PHYSIOLOGICAL AND ANATOMICAL FEATURES OF VARIABLE DROUTH RESISTANT VARIETIES OF SPRING WHEAT

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INTRODUCTION

The problem of drouth resistance in field crops has become of increasing importance during the past few years when the rainfall has been far below normal. Lack of drouth resistance in wheat is undoubtedly one of the major factors limiting production in the United States. The use of yield trials as an index for drouth resistance has not proven entirely satisfactory under dry conditions, because early varieties may have high grain yields, but are drouth escaping rather than drouth resistant. Earliness is not generally a desirable characteristic in wheat, since early varieties are apt to be injured by late spring frosts. The ability of wheat to resist drouth is largely determined by the ability of the plant to obtain and conserve moisture under dry conditions. It is the object of this paper to make a partial study of the two factors, water absorption and water conservation.

Drouth resistance, according to Maximov (1929-B) is the "capacity of plants to endure drouth and to recover readily after permanent wilting, with the minimum damage to the plant itself and to the yield produced." Briggs and Shantz (1912) stated that permanent wilting in plants is a condition of moisture reduction, after which the plants will not recover when placed in a water saturated atmosphere. They will, however, slowly recover following the addition of water to the soil. Permanent wilting reduces the leaf moisture from 30 to 40 percent of the original amount, and is harmful to plants (Maximov 1929-B), especially to the embryonic tissues of the stem and to the root hairs.

The materials, methods, and interpretation of the physiological results are widely different than those for the anatomical results. Because of this, each will be discussed separately.

DISTRIBUTION OF VARIETIES

From four to eight varieties of spring wheat which varied in their resistance to drouth were studied in these experiments. These varieties were Kubanka, Baart, Onas, Ceres, Marquis, Huston, Hope x Ceres and Hope.

Kubanka is a durum wheat (*Triticum durum*) noted for its high resistance to dry conditions. On the average, it has been the leading variety of durum in the durum wheat section, as well as in the entire United States. Baart and Onas are white spring wheats which have been high in grain yield at Lind, Washington, and Tetonia, Idaho, and at many other locations where the yearly precipitation is below fifteen inches. According to Clark (1936), Baart is the most drouth resistant wheat grown in the United States. Ceres, Marquis, Hope and Hope x Ceres (C.I.11432)[1]. are all hard red spring varieties. The first of these varieties (Ceres) was distributed to farmers in 1925, and by 1934 it comprised 32 percent of the total hard red spring acreage, while Marquis decreased from 85 percent of the acreage in 1924 to 60 percent in 1934. The higher drouth resistance of Ceres is the main reason that its acreage increased and Marquis, a semi-drouth resistant variety, decreased for the same area. Hope x Ceres and Hope are not grown extensively, even though they are nearly immune to stem rust. In 1934, Hope comprised only 0.1 percent of all the hard red spring wheat in the United States, and Hope x Ceres

1. Accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

was not even listed. The reason is that both are extremely susceptible to dry conditions. Huston is a soft red spring variety, grown only in the cool, humid Willamette valley in Oregon.

REVIEW OF LITERATURE

In the following pages, an attempt was made to review all the literature on the principal methods used in determining drouth resistance and also to review briefly the plant responses under conditions of drouth and normal soil moisture.

YIELD TRIALS

Waldron (1931) studied the drouth resistance of Ceres, Marquis and Hope in 25 trials under generally dry, rust free conditions in Montana and in western North Dakota and South Dakota. The average yields of Ceres, Marquis and Hope were 16.3, 14.1 and 12.7 bushels per acre respectively. Two years later, Waldron (1933) found Hope and its sibs to be very susceptible to dry hot weather. Ceres was highly resistant to these conditions, while Marquis was intermediate in resistance.

DRYING CHAMBERS

Drying chambers can be easily moved and adjusted to different climatic conditions. Shirley (1934) described a controlled chamber used in determining the resistance of pine seedlings to drouth such as occurs in the northern Great Plains forests. Aamodt and Johnston (1936) reported that drouth resistant varieties had less leaf injury due to atmospheric drouth than Marquis, in the chamber devised by Aamodt (1935). Hunter, Laude and Brunson (1936) found a close relation between field reaction of corn in Kansas and the behavior in their drying chambers. A close relationship was found by Bayles, Taylor and Bartel (1937) between the amount of leaf injury caused by a current of hot air to eight varieties of spring wheat and their resistance to drouth.

WATER LOSS FROM CUT PLANTS

The rate of drying of cut drouth resistant plants was found by Martin (1930) and Bayles, Taylor and Bartel (1937) to be less than that of drouth susceptible plants. Similar results were found by Martin between drouth resistant sorghum and drouth susceptible corn leaves. On the other hand, Newton and Martin (1930) reported that timothy and Western rye grass had about the same rate of water loss, even though the latter is the more drouth resistant.

ROOT SYSTEMS

Miller (1916) observed that sorghums had twice as many secondary roots as corn. The sorghum roots were also more fibrous than corn roots. Hubbard (1938) found that under dry conditions Ceres generally had a larger number of roots, more root hairs, and a higher weight of roots than Marquis or Hope. Webb and Stephens (1936) reported that, when sown at the same depth, Marquis had a slightly deeper crown and shorter subcrown internode than Baart or Onas. No significant differences were found by Haber (1938) between the root systems of drouth resistant and susceptible lines of sweet corn.

LEAF MOISTURE

The leaf moisture of corn was higher than the drouth resistant kafir or milo (Miller 1917), kafir being higher than milo. No relationships were found by Flevov, Brokert and Levin (1930) between the water content of spring wheat varieties and their drouth resistance. According to Schopmeyer (1939), the drouth resistant shortleaf pine had a higher leaf moisture than the less resistant loblolly pine, even when the soil moisture was at the wilting point.

TRANSPIRATION

Knight (1917) stated that a water deficiency did not vary the stomatal aperture, and that the stomata did not function to maintain the water constant in the leaf. After studying 40 to 50 species in Colorado, Pool (1923) concluded that little relationship existed between transpiration power and relative xerophytism. It was shown by Miller and Coffman (1918) that the transpiration per unit leaf area of corn was always lower than all of the sorghums except the kafirs. They stated that the smaller leaf area of the sorghums was one reason for the lower water loss per plant than corn. Shortleaf pine had a higher transpiration rate than loblolly pine and was therefore less able to conserve moisture (Schopmeyer 1939). Lee and Priestley (1924) reported that only a very small amount of water vapor is lost through the cuticle, and the amount decreases as the cuticle becomes thicker and older. On the other hand, Mes and Ainslie (1935) showed that the cuticular transpiration of Themeda triandra Forsk was one-half to two-thirds of the total transpiration. In this connection, Maximov (1930-1) found that, with an increase in xerophytic conditions, stomatal transpiration will increase while cuticular transpiration will decrease.

CARBOHYDRATE RELATIONSHIPS

Sorghums had a higher amount of dry matter, reducing sugars, non-reducing sugars, and starch than corn (Miller 1924), and also had the highest increase in dry matter during a day. As the intensity of drouth increases, there will be, first, a sucrose accumulation, second, a hydrolysis of sucrose to monosacchrides, and finally, as complete desiccation occurs, there will be a disappearance of both sucrose and monosacchrides (Vasiliev 1931). These sugars aid in protecting the plant against desiccation. Lvoff and Fichtenholz (1936) observed that drouth resistant plants possessed a greater power of hydrolysis of starch to monosacchrides than did susceptible plants. According to Clements (1937-A), the acid-hydrolyzable portion of the soybean (drouth resistant) leaf carbohydrates increased markedly during drouth. The cells and protoplasm of the leaves and stems had large amounts of hemicelluloses. The hemicelluloses were less abundant in the sunflower (semi-drouth resistant) than in the soybean (Clements 1937-B). In the leaves of the potato (drouth susceptible), the hemicelluloses were higher in a year of normal moisture than during a dry one. Under dry conditions, a decrease in hemicelluloses was found to accompany an increase in sugars in drouth resistant plants (Vassiliev and Vassiliev 1936). Inasmuch as starch is present in small amounts in the vegetative organs, they suggest that the hemicelluloses may take the place of starch in storage and hydrolysis. In working with Opuntia sp., Spoehr (1917) found that, under very dry conditions, a marked increase in total pentosans occurs. No changes were noted in the total hexose sugars. According to Sayre, Morris and Richey (1931), an increase in total sugars of the corn stem resulted when the plants were subjected to natural drouth conditions, this increase being entirely accounted for by an increase in sucrose. Loomis (1937) reported that in drouth injured corn stalks, the increase in carbohydrates was equally distributed between sucrose and dextrin. No increases occurred in the carbohydrates of the leaves of these plants.

NITROGEN RELATIONSHIPS

Late in the growing season, the different nitrogen factions of the soybean, sunflower and potato were much higher during the dry than during the normal year (Clements 1937 A and B). This was true in each of the crops, even though growth was less in the dry year. This was especially true with the amino acids and nitrates. An increase in nitrogenous compounds, especially nitrates, soluble organic and protein, occurred in drouth injured corn stalks (Loomis 1937), but did not occur in the leaves of such plants.

BOUND WATER

After making many physico-chemical determinations of wheats and grasses in Canada, Newton and Martin (1930) concluded that bound water is the most practical measure of drouth resistance. Using the same method as the above authors, Martin, Harris and Jones (1931) found some indications of bound water only in the internode juices of sorghums when the plants were nearly mature. Novikov (1931) reported that drouth resistant wheat varieties had a greater increase in water-retaining power (bound water) than susceptible varieties as the soil moisture decreased. The osmotic substances have a greater role in determining the water-retaining power of wild plants (Lebedincev 1930) in their native habitat (in relation to drouth resistance) than have colloids. Calvert (1935) found significant differences in the bound water only between the most resistant and most susceptible varieties when the soil moisture was definitely low. According to Schopmeyer (1939), the greater drouth resistance of shortleaf pine over loblolly pine cannot be accounted for by differences in the bound water.

OSMOTIC PRESSURE

It was found by Korstian (1924) that moisture has a greater influence on the osmotic pressure than either light or temperature. Meyer (1927) concluded that the osmotic pressure could not be safely used in central Ohio to differentiate between habitats. On the other hand, Maximov (1929-B) reported that a high osmotic pressure is generally characteristic of xerophytes. The osmotic pressure of sorghum roots and stalks was much higher than in corn (Martin 1930), but the reverse was true in the case of the leaves. Newton and Martin (1930) reported that generally a higher osmotic pressure was found in the drouth resistant wheats and grasses than in those not resistant. However, they did not consider the osmotic pressure to have the major role in determining drouth resistance.

Similar conclusions were formed by Schopmeyer (1939),who found that the drouth resistant shortleaf pine have a lower osmotic pressure in the leaves than the non-resistant loblolly pine. In the lowland prairie, where the soil moisture was abundant, Marsh (1940) found no correlation between leaf moisture and osmotic pressure. However, under dry conditions in the upland prairie, comparable plants had a low leaf moisture and high osmotic pressure.

ANATOMICAL DIFFERENCES

A xerophytic leaf, according to Maximov (1930-1) and Pool (1923), has (1) a decrease in cell size, (2) a decrease in intercellular spaces, (3) more stomata per unit leaf area, (4) a heavy, thick cuticle on the epidermis, and (5) is relatively thick. In this connection, Pool (1923) found no relationship between leaf anatomy and transpiration power. Vasiliev (1929) observed that cell size and length of stomata in wheat varieties were not related to their drouth resistance. Many investigations have found sorghums to be more drouth resistant than corn. Miller (1924) noted that the mesophyll cells of sorghums were smaller, more compact and more numerous than in corn. The anatomy of these two crops was worked out more in detail by Martin (1930). He found no difference in the thickness of the cell walls. Sorghum leaves had larger groups of motor (hygroscopic) cells, and one large row on each side of the midrib which caused the leaves to fold when rolling was incomplete. The epidermis of sorghum was more highly cutinized, and the leaves and sheaths had a heavier bloom. All of these factors serve to reduce evaporation in the sorghums. When _Zinnia_ was grown under dry conditions, smaller, more compact cells, fewer air spaces, and thicker upper epidermis were found than when grown under moist conditions (Grant 1939). No significant differences were found by Haber (1938).between (1) number of stomata in the leaves of resistant and susceptibles lines of sweet corn and (2) number of vascular bundles per square millimeter of stem, even under severe drouth conditions. Clements (1937-A) noted that the drouth resistant soybean stem and leaves had cells that were thickened with lyophilic hemicelluloses.

MISCELLANEOUS

Timofeeva (1933) soaked partially germinated wheat seeds in a two M. sugar solution for 6 days, after which time the seeds were washed and planted in clean sand. A higher percentage of the seeds of drouth resistant varieties survived and later produced plants than of susceptible varieties.

Alternate swelling and drying of the same wheat seeds caused an increase in their drouth resistance, according to Henchel and Kolotova (1934). It was found that repeating this three times gave the best results.

ADVANTAGES OF LOCATING NORMAL AND DROUTH CONDITIONS IN ADJACENT BORDERS

In the following pages, emphasis will be placed on the increase in osmotic pressure and percentage of solids due to drouth. It should be emphasized that the plants that were in the normal and drouth borders grew in soil of the same nutrient concentration and texture, and were subjected to the same precipitation, temperature, intensity of sunlight, evaporation, length of day, and wind movement. The only causal factor which varie~~s~~d between the two borders was soil moisture.

Therefore, any difference in the osmotic pressure, percentage of solids and percentage of leaf moisture between the normal and drouth borders can be attributed directly or indirectly to the difference in soil moisture.

During the growing seasons, some leaching of nitrates may have occurred, due to the application of irrigation water.

CLIMATIC CONDITIONS

The total monthly precipitations and mean monthly temperatures from January to May for each of the years during which experiments were conducted are shown in table 1.

The precipitation for 1934 was generally the lowest for any of the years. The rainfall for 1935, on the other hand, was easily the highest, especially during February and March. There were very little differences between the monthly precipitation for 1936 and 1938. In 1939, the rainfall for January was the lowest for any five years, but during February and March it had high totals, being exceeded only by that of 1935.

There were no large differences in the mean monthly temperatures for the different years. The temperature for February 1939 was much lower than it was during any of the other years.

TABLE 1: Monthly precipitation and mean monthly temperatures from January to May in 1934, 1935, 1936, 1938 and 1939, University of Arizona, Tucson, Arizona.

Year	January	February	March	April	May	Total
			PRECIPITATION			
1934	.50	.30	.39	.03	.05	1.27
1935	1.25	2.43	1.46	T	.14	5.28
1936	.96	.92	.55	.07	T	2.50
1938	.65	.88	.43	.08	.11	2.15
1939	.35	1.60	.69	.04	.00	2.68
			MEAN MONTHLY TEMPERATURE			
1934	49.3	56.4	63.9	68.6	78.4	63.3
1935	52.1	55.0	55.0	64.7	67.6	58.9
1936	48.8	53.2	59.0	66.9	75.3	60.6
1938	52.4	54.2	57.6	65.3	71.3	60.2
1939	50.4	45.5	59.2	67.2	74.0	59.3

PHYSIOLOGICAL INVESTIGATIONS

MATERIALS AND METHODS

Methods of collection and dates of planting and irrigation

A number of physiological and anatomical determinations were made on the various varieties in both the normal and drouth borders. The physiological determinations comprised the osmotic pressure, percentage of solids, percentage of leaf moisture and the percentage of soil moisture. These data were obtained on the same varieties grown in the normal and drouth borders.

In the early stages, when one or two leaves were fully extended, the samples for the above determinations were obtained by cutting off the entire plant as close to the ground as possible. As soon as three or more leaves had become fully extended, the three top leaves were collected. When the plants in the drouth border neared maturity, the third leaf from the top would be the first to dry up, and later the second from the top would dry. During these times, the top and also the top two leaves were used for the determinations.

With the exception of 1934, the collection of samples was generally made every four days. This collection was started at approximately 1:30 p. m, which time was chosen because (1) it has been found by Hawkins (1927) that the variations in the percentage of moisture of cotton leaves was less during the two hour period from 1:30 to 3:30 p. m. than at any other two hour period during the day; (2) the greatest water deficit existed at this time; and (3) the effect of dew or light precipitation would have diminished by 1:30 p. m. Immediately after the samples were collected in the field they were brought into the agronomy laboratory, where they were treated according to the method outlined by Mallery (1934).

A Fred S. Carver hydraulic laboratory press was used in pressing out the cell sap from the heated leaf samples. The pressure was gradually brought up to ten thousand pounds per square inch, held there for one minute, and then gradually released. A portion of each sample was used for osmotic pressure determinations and the remainder for percentage of solids.

The plantings were made at the new University Farm. The soil on which these tests were conducted is classified as Gila Loam, dark colored phase, and has a moisture equivalent of 23.5 percent. The experiments were carried on in 1934, 1935, 1936 and 1938. The dates of seeding for each of the years were as follows: December 10, 1933, February 18, 1935, January 22, 1936 and January 26, 1938. The plantings were made on two adjacent borders, one of which was given normal irrigations after planting, which will be referred to as the normal border. The other, which received no irrigation water after planting, will be referred to as the drouth border.

The dates of irrigation in the normal border were as follows: January 15, March 10, April 5, April 26 and May 10, 1934; March 30, April 10, April 25 and May 7, 1935; March 26, April 15 and May 9, 1936; and

March 23, April 7 and April 25, 1938.

Osmotic pressure

The osmotic pressure was calculated from the depression of the freezing point below that of distilled water. The freezing point of the sap was determined with a Drucker-Burian microthermometer. The freezing of the cell sap was done in a regular ice cream freezing cabinet in which the temperature was kept at -12° C.

A quantity of sap sufficient to cover the mercury bulb of the thermometer when it was inserted was poured into the vial used in this method. The sap was allowed to cool in the freezing chamber until the mercury was out of the top air chamber. At this time, the sap was rapidly agitated with a small stirrer placed beside the thermometer in the vial. The stirring was continued until the mercury went down to a temperature approximately one degree below the actual freezing point of the sap. A very small crystal of ice was then introduced into the sap with a fine wire rod and the sap was stirred until it reached a constant temperature. This was read to a 0.01° C. accuracy, with the aid of a small lens. By limiting the under cooling to one degree, the Drucker-Burian thermometer scale was sufficiently accurate for these readings.

The formula of Harris and Gortner (1914) was used for determining the corrected freezing point. This formula was: $\Delta = \Delta^1 - 0.0125U\Delta^2$, where Δ is the corrected or true freezing point depression, Δ^1 is the observed freezing point depression, 0.0125 the grams of water which separate from each gram of sap for each degree of undercooling, and

U the degrees of undercooling. After the true freezing point depression was obtained, this was then converted into atmospheres pressure by the use of the following formula devised by Lewis (1908): $P = 12.06\Delta$ $0.021\Delta^2$, where P is the osmotic pressure in atmospheres. The table of Harris and Gortner (1914) was used for obtaining the osmotic pressure from the true freezing point depressions (Δ).

Percentage of solids

The percentage of solids in the cell sap was determined by the use of an Abbe refractometer. The portion of the sap used for this determination was allowed to stand at room temperature for approximately one-half minute to clear it of foam. The presence of foam in the sap would cause the line in the telescope to be very irregular, both as to colors and shadows. The percentage of solids was calculated from the refractive index tables furnished by Sayre (1932). All the calculations were corrected to the temperature of 20° C.

Percentage of leaf moisture

No percentages of leaf moisture were obtained in 1934 because the determinations made that year were intended to be preliminary, for working out the technique for osmotic pressure and percentage of solids. In 1935 and 1936, the percentage of leaf moisture was obtained on all eight varieties in both the normal and drouth borders. During both of these years, the percentage of bound water in the leaves of the varieties was determined. In this method, the percentage of leaf moisture is one of the essential figures before calculations can be made. The bound water determinations are not reported in this paper because of the high variations between the different replications of the same variety, but the data as to the percentage of water in the leaves are used. This latter determination was made by collecting from two to four grams of the second leaves from the top of the plant and drying them to a constant weight in an oven at 100° C. In 1938, from five to ten grams of second leaves from the top were obtained from the four varieties grown and dried at a temperature of 80° C. The samples for the determination of leaf moisture were obtained on the same dates and time in 1935, 1936 and 1938 as those samples for the cell sap determinations.

Percentage of soil moisture

Soil samples were taken to a depth of four feet in both the normal and drouth borders during 1935, 1936 and 1938. A minimum of three different representative holes was made at each sampling with a regular soil auger in the normal and drouth borders. The samples were then taken to the laboratory and immediately weighed. After reaching constant weight in an oven at 100° C. the soil was again weighed and the percentage of soil moisture determined on the dry weight basis.

EXPERIMENTAL DATA

Osmotic pressure in the normal and drouth borders

It has been mentioned that the experiments in 1934 were preliminary in nature. The object was to learn the proper technique in making the determinations and to have some data so that the most representative varieties could be continued. Two drouth resistant varieties, Baart and Ceres, had the highest and lowest average osmotic pressures of the varieties grown in the normal border (table 2). The averages for Hope and Hope x Ceres were higher than those of the drouth resistant varieties, Onas and Kubanka. In other words, no relation existed between the osmotic pressure of the varieties and their resistance to drouth.

The variations in the osmotic pressure of 4 representative varieties, Baart, Ceres, Marquis and Hope, when grown in the normal border in 1935, 1936 and 1938, are shown in Fig. 1.[1] In 1935 and 1938, no consistent differences were found between the osmotic pressures of any of the varieties. However, in 1936 the osmotic pressure of Baart was generally slightly higher, and Hope slightly lower, than those of Ceres and Marquis.

As a general rule, the osmotic pressure decreased in the collections made immediately following the irrigations. This was especially true with the collections made after the irrigations of April 25 and May 7, 1935, and after each of the 3 irrigations applied in 1938. Baart decreased slightly over 4 atm. after the April 7, 1938 irrigation.

1. The individual determinations for all of the data obtained for Figures 1, 2 and 3 will be found in tables 17 to 25 at the back of the thesis.

TABLE 2: Osmotic pressures of varieties grown in normal and drouth borders, 1934.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Hope	Hope x Ceres	Average
				NORMAL BORDER				
April 12	16.37	14.84	15.82	15.82	17.03	16.01	16.37	16.04
" 19	17.54	15.84	16.25	15.40	17.16	16.85	16.88	16.56
" 29	19.56	16.98	14.96	15.30	16.73	16.20	14.99	16.39
Average	17.82	15.89	15.68	15.51	16.97	16.35	16.08	
				DROUTH BORDER				
April 12	21.57	20.92	19.32	21.06	19.61	19.96	20.32	20.39
" 19	25.03	21.89	20.55	20.75	19.78	20.34	20.25	21.23
" 29	35.09	27.50	26.85	23.28	23.87	22.86	21.04	25.78
Average	27.23	23.44	22.24	21.70	21.09	21.05	20.54	

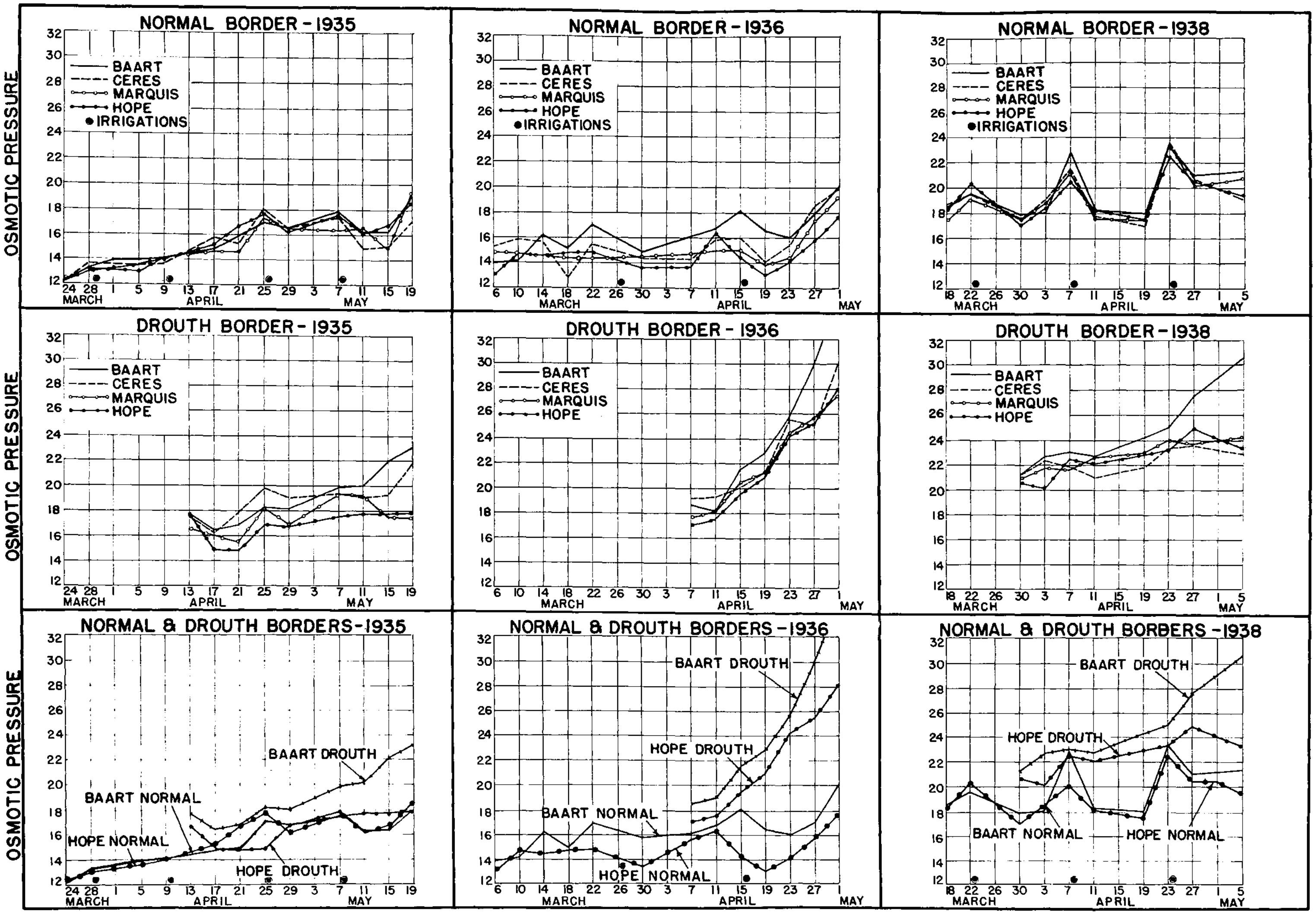

Fig. 1: Osmotic pressure of four representative varieties in normal and drouth borders in 1935, 1936 and 1938.

Much closer correlations were found in the drouth than in the normal borders between the osmotic pressures of the 4 varieties and their resistance to drouth. A very close relationship existed in 1934 between the average osmotic pressure of the varieties and their drouth resistance (table 2). The average osmotic pressure of the 4 drouth resistant varieties was 12 percent higher than in Marquis and 14 percent higher than in Hope and Hope x Ceres (drouth susceptible). It will be seen in Fig. 1 that under drouth conditions, Baart had the highest osmotic pressure during each of the 3 years, and also showed the greatest increases as the drouth conditions became more severe. In 1935, the osmotic pressure of Ceres was generally above that of Marquis and Hope, there being but little difference in the variations between the latter two varieties. However, the reverse existed in 1938, when the osmotic pressure of Ceres was generally lower than that of Marquis and Hope. There were no consistent differences between the osmotic pressures of Marquis and Hope in 1938, nor between Ceres, Marquis and Hope in 1936.

There is also seen toward the bottom of Fig. 1 the variations in the osmotic pressure of Baart and Hope when grown in the normal and drouth borders. These have, of course, the same figures as in the above charts, but since the two varieties show the extremes in drouth resistance and susceptibility, it was believed a better idea of the osmotic pressure changes could be obtained if all the data were in one chart.

Under drouth conditions, every collection of Baart for the 3 years had a higher osmotic pressure than Hope, these differences becoming greater as the drouth conditions became more severe. In 1935, there were but slight differences in the osmotic pressure of Hope when grown in the drouth border, and Baart and Hope when grown in the normal border. On the other hand, in 1936 there were greater differences between the osmotic pressure of Baart and Hope when grown in the normal than when grown in the drouth borders, even though the varieties had much the highest osmotic pressures in the drouth border. In 1938, Baart and Hope had nearly the same variations in osmotic pressure in the normal border. However, under drouth conditions, every collection of Baart had a higher osmotic pressure than Hope, with the greatest differences occurring at the last few collections.

Differences in the osmotic pressure between the normal and drouth borders

A very close relationship existed in 1934 in the differences in the osmotic pressure between the normal and drouth borders and the drouth resistance of the varieties (table 3). In the collections made on April 19 and April 29, these differences in Baart were over twice as high as in Hope. The average difference of Marquis (intermediate in resistance) was lowest of the 8 varieties. This was the only major case where the averages did not line up with their drouth resistance.

In 1935, the 4 drouth resistant varieties, Baart, Onas, Kubanka and Ceres, had the highest average differences in the osmotic pressure between the normal and drouth borders. The averages of Baart, Onas and Ceres

TABLE 3: Differences in the osmotic pressure between the varieties in normal and drouth borders.
(A - indicates normal higher than drouth.)

Date	Baart	Onas	Ku-banka	Ceres	Mar-quis	Huston	Hope	Hope x Ceres	Aver-age
					1934				
April 12	5.20	6.08	3.50	5.24	2.58	--	3.95	3.95	4.36
" 19	7.49	6.05	4.30	5.35	2.62	--	3.49	3.37	4.67
" 29	15.53	10.52	11.89	7.98	7.14	--	6.66	6.05	9.40
Average	9.41	7.55	6.56	6.19	4.11	--	4.70	4.46	
					1935				
April 17	1.56	2.28	2.16	0.36	1.32	1.50	-0.42	--	1.25
" 21	1.92	1.74	3.06	2.58	0.84	0.60	-2.04	--	1.24
" 25	1.26	2.34	2.70	1.86	0.72	0.72	-0.84	1.08	1.23
" 29	1.56	2.46	3.66	2.46	0.54	1.26	0.48	3.60	2.00
May 7	1.92	1.99	2.80	1.74	0.48	0.60	-0.16	0.54	1.24
" 11	3.85	4.92	4.62	4.08	2.64	3.66	1.62	4.38	3.72
" 15	5.70	2.76	6.90	4.32	2.58	0.60	0.96	3.90	3.47
" 19	3.96	4.14	3.36	4.80	-2.10	-1.20	-0.90	4.32	2.05
Average	2.72	2.83	3.66	2.78	0.88	0.97	-0.16	2.97	
					1936				
April 7	2.58	3.48	1.80	3.24	2.88	2.52	3.44	3.96	2.99
" 11	1.44	2.88	1.86	1.20	3.18	2.88	1.14	3.96	2.32
" 15	3.36	3.24	4.20	3.72	5.46	4.08	5.22	5.04	4.29
" 19	6.36	6.06	6.12	7.26	7.44	7.08	7.80	7.26	6.92
" 23	9.78	9.18	7.80	10.20	10.20	8.82	10.20	7.92	9.26
" 27	12.10	9.29	6.60	6.47	8.39	7.80	9.77	8.22	8.58
May 1	15.67	8.44	7.49	10.30	8.27	8.57	10.43	5.52	9.34
Average	7.33	6.08	5.12	6.06	6.55	5.96	6.86	5.98	
					1938				
March 30	3.24	--	--	3.72	3.30	--	3.60	--	3.47
April 3	4.52	--	--	3.23	3.06	--	1.66	--	3.12
" 7	0.15	--	--	0.28	0.44	--	1.97	--	0.71
" 11	4.34	--	--	3.32	5.08	--	3.88	--	4.16
" 19	6.24	--	--	4.96	5.46	--	5.32	--	5.50
" 23	1.70	--	--	0.84	0.40	--	0.73	--	0.92
" 27	6.63	--	--	3.04	3.60	--	4.48	--	4.44
May 5	9.30	--	--	3.84	3.47	--	3.92	--	5.13
Average	4.52	--	--	2.90	3.10	--	3.20	--	

showed only slight differences. It is of interest to note that the 4 drouth resistant varieties had differences from three to four times those of Marquis or Huston. The differences in the drouth resistant varieties increased as the drouth conditions became more severe. This did not occur in the varieties intermediate and susceptible to drouth. The above data are shown in table 3.

The differences in the osmotic pressure between the varieties in the normal and drouth borders were much higher in 1936 than in 1935. However, there were absolutely no differences in 1936 that were related to the drouth resistance of the varieties. Baart and Hope had the two highest average differences, while Huston and Kubanka had the lowest average differences (table 3).

Although Baart easily had the greatest differences in the osmotic pressure between the normal and drouth borders in 1938, the remaining 3 varieties had average differences in the reverse order to their drouth resistance (table 3). The average difference for Baart was 41 percent higher than Hope and 56 percent higher than Ceres.

<u>Percentage of solids in the normal and drouth borders</u>

Two drouth resistant varieties, Baart and Kubanka, had the highest and lowest average percentage of solids of the varieties when grown in the normal border in 1934 (table 4). The averages for Hope and Hope x Ceres were slightly lower than the average of the other varieties. When the varieties were grown in the drouth border, the average percentage of solids of the varieties lined up in about the

TABLE 4: Percentages of solids of varieties grown in normal and drouth borders, 1934.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Hope	Hope x Ceres	Average
				NORMAL BORDER				
April 12	11.43	10.68	11.20	11.19	11.61	11.28	11.49	11.27
" 19	12.36	10.85	10.19	10.65	11.57	10.84	11.02	11.07
" 29	12.63	13.17	10.98	11.18	11.46	10.68	9.90	11.43
Average	12.14	11.57	10.79	11.01	11.55	10.93	10.80	
				DROUTH BORDER				
April 12	14.16	13.56	12.69	13.67	12.95	12.56	12.62	13.17
" 19	15.76	14.42	13.12	12.91	12.25	11.63	12.30	13.20
" 29	19.06	17.90	16.74	14.85	15.22	13.78	12.21	15.68
Average	16.33	15.29	14.18	13.81	13.47	12.66	12.38	

same order as their drouth resistance. The average for the 4 drouth resistant varieties was 14.90 percent and 12.52 percent for Hope and Hope x Ceres.

The percentage of solids of 4 representative varieties grown in the normal borders in 1935, 1936 and 1938 are shown in Fig. 2. With the possible exception of Hope in 1936, which usually had the lowest determinations during the season, there was no relationship between the percentage of solids of the varieties during the 3 years and their resistance to drouth. The collections made after the April 7, 1938 irrigation were the only ones that showed decreases in the values after an irrigation.

When the varieties were grown in the drouth border, Baart generally had the highest and Hope the lowest values in 1935 and 1938. Baart also showed the greatest increases as the drouth conditions became more severe. In 1935, Ceres had slightly higher percentages of solids than Marquis. Although Hope usually had the lowest values in 1936 there were but little differences in the variations between the other varieties. Baart had the highest values only at the first and last collections. These data will be seen in Fig. 2.

A comparison between Baart and Hope in the normal and drouth borders is also shown in Fig. 2. With but two exceptions, the percentage of solids of Baart in the drouth border was always higher than Hope, with the differences becoming greater as the drouth conditions became more severe. Considering only the period from April 13 to May 19 in 1935, there were no consistent differences between the percentage of solids of Baart

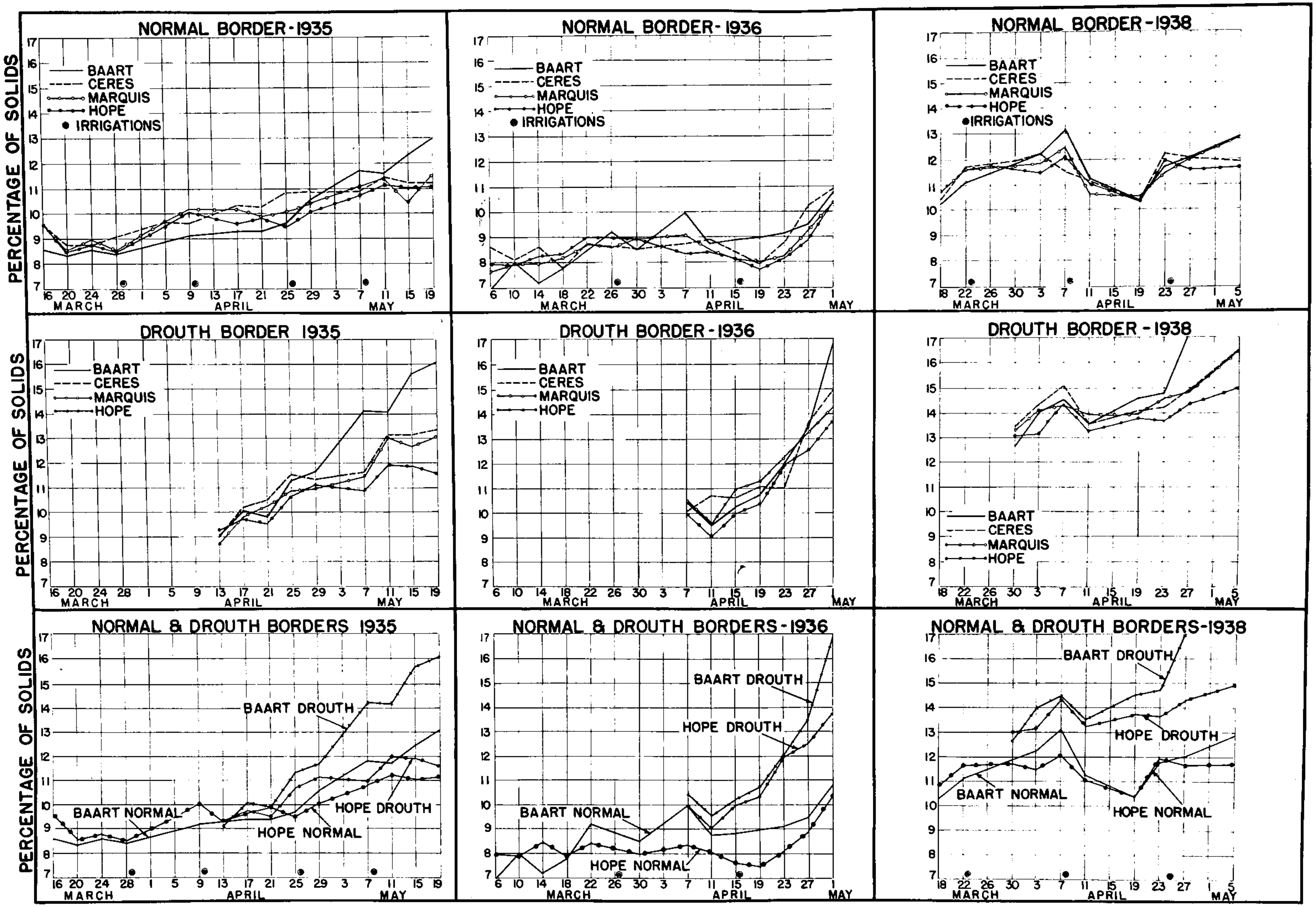

Fig. 2: Percentage of solids of four representative varieties in normal and drouth borders in 1935, 1936 and 1938.

when grown in the normal and Hope when grown in the drouth borders. The values of Hope when grown in the normal border were generally low. In 1936, there were greater differences between Baart and Hope when grown in the normal than in the drouth borders. (This was also true with the osmotic values in 1936.) There were no consistent differences in 1938 between Baart and Hope when grown in the normal border. In the drouth border, the values for Baart increased much more rapidly than for Hope, especially at the last few collections.

Differences in the percentage of solids between the normal and drouth borders

Although only three collections were made in 1934, the average differences in the percentage of solids between the normal and drouth borders varied in the same order as the drouth resistance of the varieties. The difference for Baart at the April 29 collection was over twice as high as for Hope or Hope x Ceres. The average difference of the 4 drouth resistant varieties was 3.53 percent and 1.65 percent in the two drouth susceptible varieties. These results are shown in table 5.

Somewhat similar results were obtained in 1935. The major exceptions were that the differences for Huston and Hope x Ceres had higher averages than Ceres (table 5). The average for the 4 drouth resistant varieties was 1.53 percent, and 0.83 percent for Hope and Hope x Ceres. It is of interest to note that most of the varieties had about the same differences on April 21. However, the differences for the drouth resistant varieties became greater as the drouth conditions became more severe.

There were practically no differences between the average differences

TABLE 5: Differences in the percentage of solids between the varieties in normal and drouth borders. (A - indicates normal higher than drouth.)

Date	Baart	Onas	Ku-banka	Ceres	Mar-quis	Huston	Hope	Hope x Ceres	Aver-age
					1934				
April 12	2.73	2.88	1.49	2.48	1.34	--	1.28	1.13	1.90
" 19	3.40	3.57	2.93	2.26	0.68	--	0.79	1.28	2.13
" 29	6.43	4.73	5.76	3.67	3.76	--	3.10	2.91	4.34
Average	4.19	3.73	3.39	2.80	1.93	--	1.72	1.57	
					1935				
April 17	0.72	0.26	0.42	-0.15	-0.33	0.74	0.14	--	0.26
" 21	0.50	0.38	0.39	0.24	0.37	0.46	-0.32	--	0.29
" 25	1.63	1.01	1.39	0.65	0.81	0.85	1.21	0.67	1.03
" 29	1.08	1.14	1.25	0.45	0.54	0.92	1.04	0.97	0.92
May 7	2.36	1.05	1.43	0.73	0.33	1.26	0.19	1.84	1.15
" 11	2.44	2.12	3.05	1.60	1.59	1.84	0.75	1.13	1.82
" 15	3.23	1.60	3.61	1.85	2.19	1.19	0.86	0.93	1.93
" 19	3.02	3.53	3.73	2.13	1.54	1.46	0.44	1.17	2.13
Average	1.87	1.39	1.91	0.94	0.88	1.09	0.54	1.12	
					1936				
April 7	0.48	0.91	-0.08	1.33	1.37	1.55	1.63	1.80	1.12
" 11	0.77	1.16	0.77	1.82	0.97	0.53	0.98	1.43	1.05
" 15	1.39	2.13	2.21	2.23	2.76	1.80	2.36	2.53	2.18
" 19	1.72	1.55	2.10	3.13	3.28	2.21	2.87	2.82	2.46
" 23	2.87	3.14	3.33	2.25	3.99	2.84	3.81	3.07	3.16
" 27	3.97	3.95	2.82	3.42	3.96	4.29	3.63	3.81	3.73
May 1	6.08	2.98	3.65	4.03	3.89	3.19	3.39	2.04	3.66
Average	2.47	2.26	2.11	2.60	2.89	2.34	2.67	2.50	
					1938				
March 30	0.77	--	--	1.47	1.55	--	1.34	--	1.28
April 3	1.75	--	--	2.03	2.22	--	1.69	--	1.92
" 7	1.38	--	--	3.52	1.85	--	2.26	--	2.25
" 11	2.29	--	--	2.35	3.31	--	2.19	--	2.54
" 19	4.14	--	--	3.68	3.40	--	3.43	--	3.66
" 23	2.97	--	--	1.89	3.05	--	1.71	--	2.41
" 27	5.12	--	--	2.75	2.73	--	2.63	--	3.31
May 5	7.63	--	--	4.54	3.62	--	3.20	--	4.75
Average	3.26	--	--	2.78	2.72	--	2.31	--	

of any of the varieties in 1936 (table 5). Marquis and Hope had the highest, and Onas and Kubanka (drouth resistant) the lowest, average differences. The averages for Marquis, Hope and Hope x Ceres were higher than Baart.

Although there were but little differences between the averages of Ceres and Marquis in 1938, these averages were lower than Baart and higher than Hope (table 5). The average for Baart was 41 percent higher than for Hope.

Percentage of leaf moisture

Under conditions of normal soil moisture, the percentage of leaf moisture of Baart in 1936 and 1938 was slightly lower than in the other varieties. This was probably due to the fact that Baart is about 10 days earlier in flowering than Ceres, Marquis and Hope. In 1938, the leaf moisture of Hope was generally higher than in Baart. There were no consistent differences between the leaf moisture of Ceres and Marquis in 1938; between Ceres, Marquis and Hope in 1936; or between any of the 4 varieties in 1935. These data are shown in Fig. 3.

When the varieties were grown under drouth conditions, Baart generally had the lowest leaf moisture (Fig. 3). This was especially true in 1936, when all but one collection of Baart had the lowest leaf moisture,and in 1938, when all of the collections of Baart had the lowest leaf moisture. The probable reason for this was mentioned above. In 1935, Hope had a leaf moisture just above Baart. However, there were no large or consistent differences in 1936 and 1938 in the percentage of

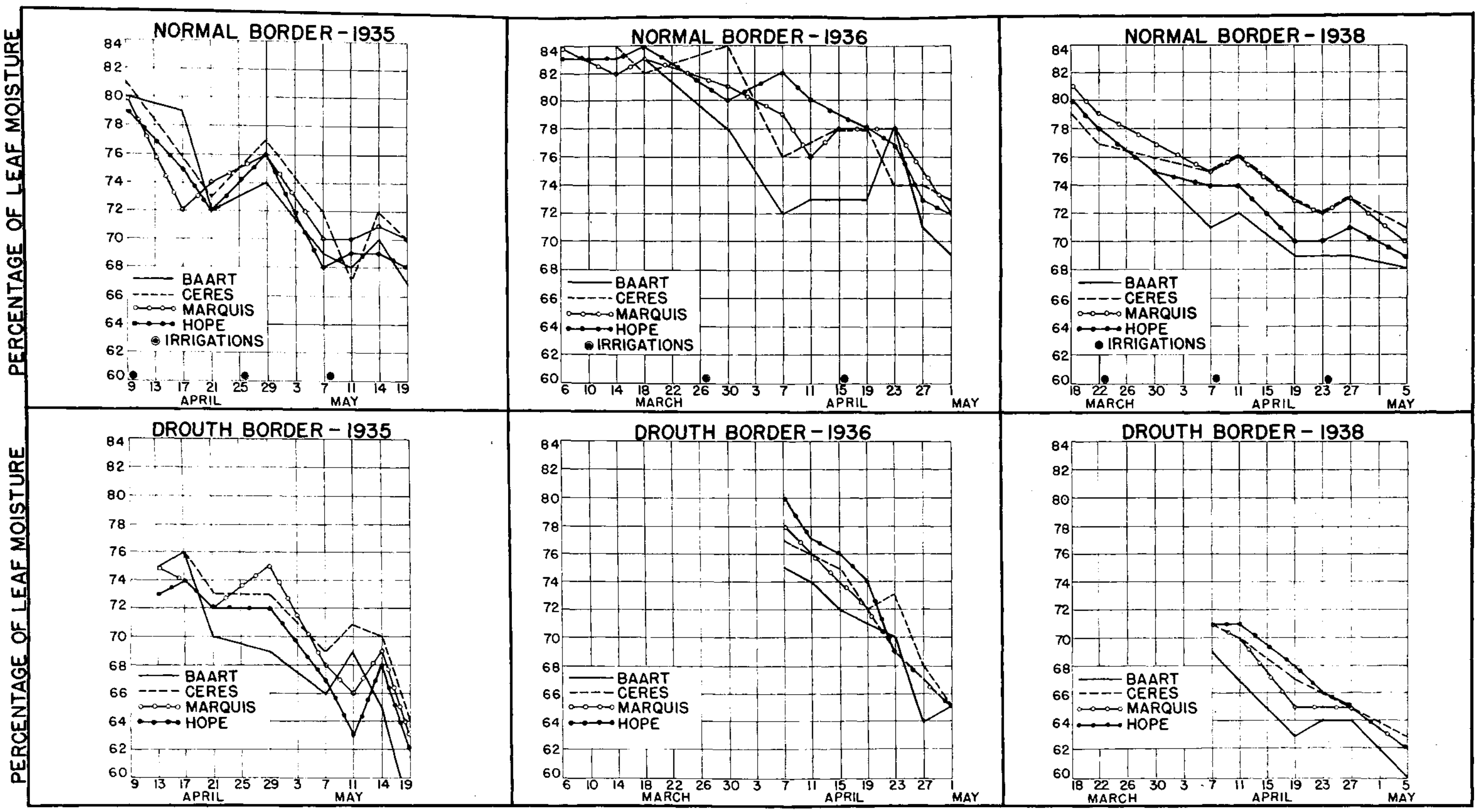

Fig. 3: Percentage of leaf moisture of four representative varieties in normal and drouth borders in 1935, 1936 and 1938.

of leaf moisture between Ceres, Marquis and Hope. The reduction in moisture content with the advance of season was most rapid in 1936 and least rapid in 1935.

Percentage of soil moisture

The percentages of soil moisture of the surface four feet of soil for 1935, 1936 and 1938 in the normal and drouth borders are shown in table 6. The wilting percentage of this soil was 12.8 percent.

The soil in the normal border usually had moisture above the wilting percentage. In general, the samples taken before the irrigations had about the same percentage of soil moisture as those taken soon after the irrigations.

All the samples from the first foot of soil of the collections in the drouth border in 1938, and all but the first collection in 1936, were below the wilting percentage as far as soil moisture was concerned. However, the second and third foot samples generally had soil moisture above the wilting percentage.

It is of interest to note that with the exception of the first foot in 1938 there were but small differences in the soil moisture at the first collections between the normal and drouth borders in 1935, 1936 or 1938.

Yearly averages

Yearly average osmotic pressure, percentage of solids and percentage of leaf moisture in the normal and drouth borders

There was but little difference between any of the varieties in the three year average of osmotic pressures, under conditions of normal soil moisture. Two drouth resistant varieties, Baart and Ceres,

TABLE 6: Percentages of soil moisture in normal and drouth borders, 1935, 1936 and 1938.

Date	Depth in feet 1	2	3	4	Average
			NORMAL BORDER 1935		
March 12	17	17	21	24	20
" 25	14	16	19	22	18
April 4	17	20	22	24	21
" 14	17	19	22	22	20
" 24	15	20	23	20	20
May 1	14	15	19	21	17
" 10	20	20	24	27	23
" 20	14	15	19	20	17
			NORMAL BORDER 1936		
March 26	15	17	18	20	18
April 10	17	18	19	23	19
" 26	11	14	13	15	14
			NORMAL BORDER 1938		
March 20	16	17	20	21	19
April 1	13	16	16	23	17
" 11	14	16	18	22	18
" 18	14	13	18	21	17
" 25	12	17	17	24	17
			DROUTH BORDER 1935		
March 12	16	18	20	22	19
" 25	15	16	20	21	18
April 4	14	17	19	20	18
" 14	13	16	18	20	17
" 24	12	15	18	20	16
May 1	11	14	18	18	15
" 10	13	15	15	17	15
" 20	9	11	12	16	12
			DROUTH BORDER 1936		
March 26	15	17	18	20	18
April 10	12	13	13	18	14
" 26	11	11	10	11	11
May 10	10	11	10	11	11
			DROUTH BORDER 1938		
March 20	11	17	17	18	16
April 1	11	15	16	18	15
" 11	10	13	15	15	13
" 18	10	12	14	17	13
" 25	10	11	13	18	13
May 5	9	11	12	17	12

had the highest and lowest averages. The average for Baart was nearly 1 atmosphere higher than that of any other varieties. These data are shown in table 7.

Similar relationships were found in the three year average percentage of solids in the normal border (table 7). Although Baart had the highest and Hope the lowest averages, there was only 0.59 percent difference between the two.

The three year average percentage of leaf moisture of Baart in the normal border was the highest of any of the varieties. Hope had the lowest average, its average being 1.2 percent lower than Baart. There were but little differences between the averages of Hope, Ceres or Marquis (table 7).

When the varieties were grown in the drouth border, there were greater differences in the osmotic pressure of the varieties as related to their drouth resistance than there were in the normal border. The three year average of Baart was easily the highest; this was at least 2 atmospheres higher than in any of the other varieties (table 8). The average difference between Baart and Hope was 1.0 atmosphere in the normal, and 3.8 atmospheres in the drouth borders. Although the averages for the drouth resistant varieties were higher than those intermediate in resistance, and both higher than the varieties susceptible to drouth, the differences were small between any of the varieties except Baart and Hope.

The three year average percentage of solids of the varieties grown

TABLE 7: Yearly averages of osmotic pressure, percentage of solids, and percentage of leaf moisture of the varieties in the normal border.

Variety	1934	1935	1936	1938	4 yr. average	3 yr. average	2 yr. average	1935	1936	1938	3 yr. average	2 yr. average
				OSMOTIC PRESSURE						PERCENTAGE OF LEAF MOISTURE		
Baart	17.82	14.84	16.37	19.93	17.24	16.34	15.61	72.4	76.8	72.3	73.8	74.6
Onas	15.89	14.18	16.26	--	--	15.44	15.22	72.0	77.6	--	--	74.8
Kubanka	15.68	14.94*	15.85	--	--	15.49	15.40	--	78.3	--	--	--
Ceres	15.51	14.68	15.67	19.36	16.31	15.29	15.18	73.6	79.0	74.5	75.7	76.3
Marquis	16.99	14.61	15.14	19.42	16.54	15.58	14.88	72.9	79.1	74.9	75.6	76.0
Huston	--	14.74	15.20	--	--	--	14.97	71.1	79.3	--	--	75.2
Hope	16.35	15.06	14.62	19.28	16.33	15.34	14.84	72.0	79.5	73.4	75.0	75.8
Hope x Ceres	16.08	14.80*	15.25	--	--	15.38	15.25	--	80.3	--	--	--
				PERCENTAGE OF SOLIDS								
Baart	12.14	9.91	8.74	11.69	10.62	10.26	9.33					
Onas	11.57	9.74	8.76	--	--	10.02	9.25					
Kubanka	10.79	10.15	9.32	--	--	10.09	9.74					
Ceres	11.01	10.17	8.80	11.58	10.39	9.99	9.49					
Marquis	11.55	9.97	8.45	11.60	10.39	9.99	9.41					
Huston	--	9.67	8.19	--	--	--	8.93					
Hope	10.93	9.83	8.24	11.44	10.11	9.67	9.04					
Hope x Ceres	10.80	10.06	8.49	--	--	9.78	9.28					

* for comparable dates.

TABLE 8: Yearly averages of osmotic pressure, percentage of solids, and percentage of leaf moisture of the varieties in the drouth border.

Variety	1934	1935	1936	1938	4 yr. average	3 yr. average	2 yr. average	1935	1936	1938	3 yr. average	2 yr. average
	OSMOTIC PRESSURE							PERCENTAGE OF LEAF MOISTURE				
Baart	27.23	19.17	24.68	24.66	23.94	23.69	21.93	68.4	70.1	64.5	67.7	69.3
Onas	23.44	18.19	23.40	--	--	21.68	20.80	68.8	71.1	--	--	70.0
Kubanka	22.24	19.84	21.58	--	--	21.22	20.71	--	71.6	--	--	--
Ceres	21.70	18.92	22.38	22.33	21.33	21.00	20.65	71.5	72.3	67.0	70.3	71.9
Marquis	21.09	17.15	22.20	22.78	20.81	20.15	19.68	70.3	71.6	66.3	69.4	71.0
Huston	--	17.09	21.60	--	--	--	19.35	69.8	72.7	--	--	71.3
Hope	21.05	16.76	21.86	22.48	20.54	19.89	19.31	68.9	72.6	67.3	69.6	70.8
Hope x Ceres	20.54	18.30*	21.43	--	--	20.09	19.87	--	72.9	--	--	--
	PERCENTAGE OF SOLIDS											
Baart	16.33	12.43	11.89	15.20	13.96	13.55	12.16					
Onas	15.29	11.45	11.57	--	--	12.77	11.51					
Kubanka	14.18	12.16	11.89	--	--	12.74	12.03					
Ceres	13.81	11.56	11.73	14.48	12.90	12.37	11.65					
Marquis	13.47	11.21	11.69	14.42	12.70	12.12	11.45					
Huston	--	10.95	10.86	--	--	--	10.91					
Hope	12.66	10.76	11.07	13.81	12.08	11.50	10.92					
Hope x Ceres	12.38	11.03	11.07	--	--	11.49	11.05					

* for comparable dates.

in the drouth border are given in table 8. Baart had the highest ane Hope the lowest three year averages. The differences between the averages of Baart and Hope were 0.58 percent in the normal and 2.05 percent in the drouth borders. The differences between the averages of any of the varieties, except between Baart and Hope, were small and probably not statistically significant.

The drouth resistant varieties, Baart and Ceres, had the lowest and highest three year average percentage of leaf moisture of the varieties when grown in the drouth border. The differences between the averages of Ceres, Marquis and Hope were less than 1 percent. These averages are given in table 8.

Yearly average differences in osmotic pressure and the percentage of solids between the normal and drouth borders

The three year average differences in the osmotic pressure between the varieties when grown in the normal and drouth borders are shown in table 9. It will be observed that these differences in the drouth resistant varieties were higher than in any of the other varieties. The average differences in the 4 drouth resistant varieties was 5.53 atmosphere, 3.85 atmosphere for Marquis and 4.08 atmosphere for Hope and Hope x Ceres.

The three year average differences in the percentage of solids of the varieties between the normal and drouth borders showed similar relationships to drouth resistance as did the osmotic pressure differences (table 9). The average difference of the drouth resistant varieties was 2.44 percent, 1.90 percent difference in Marquis and 1.64 percent difference in Hope and Hope x Ceres. Baart had a 72 percent greater difference

TABLE 9: Yearly average differences in the osmotic pressure and the percentage of solids between the normal and drouth borders.
(A - indicates that the normal was higher than the drouth.)

Variety	1934	1935	1936	1938	4 year average	3 year average	2 year average
			OSMOTIC PRESSURE				
Baart	9.41	2.72	7.33	4.52	6.00	6.49	5.03
Onas	7.55	2.83	6.08	--	--	5.49	4.86
Kubanka	6.56	3.66	5.12	--	--	5.11	4.39
Ceres	6.19	2.78	6.06	2.90	4.48	5.01	4.42
Marquis	4.11	0.88	6.55	3.10	3.66	3.85	3.72
Huston	--	0.97	5.96	--	--	--	3.47
Hope	4.70	- 0.16	6.86	3.20	3.65	3.80	3.35
Hope x Ceres	4.46	2.60*	5.98	--	--	4.35	4.29
			PERCENTAGE OF SOLIDS				
Baart	4.19	1.87	2.41	3.13	2.90	2.82	2.14
Onas	3.73	1.39	2.26	--	--	2.46	1.83
Kubanka	3.39	1.91	2.11	--	--	2.37	2.01
Ceres	2.80	0.94	2.60	2.65	2.25	2.11	1.77
Marquis	1.93	0.88	2.89	2.63	2.08	1.90	1.89
Huston	--	1.09	2.34	--	--	--	1.72
Hope	1.72	0.54	2.67	2.33	1.82	1.64	1.61
Hope x Ceres	1.57	0.84*	2.50	--	--	1.64	1.67

* for comparable dates.

in the percentage of solids between the normal and drouth borders than Hope.

Simple and partial correlations

Simple yearly correlations

Simple correlation coefficients were determined each year between all the data obtainable for that year in the normal and drouth borders. The data on only Baart, Ceres, Marquis and Hope were used in making these correlations. When the percentages of soil moisture were used in the correlations, calculated percentages were put in the correlation tables between the dates of taking soil samples. In the drouth border only, the top 3 feet were averaged for the correlations, while the entire 4 feet were used in the normal border. Since there was only one soil moisture percentage for all of the varieties in each of the normal and drouth borders, the osmotic pressures, percentages of solids and percentages of leaf moisture for the 4 varieties were averaged for each date, and this average correlated with the percentage of soil moisture. These correlations, with their probable errors, are summarized in table 10.

Highly significant positive correlations were obtained each year between the osmotic pressure and the percentage of solids of the 4 varieties in the normal border. The negative correlation between the osmotic pressure and leaf moisture was highly significant during 1935 and 1936, but only moderately so in 1938. Highly significant negative correlations were found each year between the percentage of solids and leaf moisture. None of the correlations between the osmotic pressure and soil moisture, the percentage of solids and soil moisture, and the percentages of

TABLE 10: Simple correlation coefficients between the determinations in normal and drouth borders.

	N(1)	1934	N	1935	N	1936	N	1938
				NORMAL BORDER				
Osmotic pressure and percentage of solids	12	+.796** ±.071	60	+.798** ±.032	52	+.799** ±.034	40	+.577** ±.071
Osmotic pressure and percentage of leaf moisture	--	-- --	32	-.714** ±.058	48	-.681** ±.052	34	-.465* ±.091
Osmotic pressure and percentage of soil moisture	--	-- --	15	-.205⁻ ±.167	--	-- --	9	-.405⁻ ±.188
Percentage of solids and leaf moisture	--	-- --	32	-.855** ±.032	48	-.754** ±.042	34	-.527** ±.084
Percentage of solids and soil moisture	--	-- --	15	+.081⁻ ±.173	--	-- --	9	-.278⁻ ±.208
Percentage of leaf moisture and soil moisture	--	-- --	8	-.083⁻ ±.237	--	-- --	9	+.936** ±.028
				DROUTH BORDER				
Osmotic pressure and percentage of solids	12	+.947** ±.020	36	+.832** ±.035	28	+.899** ±.025	32	+.848** ±.034
Osmotic pressure and percentage of leaf moisture	--	-- --	32	-.610** ±.075	28	-.885** ±.028	24	-.764** ±.057
Osmotic pressure and percentage of soil moisture	--	-- --	9	-.825** ±.072	7	-.888** ±.054	8	-.901** ±.045
Percentage of solids and leaf moisture	--	-- --	32	-.765** ±.050	28	-.828** ±.040	24	-.703** ±.070
Percentage of solids and soil moisture	--	-- --	9	-.829** ±.070	7	-.778* ±.101	8	-.861* ±.062
Percentage of leaf moisture and soil moisture	--	-- --	8	+.891** ±.049	7	+.954** ±.023	6	+.707⁻ ±.138

(1) N is the number of samples used in making the correlations.
** Highly significant.
* Significant.
\- Not significant.

leaf moisture and soil moisture were statistically significant, except that between the percentages of leaf moisture and soil moisture in 1938. In other words, the gradual increase in the osmotic pressure and percentage of solids of the varieties was not the direct result of variations in soil moisture. From this, it seems as though these increases are natural and probably occur on account of the increasing of the plant and of obtaining leaves higher up on the plant only to flowering, and that such increases would occur even under continuous high moisture conditions.

In practically all cases, much higher correlations were found between the different determinations in the drouth border than in the normal border. Every simple correlation listed in table 10 was either highly significant or significant, except the correlation between percentages of leaf moisture and soil moisture in 1938. The correlations between the osmotic pressure and soil moisture and the percentage of solids and soil moisture were not statistically significant in the normal border, but were significant in the drouth border.

Yearly correlations between the osmotic pressure and percentage of solids in the drouth border

Simple correlations between the average osmotic pressure and average percentage of solids of all the varieties in the drouth for the four years are summarized in table 11. Only three of the correlations of the osmotic pressure between the different years were statistically significant. Those obtained for 1934 and 1935, 1935 and 1936, and 1935 and 1938 were not significant. Every correlation for the average percentage of solids in the various years was significant. It was only during the years 1934 and 1936, and 1936 and 1938, that the correlations were higher with osmotic pressure

TABLE 11: Correlation coefficients for the different years between the average osmotic pressure and average percentage of solids of varieties in the drouth border.

Years compared	N	Osmotic pressure	N	Percentage of solids
1934 and 1935	7	+.463^{-} ±.200	7	+.756* ±.109
1934 and 1936	7	+.905** ±.046	7	+.722* ±.122
1934 and 1938	4	+.911* ±.057	4	+.988** ±.008
1935 and 1936	8	+.206^{-} ±.229	8	+.852** ±.065
1935 and 1938	4	+.547^{-} ±.236	4	+.986** ±.010
1936 and 1938	4	+.982* ±.012	4	+.893* ±.069

** Highly significant
* Significant
- Not significant

than with the percentage of solids. The fact that all the correlations were high in the percentage of solids column indicates that it was a much less variable determination than the osmotic pressure.

Partial correlations

A number of partial correlations were determined from the simple correlation coefficients (table 12) in the drouth border for the last three years. It will be remembered that only the data from Baart, Ceres, Marquis and Hope were used in these correlations. The results are shown in table 11. In the correlations, the number 1 stands for the osmotic pressure, 2 for the percentage of solids, 3 for the percentage of leaf moisture, and 4 for the percentage of soil moisture. The period between the first two and last two numbers means that the partial correlation is only between the first two numbers, and that the last two numbers are not considered. For example, a partial correlation of 13.24 means that this is a true correlation between the osmotic pressure and percentage of leaf moisture, with the percentage of solids and soil moisture held constant or their effects eliminated.

The partial correlations were generally much lower than its corresponding simple correlation. This indicates that one reason for the high simple correlations may have been that other factors were considered which had additional influences on the correlations. There were also a few cases where the relationships, for some reason or other, had negative simple correlations but positive partial correlation. This fact makes it difficult to interpret some of the results. The highest partial correlations

TABLE 12: Coefficients of partial correlation made on varieties in drouth border.

Data correlated	1935	1936	1938
12.34 (1)	+ .611	+ .711	+ .233
13.24	+ .616	+ .103	- .365
14.23	- .703	- .476	- .596
23.14	- .419	- .417	- .146
24.13	+ .129	+ .400	- .417
34.12	+ .844	+ .839	- .001

(1) See text.

were obtained between the leaf moisture and soil moisture in 1935 and 1936. The figures between osmotic pressure and the percentage of solids (12.34) were not as high as anticipated. During each of the years there were higher partial correlations between the osmotic pressure and soil moisture than between the percentage of solids and soil moisture, the other factors being held constant. Likewise, the partial correlations between osmotic pressure and percentage of leaf moisture were higher in 1935 and 1938 than those between the percentage of solids and leaf moisture. These results indicate that the osmotic pressure was more easily varied by the leaf moisture and the soil moisture than was the percentage of solids.

Crown root development

It will be noted in table 13 that under drouth conditions Baart had the lowest percentage of plants with no crown roots and the highest percentage with over three crown roots. The plants of Hope averaged between Marquis and Ceres in the above comparisons. The average number of crown roots per plant was highest in Baart and Hope and lowest in Ceres and Marquis.

There were practically no differences in the number of crown roots per plant in the varieties in the normal border in 1939.

TABLE 13: Crown root development of four representative varieties in 1938 and 1939.

	Baart	Ceres	Marquis	Hope
DROUTH BORDER, AVERAGE 1938 AND 1939				
Number of plants	243	315	260	286
Percentage of plants with:				
No crown roots	16.0	32.7	34.8	23.8
Zone crown root	23.9	30.2	27.4	25.5
Two crown roots	26.9	25.9	24.7	28.1
Three crown roots	17.9	8.4	8.2	15.2
Over three crown roots	30.5	5.7	9.9	14.9
Average number crown roots	1.93	1.19	1.21	1.57
NORMAL BORDER, 1939				
Average number crown roots	11.9	11.0	10.6	11.4

DISCUSSION

There was evidence that the plants in the drouth border had rather weak root systems because many times when a leaf was pulled off for cell sap determinations, the entire plant, with some roots, would come up. The top foot of soil generally had moisture below the wilting coefficient. This indicates that the plants absorbed a small amount of water.

A high osmotic pressure has long been associated with drouth resistant plants. Under dry conditions, a high osmotic pressure increased the drouth resistance of the plants in the following manner: (1) By protecting the protoplasm from coagulation and dessication during wilting due to the accumulation in the sap of salts and organic substances (Maximov 1929-B); (2) By contributing more to the water-retaining powers (bound water) of the cells than did hydrophilic colloids (lebedincev 1929-30); (3) By causing considerable tension on the mesophyll cells a high osmotic pressure may prevent visible wilting for a long time, although the water deficit may continue to increase (Maximov 1929-B); (4) By holding the cells together more closely and thus decreasing the intercellular spaces and likewise the water loss from the leaves; (5) By allowing resistant plants to create a high power of suction, thus enabling them to obtain moisture more readily from a very dry soil (Maximov 1929-B).

Any variations in the osmotic pressure seems to be due, either directly or indirectly, to the percentage of leaf moisture. This would probably also hold true with the percentage of soil moisture when one is dealing with soil drouth, but would not, of course, hold true when one is dealing with atmospheric drouth, since under such conditions the soil moisture may be high, yet due to hot, dry winds, the percentage of leaf moisture would be decreased and the osmotic pressure increased.

Under conditions of soil drouth, any increases in the osmotic pressure may be due to any one or all of the following:

(1) Decrease in the percentage of leaf moisture: It has been well established that the osmotic pressure is inversely proportional to the moisture content. In other words, as water vapor leaves the mesophyll cells and enters the inter-cellular spaces of the mesophyll tissue, the osmotic pressure of the cell sap is decreased in proportion to the amount of water that left the cell. Highly significant negative correlations were found in 1935, 1936 and 1938 between the osmotic pressure and the percentages of leaf moisture.

(2). Conversion of complex carbohydrates to simple carbohydrates: When glucose and sucrose are dissolved in solutions of the same molar concentration, they have the same number of molecules per liter of solution, and about the same osmotic pressure. When one mol of sucrose is digested, it yields one mol of glucose and one mol of fructose, either of which has the same number of molecules and the same osmotic pressure as the original mol of sucrose. This would result in two mols of simple sugars which would therefore have twice the osmotic pressure of the original mol of sucrose.

The percentage of solids does not show the relative number of molecules of solute present in the sap. All the important sugars in the sap have the same refractive index when they have the same percentage concentration. In other words, the concentration of the solutes can be changed from complex to simple substances, or the reverse, without any change in the percentage of solids.

It will be remembered that in the normal border the osmotic pressure generally increased in the collections made just before an irrigation was to be applied, and likewise decreased in the collections made immediately after the irrigations. The percentage of solids, on the other hand, with but very few exceptions, increased normally during this time. This indicates strongly that the solutes in the cell sap were simple substances just before the irrigations had been applied (which would increase the osmotic pressure and not affect the percentage of solids), while immediately following the irrigations the solutes would be converted to complex substances (which would decrease the osmotic pressure and not affect the percentage of solids). From this, it can be reasoned that in the drouth border, where the drouth conditions were always much more severe than in the normal border, the solutes in the sap were generally simple in nature.

It must be borne in mind, however, that an increase in the osmotic pressure has the same benefits to plants growing in dry conditions, regardless of whether all of the increases were compensated by decreases in the percentage of leaf moisture, or where the increases in osmotic pressure were due to the conversion of complex to simple solutes or to an increase in the concentration of simple or complex solutes.

Newton and Martin (1930) observed instances where the percentage of solids increased more rapidly toward maturity than the osmotic pressure. They stated that such a condition indicated that the colloids were elaborated more rapidly than the solutes. Similar results were found with Baart in 1935 in the drouth border. The more rapid rise in the percentage of solids curve than the osmotic curve indicates a more rapid increase in colloids in Baart than in the other varieties.

Since the osmotic pressure is inversely proportional to the leaf moisture, a comparison of the osmotic pressure and leaf moisture (Figs. 1 and 3) changes of the varieties in the normal and drouth borders would give a fair estimate of the extent to which the osmotic pressure increases were accompanied by decreases in leaf moisture. Under conditions of normal soil moisture, no consistent differences were found in 1935 in the increases in osmotic pressure and decreases in leaf moisture between Baart, Ceres, Marquis and Hope. In 1936, Baart usually had the lowest leaf moisture and highest osmotic pressure. Although Hope generally had the lowest osmotic pressure, there were no consistent differences in the leaf moisture in Ceres, Marquis and Hope. As a rule, the leaf moisture of Baart and Hope were the lowest in 1938. However, there were practically no differences in the osmotic pressure of any of the varieties.

Under drouth conditions, Baart usually showed the lowest and Hope the next lowest leaf moisture in 1935. The osmotic pressure of Baart had the largest and of Hope the smallest increases. This indicates that the low osmotic pressure of Hope was not due to it having a high leaf moisture but to its lack of drouth resistance. Although the osmotic pressure of Ceres was higher than Marquis, there were no consistent differences in the decreases in leaf moisture of the two varieties. As a rule, in 1936 and 1938, the leaf moisture of Baart was lower and the osmotic pressure was higher, than the other three varieties. However, the differences in the decreases in leaf moisture and increases in osmotic pressure of Ceres, Marquis and Hope were small and inconsistent. No large differences were found in the osmotic pressures between any of the varieties in 1936, except that at the last few collections, the osmotic pressure of Baart was higher than the other varieties.

In general, the relationships between the increases in the percentage of solids and the decreases in leaf moisture of the varieties in the normal border in 1935 and 1938 were very similar to those found with the osmotic pressure. Although the leaf moisture of Baart was lower than the other varieties during most of the season in 1936, the differences between the other varieties were inconsistent. However, the low leaf moisture of Baart caused the percentage of solids to be high in only a few collections.

Similar relationships were found in 1935 between the increases in the percentage of solids and decreases in leaf moisture as in the increases in the osmotic pressure and decreases in leaf moisture of the varieties in the drouth border. In 1936, Baart usually had the lowest leaf moisture, but the percentage of solids was highest only at the last collection. There were small and inconsistent differences in 1936 and 1938 between the leaf moisture of Ceres, Marquis and Hope. Hope generally had the lowest percentage of solids during the above two years. However, the differences in the percentage of solids between Baart, Ceres, and Marquis in 1936, and Ceres and Marquis in 1938, were small.

In 1936 and 1938, the percentage of leaf moisture of Baart was generally the lowest of any of the varieties in the normal and drouth borders. During both of these years, the amount that Baart was lower than the other varieties was about the same in the two borders. In other words, Baart had about the same decreases in leaf moisture under normal and drouth conditions. However, there was generally a much greater difference in the osmotic pressure and the percentage of solids between Baart and the other varieties in the drouth than in the normal borders. This indicates that the higher increase in the osmotic pressure and percentage of solids in Baart than in the other varieties, and in the drouth than in the normal borders, may not have been due to Baart having a lower leaf moisture.

The fact that Baart generally had a high osmotic pressure and percentage of solids in the drouth border may have been partly due to it having a slightly lower leaf moisture than Ceres, Marquis and Hope. This was true especially at the last few collections. On the other hand, Ceres had a higher 3 year average leaf moisture than Marquis or Hope, yet its osmotic pressure and percentage of solids were higher than either Marquis or Hope. Also, there was practically no difference in the 3 year average leaf moisture of Marquis and Hope, but the 3 year average osmotic pressure and percentage of solids of Marquis was higher than in Hope.

Although the amount of work done on the variations in the osmotic pressure at different percentages of leaf moisture has been small, there have been a number of workers who reported on the changes in the nature of the carbohydrates at varying conditions of drouth. Marsh (1940) reported that in the upland prairie, as the soil moisture decreased the leaf moisture decreased and the osmotic pressure increased. When wheat plants were subjected to drouth conditions (Vassiliev and Vassiliev 1936), a decrease in moisture first caused a decrease in sugars. This may have been due to a decrease in photosynthesis. Later, at wilting, there was a decrease in sucrose and an increase in monosacchrides. When the plants were starting to dry up, there was a gradual decrease in monosacchrides and loss of sugars. Similar results were reported by Vassiliev (1931). Loomis (1937) stated that no starch is formed in the vegetative parts of grasses. The increase in the carbohydrates of drouth injured corn stalks was equally distributed between sucrose and dextrin. When fruiting was prevented by drouth, all of the increases in sugars were accounted for by increases in sucrose (Sayre, Morris and Richey, 1931). No changes were observed in the reducing sugars. Clements (1937-A) reported that in soybean stems there was an increase in sugars during the drouth period.

The differences in the percentage of solids between the normal and drouth borders generally show a better relationship to the drouth resistance of the varieties than the osmotic pressure differences. Since the percentage of solids readings include colloids, this may indicate that colloids were present in the sap during the hardening of the varieties to drouth. According to Newton and Martin (1930), colloids are associated with drouth resistant plants.

The ability of a variety to harden to drouth is of major importance in determining its resistance to dry conditions. A variety which had high hardening ability would be one with large differences in the osmotic pressure and the percentage of solids under normal soil moisture conditions, as compared with dry conditions. Such a variety would be drouth resistant. On the other hand, a variety which had little or no differences in the osmotic value of the cell sap and the percentage of solids between moist and dry conditions would be one of low hardening ability and, likewise, probably susceptible to drouth. In the foregoing tables, all of the data which deals with the differences in the osmotic pressure and the percentage of solids between the normal and drouth borders really deals with the hardening of the varieties to drouth. These data are, therefore, of much importance.

Several investigators have gone into detail on the hardening process in plants. Rosa (1921), in his work on hardening cabbage by subjecting the plants to a minimum of moisture, stated that with such a treatment there was an increase in the osmotic pressure, an increase in sugars, an increase in the percentage of dry matter, an increase in the pentosan content, and a decrease in starch. Similar increases in sugars and percentages of solids and decreases in starch were reported by Harvey (1918). He also found an increase in the amino-nitrogen and a decrease in moisture content. The changing of the proteins to amino-nitrogen results in less precipitation, since the amino-acids are less easily precipitated than the proteins. Precipitation of the proteins increases the permeability of the cell wall to water. When the wheat plants had lost their turgor, the percentage of leaf moisture decreased from 30 to 48 percent (Vassiliev and Vassiliev, 1936), the total and soluble carbohydrates increased and the hemicelluloses decreased. The authors found a correlation between the increase in sugars and the decrease in hemicelluloses, although there was an increase in the hemicelluloses in the drouth resistant varieties. The carbohydrates aid in protecting the protoplasm from coagulation. A decrease in leaf moisture was found by Northen (1938) to increase the elasticity of the protoplasm and its gel-like properties. An increase in these gel-like properties was thought to increase the ability of the protoplasm to retain water.

Whatever may have been the direct results of hardening of the varieties to drouth, there was evident a decrease in the percentage of leaf moisture and an increase in the osmotic pressure and percentage of solids (table 9). The greatest increase in osmotic pressure due to hardening was in Baart. The four drouth resistant varieties had a three year average of 5.53 atmospheres higher osmotic pressure in the drouth border than in the normal border, while the two susceptible varieties had only a 4.08 atmosphere increase. Similarly, Baart had the greatest increase in the percentage of solids. The four drouth resistant varieties had an average of 2.44 percent higher percentage of solids in the drouth border than in the normal border; this difference was 1.64 percent for the two drouth susceptible varieties. In both the two and three year averages, Baart had the greatest decrease in the percentage of leaf moisture due to drouth. With the exception of Baart, there was no consistent relationship between the drouth resistance of the varieties and the amount of decrease in the percentage of leaf moisture. These increases in the percentage of solids and osmotic pressure, and the decreases in the leaf moisture, may be considered to be the result of drouth hardening. The three year average hardening increase in the osmotic pressure and the percentage of solids were in the same varietal rank, except that Hope x Ceres had a slightly higher osmotic pressure difference than Marquis. The percentage of solids differences due to hardening are in the same general order as the resistance of the varieties to drouth.

SUMMARY

Osmotic pressure, percentage of solids, percentage of leaf moisture and percentage of soil moisture determinations were made on the extracted leaf sap of 4 to 8 varieties of spring wheat that varied in their resistance to drouth. The seedings were made in the field in 1935, 1936 and 1938 in two adjacent borders; one was irrigated normally and called the normal border, while the other received no irrigation water after seeding and was called the drouth border. A few preliminary comparisons on the osmotic pressure and percentage of solids were made in 1934. Most of the comparisons are made with four representative varieties, Baart, Ceres, Marquis and Hope.

With the exception that the leaf moisture of Baart was slightly lower in the normal border than Ceres, Marquis and Hope in 1936 and 1938, there was generally no consistent difference in 1935, 1936 and 1938 in the decreases in leaf moisture, or the increases in osmotic pressure and percentage of solids between Baart, Ceres, Marquis and Hope.

All of the varieties showed greater decreases in leaf moisture and more abrupt increases in osmotic pressure and percentage of solids in the drouth than in the normal borders.

Baart usually had the greatest increase in osmotic pressure in the drouth border, the difference between Baart and the other varieties becoming greater as the drouth conditions became more severe. Although there were no consistent differences in the increases in the osmotic pressure of Ceres, Marquis and Hope in 1936 and 1938, the varieties lined

up in the same order as their drouth resistance in 1935.

In general, the percentage of solids relationships in the drouth border were very similar to that obtained with the osmotic pressure. There were no consistent differences in the percentage of solids between the four representative varieties in 1936, or between Ceres and Marquis in 1938. However, in all other cases the varieties increased in the same order as their resistance to drouth.

There seemed to be indications that the slightly lower leaf moisture of Baart in the drouth border played a minor part in the high increases in osmotic pressure and percentage of solids. Also, Ceres had a higher three year average leaf moisture than Marquis and Hope, yet its average osmotic pressure and percentage of solids were higher than these varieties.

With but three exceptions, all of the simple correlations made between the determinations in the drouth border for all of the years were highly significant. In most cases, comparable correlations were lower in the normal border.

ANATOMICAL INVESTIGATIONS

MATERIALS AND METHODS AND EXPERIMENTAL RESULTS

Dates and methods of collection

Anatomical measurements were made on leaves of Baart, Ceres, Marquis and Hope from plantings made in both the normal and drouth borders on January 28, 1939. The top leaves of main culms which had the same number of leaves were collected at random at two different times. The first collections were made about ten days before each variety flowered. The last collections were made just before the top leaves had started to dry up. The collection dates of the varieties were as follows:

Baart:	May 2, from the normal and drouth borders.
	May 25, from the drouth border.
	May 30, from the normal border.
Ceres, Marquis and Hope:	May 12, from the normal and drouth borders.
	May 30, from the drouth border.
	June 9, from the normal border.

The collections for the stomatal counts were made on May 19 in the drouth border and on May 30 in the normal border.

Since Baart is slightly earlier than the other varieties, the dates of collections were earlier than those of Ceres, Marquis and Hope. The last three varieties generally flowered within a few days of each other in both of the borders.

In all the comparative collections,attempts were made to get samples which had, as nearly as possible, the same degree of maturity. There was but little difference in the degree of maturity of each of the varieties between the normal and drouth borders at the first collection. However, the longer a variety was allowed to grow in the drouth border before a collection was made, the more advanced was its degree of maturity as compared with the same variety in the normal border. This necessitated the obtaining of collections on different dates.

The samples were obtained by saving the central portion of the blades. The specimens were immediately put into a formalin-aceto-alcohol killing solution and then taken to the laboratory where all the air was taken out of the tissues with a vacuum pump. They were run up to 75 percent alcohol and allowed to stand in the laboratory for one month.

After this period of storage, the samples were dehydrated with tertiary butyl alcohol and later imbedded in paraffin. The sections were cut to a thickness of ten microns. Flemings Triple stain was used, but modified to the extent that the orange G was dissolved in methyl cellosolve.

All the measurements were made with a 10X ocular micrometer with a movable scale. No determinations were made on the longitudinal sections.

In each of the tables, all of the measurements are recorded in microns.

Number of stomata

Stomatal counts were obtained with the use of flexible collodion, according to the instructions outlined by Loomis and Shull (1937). Both surfaces of the leaves were lightly brushed with 95 percent alcohol, and a collodion strip from one to two inches in length was smeared over the entire width of the leaf. The collodion was pulled off with a pair of tweezers when the outside one-eighth to one-quarter inch had turned white. Before the counts were made, the strips were soaked in tap water for one minute, and each put between a slide and cover glass. A microscope with a 44x objective and a 6x ocular was used in making the counts. All the entire stomata, and also the parts of stomata that were within the field of the microscope, were counted. The stomata were counted in five different representative areas of each surface of every leaf.

It will be seen in table 14 that there was practically no relationship between the number of stomata on either the lower or upper surfaces of the leaves and the drouth resistance of the varieties[1]. This was true in collections made from both the normal and drouth borders. Baart and Hope had exactly the same number of stomata under drouth conditions.

The drouth resistant varieties, Baart and Ceres, had the highest lower/upper ratios in the normal border. In the drouth border, Ceres and Marquis had the highest ratios.

The fact that there was (1) a decrease in the number of stomata on the lower surfaces of all the varieties in the drouth border, as compared with those from the normal border, and (2) an increase in the number of stomata on the upper leaf surfaces of all of the varieties except Ceres in the drouth border, as compared with those from the normal border, accounts for the smaller lower-upper

1. The rank of the varieties, most to least drouth resistant, is Baart, Ceres, Marquis and Hope.

TABLE 14: Number of stomata per unit leaf area on varieties in normal and drouth borders.

Variety	Lower epidermis	Upper epidermis	Total	Lower-upper ratio
		NORMAL BORDER		
Baart	11.5	15.6	27.1	.737
Ceres	14.5	19.5	34.0	.744
Marquis	13.3	18.2	31.5	.731
Hope	12.3	17.4	29.7	.707
		DROUTH BORDER		
Baart	11.3	18.3	29.6	.617
Ceres	12.8	18.5	31.3	.692
Marquis	12.7	20.1	32.8	.632
Hope	11.3	18.3	29.6	.617

ratio for every variety in the drouth than in the normal borders.

Thickness of leaves

The thickness of the leaf was obtained by measuring through every fourth vascular bundle, starting with the first bundle on one edge of the leaf.

The measurements on the first collections of the varieties are summarized in table 15. The plants of Baart in the normal border had the thickest leaves, averaging over 25 percent thicker than any of the other varieties. There was but little variation in the thickness of the leaves in the other varieties.

Although there were small differences between the leaf thickness of Baart, Ceres and Marquis, at the last collections in the normal border (table 15) the varieties lined up in the same order as their drouth resistance. The leaves of Baart averaged 12 percent thicker than those of Hope.

In the drouth border, the leaves of Ceres and Marquis were thicker than Baart at the first collections. The leaves of Ceres averaged 12 percent thicker than those of Baart and 19 percent thicker than those of Hope. These data will be seen in table 15.

The drouth resistant varieties Ceres and Baart had the thickest leaves at the last collections in the drouth border (table 15). The leaves of Baart averaged 17 percent thicker than those of Hope.

It is of interest to note that under conditions of normal soil moisture, the leaves of all of the varieties became thinner as the plants

TABLE 15: Anatomical determinations of the first and last collections of varieties in normal and drouth borders.

Variety	Number of leaves	Leaf thickness	Lower epidermal measurements: Outer wall thickness	Lower epidermal measurements: Total thickness	Upper epidermal measurements: Outer wall thickness	Upper epidermal measurements: Total thickness	Motor cells: Number of rows	Motor cells: Number per row
			FIRST COLLECTIONS - NORMAL BORDER					
Baart	7	201	2.60	20.98	2.21	21.00	-	-
Ceres	6	157	2.97	13.88	2.38	17.04	-	-
Marquis	7	157	2.90	15.13	2.43	17.73	-	-
Hope	8	159	2.96	13.85	2.57	16.58	-	-
			LAST COLLECTIONS - NORMAL BORDER					
Baart	7	146	2.79	14.90	2.18	16.77	46.6	3.9
Ceres	5	145	3.09	14.33	2.67	16.05	47.3	3.3
Marquis	7	141	2.84	14.93	2.17	16.62	43.3	3.2
Hope	6	130	2.48	13.69	2.13	14.61	36.0	2.9
			FIRST COLLECTIONS - DROUTH BORDER					
Baart	8	149	3.43	13.89	2.64	15.96	-	-
Ceres	8	167	3.49	15.11	2.83	16.72	-	-
Marquis	8	152	3.36	14.16	2.64	16.16	-	-
Hope	7	140	3.28	13.30	2.54	15.38	-	-
			LAST COLLECTIONS - DROUTH BORDER					
Baart	8	166	4.15	15.57	2.97	16.89	42.1	3.1
Ceres	8	167	3.67	14.89	3.15	17.22	41.3	3.7
Marquis	6	147	3.45	13.93	2.38	14.52	41.0	3.1
Hope	8	142	2.98	13.69	2.71	15.42	32.2	3.3

became more mature (table 16). However, under drouth conditions, every variety except Marquis had the thickest leaves at the last collections. The leaves of Baart increased in thickness 11 percent during the 18 day period between the first and last collections in the drouth border, while the other varieties showed little or no changes.

Lower and upper epidermal measurements

Total thickness

This represented the depth of the epidermal cell from the inner edge of the inner primary wall to the outer edge of the epidermis in 12 cells in each leaf. This was obtained by measuring 4 representative adjacent cells in 3 different areas per leaf.

The measurements of the total thickness of the lower and upper epidermis at the first collections in the normal border are shown in table 15. The leaves of Baart easily had the thickest lower and upper epidermis of any of the varieties, averaging 51 percent and 27 percent, respectively, thicker than those of Hope. The lower epidermis of Ceres and of Hope did not differ greatly in thickness.

The leaves of Marquis and Baart had the thickest, and of Hope the thinnest, lower and upper epidermis, at the last collections made in the normal border (table 15).

Under drouth conditions, the leaves of Ceres had the thickest lower and upper epidermis at the first collections (table 15). The lower epidermis of Ceres was 14 percent thicker than that of Hope. The lower and upper epidermis of Hope was thinner than in any of the other varieties.

TABLE 16: Differences in the leaf measurements between the first and last collections of varieties in normal and drouth borders.
(A - indicates that the first collections had higher measurements than the last.)

Variety	Leaf thickness	Lower epidermal measurements		Upper epidermal measurements	
		Outer wall thickness	Total thickness	Outer wall thickness	Total thickness
NORMAL BORDER					
Baart	-55.0	0.19	-6.08	-0.03	-4.23
Ceres	-12.0	0.12	0.45	0.29	-0.99
Marquis	-16.0	-0.06	-0.20	-0.26	-1.11
Hope	-29.0	-0.48	-0.16	-0.44	-1.97
DROUTH BORDER					
Baart	17.0	0.72	1.68	0.33	0.93
Ceres	0	0.18	-0.22	0.32	0.50
Marquis	- 5.0	0.09	-0.23	-0.26	-1.64
Hope	2.0	-0.30	0.39	0.17	0.04

The varieties ranked in the same order as their drouth resistance in the thickness of the lower epidermis at the last collections made in the drouth border (table 15). The average for Baart was 14 percent higher than for Hope. There was not a great deal of difference between the averages for Marquis and Hope. Ceres had the thickest, and Marquis the thinnest, upper epidermis.

With the exception of the lower epidermis of Ceres, all of the varieties had thicker lower and upper epidermis at the first than at the last collections made in the normal border. The leaves of Baart had the greatest differences. These data are shown in table 16.

The increases or decreases in the thickness of the lower and upper epidermis between the first and last collections in the drouth border are shown in table 16. The lower epidermis of Baart and Hope had the highest increases, the differences for Baart being four times that of Hope. Baart and Ceres had the highest increases in the upper epidermis.

Outer wall thickness

The outer wall thickness was obtained by measuring the distance between the outermost portions of the lumen to the outer edge of the epidermis in the same areas where the total thickness was obtained.

The outer walls of the lower and upper epidermis of Baart (table 15) were thinner than any of the other varieties at the first collections made in the normal border. There was not a great deal of difference between the other varieties in the outer wall thickness of the lower epidermis. In the upper epidermis, the varieties ranked inversely to their drouth resistance, as to the outer wall thickness.

At the last collections made in the normal border, the leaves of Ceres had the thickest outer wall in the lower and upper epidermis (table 15). The outer wall in the lower epidermis was 25 percent thicker than in Hope. There were only small differences between the outer walls in the upper epidermis of Baart, Marquis and Hope.

At the first collections made in the drouth border, the outer wall thickness of the lower and upper epidermis of the varieties also showed small differences. In the lower epidermis, the outer wall of Ceres was only 6 percent thicker than in Hope (table 15).

In the thickness of the outer wall in the lower epidermis, the varieties lined up in the same order as their drouth resistance, at the last collections made in the drouth border. Although the differences between Ceres and Marquis were small, the average for Baart was 39 percent higher than for Hope. In the upper epidermis, Ceres had the thickest, and Marquis the thinnest, outer wall thickness.

With the possible exception of Hope, there were no outstanding differences in the outer wall thickness of the lower and upper epidermis between the first and last collections of the varieties grown in the normal border (table 16). The general trend, however, indicated that the measurements were higher at the first than at the last collections.

The differences in the outer wall thickness of the lower and upper epidermis between the first and last collections, when the varieties were grown in the drouth border, are recorded in table 16. In the lower epidermis, these differences for Baart were four times that of

Ceres and eight times that of Marquis. The differences for Baart were nearly twice that of Hope.

The outer walls of every variety in the normal and drouth borders at both collections were always thicker in the lower epidermis than comparable outer walls in the upper epidermis.

Number of rows of motor cells and number of cells per row

At the last collections in the normal and drouth borders, the number of rows of motor cells and the number of cells per row were counted in every leaf.

In the normal border, the leaves of Ceres and Baart had the highest number of rows and also the largest number of cells per row. The leaves of Baart had 29 percent more rows per leaf, and one more cell per row, than Hope (table 15).

In the drouth border, although Baart had 31 percent more rows of motor cells than Hope, there were but small differences in these determinations between Baart, Ceres and Marquis (table 15). The differences were also small between the number of cells per row of the varieties.

Comparative amount of bloom

Observations were made during four different years as to the amount of bloom on the leaves, leaf sheaths, culms and spikes. These were obtained for all the varieties grown in the normal and drouth borders. Since there was but little difference between the amount and location of the bloom for a variety during these years, the results will be discussed as if they were for only one year.

The greatest amount of bloom occurred between two and three weeks before heading, after which there was a rapid decrease, especially in the awned varieties. There was always much more bloom developed on the varieties when grown in the drouth border than when the same varieties were grown in the normal border, and more bloom on the lower than on the upper leaf surfaces. There was also generally more bloom on the leaves and leaf sheaths that were located high on the culm.

Under drouth conditions, Baart developed bloom on both surfaces of the leaves. There was also bloom on the leaf sheaths, on the culms above the leaf sheaths, and on the lower area of the glumes, rachis and awns of the spikes. The extent of bloom development in Ceres was about the same as in Baart, except that there was a thicker coating. It was found on both surfaces of the leaves, on the leaf sheaths, on the entire surfaces of the glumes, and even on a portion of the awns nearest to the spikes. It was especially thick on the leaf sheaths and the lower surface of the leaves. In Marquis, the bloom was prevalent on the lower surface of the leaves and on the leaf sheaths. A trace was found on the upper surface of the leaves and on the glumes, but these were covered to a less extent than in Hope. Only a slight amount occurred on the leaf sheaths and lower surfaces of the leaves in Hope, and none on the upper leaf surfaces. A small amount was also found on the inside portions of the glumes. Under drouth conditions, the varieties may be listed in the following order, as to the amount and extent of bloom development: Ceres, Baart, Marquis and Hope.

When the varieties were grown under normal soil moisture conditions, there was a much decreased development of bloom. The leaves, leaf sheaths and spikes seemed to be covered to the same extent as when the same variety was grown under drouth conditions, but to a reduced amount. Baart and Ceres had more bloom than either Marquis or Hope.

Comparison of mesophyll

A number of comparative observations were made on the amount of intercellular spaces and size of mesophyll in the top leaves of the varieties in the normal and drouth borders. These were made only at the last collections.

Under drouth conditions, the mesophyll cells of Baart were short and very compactly arranged, while those of Ceres were slightly longer and narrower. The amount of intercellular spaces in Baart was generally less than in Ceres. No comparisons were made with Marquis, due to difficulties in sectioning. The amount of intercellular spaces in Ceres was definitely less than in Hope. The mesophyll cells of the latter variety were generally slightly longer and wider than in Ceres, and rather loosely arranged.

When the varieties were grown in the normal border, there were smaller differences between them as to the comparative size of mesophyll cells than when they were grown in the drouth border. The mesophyll cells of Ceres were shorter, narrower, and generally more compact than in Baart. The leaves of Marquis had mesophyll that was more compact than in Hope. The latter variety had cells that were generally large and rectangular shaped, while in Marquis they were smaller and more rounded.

DISCUSSION

In table 14, it was noted that the lower epidermis of every variety had a smaller number of stomata per unit leaf area in the drouth border than in the normal border. This may be partially accounted for by the fact that the thick coat of bloom may have closed some of the stomatal openings, thus leaving no prints on the collodion strips. The lower surface of Ceres had the greatest amount of bloom and likewise had the greatest decrease in the stomatal count. Most of the bloom on the leaves of Baart had disappeared by the time the stomatal prints were obtained. Likewise, in the drouth border, an increase occurred in the number of stomata (upper epidermis) of every variety except Ceres. This may have been due to a slight rolling of the leaves in the drouth border, which would put the rows of stomata closer together.

According to Maximov (1929-B) and Pool (1923), thick leaves are xerophytic structures. Although none of the leaves in this experiment can be classed as thick, the leaves of Baart and Ceres were the thickest, and Hope the thinnest, at the last collections in the normal and drouth borders (table 15). Thick leaves offer considerable resistance to transpiration, due to the large amount of intercellular spaces through which water vapor would have to pass before it reached the stomata.

There was generally a slightly closer relationship between the measurements and the drouth resistance of the varieties in the drouth than in the normal borders. This was especially true in the thickness of the outer wall in the lower epidermis and the thickness of the lower epidermis (table 15). These determinations ranked in the same order as the drouth resistance of the varieties at the last collections made in the drouth border. Ceres and Marquis had the thickest upper epidermis at the first collections, and Baart and Ceres the thickest at the last collections made in the drouth border.

Under severe drouth conditions, the lower epidermis is of much greater importance in decreasing water loss than the upper epidermis. This is true because under such conditions the leaves roll, thus exposing the lower epidermis to the atmosphere. In every variety, the lower epidermis had the following characteristics which made it more economical to water loss than the upper epidermis:

1. The outer walls were thicker than in the upper epidermis (table 15)
2. A much lower number of stomata per unit leaf area were found in the lower than in the upper epidermis (table 14).
3. A thicker layer of bloom was observed on the lower epidermis.

The bloom is a covering of wax insoluble in water or water vapor. The fact that it is white in color may result in a lowered absorption of heat by the leaves. Martin (1930) stated that the high amount of bloom on the sorghum leaves was one reason they were more drouth resistant than corn.

Maximov (1929), Pool (1923) and Eames and MacDaniels (1925) stated that drouth resistant plants generally had a thicker cuticle than drouth susceptible plants. Similar results were found by Martin (1930), who reported that the epidermis of sorghum leaves was more highly cutinized than that of corn leaves.

Attempts were made to measure the thickness of the cuticle in the lower and upper epidermis at the last collections in the normal and drouth borders. Although about one-half dozen methods were tried, none gave a cuticle distinct enough for measurement or even for comparison between the varieties. It is for this reason that no determinations are given as to the thickness of the cuticle. However, the importance of a thick cuticle in drouth resistant plants, especially in the lower epidermis, is well recognized.

It is generally believed that cuticular transpiration is very small, usually from 3 to 5 percent of the total transpiration. However, Mes and Ainslie (1935) reported that cuticular transpiration was between one-half and two-thirds of the total transpiration. In such cases, a thick cuticle would be highly effective in reducing water loss.

When comparisons were made on the measurements from the first and last collections in the normal border (table 16), it was noted that, with but one exception, every variety had a thinner leaf and a thinner lower and upper epidermis at the last collections. This may be attributed to the decreases in the percentage of leaf moisture at that time. On the other hand, in the drouth border, even though there were also decreases in the leaf moisture between the first and last collections, there was only one case (Marquis) that had the thickest leaves at the first collections. The high increase in the leaf thickness of Baart between the first and last collections was due to a thicker lower and upper epidermis and possibly to thicker mesophyll cell walls.

According to Martin (1930), "the larger number of motor cells in the group which quickly collapse during drying cause the folding of sorghum leaves to take place more rapidly and completely than the rolling of corn leaves." Contrary results were found in our tests, in that Hope had a higher number of rows which had collapsed motor cells than had Ceres, regardless of whether the leaves were rolled or not rolled prior to the collections.

A slightly higher amount of intercellular spaces were observed in Ceres than in Baart, and a much higher amount in Hope than in Ceres, especially under drouth conditions. The larger amount of intercellular spaces indicated larger mesophyll cells. Baart and Ceres had small mesophyll cells and thick leaves. This indicates that the total exterior surface of the mesophyll cells of these varieties would be much higher than in Hope, which had large cells and thinner leaves. Since the chloroplasts generally occur around the exterior of a cell, a larger exterior surface would mean that more chloroplasts would be exposed to the light than where there was a small total exterior surface. The former condition would favor photosynthesis. Under comparable conditions, a greater intensity of photosynthesis would increase the carbohydrate content. This would, in turn, account for the high osmotic pressure of Baart and Ceres.

SUMMARY

Anatomical measurements and observations were made on plantings made in the spring of 1939. Four varieties of spring wheat, Baart, Ceres, Marquis and Hope (listed in order of their drouth resistance) were grown in adjacent borders, one of which was irrigated normally and is called the normal border; the other received no irrigation water after planting and is called the drouth border.

It may be said that, in general, there was no relationship between the number of stomata per unit leaf area of either the lower or upper leaf surfaces and the drouth resistance of the varieties. This was true in both the normal and drouth borders.

Between the first and last collections in the drouth border, the differences in the outer wall thickness of the lower epidermis of Baart were four times that of Ceres and eight times that of Marquis. The first collections had the thickest walls in the case of Hope. Baart and Ceres likewise had the greatest differences in the upper epidermis.

In the drouth border, especially at the last collections, the lower epidermis had more xerophytic structures than the upper epidermis.

A closer relationship was generally found between the measurements and the drouth resistance of the varieties, in the drouth borders than in the normal borders, and at the last rather than the first collections.

In conclusion, the outstanding results were that under severe drouth conditions (last collections) the two drouth resistant varieties, Baart and Ceres, had the thickest leaves, the thickest lower and upper epidermis and the thickest outer walls in the lower and upper epidermis. These varieties also had the smallest mesophyll cells, the least amount of intercellular spaces and a greater number of rows of motor cells per leaf. Hope generally had the smallest measurements in these cases.

GENERAL SUMMARY

1. The physiological determinations were made in 1934, 1935, 1936 and 1938 on from four to eight varieties of spring wheat which varied in their resistance to drouth. In 1934, only the osmotic pressure and percentage of solids determinations were obtained. During 1935, 1936 and 1938, the percentages of leaf moisture and soil moisture data were added. The plantings were made in the field in two adjacent borders, one of which received normal irrigations and is called the normal border; the other received no irrigations after planting and is called the drouth border. A study of the development of crown roots was made in 1938 and 1939.

2. The anatomical investigations were conducted in 1939 on the leaves of Baart, Ceres, Marquis and Hope obtained from the normal and drouth borders. Measurements were made of the leaf thickness, the thickness of the lower and upper epidermis, and the thickness of the outer wall in the lower and upper epidermis. These measurements were made at two collections from the normal and drouth borders; the first collections were made when all of the leaves were fully extended, while the last collections were made just before the top leaves had started to dry up. Counts were made on the number of stomata per unit leaf area, the number of motor cells and the number of motor cells per row.

3. Under normal soil moisture conditions, there were no large consistent variations in the osmotic pressure and the percentage of solids between the varieties during the seasons.

4. The drouth resistant varieties generally had a higher osmotic pressure and percentage of solids in the drouth border than the drouth susceptible varieties. There were also greater increases of the resistant varieties as the drouth conditions became more severe.

5. There were rather strong indications that the slightly low leaf moisture of Baart in the drouth border played a minor role in producing the high osmotic pressure.

6. In the drouth border, Ceres had a higher three year average osmotic pressure and percentage of leaf moisture than either Marquis or Hope.

7. Every correlation with the yearly average percentage of solids for all of the years was significant for each of the six comparisons. Only three yearly comparisons were significant when the osmotic pressure was considered.

8. There were no outstanding differences in the number of stomata on the lower or upper epidermis between the varieties in either the normal or drouth borders.

9. There was a general tendency for the anatomical measurements on the normal border to be higher at the first than at the last collections. The reverse was true with the measurements made on the varieties in the drouth border.

10. The mesophyll cells of Baart in the drouth border were small and compactly arranged. Hope had rather large and loosely arranged mesophyll cells.

11. Under drouth conditions, Baart and Ceres had the following

features which aided them in maintaining a greater rate of water absorption and a reduced rate of water loss than Hope:

(a) Higher osmotic pressure and percentage of solids.

(b) Thicker leaves.

(c) Thicker lower and upper epidermis.

(d) Thicker outer walls in the lower and upper epidermis.

(e) Smaller mesophyll cells with lesser amounts of intercellular spaces.

(f) Heavier coat of bloom on both surfaces of the leaves, on the leaf sheaths, culm, and on the lower portion of the spike.

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TABLE 17: Osmotic pressures of varieties grown in normal and drouth borders, 1935.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
				NORMAL BORDER					
March 12	11.86	11.80	---	11.56	11.26	11.38	11.80	---	11.61
" 16	12.22	12.88	---	12.94	13.18	13.00	13.00	---	12.87
" 20	12.16	11.92	12.58	12.16	11.62	12.40	12.52	12.40	12.22
" 24	12.16	11.98	12.88	12.16	12.10	12.76	12.46	12.34	12.36
" 28	13.24	12.76	---	13.66	13.30	13.36	13.06	---	13.23
April 5	13.96	13.18	14.44	13.48	13.12	13.72	13.66	14.56	13.77
" 9	14.02	12.76	14.92	13.78	14.02	15.52	14.00	13.96	14.12
" 17	14.86	13.72	15.04	15.82	14.68	14.38	15.28	---	14.83
" 21	14.92	14.56	14.50	15.28	14.68	14.74	16.78	---	15.07
" 25	17.02	15.82	17.32	18.04	17.38	16.06	17.74	17.80	17.15
" 29	16.48	15.16	16.06	16.54	16.54	16.30	16.24	15.28	16.08
May 7	17.98	16.48	16.84	17.56	16.42	16.36	17.66	18.64	17.24
" 11	16.24	15.64	16.78	14.98	16.60	15.34	16.12	15.22	15.87
" 15	16.36	15.28	15.64	15.04	14.98	16.84	16.78	15.64	15.82
" 19	19.18	18.82	19.78	17.14	19.54	18.88	18.76	16.24	18.54
Average	14.84	14.18	15.57	14.68	14.63	14.74	15.06	15.21	
				DROUTH BORDER					
April 13	17.80	15.58	17.38	17.68	16.48	17.14	16.78	---	16.98
" 17	16.42	16.00	17.20	16.18	16.00	15.88	14.86	---	16.08
" 21	16.84	16.30	17.56	17.86	15.52	15.34	14.74	---	16.31
" 25	18.28	18.16	20.02	19.90	18.10	16.78	16.90	18.88	18.38
" 29	18.04	17.62	19.72	19.00	17.08	17.56	16.72	18.88	18.08
May 7	19.90	18.47	19.64	19.30	16.90	16.96	17.50	19.18	18.48
" 11	20.09	20.56	21.40	19.06	19.24	19.00	17.74	19.60	19.59
" 15	22.06	18.04	22.54	19.36	17.56	17.44	17.74	19.54	19.29
" 19	23.14	22.96	23.14	21.94	17.44	17.68	17.86	20.56	20.59
Average	19.17	18.19	19.84	18.92	17.15	17.09	16.76	19.44	

TABLE 18: Osmotic pressures of varieties grown in normal and drouth borders, 1936.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
				NORMAL BORDER					
March 6	13.96	14.08	14.80	15.28	14.86	13.72	12.88	13.66	14.16
" 10	14.14	14.68	15.64	15.88	14.74	14.56	14.68	14.74	14.88
" 14	16.24	15.04	15.16	15.64	14.56	15.57	14.44	15.76	15.30
" 18	15.16	15.52	14.80	12.76	14.32	15.40	14.74	14.86	14.70
" 22	17.02	15.76	15.10	15.52	14.26	14.98	14.80	16.30	15.47
" 30	14.80	15.04	15.28	14.32	14.44	13.84	13.48	14.80	14.50
April 7	16.06	15.34	16.48	14.32	14.74	14.14	13.64	13.90	14.83
" 11	16.72	16.42	16.18	15.82	14.92	14.56	16.36	14.92	15.74
" 15	18.16	17.20	15.82	16.00	15.04	15.52	14.38	15.28	15.93
" 19	16.48	15.70	14.26	14.08	13.84	13.66	13.12	13.60	14.34
" 23	16.00	15.64	15.64	15.46	14.38	14.98	14.02	14.62	15.09
" 27	17.98	18.88	17.74	18.64	17.32	17.08	15.76	16.48	17.49
May 1	20.08	22.06	19.18	19.96	19.36	19.54	17.74	19.36	19.66
Average	16.37	16.26	15.85	15.67	15.14	15.20	14.62	15.25	
				DROUTH BORDER					
April 7	18.64	18.82	18.28	17.56	17.62	16.66	17.08	17.86	17.82
" 11	18.16	19.30	18.02	17.02	18.10	17.44	17.50	18.88	18.05
" 15	21.52	20.44	20.02	19.72	20.50	19.60	19.60	20.32	20.22
" 19	22.84	21.76	20.38	21.34	21.28	20.74	20.92	20.86	21.27
" 23	25.78	24.82	23.44	25.66	24.58	23.80	24.22	22.54	24.36
" 27	30.08	28.17	24.34	25.11	25.71	24.88	25.53	24.70	26.07
May 1	35.75	30.50	26.67	30.26	27.63	28.11	28.17	24.88	29.00
Average	24.68	23.40	21.59	22.38	22.20	21.60	21.86	21.43	

TABLE 19: Osmotic pressures of varieties grown in normal and drouth borders, 1938.

Date	Baart	Ceres	Marquis	Hope	Average
		NORMAL BORDER			
March 18	18.56	18.72	17.56	18.20	18.26
" 22	19.64	19.48	19.19	20.28	19.65
" 30	17.98	17.56	17.56	17.02	17.53
April 3	18.16	19.18	18.82	18.46	18.66
" 7	22.89	21.64	21.24	20.59	21.59
" 11	18.36	17.76	17.56	18.16	17.96
" 19	18.04	16.96	17.56	17.56	17.53
" 23	23.37	22.60	23.64	22.56	23.04
" 27	21.00	20.60	20.16	20.44	20.55
May 5	21.32	19.12	20.88	19.48	20.20
Average	19.93	19.36	19.42	19.28	
		DROUTH BORDER			
March 30	21.22	21.28	20.86	20.62	21.00
April 3	22.68	22.41	21.88	20.12	21.77
" 7	23.04	21.92	21.68	22.56	22.30
" 11	22.70	21.08	22.64	22.04	22.12
" 19	24.28	21.92	23.02	22.88	23.03
" 23	25.07	23.44	24.04	23.29	23.96
" 27	27.63	23.64	23.76	24.92	24.99
May 5	30.62	22.96	24.35	23.40	25.33
Average	24.66	22.33	22.78	22.48	

TABLE 20: Percentages of solids of varieties grown in normal and drouth borders, 1935.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
				NORMAL BORDER					
March 12	8.86	9.03	---	9.47	8.92	9.05	9.35	---	9.11
" 16	8.58	8.93	---	9.59	9.59	9.90	9.57	---	9.36
" 20	8.31	8.72	8.71	8.82	8.52	8.03	8.56	8.79	8.56
" 24	8.59	8.62	9.02	8.74	8.95	8.78	8.74	9.02	8.81
" 28	8.38	9.22	---	9.05	8.56	9.02	8.50	---	8.79
April 5	8.90	9.17	9.34	9.66	9.66	9.51	9.54	9.40	9.40
" 9	9.14	8.96	9.53	9.61	10.24	9.64	10.03	9.39	9.57
" 17	9.32	9.07	9.92	10.38	10.17	9.09	9.61	---	9.65
" 21	9.34	9.24	9.56	10.28	9.89	9.50	9.85	---	9.67
" 25	9.67	9.41	9.87	10.89	10.08	9.68	9.49	10.29	9.92
" 29	10.57	9.67	10.14	10.91	10.44	10.10	10.07	10.27	10.27
May 7	11.79	11.11	10.85	10.91	11.09	10.67	10.79	10.25	10.93
" 11	11.66	11.28	11.33	11.55	11.43	10.65	11.21	11.21	11.29
" 15	12.44	11.63	11.37	11.32	10.49	10.64	11.03	11.30	11.28
" 19	13.05	12.10	12.10	11.31	11.50	10.73	11.15	10.65	11.57
Average	9.91	9.74	10.15	10.17	9.97	9.67	9.83	10.06	
				DROUTH BORDER					
April 13	9.06	8.43	9.05	9.00	8.74	8.79	9.29	---	8.91
" 17	10.04	9.33	10.34	10.23	9.84	9.83	9.75	---	9.91
" 21	9.84	9.62	9.95	10.52	10.26	9.96	9.53	---	9.95
" 25	11.30	10.42	11.26	11.54	10.89	10.53	10.70	10.96	10.95
" 29	11.65	10.81	11.39	11.36	10.98	11.02	11.11	11.24	11.20
May 7	14.15	12.16	12.28	11.64	11.42	11.93	10.98	12.09	12.08
" 11	14.10	13.40	14.38	13.15	13.02	12.49	11.96	12.34	13.11
" 15	15.67	13.23	14.98	13.17	12.68	11.83	11.89	12.23	13.21
" 19	16.07	15.63	15.83	13.44	13.04	12.19	11.59	11.82	13.70
Average	12.43	11.45	12.16	11.56	11.21	10.95	10.76	11.78	

TABLE 21: Percentages of solids of varieties grown in normal and drouth borders, 1936.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
				NORMAL BORDER					
March 6	6.97	7.20	8.19	8.62	7.67	7.63	7.56	7.96	7.73
" 10	8.00	7.82	8.43	8.10	7.91	7.86	7.96	7.89	8.00
" 14	7.21	8.36	8.12	8.62	7.97	8.03	8.44	8.26	8.13
" 18	7.79	8.44	8.91	7.81	8.14	8.11	7.90	8.37	8.18
" 22	9.19	8.65	8.72	8.76	8.69	7.61	8.41	9.00	8.63
" 30	8.51	9.22	10.41	8.58	8.90	7.69	7.97	8.94	8.78
April 7	9.99	9.33	11.42	8.76	9.03	7.93	8.33	8.39	9.15
" 11	8.76	8.97	9.40	8.91	8.50	8.05	8.06	8.41	8.63
" 15	8.86	8.73	8.87	8.40	8.15	7.59	7.62	8.12	8.29
" 19	8.98	8.69	8.92	7.95	8.01	7.79	7.47	7.76	8.20
" 23	9.13	8.76	9.03	8.75	8.25	8.38	8.14	8.32	8.60
" 27	9.48	9.64	10.22	10.24	9.29	9.38	8.88	8.54	9.46
May 1	10.77	11.07	10.56	10.91	10.38	10.48	10.35	10.45	10.62
Average	8.74	8.84	9.32	8.80	8.53	8.19	8.24	8.49	
				DROUTH BORDER					
April 7	10.47	10.24	11.34	10.09	10.40	9.48	9.96	10.19	10.27
" 11	9.53	10.13	10.17	10.73	9.47	8.58	9.04	9.84	9.69
" 15	10.25	10.86	11.08	10.63	10.91	9.39	9.98	10.65	10.47
" 19	10.70	10.24	11.02	11.08	11.29	10.00	10.34	10.58	10.66
" 23	12.00	11.90	12.36	11.00	12.24	11.22	11.95	11.39	11.76
" 27	13.45	13.59	13.04	13.66	13.25	13.67	12.51	12.35	13.19
May 1	16.85	14.05	14.21	14.94	14.27	13.67	13.74	12.49	14.28
Average	11.89	11.57	11.89	11.73	11.69	10.86	11.07	11.07	

TABLE 22: Percentages of solids of varieties grown in normal and drouth borders, 1938.

Date	Baart	Ceres	Marquis	Hope	Average
		NORMAL BORDER			
March 18	10.28	10.41	10.75	10.79	10.56
" 22	11.10	11.76	11.64	11.62	11.53
" 30	11.86	11.98	11.75	11.70	11.82
April 3	12.24	12.27	11.89	11.48	11.97
" 7	13.12	11.52	12.46	12.08	12.30
" 11	11.24	11.18	10.67	11.05	11.04
" 19	10.38	10.33	10.51	10.33	10.39
" 23	11.75	12.27	11.46	11.94	11.86
" 27	12.04	12.10	12.05	11.69	11.97
May 5	12.88	11.93	12.82	11.72	12.34
Average	11.69	11.58	11.60	11.44	
		DROUTH BORDER			
March 30	12.63	13.45	13.30	13.04	13.11
April 3	13.99	14.30	14.11	13.17	13.89
" 7	14.50	15.04	14.31	14.34	14.55
" 11	13.53	13.53	13.98	13.24	13.57
" 19	14.52	14.01	13.91	13.76	14.05
" 23	14.72	14.16	14.51	13.65	14.26
" 27	17.16	14.85	14.78	14.32	15.28
May 5	20.51	16.47	16.44	14.92	17.09
Average	15.20	14.48	14.42	13.81	

TABLE 23: Percentages of leaf moisture of varieties grown in normal and drouth borders, 1935.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
				NORMAL BORDER					
April 9	80	81	--	81	80	77	79	--	79.7
" 17	79	75	--	76	72	75	75	--	75.3
" 21	72	71	--	73	74	73	72	--	72.5
" 29	74	75	75	77	76	73	76	77	75.4
May 7	69	69	70	72	70	68	68	71	69.6
" 11	68	68	--	67	70	64	69	--	67.7
" 14	70	70	--	72	71	70	69	--	70.3
" 19	67	67	--	70	70	69	68	--	68.5
Average	72.4	72.0	--	73.5	72.9	71.1	72.0	--	
				DROUTH BORDER					
April 13	75	77	--	76	75	73	73	--	74.8
" 17	76	78	--	76	74	75	74	--	75.5
" 21	70	72	--	73	72	72	72	--	71.8
" 29	69	71	74	73	75	75	72	76	73.1
May 7	66	66	69	69	68	66	67	68	67.4
" 11	69	63	--	71	66	68	63	--	66.7
" 14	65	66	--	70	69	67	68	--	67.5
" 19	57	57	--	64	63	62	62	--	60.8
Average	68.4	68.8	--	71.5	70.3	69.8	68.9	--	

TABLE 24: Percentages of leaf moisture of varieties grown in normal and drouth borders, 1936.

Date	Baart	Onas	Kubanka	Ceres	Marquis	Huston	Hope	Hope x Ceres	Average
NORMAL BORDER									
March 6	84	84	84	84	84	84	83	84	83.9
" 10	85	84	83	84	83	84	83	83	83.6
" 14	83	84	83	84	82	82	83	83	83.0
" 18	83	81	82	82	83	84	84	84	82.9
" 30	78	79	80	84	81	81	80	82	80.6
April 7	72	77	77	76	79	81	82	82	78.3
" 11	73	76	76	77	76	78	80	81	77.1
" 15	73	75	76	78	78	77	79	80	77.0
" 19	73	75	76	78	78	77	78	80	76.9
" 23	78	76	75	74	78	76	77	77	76.4
" 27	71	72	73	74	75	74	73	74	73.3
May 1	69	68	75	73	72	74	72	73	72.0
Average	76.8	77.6	78.3	79.0	79.1	79.3	79.5	80.3	
DROUTH BORDER									
April 7	75	76	76	77	78	78	80	79	77.4
" 11	74	75	75	76	76	77	77	73	75.4
" 15	72	73	73	75	74	75	76	76	74.3
" 19	71	71	71	72	72	74	74	74	72.4
" 23	70	70	69	73	69	70	69	71	70.1
" 27	64	67	70	68	67	68	67	69	67.5
May 1	65	66	67	65	65	67	65	68	66.0
Average	70.1	71.1	71.6	72.3	71.6	72.7	72.6	72.9	

TABLE 25: Percentages of leaf moisture of varieties grown in normal and drouth borders, 1938.

Date	Baart	Ceres	Marquis	Hope	Average
		NORMAL BORDER			
March 18	80	79	81	80	80.0
" 22	78	77	79	78	78.0
" 30	75	--	--	75	75.0
April 7	71	75	75	74	73.8
" 11	72	76	76	74	74.5
" 19	69	73	73	70	71.3
" 23	69	72	72	70	70.8
" 27	69	73	73	71	71.5
May 5	68	71	70	69	69.5
Average	72.3	74.5	74.9	73.4	
		DROUTH BORDER			
April 7	69	71	71	71	70.5
" 11	67	70	70	71	69.5
" 19	63	67	65	68	65.8
" 23	64	66	65	66	65.3
" 27	64	65	65	65	64.8
May 5	60	63	62	63	62.0
Average	64.5	67.0	66.3	67.3	