitation (inches):							
1908	1.70	3.30	2.37	2.42	1.47	0.05	11.31
1909	.40	1.87	3.32	4.61	3.77	2.12	16.09
1910	3.96	2.06	1.38	1.47	3.72	3.81	16.40
1911	2.63	1.15	1.48	1.34	1.30	2.40	10.30
1912	2.49	2.86	3.39	3.58	1.58	1.88	15.78
1913	2.19	1.44	1.35	1.85	1.14	2.08	10.05
1914	4.01	1.46	3.54	1.66	1.05	.23	11.95
1915	5.19	4.13	3.75	1.10	3.51	1.76	19.44
1916	1.59	2.24	2.09	1.77	2.82	.26	10.77
1917	.96	7.79	.56	1.52	1.78	2.19	14.80
1918	1.20	1.76	.96	3.10	7.36	2.43	16.81
1919	1.96	1.59	2.27	1.79	.44	2.62	10.67
1920	3.28	2.90	3.97	4.72	1.45	1.80	18.12
1921	2.77	.47	1.32	2.88	.92	.79	9.15
1922	3.96	3.63	1.43	3.24	1.24	.06	13.56
1923	1.65	4.94	2.17	3.62	.75	.82	13.95
1924	.31	3.26	.35	1.71	.77	[1]4.04	10.44
1925	2.24	1.19	2.90	1.08	1.01	.50	8.92
Average 1908–1925	2.36	2.67	2.14	2.41	2.00	1.60	13.25
Average 1911–1917	2.72	3.01	2.31	1.83	1.88	1.54	13.29
Evaporation (inches):							
1908	4.74	7.71	8.64	8.47	7.83	8.55	45.94
1909	4.73	6.83	7.00	9.40	8.54	5.86	42.36
1910	6.39	5.80	8.72	9.76	7.14	5.81	43.62
1911	5.84	7.32	9.75	9.77	8.94	7.18	48.80
1912	4.58	7.10	6.75	7.62	7.05	4.65	37.75
1913	4.44	5.84	8.18	9.26	9.30	6.04	43.06
1914	4.29	5.61	7.51	8.65	8.36	7.44	41.86
1915	4.22	5.03	5.88	6.66	5.82	5.79	33.40
1916	6.21	7.81	7.98	11.12	7.22	6.84	47.18
1917	4.08	4.93	8.42	10.19	8.46	6.62	42.70
1918	4.10	6.78	9.33	9.25	7.68	4.28	41.42
1919	4.95	7.38	8.76	10.28	9.72	6.14	47.23
1920	4.79	6.84	6.96	8.58	6.92	6.83	40.92
1921	5.51	6.25	7.77	10.71	8.59	7.08	45.91
1922	4.28	6.79	8.23	9.20	8.85	7.23	44.58
1923	5.09	5.48	7.81	9.06	7.70	6.29	41.43
1924	4.89	[1]7.65	8.64	10.54	10.15	5.82	47.69
1925	5.83	7.32	8.86	10.27	8.72	6.30	47.30
Average 1908–1925	4.94	6.58	8.07	9.38	8.17	6.38	43.51
Average 1911–1917	4.81	6.23	7.78	9.04	7.88	6.37	42.11

[1] Interpolated mean, average from 1908–1923.

Northwestern Dent, a variety of corn grown in the northwest portion of the Great Plains was used in the experiments. During the hot, dry year 1916, its value was 7 points above the mean, but in 1915, a cool, damp year, its value was 6 points below. Northwestern Dent is most economical in its use of water, therefore, during cool, damp years, while its water requirement rises in hot, dry years.

Although it has a very low water requirement and is an excellent, dry-land crop, Kursk millet gave a relatively higher water requirement in hot, dry years than in cool, damp ones. Its requirement in 1916, a damp, cool year, was 3 points above the mean; while in 1912 and 1915 it was 10 and 3 points, respectively, below the mean.

Sorghum showed remarkable efficiency in the use of water during the hot, dry years. Its water requirement in 1916, for instance, was 21 points below the mean. During the cool, damp year 1912, on the other hand, it was 11 points above the mean.

The crops grown from 1911 to 1917, considered consecutively as to their range in water requirement, are as follows:

	Lowest index value	Highest index value	Range in points
Oats, Swedish Select	70	146	76
Corn, Northwestern Dent	71	138	67
Millet, Kursk	68	134	66
Oats, Burt	74	135	61
Barley, Hannchen	79	130	51
Wheat, Kubanka	81	131	50
Alfalfa, Grimm	76	124	48
Sorghum	75	110	35
Evaporation	79	116	37

Sorghum, alfalfa, wheat, and barley showed the low ranges in the order given. Swedish Select oats, corn, millet, and Burt oats showed high ranges. Only one crop, sorghum, was exceeded in range by evaporation.

The crops used in the experiments may be separated on the basis of the lowest relative water requirement recorded during cool, damp years and the highest water requirement recorded during hot, dry years, as follows:

	Departure from mean water requirement of crops in—		Difference[a]
	Cool, damp years	Hot, dry years	
Oats, Swedish Select	−8	+15	+23
Corn, Northwestern Dent	−6	+7	+13
Millet, Kursk	−10	+3	+13
Oats, Burt	−3	+4	+7
Barley, Hannchen	+2	−1	−3
Alfalfa, Grimm	−2	[b] −9	−7
Wheat, Kubanka	+3	0	−3
Sorghum	−2	−21	−19

[a] Those marked plus (+) are adapted to the cool, damp year, and those marked minus (−) to the hot, dry year.

[b] The outstanding value for 1911 is omitted.

This tabulation is practically a comparison of the 1912 or 1915 water-requirement results with those of 1916. The first four crops do much better during cool, damp years than the last four. Burt oats, which is low in water requirement, is relatively a much better hot-weather crop than Swedish Select oats. The last four crops do well during hot, dry years, the water requirement being at or below the average for the crops. The behavior of the crops, independent of actual values, is indicated by the index numbers in the last column. The crops which were most efficient during cool, damp years and least efficient during hot, dry years, are indicated at the top with the highest (+) values; and those which were relatively most efficient during hot. dry years and least efficient during cool, damp years, are indicated at the bottom by the highest (−) values.

The comparison of the results of water-requirement measurements in cool, damp years with the results in dry, hot years omits the outstanding water-requirement values of alfalfa in 1911. Had these been included, alfalfa would have had an index number of + 19, thus placing it first among the crops showing a low water requirement in cool, damp years.

The behavior of Kubanka wheat in 1916, when its index value was as low as the mean value for all crops, and in 1912 and 1915, when its index value was higher than the mean for all crops, indicates clearly that during cool years it is inefficient and places it among the crops which show the greatest relative efficiency in the use of water during the hot years; and a comparison of the results obtained in 1911, with those obtained in 1916, confirms this indication. (Compare figs. 8, 9, 10, and 11.) Alfalfa did not depart markedly from the mean of all crops except to fall 9 points below during 1916 and 17 points above in 1911. Since these years were both hot and dry, these variations are in opposite directions. Either or both may be regarded as outstanding. The fact that the result in 1911 is so great and is in direct opposition to that in 1916, may account to some extent for the slightly favorable performance during the other years. In any case, the 1911 result is probably outstanding, and if it were omitted, alfalfa would not be at the head of the crops with a low relative water requirement in cool weather, but rather among those relatively well adapted to hot, dry weather. It should be clearly borne in mind that this discussion does not concern itself with actual values but with relative performances of the same crop, during cool, damp and hot, dry years.

Cotton, which was included in the experiments for the period 1912–1917 ranged in water-requirement value from 81 to 120 points, or 39 points in all. It was inefficient during the cool years, its index value being 3 points above in 1915, and 9 points above in 1912, but very efficient during the hot, dry year 1916, when its value was 19 points below the mean of the crops grown that season. Cotton belongs with the warm season crops.

In the comparison of the water-requirement results for the crops tested during the period 1913 to 1917, cowpea, pigweed, and grama grass were added. They varied as follows: Cowpea, from 71 to 133, or 62 points in all; pigweed, from 76 to 113, or 37 points in all; grama grass, from 85 to 113, or 28 points in all.

A comparison of the water-requirement results for these three crops during cool, damp and hot, dry years on the basis of their relation to the mean water requirement shows the following departures from the mean:

	Cool, damp years	Hot, dry years	Difference
Cowpeas	−5	+11	+16
Pigweed	0	−9	−9
Grama grass	+15	−24	−39

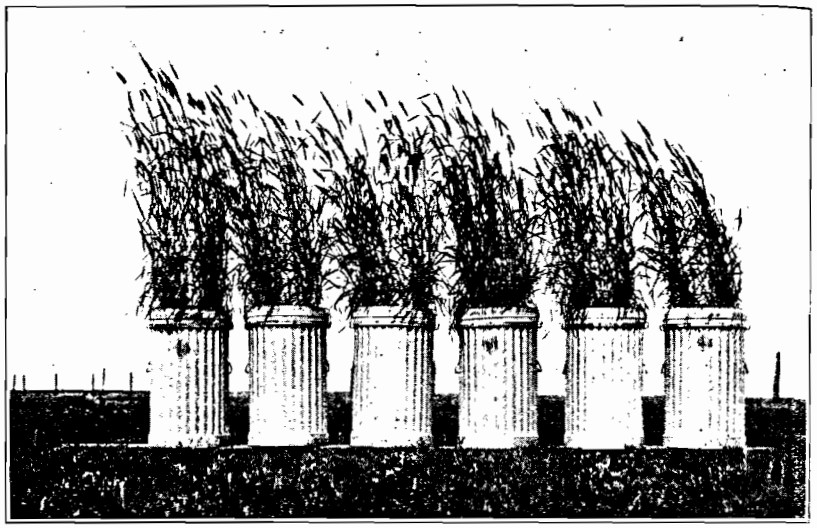

FIG. 8.—Kubanka wheat C. I. 1440, grown in 1912, producing an average quantity of dry matter per pot of 274 grams, with a water requirement of 394. Based on the average for all years, the dry matter and water requirement index values for this crop were 134 and 81, respectively. Photographed at Akron, Colo., July 19, 1912

FIG. 9.—Kubanka wheat C. I. 1440, grown in 1913, producing an average quantity of dry matter per pot of 280 grams, with a water requirement of 496. Based on the average for all years, the dry matter and water requirement index values for this crop were 137 and 102, respectively. Photographed at Akron, Colo., July 8, 1913

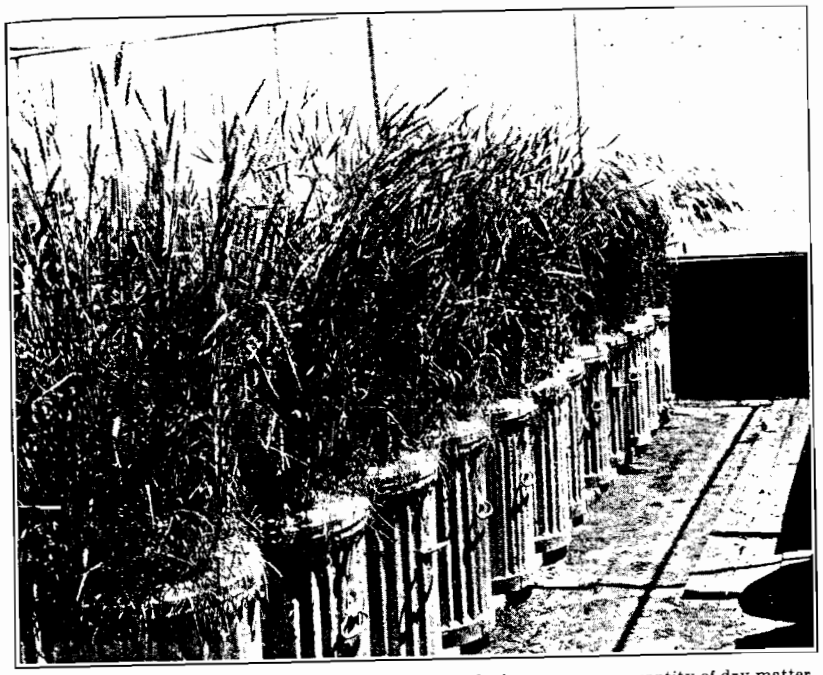

FIG. 10.—Kubanka wheat C. I. 1440, grown in 1914, producing an average quantity of dry matter per pot of 305 grams, with a water requirement of 518. Based on the average for all years, the dry matter and water requirement index values for this crop were 149 and 107, respectively. Photographed at Akron, Colo., August 11, 1913

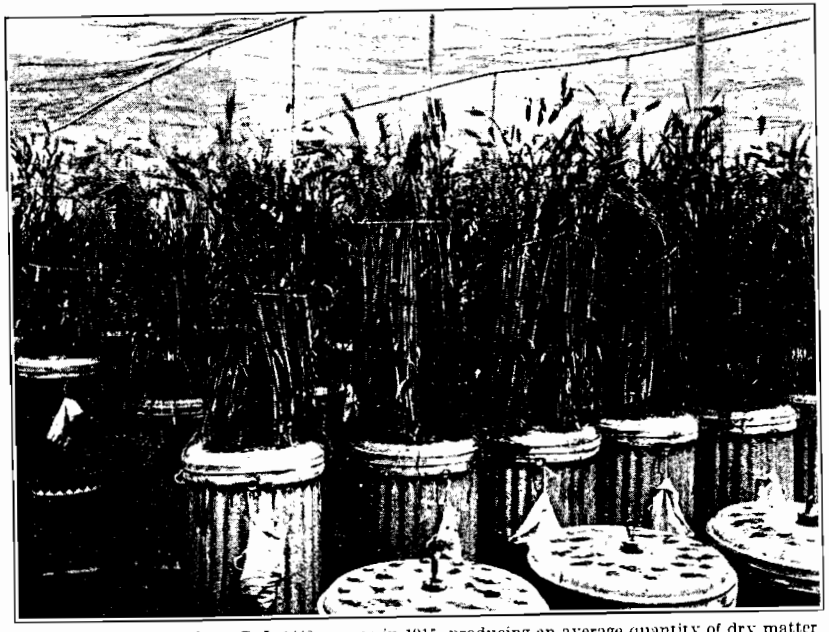

FIG. 11.—Kubanka wheat C. I. 1440, grown in 1915, producing an average quantity of dry matter per pot of 237 grams, with a water requirement of 405. Based on the average for all years, the dry matter and water requirement index values for this crop were 116 and 84, respectively. Photographed at Akron, Colo., August 20, 1915

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Cowpeas did not do as well during the hot, dry years as during the cool, damp year. Pigweed showed no advantage during the cool, damp year but was very efficient during the hot, dry year. Grama grass was inefficient during the cool, damp years but exceedingly efficient during the hot, dry year. Although grama grass does not produce, within its range, as efficiently as the cultivated crops, such as sorghum and millet, it is most efficient during hot, dry periods such as that experienced in 1916.

Rye, Galgalos wheat, and Sudan grass were added in the comparison of water-requirement results for the crops grown during the period 1914 to 1917. They varied as follows: Rye, from 75 to 127, or 52 points in all; Sudan grass, from 71 to 117, or 46 points in all; Galgalos wheat, from 84 to 113, or 29 points in all.

A comparison of the water-requirement results for these three crops during cool, damp seasons and hot, dry years on the basis of their relation to the mean water requirement shows the following departures from the mean:

	Cool, damp years	Hot, dry years	Difference
Rye	−2	+5	+7
Sudan grass	−6	−5	+1
Galgalos wheat	+7	−9	−16

Rye showed an efficient water requirement during the cool, damp year but an inefficient requirement during the hot, dry year. Sudan grass and Galgalos wheat were efficient during the hot, dry year but Sudan grass was efficient also during the cool, damp year, which reduced the value of the combined index and does not indicate a preference to either extreme. Galgalos wheat was very inefficient during the cool year. This was due in part at least to rust infection.

A comparison of the relative efficiency of the crops grown in 1915, a very favorable year, with those grown in 1916, a very unfavorable year, the former relatively damp and cool, the latter hot and dry, gives the following departures from the mean water requirement for the series:

	Departure from the mean		Difference
	1915	1916	
Oats, Swedish Select	−7	+15	+22
Corn, Northwestern Dent	−8	+13	+21
Cowpeas	−6	+10	+16
Oats, Burt	−6	+7	+13
Millet, Kursk	−7	+6	+13
Rye, Vern	−2	+5	−7
Barley, Hannchen	0	+5	−5
Sudan grass	−6	−5	−1
Mean of all crops	0	0	0
Wheat, Kubanka	+3	+3	0
Alfalfa, Grimm	+4	−1	−5
Pigweed	0	−7	−7
Sorghum, Minnesota Amber	0	−10	−10
Cotton, Triumph	+5	−8	−13
Wheat, Galgalos	+7	−9	−16
Grama grass	+17	−21	−38
Evaporation	+4	+8	−4

The low values in the first column represent water-requirement efficiency on the part of crops during the cool, damp year, and the high values represent inefficiency. The high values during the hot, dry year, 1916, represent inefficiency and the low values, efficiency. These values are combined in the last column in a linear scale. High values indicate crops which are efficient in the use of water during cool years and inefficient during hot years; while those of low value indicate crops which are inefficient during cool years and efficient during hot, dry years.

This table shows clearly that certain crops were more efficient in their use of water during the cool, damp year, 1916, and others during the dry, hot year, 1915. Corn, oats, cowpeas, and millet gave the lowest relative water requirement results during the damp, cool year; and grama grass, Galgalos wheat, cotton, and sorghim during the hot, dry year. The relative water requirement of Sudan grass and Kubanka wheat fall at or very near the mean water requirement for all crops. The position of Galgalos wheat is probably due to its susceptibility to rust, which increased the water-requirement value during 1915. The water-requirement values are all relative, but the rating and spread for the various crops are significant.

On the basis of the ratio of 1915 to 1916, the crops would fall in the following order, those having the lowest values being least adapted to a year like 1916 and best adapted to a year like 1915; and those having the highest ratios are best adapted to a year like 1916 and least adapted to a year like 1915: Wheat, C. I. 4131, 50; oats, Swedish Select, 51; corn, Northwestern Dent, 51; potato, Irish Cobbler, 52; alfalfa, Grimm E–23, 54; oats, Burt, 55; millet, Kursk, 55; rye, 59; Sudan grass, 61; barley, Hannchen, 61; wheat, Marquis, 61; wheat, Kubanka C. I. 4082, 62; flax, Jalaun, 62; wheat, Kubanka C. I. 1440, 64; alfalfa, A. D. I. E–23, 66; pigweed, 67; sorghum, Minnesota Amber, 69; Kashgar flax, 70; evaporation, 71; wheat, Pacific Bluestem, 71; cotton, 72; wheat, Galgalos, 74; grama grass, 93.

These values range from 13 below the average to 30 above, or 21 below evaporation to 22 above. The results are significant in that they show that the plants with high values which are at the bottom of the above list gave an unusually low relative water requirement during the hot, dry year 1916, and those with low values which are at the top of the list did best during the damp, cool year. These results confirm in a general way those based on Table 28 but are not as reliable, since only the results of two years are involved; while in the case of the results of crops grown for four years continuously the departures are taken from the mean. Either method affords a means of grading crops as to their relative efficiency in the use of water during extreme years.

EFFECT OF DIFFERENT SEASONS ON THE WATER REQUIREMENT AND THE PRODUCTION OF DRY MATTER

Although this study is concerned primarily with water requirement, the total amount of crops produced is important. It is possible for crops to utilize water very efficiently and yet to produce only a small amount of growth. This possibility is emphasized in the results here considered. In general there is a negative correlation between the

amount of total dry matter produced and either the water requirement or evaporation. The years of heavy growth were years of low evaporation and low water requirement. The negative correlation is not very close, due to the marked dissimilarity in the behavior of the different crops. The figures here presented are index values only, based on 100, and are taken from Tables 28 and 30. The temperature values are derived from an analysis of thermograph records for the years 1911 to 1916, inclusive. The total number of hours during which the temperature was above 80° F. for the period May to September was recorded for each year. The following are the index values of growth, water requirement, and evaporation for crops grown at Akron, Colo., as percentages of the mean fixed arbitrarily for the years 1911 to 1917 at 100.

	1911	1912	1913	1914	1915	1916	1917	Average
Growth	72	145	126	122	101	54	84	100
Water requirement	107	78	104	103	77	131	101	100
Evaporation	116	90	102	99	79	112	101	100
Hours with temperature above 80° F., April to September, inclusive	141	82	141	75	44	115	-----	100

In general, when growth is low, evaporation and water requirement are both high, and vice versa. The correlation between growth and water requirement is -0.70 ± 0.13, and between growth and evaporation is -0.59 ± 0.17. The temperature record is startling in several respects. The temperature value for 1917, an average year, was omitted. The years 1911 and 1913 were exactly alike in hours with temperature above 80° F., but if only hours above 90° F. were considered, 1911 had only 65 per cent as many hours as 1913. On this basis, therefore, 1913 was a hotter year then 1911. Increased growth was recorded for Kubanka wheat, sorghum, and corn during 1913.

The water requirement of crops was slightly less in 1913 than in 1911, due largely to the excessively high value of the water requirement of alfalfa in 1911. The evidence indicates about equal water requirement for those two years but very unequal growth. Evaporation was higher in 1911 than in 1913 for the period April to September, inclusive, and for each month during the period with the exception of August. The data obtained seem to provide no adequate explanation for the greater amount of growth in 1913 as compared with 1911.

The 1912 results are more easily explained. Due to the low intensity of light in 1912 it was an exceptionally good year for the economic use of water and for the production of heavy crops. The index numbers show growth 45 points above the mean, evaporation 10 points below, hours above 80° F., 18 points below the average, and water requirement 22 points below average.

Both evaporation and water-requirement values were in 1914 near the mean, but temperature was 25 points below and growth 22 points above. It was a favorable year for Kubanka wheat and Kursk millet, but unfavorable for barley, Swedish Select oats, and corn.

Based on the mean of all the crops the 1915 crops made an average growth. The distribution of growth among the various crops, however, was very unequal. The water requirement, however, was 23 points and evaporation 21 points below the mean. It was by far the coolest year encountered in this study, the temperature in hours above 80° F. being 56 points below the average. Apparently, the weather was too cool for certain crops.

In 1916 growth was 46 points below the mean or lower than for any other year. The water requirement was 31 points, evaporation 12 points, and temperature 15 points above the mean. It was a dry, hot year, and on the basis of results obtained in previous experiments was favorable to sorghum and alfalfa and unfavorable to oats, corn, and millet.

During 1917 crops showed a normal water requirement and evaporation, but a growth 16 points below the mean. On the basis of production, corn and millet were high while all other crops were low, Swedish Select oats being 14 points below the mean. On the basis of water requirement alfalfa, wheat, and corn were the most efficient and Burt oats the least efficient. On the basis of the larger series of crops, corn, cotton, cowpea, and Sudan grass were most productive, and Swedish Select oats, Kubanka wheat, rye, barley, and pigweed least productive. The most efficient in the use of water were cowpea, grama grass, and Kubanka wheat, and the least efficient Sudan grass, pigweed, and sorghum.

A comparison of the relative position of crops on the basis of total dry matter produced and of the water requirement for two extreme years, such as 1915 and 1916, is of interest. In the following tabulation the index values of the crops have been arranged in order, with the crops showing the lowest relative water requirement at the top of the list and those showing the highest relative water requirement at the bottom of the list. In the second column the departure above or below the mean in production of dry matter is recorded. The difference between the index values of the first and second columns is recorded in the third column:

Crop	Water requirement, 1915	Total dry matter, 1915	Difference, 1915
Corn	−8	−54	−46
Millet	−7	+5	+12
Oats, Swedish Select	−7	+51	+58
Cowpea	−6	−15	−9
Oats, Burt	−6	+27	+33
Sudan grass	−6	−23	−17
Rye	−2	+33	+35
Barley	0	+50	+50
Pigweed	0	+2	+2
Sorghum	0	−30	−30
Wheat, Kubanka	+3	+19	+16
Alfalfa	+4	+2	−2
Cotton	+5	−53	−58
Wheat, Galgalos	+7	−4	−11
Grama grass	+17	−8	−25

The figures in the comparison may be interpreted more readily by the use of the third column of figures. Minus values in the first column show low water requirement, while plus values in the second column show high dry-matter production. On the basis of water requirement only, the most efficient crops stand at the head of the

list and show the greatest minus departures, but on the basis of production those showing the greatest plus departures are the most efficient. These may be combined as in the third column. Crops in this column having the greatest plus values are those which are either efficient in the production of dry matter and economical in the use of water or which show both these characteristics. Swedish Select oats, with an index value of +58, and barley, rye, Burt oats, Kubanka wheat, and millet, with index values of +50, +35, +33, +16, and +12, respectively, gave the best performance records during this damp, cool year. The crops which made poor showings during the year are: Cotton with an index value of −58, and corn, sorghum, grama grass, Sudan grass, Galgalos wheat, and cowpea with index values of −46, −30, −25, −17, −11, and −9, respectively.

While the data here presented are not as complete as they might be, they indicate rather clearly that plants are delicately adjusted to different optimum conditions. The water-requirement and growth data for 1915 indicate that corn exhibits a high degree of efficiency in the use of water but that this efficiency is accompanied by a greatly reduced growth. Apparently the season was too cool for a good crop of corn, but the cool and damp weather cut down the water loss, which accounted for the low water requirement. The same was true also of cowpea and Sudan grass. Sorghum showed an efficiency in the use of water equal to the average efficiency of all crops, but produced a very small crop, while cotton was less efficient in the use of water and produced relatively less than any other crop. Although it did not fall so far below the mean of all the crops in production of dry matter, grama grass required for its growth a relatively great amount of water. All of these crops responded unfavorably to the cool season. Several other crops, however, responded favorably to the season. Swedish Select oats produced 51 points more dry matter than the mean production for all plants, the water requirement to produce which was 7 points below the average for all crops. Burt oats was almost equally efficient in the use of water, but did not produce as much dry matter, while rye, only 2 points more efficient in the use of water than the average for all crops, was 33 points more productive in dry matter. Although barley was not above the average in efficiency, it was 50 points above the average in production. Kubanka wheat was 3 points less efficient but 19 points more productive than the average for all crops.

In the results of the 1916 experiments the relative positions of the crops mentioned above are somewhat different. There is a general tendency, however, for those crops which stood high in efficiency in use of water in 1915 to stand low in 1916, and vice versa.

While the hot, dry season of 1916 caused all plants to have a high water requirement, it did not by any means affect them equally. Oats, corn, and cowpea used relatively a great amount of water, while grama grass, sorghum, Galgalos wheat, cotton, and pigweed were relatively efficient. On the basis of total production, however, neither the same relative position nor the reverse position is maintained. Cowpea, corn, pigweed, grama grass, millet, and cotton were relatively most productive, while Galgalos wheat, Kubanka wheat, and the oats varieties were least productive.

On the basis of dry matter production, cowpea, which produced a quantity 19 points above the average for all crops, ranked first in the 1916 tests. This dry matter, however, was produced at a water requirement 10 points above the average for all crops. Like cowpea, corn also gave a relatively high dry matter yield, 15 points above the average for all crops but at a water requirement 13 points above the average for all crops. Millet made a similar record, producing a quantity of dry matter 9 points above at a water requirement 6 points above the average for all crops. The exceptional production made by these three crops was obtained only with the abundant use of water. The high temperature not only favored their growth but also increased their transpiration.

Crop	Water requirement, 1916	Total dry matter, 1916	Difference, 1916
Grama grass	−21	+9	+30
Sorghum	−10	+6	+16
Wheat, Galgalos	−9	−29	−20
Cotton	−8	+7	+15
Pigweed	−7	+10	+17
Sudan grass	−5	+5	+10
Alfalfa	−1	−2	−1
Wheat, Kubanka	+3	−15	−18
Barley	+5	−2	−7
Rye	+5	−6	−11
Millet	+6	+9	+3
Oats, Burt	+7	−15	−22
Cowpea	+10	+19	+9
Corn	+13	+15	+2
Oats, Swedish Select	+15	−15	−30

Another group of plants tested gave a good dry matter production with an economical use of water. In this group, grama grass made the best record, producing 9 points more dry matter than the average with a water requirement 21 points less than the average. Pigweed produced a quantity of dry matter 10 points above at a water requirement 7 points less than the average for all crops; while sorghum produced a quantity of dry matter 6 points above with a water requirement 10 points less than the average; and cotton a quantity of dry matter 7 points above at a water requirement 8 points less than the average. Here is a group of plants that not only produced more dry matter than the average for all crops during this hot dry year but did so at an increased relative efficiency in the use of water.

The high temperature was very unfavorable to some of the crops, however. Swedish Select oats, for instance, produced a quantity of dry matter 15 points less at a water requirement 15 points above the average for all crops. Burt oats gave a similar result, producing a quantity of dry matter 15 points less at a water requirement 7 points higher than the average for all crops. Kubanka wheat also fell 15 points below the average in dry matter production and was 3 points high in water requirement. Rye with a dry matter production 6 points below and a water requirement 5 points above the average for all crops; and barley with a growth 2 points below and a water requirement 5 points above the average for all crops, complete the list of plants showing poor dry matter production and high-water requirement during 1916. Galgalos wheat which fell 29 points below on dry matter production and was 9 points below

the average for all crops in water requirement, should probably have been included in the above series. The water requirement value is influenced by the fact that the values during damp years have been considerably raised by rust. It is probable, therefore, that this value should fall nearer to that of Kubanka wheat than is indicated by the records.

On the basis of efficiency in the use of water, grama grass stands at the head and Swedish Select oats at the bottom of the list. This is almost exactly the reverse of the results obtained in 1915. Of the plants showing the best combined result, that is, high productivity and efficiency in the use of water, grama grass, with an index value of +30, stands first, followed by pigweed, sorghum, cotton, Sudan grass, and cowpea, with index values of +17, +16, +15, +10, and +9 points, respectively. The poorest showing was made by Swedish Select oats, with an index value of −30, and Burt oats, Galgalos wheat, Kubanka wheat, rye, and barley, with index values of −22, −20, −18, −11, and −7 points, respectively.

A comparison of the figures representing the combined departures of different crops during 1915 and 1916 from the mean water requirement for all crops, is shown in the tabulation on page 1158.

It is clear from this comparison that the crops that were efficient in 1915 were, as a rule, inefficient in 1916, and that those most efficient in 1916 were inefficient in 1915. The highest minus values in the third column below are for the crops which were efficient in the use of water in 1915 and inefficient in 1916. Those at the bottom of the column with the highest plus values were efficient during 1916 and inefficient during 1915. It is somewhat surprising to find corn, cowpea, and millet so efficient in the use of water during the cool year 1915 and so inefficient during 1916. The position of Galgalos wheat is due, at least in part, to the fact that the crop rusted during the cool, damp year, 1915. This affected the value not only for this year but also the values for all other years as well.

If the figures representing combined departures of crops during 1915 and 1916 from the mean dry matter measurement are compared the order of the crops differs considerably from the order they present when compared on the basis of water requirement departures, as shown by the following tabulation:

Crop	Dry matter produced in—		Difference
	1915	1916	
Oats, Swedish Select	+51	−15	+66
Barley	+50	−2	+52
Oats, Burt	+27	−15	+42
Rye	+33	−6	+39
Wheat, Kubanka	+19	−15	+34
Wheat, Galgalos	−4	−29	+25
Alfalfa	+2	−2	+4
Millet	+5	+9	−4
Pigweed	+2	+10	−8
Grama grass	−8	+9	−17
Sudan grass	−23	+5	−28
Cowpea	−15	+19	−34
Sorghum	−30	+6	−36
Cotton	−53	+7	−60
Corn	−54	+15	−69

On the basis of dry matter production, crops showing high plus values were favored by 1915 and held back by conditions in 1916. The crops showing high minus values were favored by the hot year, 1916, and were greatly retarded in growth by the cooler year, 1915. The hot season crops on the basis of dry matter production are corn, cotton, sorghum, cowpea, Sudan grass, and grama grass, while the cool-weather crops are oats, barley, rye, and wheat.

If the results of the experiments based on dry matter and those based on water requirement are compared it will be seen that the crops are not similarly arranged. In other words, it does not follow that a crop efficient in the use of water will produce a big yield or that a high yield is produced with efficient use of water.

The crops which responded favorably to the cool season and unfavorably to the hot season in both water requirement and dry matter production were: Swedish Select oats, barley, Burt oats, and rye. Those that responded favorably to the hot season and unfavorably to the cool season were cotton, grama grass, and sorghum. The other crops were either inconsistent in their response or did not show any decidedly better performance either year. This may indicate a wider range of adjustment to weather conditions or an adaptation to mean conditions. Corn, which was efficient in the use of water was inefficient in the production of dry matter in 1915. In 1916, however, it was inefficient in the use of water but efficient in the production of dry matter. Cowpea responded in a similar way in the experiments for 1915 and 1916. Kubanka wheat showed no difference in water requirement but produced a heavy crop in 1915 and a light crop in 1916. These differences are emphasized by combining the plus and minus water requirement values and the plus and minus dry matter production values as follows:

Crop	Difference of departure from mean in water requirement in 1915 and 1916	Difference in departure from mean in total dry matter produced in 1915 and 1916	Combined results
Oats, Swedish Select	+22	−66	+88
Barley	+5	−52	+57
Oats, Burt	+13	−42	+55
Rye	+7	−39	+46
Wheat, Kubanka	0	−34	+34
Millet	+13	+4	+9
Wheat, Galgalos	−16	−25	+9
Alfalfa	−5	−4	−1
Pigweed	−7	+8	−15
Cowpea	+16	+34	−18
Sudan grass	+1	+28	−27
Sorghum	−10	+36	−46
Corn	+21	+69	−48
Grama grass	−38	+17	−55
Cotton	−13	+60	−73

High values such as shown by Swedish Select oats indicate the ability of a crop to produce a good yield and at the same time be efficient in the use of water during a season such as 1915, and to pro-

duce a poor yield and consume a relatively great amount of water during a season such as 1916. (Compare figs. 12, 13, 14, 15, and 16.) The low values such as shown for cotton indicate good yield and efficient use of water during hot seasons like 1916 and poor yield and inefficient use of water during cool seasons like 1915. In other words, crops with high values are favored by cool, damp seasons and those with low values by hot, dry seasons, measured in terms of Akron climate.

It is not necessary to repeat here the values or the order shown in the table. The cool season crops as shown by these figures are oats, barley, rye, wheat, and millet; the hot season crops, cotton, grama grass, corn, sorghum, sudan grass, cowpea, and pigweed. Alfalfa stands at the mean of this series of crops.

It is evident from the data here presented that crops when arranged in increasing order as to water requirement in one location or during

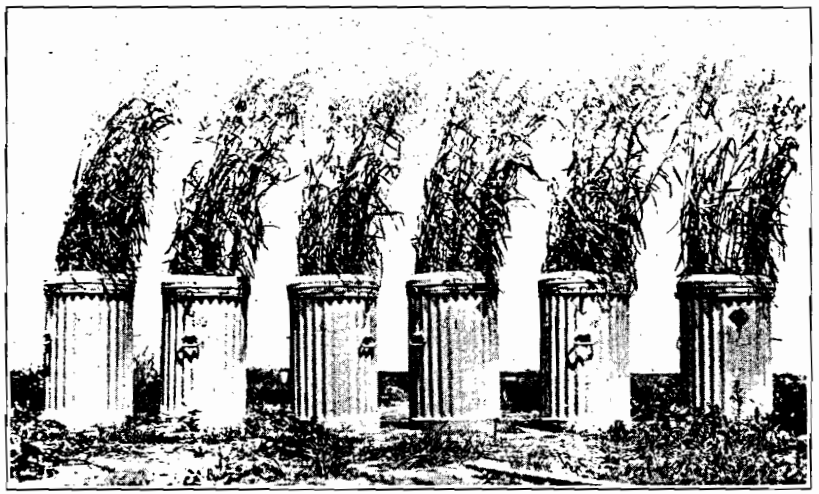

FIG. 12.—Swedish Select oats, grown in 1911, producing an average quantity of dry matter per pot of 174 grams, with a water requirement of 615. Based on the average for all years, the dry matter and water requirement index values for this crop were 71 and 102, respectfully. Photographed at Akron, Colo., July 22, 1911

one season can not be expected to maintain the same order when conditions are changed; that each crop is nicely adjusted to optimum conditions and that the optimum for growth may not necessarily be the optimum for economic use of water. Probably the most economical use of water would be recorded where plants were grown with conditions of temperature somewhat too low and humidity somewhat too high, but any departure from this optimum would increase the water requirement; and if the temperature is too high and the air too dry the water requirement would rapidly increase as compared with growth. If only transpiration were considered the conditions would be even more extreme. The data also shows the danger of phytometer work, which involves the assumption that results obtained with one species of plant can be rigidly applied to another.

PHYTOMETRY

The great difference in behavior of crops here recorded indicates to some extent the danger of placing too much reliance upon, or making too broad an application of, phytometric records. For these two years the results of phytometer measurements might differ by almost 60 points. While the plant measures the environment, it measures it only in terms of its own requirements and the various plants of a population will differ much more from each other than they would from such a physical approximation as evaporation. If the evaporation is embodied as are the individual plants, the value falls surprisingly near the mean for all the plants here grown.

Phytometry is now receiving considerable attention by experimental ecologists. It is clear, from the behavior of this extensive

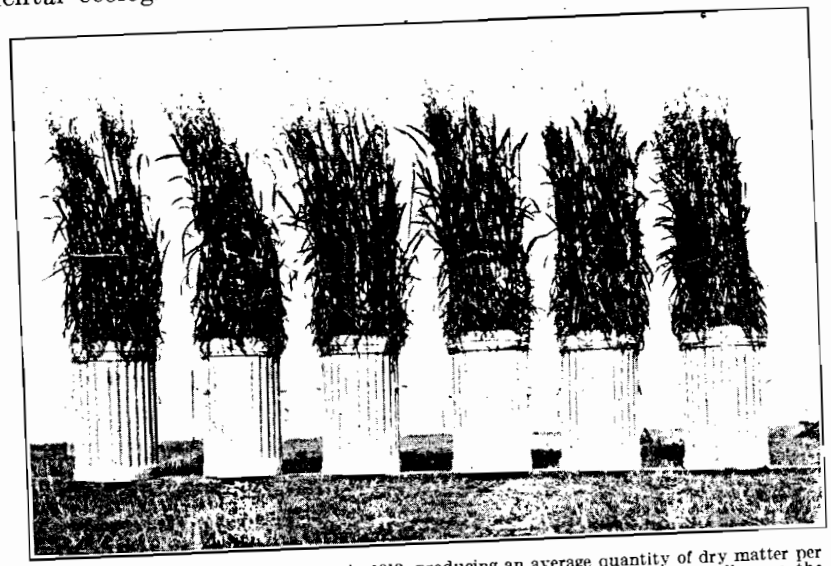

FIG. 13.—Swedish Select oats, grown in 1912, producing an average quantity of dry matter per pot of 396 grams, with a water requirement of 423. Based on the average for all years, the dry matter and water requirement index values for this crop were 162 and 70, respectively. Photographed at Akron, Colo., July 25, 1912

series of plants that they respond very differently to variations in weather conditions. In all probability no plant is a correct phytometer for any other plant. On the whole, plants are much more responsive to dryness of the air and the conditions that favor water loss than is a water surface. The evaporation range for the period 1911 to 1917 (Table 28), varied from 79 points for 1915 to 116 points for 1911, or 37 points, while the water requirement for eight representative crops ranges from 77 points for 1915 to 131 points for 1916, or 54 points. For the hot weather crop, sorghum, the water requirement varied from 75 points for 1915 to 110 points for 1911 and 1917, a range of 35 points. For the cool weather crop, Swedish Select oats, the water requirement varied from 70 points for 1912 to 146 points for 1916, a range of 76 points, more than twice as much as sorghum. Grama grass gave high water requirement values during the years 1913 and 1914, when conditions were not extreme; very high values

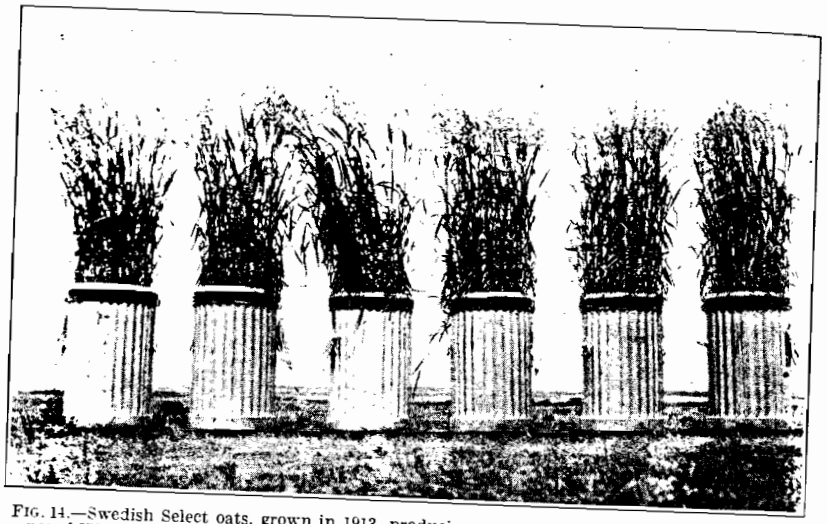

FIG. 14.—Swedish Select oats, grown in 1913, producing an average quantity of dry matter per pot of 276 grams, with a water requirement of 617. Based on the average for all years, the dry matter and water requirement index values for this crop were 112 and 104, respectively. Photographed at Akron, Colo., July 19, 1913

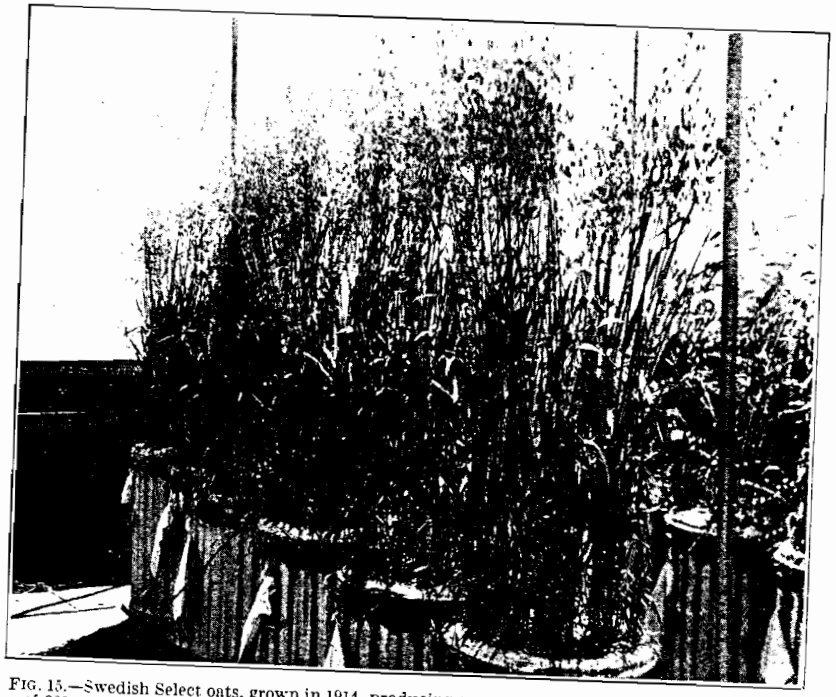

FIG. 15.—Swedish Select oats, grown in 1914, producing an average quantity of dry matter per pot of 265 grams, with a water requirement of 599. Based on the average for all years, the dry matter and water requirement index values for this crop were 108 and 100, respectively. Photographed at Akron, Colo., August 1, 1914

during 1915, a year of low evaporation; and unusually low values during 1916, a year of high evaporation. In other words, sorghum and grama grass are unusually efficient during hot dry years. Oats is unusually efficient during cool, damp years. To choose any one of these plants as a general measure of climatic conditions would introduce all the errors due to the adaptability of the plant to a narrow range of conditions. Phytometry provides a method of determining the relative adaptability of a plant to special conditions through the measure of its efficiency in the use of water.

CORRELATION OF WATER REQUIREMENT WITH EVAPORATION

The figures here presented do not adequately represent the correlation of evaporation and water requirement, since no account is

FIG. 16.—Swedish Select oats, grown in 1916, producing an average quantity of dry matter per pot of 103 grams, with a water requirement of 876. Based on the average for all years, the dry matter and water requirement index values for this crop were 42 and 146, respectively. Photographed at Akron, Colo., August 2, 1916

taken of the period of growth and relative size of the crop during each period. The evaporation data are for the six months' period, April to September, while most of the growth of crop plants is made during the latter part of June, July, and the early part of August. A very close agreement between the water requirement and evaporation would, therefore, not be expected. It is necessary here only to point out that the variation of evaporation during the different years is not as great as that of transpiration, and a tendency on the part of the plant is to give a water requirement much higher during extreme years and much lower during the favorable years than would be expected from the evaporation data. In other words, there is a

wider range in the water requirement of plants in proportion to season than there is in evaporation.

The population is so small, there being only seven observations in evaporation, that the correlation is not as significant as might be desired. The correlation of evaporation and transpiration for the different periods is as follows: 1911 to 1917, 0.76 ± 0.04; 1912 to 1917, 0.87 ± 0.02; 1913 to 1917, 0.82 ± 0.03; 1914 to 1917, 0.87 ± 0.02. This correlation, although only an approximation, indicates a very high degree of dependence of water requirement on evaporation.

The following are the correlations of each crop with the seasonal evaporation: Grimm alfalfa, 0.74 ± 0.11; Swedish Select oats, 0.76 ± 0.11; Burt oats, 0.79 ± 0.09; Hannchen barley, 0.86 ± 0.07; Kubanka wheat, 0.67 ± 0.16; Northwestern Dent corn, 0.76 ± 0.11; Kursk millet, 0.74 ± 0.11; Minnesota Amber sorghum, 0.90 ± 0.05.

It is evident from the consideration of the individual crops and their response to different types of seasons, that no close correlation would be likely between evaporation and each of the single crops. It is apparent, however, that water requirement depends to a large extent on evaporation. This correlation is shown also in the graphs in Figures 6 and 7.

RELATIVE WATER REQUIREMENT AT AKRON, COLO.

There are two chief causes of variation in the water requirement measurements presented in this study: (1) The kind of crop, and (2) the character of the growing season. Other causes were largely eliminated by the method of experimentation. In order to bring out more clearly the effect of season or year on the water requirement, the results have been arranged (Table 27) in such a way as to give the greatest number of crops used in the determinations during the period of experimentation.

In order to reduce the measurements made during different years to a comparable scale in which the relative water requirements of the different crops can be expressed, it is necessary to weight the values for each year. This has been done in accordance with the values shown in Table 27 for the respective years. Index values derived from the actual values shown in Table 27 are given in Table 28. These index values show that the plants do not respond proportionately season to season. Therefore it is impossible to weight these values without considerable error and the weighted values are probably not what they would have been had the crops been grown for the whole period of experimentation, nor is the mean of these values equal to 100; but the evident mathematical discrepancy is more than offset by the use of the longer crop series where available. These are therefore relatively close approximations and the errors due to crop variation are usually under 10 per cent and never exceed 21 per cent during any one year. With the data available this is as close an approximation as seems justified. It seemed best to the writers to present the material in this form; otherwise the reader would be left to make his own scale. The values of the results for each crop have been raised or lowered in proportion to the following scale of index values: 1911, 107; 1912, 80; 1913, 104; 1914, 104; 1915, 77; 1916, 122; 1917, 97.

In other words, the results of the year 1911 have been lowered by 7 points and those of 1912 raised by 20 points. By this method it has been possible to give in the final table a weighted column in which the relative values of the different crops are presented. (See Tables 33 and 34.) These are estimates based on actual measurements for one or more years, and in the case of some crops represent approximately the actual average of the seasons where the crop has been grown for a period of seven years. The slight discrepancy between the actual averages and the weighted mean is due to the fact that more crops were included in the values for the later years than were included in 1911. Had only the crops which were included in the 1911 value been considered, there would be no discrepancy between the weighted and actual mean. The method here employed, it is believed, gives truer values when applied to a wide range of plants.

TABLE 33.—*Actual water requirement, based on total dry matter, and the weighted mean for each variety, genus, and crop or group, of all plants grown at Akron, Colo., during the years 1911–1917, inclusive*

Plant	Year							Number of years for which record was made	Weighted mean of—		
	1911	1912	1913	1914	1915	1916	1917		Species or variety	Genus	Crop or group
Proso (Panicum miliaceum):											
Black Voronezh, C. I. 15		206±1						1	258±1		
Tambov, S. D. 366, Akron 366-1-0		208±1						1	260±1		
Black Voronezh, S. D. 331		226±7						1	283±9	267±5	267±5
Millet (Chaetochloa italica):											
Kursk, S. P. I. 30029		173±10						1	216±13		
Kursk, S. P. I. 22420	287±2							1	274±3		
Kursk, S. P. I. 34771		187±2	286±4	295±2	202±1	367±4	284±5	6			
German, S. P. I. 26845	263±15	248±7						2	278±12		
Siberian, A. D. I. 3-4				316±5				1	304±5		
Turkestan, S. P. I. 20694		294±6						1	368±8	285±8	285±8
Sorghum (Andropogon sorghum):											
Sorgo—											
Minnesota Amber, A. D. I. 341-13		239±2	298±2	284±3	203±3	296±4	272±5	6	274±3		
Dakota Amber, A. D. I. 341-10-A				296±1				1	285±1		
Red Amber, S. P. I. 17543	298±4	237±4	296±1					3	287±3		282±3
Grain sorghum—											
Brown Kaoliang, S. P. I. 24963	301±3	223±1						2	282±2		
Blackhull Kafir, S. P. I. 24975	278±5	259±5						2	292±6		
White Durra, S. P. I. 24997	321±2	255±3						2	312±3		
Milo, S. P. I. 24960		249±3						1	311±4		
Dwarf Milo, S. P. I. 24970	333±3	273±4						2	324±4		304±4
Grass sorghum—											
Sudan grass, S. P. I. 25017 (var. Aethiopicus)		359±2		394±4	260±3	426±3	378±3	5	380±3	305±3	380±3
Corn (Zea mays):											
Esperanza	319±5	239±3						2	299±5		
Tom Thumb				315±8				1	303±8		
Algeria				330±4				1	317±4		
Indian Flint			342±5					1	329±5		
Budapest				345±3				1	332±3		
Hopi		285±7	350±8					2	347±9		
Pima				365±7				1	351±7		
Joaquin				368±9				1	354±9		
German C24-2				372±3				1	358±3		
Northwestern Dent	368±10	280±10	399±12	368±6	253±7	495±13	346±3	7	361±10		
Laguna		285±6						1	369±8		
German C24-1				385±5				1	370±5		
China White		315±7	415±4	344±7				3	375±7		
Iowa Silvermine	420±3	302±7						2	386±7		
Bloody Butcher			405±7					1	389±7		349±7
Hybrids—											
China White×Esperanza		250±2						1	313±3		
China White×Hopi			345±3					1	332±3		
Algeria×China				347±5				1	334±5		
Joaquin×Budapest				365±5				1	351±5		
German C24-1×2				372±1				1	358±1		
China White×Laguna		289±4						1	361±5		
Budapest×Pima				388±5				1	373±5		
Joaquin×Pima				389±9				1	374±9	349±6	350±5
Teosinte (Euchlaena Mexicana):											
Durango			390±11					1	375±11	375±11	375±11
Hybrids—											
China White×Teosinte			376±4					1	362±4	362±4	362±4
Sugarbeet (Beta vulgaris):											
Morrison grown, Kleinwanzleben	377±8	321±8						2	377±9	377±9	377±9
Tumbleweed (Amaranthus graecizans)	275±7			272±4				2	260±6		
Pigweed (Amaranthus retroflexus)	350±4		320±7	306±1	229±3	340±13	307±6	6	305±6	283±6	
Russian thistle (Salsola pestifer)	336±5							1	314±5	314±5	
Lamb's quarters (Chenopodium album)			801±41			660±27		2	658±32	658±32	
Polygonum (Polygonum aviculare)				705±50				1	678±48	678±48	443±26
Barley (Hordeum vulgare):											
Beardless, C. I. 716	544±9	403±8						2	506±9		
Beldi, C. I. 190	543±2	416±4						2	514±4		
Hannchen, C. I. 531 (Hordeum distichon)	527±8	443±3		501±5	404±11	664±9	522±4	6	523±8		
Nepal, C. I. 595	542±3	439±1						2	528±2	518±6	518±6
Buckwheat (Fagopyrum vulgare)	578±13							1	540±12	540±12	540±12
Wheat:											
Emmer, C. I. 2951 (Triticum dicoccum)	534±14	428±3						2	517±10		517±10
Durum (Triticum durum)—											
Beloturka, C. I. 3705, S. P. I. 35480				458±10	390±2			2	483±6		
Beloturka, C. I. 3705 (old seed)					387±3			1			
Kubanka, C. I. 1440	468±8	394±7	496±5	518±6	405±3	636±14	471±4	7	491±7		
Jumillo, C. I. 1736				496±10	396±6			2	496±10		
C. I. 4131, S. P. I. 3715 (from Siberia)				507±8	364±6			2			
C. I. 4131 (old seed)					357±4	719±15		2	531±13		
C. I. 4131 (first generation)						717±30		1			
C. I. 4131 (second generation)						712±10		1			
C. I. 4082, S. P. I. 36388 (from Peru)				538±5	431±3		517±12	3			
C. I. 4082 (old seed)					413±6	666±24		2	548±12		
C. I. 4082 (first generation)						710±9		1			
C. I. 4082 (second generation)						683±18		1			
Kubanka, C. I. 2094						696±30		1	570±25		542±14
Common (Triticum aestivum)—											
Turkey, C. I. 1571		364±6						1	455±8		
Kharkof, C. I. 1583		365±6						1	456±8		
Ghirka, C. I. 1517	506±3	457±3					526±63	3	529±38		
Power, C. I. 3697							510±9	1	530±9		
Marvel Bluestem, C. I. 3082	531±5	451±4						2	534±5		
Preston, C. I. 3328				510±3	452±6			2	539±7		
Glyndon, C. I. 2873							524±4	1	540±4		

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TABLE 33.—*Actual water requirement, based on total dry matter, and the weighted mean for each variety, genus, and crop or group, of all plants grown at Akron, Colo., during the years 1911–1917, inclusive*—Continued

Plant	Year							Number of years for which record was made	Weighted mean of—		
	1911	1912	1913	1914	1915	1916	1917		Species or variety	Genus	Crop or group
Wheat—Continued.											
Common—Continued.											
Marquis, C. I. 3641				498±5	424±3			2	550±8		
Marquis, C. I. 3641 (old seed)					412±3	680±12		2			
Marquis, C. I. 3641 (first generation)						726±5		1			
Marquis, C. I. 3641 (second generation)						713±19		1			
Prelude, C. I. 4323							536±28	1	553±29		
Galgalos, C. I. 2398	496±4			624±5	481±4	652±8	543±6	5	557±5		
Pioneer							545	1	562		
C. I. 4090, S. P. I. 36502, Turkestan				567±6	409±4			2	584±6		
C. I. 4090 (old seed)					461±5			1			
Haynes Bluestem, Minn. 169, C. I. 2874						743±11	572±7	2	600±8		
Pacific Bluestem, C. I. 4067				679±3	491±4	690±7		3	619±5		
C. I. 4087, S. P. I. 36499				639±2	501±4			2	640±4		
C. I. 4087 (old seed)					505±3			1			
C. I. 4103				689±8				1	663±8		
C. I. 4127				[a] 916±15				1	[a] 881±14		557±13
Hybrids—											
Kubanka×Haynes Bluestem						636±21		1	521±17		
Jumillo×Preston				574±2	417±2			2	547±3	545±14	534±12
Cotton:											
Triumph (Gossypium hirsutum)		488±14	657±11	574±9	443±8	612±9	522±4	6	568±10	568±10	568±10
Potato:											
Irish Cobbler (Solanum tuberosum)	448±11		659±15		329±4	630±17		4	499±11		
McCormick (Solanum tuberosum)			717±11			744±28		2	650±18	[a] 543±13	575±15
Oats:											
Canadian C. I. 444 (Avena sativa)	598±14	399±6						2	529±11		
Sixty-Day, C. I. 165 (Avena sativa)	605±5	491±13						2	594±12		
Swedish Select, C. I. 134 (Avena sativa)	615±7	423±5	617±9	599±2	448±10	876±21	635±5	7	604±10		
Burt, C. I. 293 (Avena sativa)	639±7	449±3	617±5	615±6	445±5	809±5	636±5	7	606±5	583±10	583±10
Native weeds:											
Purslane (Portulaca oleracea)			292±11					1	281±11	281±11	
Cocklebur (Xanthium commune)			432±13					1	415±13	415±13	
Nightshade (Solanum triflorum)				500±14				1	487±13		
Buffalo Bur (Solanum rostratum)				557±7				1	536±7	[b] 543±13	
Gumweed (Grindelia squarrosa)		468±18						1	585±23	585±23	
Sunflower, annual (Helianthus annuus)			705±8			579±10		2	577±8		
Sunflower, narrow-leaved from sand-hills (Helianthus petiolaris)			570±11					1	548±11		

Sunflower, narrow-leaved from heavy soil (Helianthus petiolaris)			774±20					1	744±19	623±13	
Mountain sage (Artemisia frigida)	765±24	474±14		730±20				2	654±20	654±20	
Verbena (Verbena bractiosa)			881±26					1	702±19	702±19	
Fetid marigold (Boebera papposa)								1	847±25	847±25	580±16
Crucifers:			539±7					1	518±7		
Cabbage, Early Jersey Wakefield (Brassica oleracea capitata)			639±31					1	614±30		
Turnip, purple top (Brassica rapa)	[a] 441±12		743±7					1	714±7	615±18	615±18
Rape (Brassica napus)				622±7	469±8	800±11	625±5	6	634±8	634±8	634±8
Rye:	724±7	496±9						1	296±16	296±16	
Vern, C. I. 73 (Secale cereale)			308±17					4	338±11	338±11	
Native plants:				389±7	312±14	336±8	290±9	1	374±12	374±12	
Buffalo grass (Bulbilis dactyloides)								1	483±11	483±11	
Grama grass (Bouteloua gracilis)			389±12	502±11				1	534±5	534±5	
Buffalo and grama grass mixed (Bulbilis dactyloides and Bouteloua gracilis)						652±6		1	912±63	912±63	
Clammyweed (Polanisia trachysperma)								1	1035±28	[c] 857±27	
Iva (Iva xanthifolia)			948±66					1	1131±50	1131±50	638±31
Western ragweed (Ambrosia elatior)			1076±29	1176±52							
Western wheat grass (Agropyron smithii)								1	577±14	577±14	
Franseria (Franseria tenuifolia)			600±15					1	597±26		
Cucurbits:			621±27					1	686±11	642±21	
Watermelon, Rocky Ford (Citrullus vulgaris)			713±11					1	719±8		
Cantaloupe, Rocky Ford (Cucumis melo)			748±8					1	802±16	761±13	676±16
Cucumber, Boston pickling (Cucumis sativus)			834±17								
Squash, Hubbard (Cucurbita maxima)								2	682±17	682±17	682±17
Pumpkin, common (Cucurbita pepo)		519±13	744±17								
Rice:				544±8				1	523±8	523±8	
Honduras, C. I. 1643 (Oryza sativa)				659±5	413±5	767±8	481±4	5	569±6	569±6	
Legumes:			571±3					1	638±18	638±18	
Guar (Cyamopsis)		510±14						2	630±18		
Cowpea, S. P. I. 29282 (Vigna sinensis)			805±8	517±19				1	759±9	698±14	
Chickpea, S. P. I. 24322 (Cicer arietinum)			789±9					1	656±4		
Clover, Crimson, S. P. I. 33742 (Trifolium incarnatum)			682±4					1	743±8	700±6	
Clover, Red, S. P. I. 34869 (Trifolium pratense)			773±8					1	562±12		
Bean, navy (Phaseolus vulgaris)				584±12				2	587±6		
Bean, Mexican (Phaseolus vulgaris)			690±8	531±3				1	742±11		
Vetch, Black Bitter (Vicia ervillea)			772±11					1	750±18		
Vetch, hairy, S. P. I. 34298 (Vicia villosa)			780±19					1	899±9	708±12	
Bean, horse, S. P. I. 25645 (Vicia faba)			935±9					1	646±9		
Bean, horse, S. P. I. 15429 (Vicia faba)			672±9					1	784±24	715±18	
Vetch, purple, S. P. I. 18131 (Vicia atropurpurea)			815±25					2	731±7	731±7	
Bean, soy, cultivated, S. P. I. 21755 (Soja max)								1	745±5	747±6	
Bean, soy, wild, S. P. I. 25138 (Soja max)	709±9	638±4	775±5				[d]	1	748±7		
Clover, sweet, S. P. I. 21216 (Melilotus alba)								1	837±33	837±33	
Pea, Canada field, S. P. I. 30134 (Pisum sativum)	890±7			870±34				1	813±26		
Pea, Canada field, S. P. I. 22637 (Pisum sativum)				846±27				1	626±12		
Lupinus albus, S. P. I. 35477 (Lupinus albus)			651±12								
Alfalfa (Hansen seed) (Medicago falcata)											
Alfalfa, Peruvian, S. P. I. 30203 (Medicago sativa)											

[a] Not included in the mean.

[b] Average of genus Solanum.

[c] Average of genus Agropyron.

TABLE 33.—*Actual water requirement, based on total dry matter, and the weighted mean for each variety, genus, and crop or group, of all plants grown at Akron, Colo., during the years 1911–1917, inclusive*—Continued

Plant	Year							Number of years for which record was made	Weighted mean of—		
	1911	1912	1913	1914	1915	1916	1917		Species or variety	Genus	Crop or group
Legumes—Continued.											
Alfalfa, Grimm, A. D. I. 162-98-A (Medicago sativa)				810±5	685±13			2	835±13		
Alfalfa, Grimm, A. D. I. E-23-20-52 (Medicago sativa)		657±11	834±8	906±11				3	831±11		
Alfalfa, Grimm, A. D. I. E-23 (Medicago sativa)				890±6	695±9	1047±9	822±8	4	866±9		
Alfalfa, Grimm, A. D. I. 162-98 (Medicago sativa)				904±12				1	869±12		
Alfalfa, Grimm, A. D. I. 162-98-B (Medicago sativa)				906±12				1	871±12		
Alfalfa, Grimm, A. D. I. E-5-30 (Medicago sativa)				933±11				1	897±11		
Alfalfa, Grimm, S. P. I. 25695 (Medicago sativa)	1068±16	659±6						2	911±12		
Alfalfa, Grimm, A. D. I. H-4-60 (Medicago sativa)				957±8				1	920±8	844±13	750±14
Flax:											
Damont, C. I. 3 (Linum usitatissimum)							605±13	1	624±13		
Kashgar, S. P. I. 37719, C. I. 50-1 (Linum usitatissimum)					569±4	812±0		2	703±5		
North Dakota Resistant No. 114, C. I. 13 (Linum usitatissimum)					579±10			1	752±13		
Reserve, C. I. 19 (Linum usitatissimum)			905±25		615±7			2	835±18		
Soddo White, S. P. I. 37086, Abyssinia, C. I. 36 (Linum usitatissimum)					625±4			1	812±5		
Smyrna, S. P. I. 36949 (Turkey), C. I. 30 (Linum usitatissimum)					663±16			1	861±21		
Jalaun, S. P. I. 36566, (India), C. I. 21 (Linum usitatissimum)					682±14	1098±10		2	893±14	783±14	783±14
Grasses:											
Wheat-grass, S. P. I. 19537 (Agropyron desertorum)			705±27					1	678±26	[a] 857±27	
Brome-grass, S. P. I. 29880 (Bromus inermis)			1016±26					1	977±25	977±25	828±26

[a] Average of genus Agropyron.

TABLE 34.—*Actual water requirement, based on grain, seed or tuber production, for each year, for each variety, genus and crop or group of all plants grown at Akron, Colo., period, 1911–1917, inclusive*

Plant	Year							Number of years for which record was made	Weighted mean of—		
	1911	1912	1913	1914	1915	1916	1917		Species or variety	Genus	Crop or group
Proso:								1	531±5		
Black Voronezh, C. I. 16		425±4						1	603±11	567±9	567±9
Tambov, S. D. 366, Akron 366-1-0		482±9						1	863±37		
Millet:								5	898±51		
Kursk, S. P. I. 22420	923±40			1075±38	665±24	1267±45		1	1117±49	959±46	959±46
Kursk, S. P. I. 34771		483±11	985±99	1162±51				1	969±31	969±31	969±31
Siberian, A. D. I. 3-4	1037±33										
Buckwheat								1	863±48		
Sorghum:								6	1043±96		
Sorgo—				898±50				3	1804±179	1237±120	
Dakota Amber, A. D. I. 341-10-A		607±15	765±12	893±26	1116±105	853±26	1700±224				
Minnesota Amber, A. D. I. 341-13	1494±202	2366±194	1100±31								
Red Amber, S. P. I. 17543								1	750±24		
Grain sorghum—								1	753±11		
Blackhull Kafir, S. P. I. 24975	803±26							2	919±35		
White Durra, S. P. I. 24997	806±12							1	1050±53	868±34	1026±83
Brown Kaoliang, S. P. I. 24993	726±12	927±38									
Dwarf Milo, S. P. I. 24970	1123±57							2	1128±15		
Barley:								6	1172±37		
Beldi, C. I. 190	1155±18	941±10		1179±28	949±50	1425±27	1148±12	2	1201±78		
Hannchen, C. I. 531	1134±27	1005±36						2	1464±28	1241±46	1241±46
Beardless, C. I. 716	1210±38	1017±83									
Nepal, C. I. 595	1475±40	1239±11						1	821±30		
Corn:			854±31					6	1098±199	1405±114	1405±114
Indian Flint	2040±342	954±106	1241±77		2060±108	3634±19	1929±73				
Northwestern Dent								1	1102±47	1102±47	
Cucurbits:			1146±49					1	1549±64		
Watermelon, Rocky Ford			1611±67					1	1754±228	1652±167	1468±139
Cucumber, Boston pickling			1824±237								
Cantaloupe, Rocky Ford								1	1471±127	1471±127	1471±127
Crucifers:			1530±132								
Turnip, purple top								2	1379±119		
Oats:	1383±30	1172±133						7	1566±55		
Sixty-Day, C. I. 165	1500±57	1224±55	1641±33	1483±31	1150±27	1975±49	1854±91	7	1648±36		
Burt, C. I. 293	1632±35	1103±18	1876±55	1421±8	1102±34	2288±39	2088±37	2	1915±140	1627±97	1627±97
Swedish Select, C. I. 134	2204±140	1416±119									
Canadian, C. I. 444								2	1167±32	1167±32	
Wheat:	1180+42	984+18									
Emmer, C. I. 2951								7	1365±44		
Durum—	1191±14	1111±37	1322±16	1367±13	1232±13	1779±108	1367±21	2	1372±23		
Kubanka, C. I. 1440				1240±35	1122±11			1			
Beloturka, C. I. 3705					1129±11			2	1396±20		
Beloturka, C. I. 3705 (old seed)				1310±22	1179±15						
Jumillo, C. I. 1736											

Kubanka, C. I. 2094						1857±142		1	1522±116		
C. I. 4131, S. P. I. 37159 (from Siberia)				1286±23	1042±28			2			
C. I. 4131 (old seed)					944±15	2125±104		2	1573±77		
C. I. 4131 (1st generation)						2640±170		1			
C. I. 4131 (2d generation)						2095±104		1			
C. I. 4082, S. P. I. 36388 (from Peru)				1461±38	1315±28			2			
C. I. 4082 (old seed)					1299±38	2291±172		2	1622±73	1475±68	
C. I. 4082 (1st generation)						1903±80		1			
C. I 4082 (2d generation)						1821±60		1			
Common—											
Turkey, C. I. 1571		995±22						1	1244±28		
Kharkof, C. I. 1583		1064±60						1	1330±75		
Ghirka, C. I. 1517	1382±43	1468±34						2	1564±42		
Marquis, C. I. 3641				1469±14	1279±22			2			
Marquis, C. I. 3641 (old seed)					1190±15	2395±232		2	1691±91		
Marquis, C. I. 3641 (1st generation)						2339±126		1			
Marquis, C. I. 3641 (2d generation)						2008±43		1			
Galgalos, C. I. 2398	1245±13			1900±30	1551±65	2445±155	1516±19	5	1714±76		
Marvel Bluestem, C. I. 3082	1786±60	1573±49						2	1818±60		
C. I. 4090, S. P. I. 36502 (Turkestan)				1631±26	1617±20			2	1851±36		
C. I. 4090 (old seed)					1451±39			1			
Preston, C. I. 3328				1512±22	1788±71			2	1888±67		
Haynes Bluestem, Minn., 169, C. I. 2874						2338±78		1	1916±64		
C. I. 4087, S. P. I. 36499				2093±43	1766±39			2	2182±42		
C. I. 4087 (old seed)					1725±25			1			
Pacific Bluestem, C. I. 4067				3564±98	3343±119	2959±346		3	3398±195	1872±82	
Hybrids—											
Kubanka, C. I. 2094×Haynes Bluestem, C. I. 2874						2434±103		1	1995±84		
Jumillo, C. I. 1736×Prestor, C. I. 3328				1987±30	1859±103			2	2163±97	2079±91	1739±77
Potato:											
Irish Cobbler			2327±197		945±134	974±63		3	1325±151		
McCormick						3510±452		1	2877±370	2101±283	2101±283
Rye:											
Vern, C. I. 73	2215±37	1802±62		2291±54	1485±80	2871±99	1982±84	6	2142±76	2142±76	2142±76
Legumes:											
Cowpea, S. P. I. 29282			1576±32	1962±27	1257±39	2373±77	1144±17	5	1632±41	1632±41	
Bean, navy			1646±36					1	1583±35		
Bean, Mexican			1888±62					1	1815±60	1699±49	
Chickpea, S. P. I. 21322		1348±114						1	1685±143	1685±143	
Bean, soy, cultivated, S. P. I. 21755			2053±51					1	1974±49	1974±49	
Pea, Canada, field, S. P. I. 22637	2218±100		2322±121					2	2153±105	2153±105	
Lupinus albus, S. P. I. 35477				4923±478				1	4734±460	4734±460	2225±190
Flax:											
Soddo, White, S. P. I. 37086, Abyssinia, C. I. 36					1548±17			1	2010±22		
North Dakota Resistant No. 114, C. I. 13					2054±87			1	2668±113		
Reserve, C. I. 19			2835±52		2388±57			2	2914±63		
Jalaun, S. P. I. 36566, Indian, C. I. 21					2420±101			1	3143±131		
Smyrna, S. P. I. 36949, Turkey, C. I. 30					2785±82			1	3617±106		
Kashgar, S. P. I. 37719, C. I. 50-1					3975±32			1	5162±42	3252±89	3252±89

THE PROBABLE RANGE OF WATER REQUIREMENT OF DIFFERENT CROPS AT AKRON, COLO.

The weighted values in the last three columns of Tables 33 and 34 approximate closely the values for the period 1911 to 1917. A comparison of the evaporation rate for the period 1911–1917 with that of the longer period 1908–1925 shows that the means are very nearly the same and that no extremes exceed those recorded during the period 1911–1917. (See Table 32.) The writers feel justified, therefore, in concluding that the values of the water requirement given in Table 33 are essentially the values that would have been obtained had the experiment covered the full period 1908–1925 and therefore represent with considerable accuracy the water requirement of plants at this station. In Table 35 is given the weighted average value, the probable low values during damp cool years, and the probable high values during hot, dry years for the crops grown at Akron. The fourth column of the table under the heading "Probable extremes" indicates the basis on which these values have been obtained. The extremes serve as a correction of the more truly mathematical values given in column 3 under weighted mean. These are not to be regarded as measurements, but merely as the writers' deductions from the data in hand. They should serve as an expression of the probable results in the absence of actual measurements.

TABLE 35.—*Weighted mean water requirement based on dry matter, probable lowest and highest value, and units of dry matter produced for each 1,000 units of water consumed, based on the value of the weighted mean, for all plants grown at Akron, Colo., period 1911–1917, inclusive*

Plant	Number of years for which record was made	Weighted mean	Probable extremes of water requirement				Units of dry matter produced for every 1,000 units of water consumed (a)
			Lowest	Based on—	Highest	Based on—	
Proso:							
Black Voronezh, C. I. 15	1	258±1	206±1	Actual value 1912	346±1	Kursk millet, S. P. I. 34771	3.88
Tambov, S. D. 366, Akron 366–1–0	1	260±1	208±1	do	348±1	do	3.85
Black Voronezh, S. D. 331	1	283±9	226±7	do	379±12	do	3.53
Millet:							
Kursk, S. P. I. 30020	1	216±13	173±10	do	289±17	do	4.63
Kursk, S. P. I. 34771	7	274±3	187±2	do	367±4	Actual value 1916	3.65
German, S. P. I. 26845	2	278±12	248±7	do	373±16	Kursk millet, S. P. I. 34771	3.60
Siberian, A. D. I. 3–4	1	304±5	207±2	Kursk millet, S. P. I. 34771	407±7	do	3.29
Turkestan, S. P. I. 20694	1	368±8	250±5	do	493±11	do	2.72
Sorghum:							
Sorgo—							
Minnesota Amber, A. D. I. 341–13	6	274±3	239±2	Actual value, 1912	298±2	Actual value 1913	3.65
Dakota Amber, A. D. I 341–10–A	1	285±1	214±1	Minnesota Amber	314±1	Minnesota Amber	3.51
Red Amber, S. P. I. 17543	3	287±3	215±2	do	316±3	do	3.48
Grain sorghum—							
Brown Kaoliang, S. P. I. 24993	2	282±2	212±2	do	310±2	do	3.55
Blackhull Kafir, S. P. I. 24975	2	292±6	219±5	do	321±7	do	3.42
White Durra, S. P. I. 24997	2	312±3	234±2	do	343±3	do	3.21
Milo, S. P. I. 24960	1	311±4	233±3	do	342±4	do	3.22
Dwarf Milo, S. P. I. 24970	2	324±4	243±3	do	356±4	do	3.09
Grass sorghum—							
Sudan Grass, S. P. I. 25017	5	380±3	266±3	Actual value 1915	426±3	Actual value 1916	2.63
Corn:							
Esperanza	2	299±5	212±4	Northwestern Dent	413±7	Northwestern Dent	3.34
Tom Thumb	1	303±8	215±6	do	418±11	do	3.30
Algeria	1	317±4	225±3	do	437±6	do	3.15
Indian Flint	1	329±5	234±4	do	454±7	do	3.04
Budapest	1	332±3	236±2	do	458±6	do	3.01
Hopi	2	347±9	246±6	do	479±12	do	2.88
Pima	1	351±7	249±5	do	484±10	do	2.85
Joaquin	1	354±9	251±6	do	489±12	do	2.82
German C24–2	1	358±3	254±2	do	494±4	do	2.79
Northwestern Dent	7	361±10	253±7	Actual value 1915	495±13	Actual value 1916	2.77
Laguna	1	369±8	262±6	Northwestern Dent	509±11	Northwestern Dent	2.71
German C24–1	1	370±5	263±4	do	511±7	do	2.70
China White	3	375±7	266±5	do	518±10	do	2.67
Iowa Silvermine	2	386±7	274±5	do	533±10	do	2.59
Bloody Butcher	1	389±7	276±5	do	537±10	do	2.57
Hybrids—							
China White×Esperanza	1	313±3	222±2	do	432±4	do	3.19
China White×Hopi	1	332±3	236±2	do	458±4	do	3.01
Algeria×China	1	334±5	237±4	do	461±7	do	2.99
Joaquin×Budapest	1	351±5	249±4	do	484±7	do	2.85
German C24–1×2	1	358±1	254±1	do	494±1	do	2.79
China White×Laguna	1	361±5	256±4	do	498±7	do	2.77
Budapest×Pima	1	373±5	285±4	do	515±7	do	2.68
Joaquin×Pima	1	374±9	266±6	do	516±12	do	2.67
Teosinte:							
Durango	1	375±11	266±8	do	518±15	do	2.67
Hybrids—							
China White×Teosinte	1	362±4	257±3	do	500±6	do	2.76
Sugar beet:							
Morrison-grown, Kleinwanzleben	2	377±9	305±7	Kubanka wheat, C. I. 1440	494±12	Kubanka wheat, C. I. 1440	2.65
Weeds:							
Tumbleweed	2	260±6	198±5	Pigweed	294±7	Pigweed	3.85
Pigweed	6	305±6	229±3	Actual value, 1915	356±4	Actual value, 1911	3.28
Russian thistle	1	314±5	236±4	Pigweed	367±6	Pigweed	3.18
Lamb's-quarters	2	658±32	506±25	All crops	803±39	All crops	1.52
Polygonum	1	678±48	522±37	do	827±59	do	1.47
Barley:							
Beardless, C. I. 716	2	506±9	400±7	Hannchen, C. I. 531	658±12	Hannchen, C. I. 531	1.98
Beldi, C. I. 190	2	514±4	406±3	do	668±5	do	1.95
Hannchen, C. I. 531	6	523±8	404±11	Actual value, 1915	664±9	Actual value, 1916	1.91
Nepal, C. I. 595	2	528±2	417±2	Hannchen, C. I. 531	686±3	Hannchen, C. I. 531	1.89
Buckwheat	1	540±12	416±8	All crops	659±15	All crops	1.85
Wheat:							
Emmer, C. I. 2951	2	517±10	419±8	Kubanka wheat, C. I. 1440	677±13	Kubanka wheat, C. I. 1440	1.93
Durum—							
Beloturka, C. I. 3705, S. P. I. 35480	3	483±6	391±5	do	633±8	do	2.07
Kubanka, C. I. 1440	7	491±7	394±7	Actual value, 1912	636±14	Actual value, 1916	2.04
Jumillo, C. I. 1736	2	496±10	402±8	Kubanka wheat, C. I. 1440	650±13	Kubanka wheat, C. I. 1440	2.02
C. I. 4131, S. P. I. 3715 (from Siberia)	6	531±13	357±4	Actual value, 1915	719±15	Actual value, 1916	1.88
C. I. 4082, S. P. I. 36388 (from Peru)	7	548±12	413±6	do	710±9	do	1.82
Kubanka, C. I. 2094	1	570±25	462±20	Kubanka wheat, C. I. 1440	747±33	Kubanka wheat, C. I. 1440	1.75
Common—							
Turkey, C. I. 1571	1	455±8	369±6	do	596±10	do	2.20
Kharkof, C. I. 1583	1	456±8	369±6	do	597±10	do	2.19
Ghirka, C. I. 1517	3	529±38	428±31	do	693±50	do	1.89
Power, C. I. 3697	1	530±9	429±7	do	694±12	do	1.89
Marvel Bluestem, C. I. 3082	2	534±5	433±4	do	700±7	do	1.87
Preston, C. I. 3328	2	539±7	437±6	do	706±9	do	1.86
Glyndon, C. I. 2873	1	540±4	437±3	do	707±5	do	1.85
Marquis, C. I. 3641	6	550±8	412±3	Actual value, 1915	726±5	Actual value, 1916	1.82
Prelude, C. I. 4323	1	553±29	448±23	Kubanka wheat, C. I. 1440	724±38	Kubanka wheat, C. I. 1440	1.81
Galgalos, C. I. 2398	5	557±5	481±4	Actual value, 1915	652±8	Actual value, 1916	1.80
Pioneer	1	562	455	Kubanka wheat, C. I. 1440	736	Kubanka wheat, C. I. 1440	1.78

TABLE 35.—*Weighted mean water requirement based on dry matter, probable lowest and highest value, and units of dry matter produced for each 1,000 units of water consumed, based on the value of the weighted mean, for all plants grown at Akron, Colo., period 1911–1917, inclusive*—Continued

Plant	Number of years for which record was made	Weighted mean	Probable extremes of water requirement				Units of dry matter produced for every 1,000 units of water consumed (a)
			Lowest	Based on—	Highest	Based on—	
Wheat—Continued.							
Common—Continued.							
C. I. 4090, S. P. I. 36502, Turkestan	3	584±6	473±5	Kubanka wheat, C. I. 1440	765±8	Kubanka wheat, C. I. 1440	1.71
Haynes Bluestem, Minn. 169, C. I. 2874	2	600±8	486±6	do	743±11	Actual value, 1916	1.67
Pacific Bluestem, C. I. 4067	3	619±5	491±4	Actual value, 1915	690±7	do	1.62
C. I. 4087, S. P. I. 36499	3	640±4	518±3	Kubanka wheat, C. I. 1440	838±5	Kubanka wheat, C. I. 1440	1.56
C. I. 4103	1	663±8	537±6	do	869±10	do	1.51
Hybrids—							
Kubanka×Haynes Bluestem	1	521±17	422±14	do	683±22	do	1.92
Jumillo×Preston	2	547±3	443±2	do	717±4	do	1.83
Cotton:							
Triumph	6	568±10	443±8	Actual value, 1915	657±11	Actual value, 1913	1.76
Potato:							
Irish Cobbler	4	499±11	329±4	do	659±15	do	2.00
McCormick	2	650±18	501±14	All crops	744±18	Actual value, 1916	1.54
Oats:							
Canadian, C. I. 444	2	529±11	370±8	Swedish Select, C. I. 134	772±16	Swedish Select, C. I. 134	1.89
Sixty-Day, C. I. 165	2	594±12	416±8	do	867±18	do	1.68
Swedish Select, C. I. 134	7	604±10	423±5	Actual value, 1912	876±21	Actual value, 1916	1.66
Burt, C. I. 293	7	606±5	445±5	Actual value, 1915	809±5	do	1.65
Native weeds:							
Purslane	1	281±11	214±8	Pigweed	318±12	Pigweed	3.56
Cocklebur	1	415±13	320±10	All crops	506±16	All crops	2.41
Nightshade	1	587±13	375±10	do	594±16	do	2.05
Bullalo Bur	1	536±7	413±5	do	654±9	do	1.87
Gumweed	1	585±23	450±18	do	714±28	do	1.71
Sunflower, annual	2	577±8	444±6	do	704±10	do	1.73
Sunflower, narrow-leaved from sand hills	1	548±11	422±8	do	669±13	do	1.82
Sunflower, narrow-leaved from heavy soil	1	744±19	573±15	do	908±23	do	1.34
Mountain sage	2	654±20	504±15	do	798±24	do	1.53
Verbena	1	702±19	541±15	do	856±23	do	1.42
Fetid marigold	1	847±25	652±19	do	1033±31	do	1.18
Crucifers:							
Cabbage, Early Jersey Wakefield	1	518±7	399±5	do	632±9	do	1.93
Turnip, purple top	1	614±30	473±23	do	749±37	do	1.63
Rape	1	714±7	550±5	do	871±9	do	1.04

Rye:							
Vern, C. I. 73	6	634±8	469±8	Actual value, 1915	800±11	Actual value, 1916	1.58
Native plants:							
Buffalo grass	1	290±16	258±14	Grama grass, series 1914–1917	346±19	Grama grass, series 1914–1917	3.38
Grama grass	4	338±11	290±9	Actual value, 1917	389±7	Actual value, 1914	2.96
Buffalo and grama grass mixed	1	374±12	325±10	Grama grass, series 1914–1917	439±14	Grama grass, series 1914–1917	2.67
Clammyweed	1	483±11	372±8	All crops	589±13	All crops	2.07
Iva	1	534±5	411±4	do	651±6	do	1.87
Western ragweed	1	912±63	702±49	do	1113±77	do	1.10
Western wheat-grass	1	1035±28	797±22	do	1263±34	do	.97
Franseria	1	1131±50	871±39	do	1380±61	do	.88
Cucurbits:							
Watermelon, Rocky Ford	1	577±14	444±11	do	704±17	do	1.73
Cantaloupe, Rocky Ford	1	597±26	460±20	do	728±32	do	1.68
Cucumber, Boston pickling	1	686±11	528±8	do	837±13	do	1.46
Squash, Hubbard	1	719±8	554±6	do	877±10	do	1.39
Pumpkins, common	1	802±16	617±12	do	978±20	do	1.25
Rice:							
Honduras, C. I. 1643	2	682±17	525±13	do	832±21	do	1.47
Legumes:							
Guar	1	523±8	371±6	Cowpea	696±15	Cowpea	1.91
Cowpea, S. P. I. 29282	5	569±6	413±5	Actual value 1915	767±8	Actual value 1916	1.70
Chickpea, S. P. I. 24322	1	638±18	491±14	All crops	778±22	All crops	1.57
Clover, crimson, S. P. I. 33742	2	630±18	490±14	do	805±8	Actual value 1913	1.57
Clover, red, S. P. I. 34869	1	759±9	584±7	do	926±11	All crops	1.32
Bean, navy	1	656±4	505±3	do	800±5	do	1.52
Bean, Mexican	1	743±8	572±6	do	906±10	do	1.35
Vetch, Black Bitter	1	562±12	433±9	do	686±15	do	1.78
Vetch, hairy, S. P. I. 34208	2	587±6	452±5	do	716±7	do	1.70
Bean, horse, S. P. I. 25045	1	742±11	571±8	do	905±13	do	1.35
Bean, horse, S. P. I. 15429	1	750±18	578±14	do	915±22	do	1.33
Vetch, purple, S. P. I. 18131	1	899±9	692±7	do	1097±11	do	1.11
Bean, soy, cultivated, S. P. I. 21755	1	646±9	497±7	do	788±11	do	1.55
Bean, soy, wild, S. P. I. 25138	1	784±24	604±18	do	956±20	do	1.28
Pea, Canada field, S. P. I. 30134	1	745±5	574±4	do	909±6	do	1.34
Pea, Canada field, S. P. I. 22637	1	748±7	576±5	do	913±9	do	1.34
Clover, sweet, S. P. I. 21216	2	731±7	563±5	do	892±9	do	1.37
Lupinus alpus, S. P. I. 35477	1	837±33	644±25	do	1021±40	do	1.19
Alfalfa (Hansen seed)	1	813±26	626±20	do	992±32	do	1.23
Alfalfa, Peruvian, S. P. I. 30203	1	626±12	482±9	do	764±15	do	1.60
Alfalfa, Grimm, A. D. I. 162–98–A	2	835±13	668±10	Alfalfa, series 1912–1917	1060±17	Alfalfa, series 1912–1917	1.20
Alfalfa, Grimm, A. D. I. E–23–20–52	3	831±11	665±9	do	1055±14	do	1.20
Alfalfa, Grimm, A. D. I. E–23	4	866±9	693±7	do	1100±11	do	1.15
Alfalfa, Grimm, A. D. I. 162–98	1	869±12	695±10	do	1103±15	do	1.15
Alfalfa, Grimm, A. D. I. 162–98–B	1	871±12	697±10	do	1106±15	do	1.15
Alfalfa, Grimm, A. D. I. E–5–30	1	897±11	718±9	do	1139±14	do	1.11
Alfalfa, Grimm, S. P. I. 25695	1	911±12	729±10	do	1157±15	do	1.10
Alfalfa, Grimm, A. D. I. H–4–60	1	920±8	736±6	do	1168±10	do	1.09

TABLE 35.—*Weighted mean water requirement based on dry matter, probable lowest and highest value, and units of dry matter produced for each 1,000 units of water consumed, based on the value of the weighted mean, for all plants grown at Akron, Colo., period 1911–1917, inclusive*—Continued

Plant	Number of years for which record was made	Weighted mean	Probable extremes of water requirement				Units of dry matter produced for every 1,000 units of water consumed [a]
			Lowest	Based on—	Highest	Based on—	
Flax:							
Damont, C. I. 3	1	624±13	480±10	All crops	761±16	All crops	1.60
Kashgar, S. P. I. 37719, C. I. 50-1	2	703±5	541±4	do	858±6	do	1.42
North Dakota Resistant No. 114, C. I. 13	1	752±13	579±10	do	917±16	do	1.33
Reserve, C. I. 19	2	835±18	643±14	do	1019±22	do	1.20
Soddo White, S. P. I. 37086, Abyssinia, C. I. 36	1	812±5	625±4	do	991±6	do	1.23
Smyrna, S. P. I. 36949 (Turkey), C. I. 30	1	861±21	663±16	do	1050±26	do	1.16
Jalaun, S. P. I. 36566 (India), C. I. 21	2	893±14	688±11	do	1089±17	do	1.12
Grasses:							
Wheat-grass, S. P. I. 19537	1	678±26	522±20	do	827±32	do	1.47
Brome-grass, S. P. I. 29880	1	977±25	752±19	do	1192±31	do	1.02

[a] The term "productivity of transpiration" has been used to express the water requirement and is applied to the units of dry matter produced for every 1,000 units of water consumed, and is the reciprocal of the water-requirement multiplied by 1,000. See MAKSIMOV, N. A. (MAXIMOW, N. A.) THE PHYSIOLOGICAL BASIS OF DROUGHT-RESISTANCE OF PLANTS. Trudy Prikl. Bot. i Selek. (Bul. Appl. Bot. and Plant Breeding) Sup. 26, 436 p., illus. 1926. [In Russian, English abstract, p. 393–407.]

[b] In 1911, S. P. I. 22420 was used.

THE PROBABLE ERROR OF THE WEIGHTED VALUES FOR WATER REQUIREMENT

The probable error expressed in these summary tables shows only the error due to experimentation or to the lack of uniformity of the six pots used in each set. Where several sets are averaged the probable error is also expressed for the average. In order to check these probable errors and to determine to what degree it is justifiable to weight the results, the whole series has been regarded as a single population and the value of each observation in the series has been raised or lowered by the proportionate amount. (See Table 36.) These weighted values have then been regarded as one population and their probable error estimated. The error of the weighted average includes only the experimental errors and does not take into account the variation of the weighted values during different years; while the error of the average of the weighted values includes in addition to the experimental errors the errors due to the weighting and the variations one year with another. A comparison of the errors of these averages shows that the error is not increased by including the errors due to the weighting of the values.

TABLE 36.—*Comparison of probable errors derived from weighted means of water-requirement measurements with probable errors derived from weighted individual determinations treated as a single population for crops grown at Akron, Colo., 1911–1917, inclusive*

Year	Alfalfa, weighted individual pots	Oats, Swedish Select, weighted individual pots	Oats, Burt, weighted individual pots	Barley, Hannchen, weighted individual pots	Wheat, Kubanka, weighted individual pots	Corn, Northwestern Dent, weighted individual pots	Millet, Kursk, weighted individual pots	Sorghum, Minnesota Amber, weighted individual pots
1911	1006	583	617	500	419 479 426	288	277	[a] 271
	1000	564	591	445	402	325	263	292
	1007	615	621	499	420	356	267	267
	879	562	582	484	372	356	270	293
	1024	576	566	491	446	379	264	270
	1073	549	606	538	464	360	266	276
					489			
					438			
					460			
Weighted mean	998±15	575±7	597±7	493±7	437±7	344±9	268±2	[a] 279±4
1912	905	520	544	573	440	429	240	284
	823	543	583	565	480	365	230	303
	790	523	566	553	491	358	228	295
	775	498	548	555	514	310	235	300
	784	544	570	545	523	316	228	303
	848	549	559	530	508	321	244	305
Weighted mean	821±14	520±6	561±4	554±4	493±9	350±13	234±3	299±3
1913	852							
	831							
	744							
	770	621	588		490	419	269	284
	838	631	592		478	350	275	298
	789	581	625		458	390	277	288
	783	568	590		493	434	269	289
	782	586	599		460	349	255	279
	820	573	563		483	361	303	284
	852							
	799							
	769							
Weighted mean	802±8	593±9	593±5		477±5	384±12	275±4	287±2
1914	897	570	604	462	483	372	277	288
	838	578	612	470	483	369	286	284
	861	578	605	493	520	352	279	268
	852	582	588	477	508	364	289	268
	846	567	571	478	488	349	283	269
	843	582	569	511	510	317	288	260
	856±6	576±2	591±6	482±5	498±6	354±6	284±2	273±3
Weighted mean								
1915	939	560	581	461	548	336	258	256
	891	538	582	492	547	273	261	286
	965	623	623	505	548	353	262	265
	857	638	579	578	506	322	255	270
	901	583	558	523	497	323	262	258
	866	551	547	588	506	366	275	249
	903±12	582±13	578±6	525±14	526±8	329±9	262±1	264±4
Weighted mean								
1916	848	752	652	580	570	380	309	253
	860	785	643	564	503	424	311	249
	832	746	665	537	466	393	302	244
	835	659	679	516	535	363	281	233
	880	721	678	539	548	430	307	235
	895	642	661	530	507	447	293	
	858±7	718±17	663±4	544±7	521±11	406±11	301±3	243±3
Weighted mean								
1917	802	639	682	527	504	340	307	261
	837	639	666	522	494	362	287	300
	881	672	658	559	490	357	279	286
	840	654	658	542	474	373	312	
	849	680	640	553	477	354	268	271
	874	641	630	535	472		304	284
	847±8	655±5	656±5	538±4	486±4	357±3	293±5	280±5
Weighted mean	861±6	604±7	606±4	523±4	485±4	361±4	274±2	275±2
Weighted average (all values regarded as a single population)	869±11	604±10	606±5	523±8	491±7	361±10	274±3	275±4
Average of weighted means								

[a] Red Amber, S. P. I. 17543.

SUMMARY OF WATER-REQUIREMENT MEASUREMENTS AT AKRON, COLO.

The results of the water-requirement measurements at Akron, Colo., from 1914 to 1917, inclusive, are here presented in detail. With these are summarized those previously published. Measurements totaled 288 sets of plants, or more than 1,800 pots, covering the period from 1911–1917, inclusive.

On the basis of the average year at Akron, Colo., it is possible to compare the widely different crops grown in this experiment with each other. The lowest values, based on total dry matter, were obtained for the millets, sorghums, and corns; the highest values for the native plants, flaxes, and legumes. The water-requirement range is very great, from 216 for Kursk millet to 1,131 for Franseria, a native weed. In other words, Franseria required five times as much water to produce a ton of dry matter as did Kursk millet.

If the water requirement of proso millet is taken as 1.00 the water-requirement values for the various crops in terms of proso would be: Millets 1.07, sorghum 1.14, corn 1.31, teosinte 1.40, sugar beet 1.41, weeds 1.66, emmer 1.94, barley 1.94, buckwheat 2.02, durum wheat 2.03, common wheat 2.09, crucifers 2.12, cotton 2.13, potato 2.15, native weeds 2.17, oats 2.18, rye 2.37, native plants 2.39, cucurbits 2.53, rice 2.55, legumes 2.81, flax 2.93, grasses 3.10. These are often large groups and there is great variation within the groups. In general terms, the millets, sorghums, and corns are most efficient. The small grains—barley, wheat, oats, and rye—required almost twice as much water, while the legumes required almost three times as much as the millets, sorghums, and corns. The lowest value obtained was for Kursk millet, S. P. I. 30029, 216, or on the basis of the comparison of groups given above a value of 0.81; the most efficient proso 258, or 0.97; the most efficient sorghum, Minnesota Amber, 274, or 1.03; the most efficient native weed, purslane, 281, or 1.05; the most efficient native plant, buffalo grass, 296, or 1.11; the most efficient corn, Esperanza, 299, or 1.12; the most efficient common wheat, Turkey, 455, or 1.70; the most efficient durum wheat, Beloturka, 483, or 1.81; the most efficient potato, Irish Cobbler, 499, or 1.87; the most efficient barley, Beardless, 506, or 1.90; the most efficient crucifer, cabbage, 518, or 1.94; the most efficient legume, guar, 523, or 1.96; the most efficient oats, Canadian, 529, or 1.98; the most efficient cucurbit, watermelon, 577, or 2.16; the most efficient flax, Damont, 624, or 2.34.

The most efficient plant is the introduced millet, Kursk, S. P. I. 30029, followed in order by Black Veronezh proso, C. I. 15; tumbleweed; Tambov proso; Kursk millet, S. P. I. 22420; Minnesota Amber sorghum; Kursk millet, S. P. I. 34771; German millet; purslane; brown kaoliang; Black Veronezh, S. D. 331, millet; Dakota Amber sorghum; Red Amber sorghum; Blackhull kafir; buffalo grass; and Esperanza corn, all of which have a water requirement under 300.

This list includes all prosos and sorgos and most of the millets, a few of the grain sorghums, and one each of native plants, native weeds, and corn. In other words, 16 of the 151 plants measured gave a water-requirement value based on dry matter below 300. Some of these belong to the group of plants showing most efficient use of water during hot, dry years, but others were relatively most efficient during the cool, damp years.

A list of the crops with water-requirement values ranging between 300 and 400 would include only the more inefficient millets, Siberian and Turkestan; three of the grain sorghums, White Durra, Milo, and Dwarf Milo; all of the corns except the most efficient, Esperanza; and sugar beet, pigweed, Russian thistle, and grama grass.

Crops with water-requirement values between 400 and 500 include only three of the most efficient durum wheats, Beloturka, Kubanka C. I. 1440, and Jumillo; the common wheats, Turkey and Kharkof; Irish Cobbler potato; cocklebur and nightshade among the weeds; and clammy weed, a native plant.

Crops with a water requirement between 500 and 600 include all the barleys; buckwheat; the three least efficient durum wheats, C. I. 4131 from Siberia, C. I. 4082 from Peru, and Kubanka C. I. 2094; most of the spring common wheats such as Ghirka, Power, Marvel Bluestem, Preston, Glyndon, Marquis, Prelude, Galgalos, Pioneer, and C. I. 4090 from Turkestan, and two wheat hybrids; two crucifers, cabbage and rape; cotton; three oat varieties, Canadian, Sixty-Day, and Swedish Select. Among the native weeds, buffalo bur, the annual sunflower, and one planting of narrow-leaved sunflowers from the sand hills, Iva, and gum weed; two cucurbits, watermelon and cantaloupe; four legumes, guar, cowpea, black bitter and hairy vetch.

The plants having water requirement values between 600 and 700 include two weeds, lamb's-quarters and polygonum; three common wheats, Haynes, Pacific Bluestem, and C. I. 4087; turnip; McCormick potato; Burt oats; mountain sage; rye; cucumber; rice; the legumes, chickpea, crimson clover, navy bean, and soy bean; the most efficient flax, Damont; and wheat grass.

The narrow-leaved sunflower and verbena, both native weeds; the Hubbard squash; the legumes, horsebean, Mexican bean, wild soy bean, Canada field pea, and sweet clover; the Kashgar and North Dakota Resistant flaxes are among the plants whose water requirement values range from 700 to 800.

Only a few plants have a water requirement as high as 800 to 900. They include a fall wheat, C. I. 4127, grown in the spring; fetid marigold, pumpkin, purple vetch, and all the alfalfas except two of the least efficient Grimms; and Reserve, Soddo White, Smyrna, and Jalaun flaxes.

Two varieties of Grimm alfalfa, S. P. I. 25695, and A. D. I. H–4–60, have a water requirement between 900 and 1,000. Within this range also are found brome grass and western ragweed. Western wheat grass exceeds 1,000, and *Franseria*, a weed, 1,100 in water requirement.

On the basis of unit production per 1,000 units of water required, values for the different crops range from 0.88 for Franseria to 4.64 for Kursk millet. The millets, sorghum, and the best of the corns, weeds, and native plants produce over 3 units of dry matter per 1,000 units of water; the corns, sugarbeet, the most efficient wheats, and some of the native weeds, and native plants produce 2 units of dry matter per 1,000 units of water; while the great majority of plants produce more than 1 but less than 2 units of dry matter per 1,000 units of water consumed.

The range in water requirement during different years at Akron is very great, the lowest values averaging about 60 per cent of the

highest. The greatest range is for oats, for which crop the lowest value is only 48 per cent of the highest value; while the lowest range is for sorghum, for which the lowest value is 80 per cent of the highest.

If the crops are so arranged that those having relatively the lowest water requirement during the cool, damp years are placed at the plus end of the scale and those having the lowest relative water requirement during the hot, dry years at the minus end of the scale, the values (+) or (−) being the difference of departures from the mean of all crops for the cool, damp year and the hot, dry year, they will rank as follows: Swedish Select oats +22, Northwestern Dent corn +21, cowpea +16, Burt oats +13, Kursk millet +13, Vern rye +7, Hannchen barley +5, Sudan grass +1, Kubanka wheat 0, alfalfa −5, pigweed −7, Minnesota Amber sorghum −10, Triumph cotton −13, Galgalos wheat −16, grama grass −38. The mean of all crops included is 0 and Kubanka wheat falls on this mean. If evaporation is treated as a crop its value is −4. If the plant is used as a potometer and the value is expressed as the water requirement, the value applies only to the particular plant used. If the water requirement obtained for a plant like oats were applied to a plant like grama grass to get the measure of seasonal difference in 1915 and 1916, granting that 1915 were known, the resulting error would have raised the value in 1916 from its proper figure of say 100, to 183. On the basis of evaporation from a water surface this error would have raised the value of grama grass for 1916 from 100 to 132. Based on the results of this study which cover only about 23 plants, the evaporation data falls near the mean for all plants and therefore probably represent a safer value for comparing year with year than the water requirement of a plant chosen at random. To apply the results obtained from any evaporation system or from any plant to another evaporation system or plant would almost surely lead to error.

If both water requirement and total production of dry matter of plants are measured during a dry, hot year and a cool, damp year their relative efficiency in use of water and production of dry matter may be easily shown. The values of combined units of departure from the mean of crops grown at Akron from 1914–1917, in terms of Akron climate, are as follows: Swedish Select oats, +88; barley, +57; Burt oats, +55; rye, +46; Kubanka wheat, +34; millet, +9; Galgalos wheat, +9; alfalfa, −1; pigweed, −15; cowpea, −18; Sudan grass, −27; sorghum, −46; corn, −48; grama grass, −55, and cotton, −73. The plus values indicate efficient use of water and production of dry matter during cool, damp years and inefficient use of water and production of dry matter during hot, dry years. The minus values show relative high production of dry matter and efficient use of water during dry, hot years and low production and inefficient use of water during damp, cool years.

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