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SUMMARY OF BULLETIN

1. Sweet clover (white) will apparently live in the loam soils employed in the present trial with as little moisture as 9 percent of the dry weight of the soil in which it grows. On the clay soil employed in this series sweet clover appeared to cease growth when the percentage of water on the basis of the dry soil approached 11 percent as a minimum. It is thus indicated that even under conditions otherwise identical variations in soil type may produce some variation in the amounts of water necessary for growth of sweet clover. The observation that soil type, regardless of other conditions may furnish a factor influencing "water requirement" is in substantial agreement with other investigators. Pages 259, 261, 272, 273.

2. When the factor of soil type was equalized, it was observed that as the percentage content of moisture in soil was increased, the total amount of water utilized by the plants increased. With increase of moisture content by degrees, in soil from 9 percent, to a maximum of 32 percent, the total water used increased regularly from 6.6 kilos to 79 kilos. Thus in general, sweet clover plants can make some growth with very limited moisture, but if water is available to them they can adapt themselves to use it. Pages 261, 273.

3. It is also apparent that the average production of dry matter per plant increases with the total amount of water utilized. Page 261.

4. One chief factor in the increase of dry matter of sweet clover produced with the increase of available water was the increase in height of main stems; the extreme height of plant (main stem) was found to increase, with the increase of water available, up to 22 percent of the dry weight of soil. When the percentage of available water was still further increased the corresponding increase in dry matter apparently was produced not by increase in extreme height but by increase in number of stems and branches. Such was the means by which sweet clover plants adapted their manner of growth to the increases in water. Page 273.

5. Also in regard to the manner of growth of sweet clover plants as affected by increases in amount of water; it appeared that the average weight of the leaves of plants increased, and that the mean area per leaf increased with increase in the amount of moisture available. This statement is based on measurements made in 1918. Pages 273, 275.

6. It appeared that the average actual "water-requirement" (as indicated by the ratio of grams water used to grams of air-dry tops produced) increased with an increase in the amount of the water available, up to 18 percent of the weight of soil, possibly beyond. In short sweet clover will not only utilize more total water within limits when it becomes available, but also will utilize more water per gram of dry matter up to a maximum. Pages 272, 273.

7. The present researches indicate that as an average on all soils the water requirement for sweet clover varies according to the percentage of water available, from 675 to 789. Page 275.

8. These figures for water requirement as determined agree substantially with those furnished by Briggs and Shantz, for conditions at Akron, Colorado, they having secured a water requirement of 770. Page 294.

9. Sweet clover may be said to have an average water requirement, as compared to plants listed in general; tumble weed with 277 and millet with 310 are among the lowest and brome grass, with 1016, highest in respect to water requirement. Page 294.

10. Previous to beginning the present researches, South Dakota Experiment Station published Bulletin 151, "Trials with Sweet Clover as a Field Crop," which indeed may have been the earliest bulletin published giving results with growing, harvesting and feeding the plant in question as a harvested crop. At the beginning of the present researches it was intended to get quantitative information about the capacity of the sweet clover plant to adapt itself to a wide range of cropping conditions. It becomes more apparent that sweet clover possesses that range of adaptability. In spite of some limitations as a crop-plant it may well increase in importance as a farm crop, in South Dakota and throughout the world.

WATER AS A LIMITING FACTOR IN THE GROWTH OF WHITE SWEET CLOVER (M. ALBA)

by
A. N. HUME, H. LOOMIS and J. G. HUTTON

INTRODUCTION

* * * *

The effects of varying conditions of soil moisture upon the growth of plants have long been recognized. In regions of limited annual precipitation the amount of soil moisture usually is the first limiting factor in crop production, and it often happens that even in regions more favored as regards the amount of rainfall, unequal distribution of the same acts in like manner to limit the quantity of the crops that are raised in a given season. These facts were early recognized by investigators, and since the time of Lawes (1850), many have undertaken experimental work to determine the exact relations and duty of water in crop production. It is not the purpose here to review in detail the extensive literature covering the general subject, but merely to point out certain well established facts that bear upon the problem of the water requirement of plants.[1] These may be briefly summarized:

1. Water requirement: The term "water requirement" is now generally understood to mean "the ratio of the weight of water absorbed by the plant during its growth to the weight of dry matter produced." (Briggs and Shantz, 1913, 1914.)[2]

It is, therefore, the quantity of water necessary to produce unit quantity of dry matter. In this bulletin the term is used to signify the quantity of water necessary to produce unit quantity of dry, or air dry matter, exclusive of roots and two inches of stubble.

2. Factors affecting the water requirement of plants: There are three main factors which have been shown to affect the water requirement of plants, namely: (a) climate (b) soil, and (c) water supply. In addition there are two other factors which affect the determination of the water requirement under control conditions; the kind of pot used and the kind of plant under investigation. As is well known, the determination of the water requirement of plants under field condi-

[1]Very complete bibliographies of water requirement are given by Briggs and Shantz, 1913-b; Kiesselbach, 1916; Harris, 1914; and others. See bibliography, end of bulletin.

[2]Numbers refer to bibliography appended. See (1) above.

tions presents many difficulties which are not easily overcome. Most investigators have therefore devised and used some kind of pot in which the plants were grown, and thus were under more or less accurate control. It has been shown that this method, when properly safeguarded, lends itself well to fairly accurate determinations.

The effect, then, of the factors mentioned above, may be discussed briefly under the following heads:

1. The Pot;
2. The Environment;
3. The Soil;
4. The Water Supply; and
5. The Plant.

1. The Pot: The effect of the pot upon the water requirement depends both upon (a) its size and (b) its type. Kiesselbach (1916) has shown that the size of the pot determines the quantity of soil available for plant growth, hence limiting the available fertility. This also limits the number of plants which may be grown to maturity. Montgomery (1912) points out the effect which the type of pot may have upon the distribution of air and water throughout the soil mass and hence to the plant, which may modify profoundly the root development of the plant.

2. The Environment: The effects of the environment may be considered (a) relative to latitude and climate, and (b) relative to exposure of pot. Briggs and Shantz (1913a) found that both wheat and sorghum had relatively higher water requirements when grown at Amarillo, Texas, than when grown at Akron, Colorado. Since it is well known that altitude produces differences in climatic conditions similar to latitude, this element must also be noted, although no definite data on this point seems to exist. Since the changes both of latitude and of altitude bring about changes in climatic conditions, it will be seen that these latter conditions are of great importance in their effect upon the water requirement. Kiesselbach and Montgomery (1911) have shown that the elevation of the pot relative to the surface of the earth affects directly the evaporation from a free water surface, which factor they have also shown to be related to the transpiration of water by the corn plant. Further, it has been shown both by Kiesselbach and Montgomery, (loc. cit.), and by Briggs and Shantz (1916) that certain other environmental factors chiefly meteorological,—temperature, relative humidity, wind velocity and solar radiation,—have a very definite relationship to the quantity of water transpired by the plant.

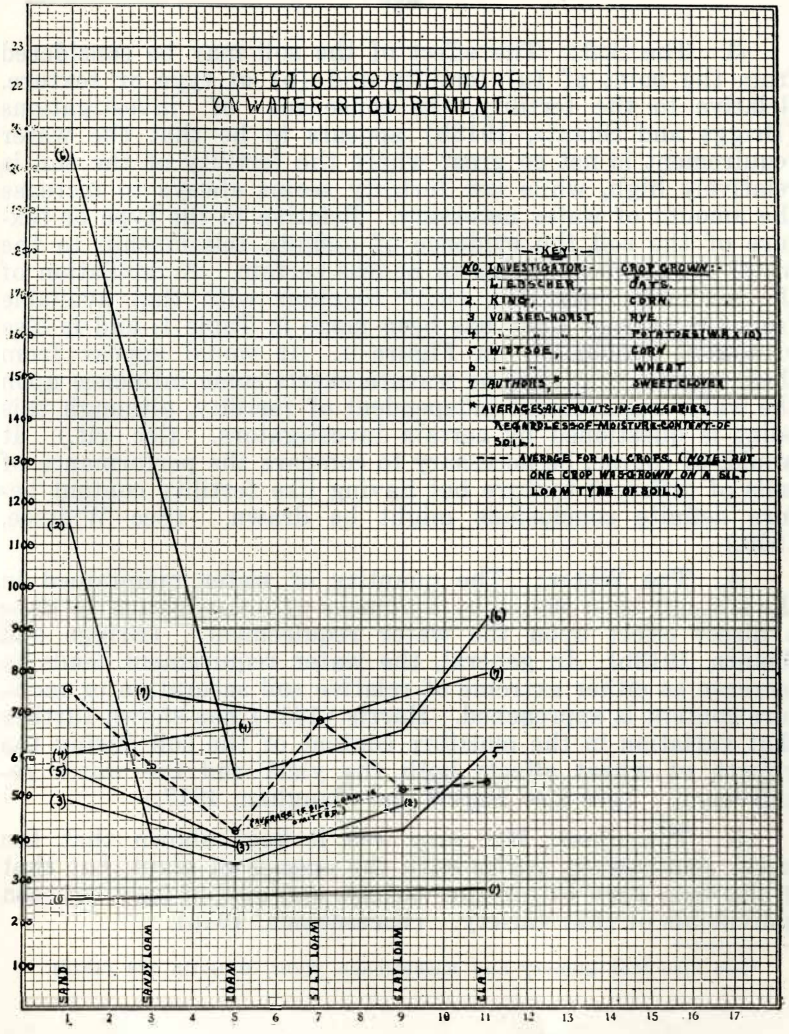

Fig. 1. The Effect of Soil Type on Water Requirement, According to Several Investigators.

In the above figure the water requirement has been plotted as the vertical component, while the soil type has been plotted as the horizontal component. Each curve represents the effect of the type upon the water requirement of a given plant. Note that the results of Liebscher and von Seelhorst were obtained with but two types of soil. Table 1-a gives the relative fertility of the soils used by the authors of this bulletin.

TABLE 1-A. FERTILITY IN THE SOILS.
Used by the Authors.

SOIL TYPE	Percent. Total Element in Surface Soil Nitrogen	Phosphorus	Potassium
Marshall sandy loam	.3178	.0733	1.798
Rosebud silt loam	.1368	.0604	2.393
Pierre clay	.1167	.0462	2.205

(Analyses calculated to basis of dry soil.)

3. The Soil: The effect of the soil may be considered from the point of (a) fertility and (b) of type or texture. Relative to the fertility, the consensus of investigations (Briggs and Shantz, 1913b) appears to be that the water requirement is not so great where the fertility of the soil is relatively high, while low fertility seems always to increase the amount of water necessary. Relative to the type or texture of the soil the evidence of definite relationship to the water requirement seems to be less certain. A tabulation of the available data (loc. cit.)* together with that available from the present work has been made in Table 1, and is also presented graphically in Figure 1. It would appear from these results that type or texture exerts some influence upon the water requirement independent of fertility, although this point is questioned by certain investigators. (loc. cit.) It would, of course, be necessary to compare the performance of soils of different texture but having like fertility content before definite conclusions might be drawn. (See Widtsoe, 1909.)

4. The Water: The quantity of water maintained in the soil has been shown by a number of investigators to have a direct effect upon the water requirement. (Briggs and Shantz, 1913b) In general, the water requirement tends to increase as either extreme of relative soil saturation or moisture content is approached. Harris (1914) has shown further that variation in the moisture content of the soil during the growth of wheat affects both the yield and the water requirement. (See also Harris and Maughan, 1917.)

5. The Plant: Not only has it been shown that the water requirement varies with the species of plant, but that it also may vary within the variety, and also to vary between individuals of that variety. (Kiesselbach, 1916).

*See also Montgomery and Kiesselbach, Nebr. Bulletin 128 (1912).

TABLE I.
EFFECT OF SOIL TEXTURE ON THE WATER REQUIREMENT
(According to results of several investigators.)

Year	Investigator	Crop	Soil Type	Water Requirement
1895	Liebscher	Oats	Sand	251
1895	Liebscher	Oats	Clay	278
1905	King	Corn	Sand	1152
1905	King	Corn	Sandy loam	387
1905	King	Corn	Loam	336
1905	King	Corn	Clay loam	474
1906	von Seelhorst	Rye	Sand	486
1906	von Seelhorst	Rye	Loam	375
1906	von Seelhorst	Potatoes	Sand	60
1906	von Seelhorst	Potatoes	Loam	66
1909	Widtsoe	Corn	Sand	561
1909	Widtsoe	Corn	Loam	386
1909	Widtsoe	Corn	*Clay loam	408
1909	Widtsoe	Corn	Clay	601
1909	Widtsoe	Wheat	Sand	2017
1909	Widtsoe	Wheat	Loam	546
1909	Widtsoe	Wheat	*Clay loam	658
1909	Widtsoe	Wheat	Clay	917
1920	**Authors (Mean)	Sweet Clover	Sandy loam	743
1920	**Authors (Mean)	Sweet Clover	Silt loam	680
1920	**Authors (Mean)	Sweet Clover	Clay	789

*Widtsoe classes this soil as a clay, but on the basis of classification which he uses (Hopkins') and the mechanical analysis given by him, it is distinctly within the clay loam class. (Cf. Widtsoe: Utah Bul. 105, p. 11, Table 2 and note; also Hopkins et al., Univ. Ill., Soil Report No. 4, "Sangamon Co. Soils," (1912); pp. 30-31; or any Ill. Soil Report, or Mosier and Gustafson, "Soil Physics and Management" (Philadelphia, 1917) p. 114-115, and p. 124.)

**The values here given for water requirement are the averages of all plants grown on the soil type, regardless of water content of the soil.

Within the scope of the present project the influence of the foregoing factors was briefly as follows:

1. **The Pots** were of uniform type throughout the work, with certain minor exceptions relative to coverings, as will be noted later.

2. **The Environment** was constant for all plants during a given season. No group of pots which was being compared with other groups possessed any known advantage of exposure over the others.

3. **The Soil** was a constant factor for each of the three series of pots employed. Each series of pots was provided with a single soil type.

4. **The Water.** The quantity of water in each pot was kept at a certain definite percentage of the dry weight of the soil, as will presently appear.

5. **The Plant.** Plants of the same variety were used throughout the work. Individual differences were very marked during the first season. Selection however later reduced the variations due to such causes to the minimum, consistent with trustworthy results.

OBJECT OF THE WORK

The object of the work reported in this bulletin was to determine definitely the extent to which water was a limiting factor in the growth of white sweet clover upon certain types of soil occurring in South Dakota.

For the purposes of the project the work was limited to the study of the behavior of sweet clover grown in large pots filled with soils representative of three distinct and extensive types, which represent large areas of the state. Also, each soil was studied in its effects upon the growth of sweet clover when the soil was supplied with different quantities of water.

SOIL TYPES EMPLOYED

The soil types employed are described as follows:

1. Marshall sandy loan, Brookings. The soil was secured from the college farm and is described in U. S. D. A., Bur. Soils, Field Operations, 1903; Brookings Area. (Note: The name of this series is now Barnes.) This type is representative of the soils of the eastern part of the state.

2. Rosebud silt loam, Interior. This soil was secured from the vicinity of Interior, and it is described and located in U. S. D. A., Bur. Soils, Field Operations, 1909; Reconnoissance Soil Survey of Western South Dakota. The Rosebud is representative of large areas of the south-central portion of the state west of the Missouri river.

3. Pierre clay, Cottonwood. This soil was secured from the substation farm at Cottonwood. It is located and described in the same publication as the Rosebud soil, above. The Pierre is typical of west-central portions of the state west of the Missouri river.

The soils used in this work were secured by Professor J. Gladden Hutton, Soils Division, Agronomy Department.

TYPE OF POTS EMPLOYED

The pots employed in this project were made after the so-called von Seelhorst pattern. The distinctive feature of this pattern is that each pot is provided with two side tubes within the pot designed to carry water to the bottom where they connect with either end of a perforated semi-cylindrical tube across the bottom of the pot. Thus these pots were provided with sub-irrigation and also aeration. In the pots employed the side tubes had an inside diameter of about one-half inch, while the bottom tube was two inches in diameter, with three rows of perforations, one inch apart in the rows.

Twenty-four such pots were secured. Each pot was 16 inches in diameter and 36 inches high. Each pot was at first supplied with a slightly conical cover with a four-inch central

opening for the growth of the plant. These covers fitted tightly over the pots. During the first season (1915) these covers were used. During the growth of the crops of 1917 and 1918 short galvanized cylinders were inserted through these openings, the lower end projecting slightly (one-half to one inch) into the top soil, the other end being flush with the top of the cover. The purpose of these cylinders was to prevent growth of branches or stems under the cover, by forcing growth through the cover opening. During the growth of the crop of 1919 new covers were employed, each cover carried four tubulated openings. A central one for supplying water was one inch in diameter; three others for the growth of the plants were placed equidistant from the central one and from each other, and about four inches from the edge of the cover. These openings were one and one-fourth inches in diameter.

PREPARATION OF THE POTS FOR USE

Each pot was filled with soil as follows:

1. A two-inch layer of coarse gravel was weighed into the pot.
2. This was followed by a definite weight of subsoil corresponding to the depth to which it occurred beneath the surface in place.
3. This in turn was followed by a definite weight of subsurface soil in like manner.
4. The surface soil was then weighed into its corresponding depth.
5. The surface soil was covered with a two-inch mulch of medium gravel. The soil was compacted as it was placed in the pot. In this manner each pot contained a definite amount of soil of each stratum. The moisture in each stratum was determined and the exact quantity of dry soil in the pot calculated. This amounted to 116.37 kilos per pot. At the beginning of the project this quantity of soil practically filled the pot, but during the progress of the work over the period of five years the soil settled from one to two inches. The hygroscopic moisture content of each stratum of each of the three soil types is shown in Table 2.

TABLE 2.
HYGROSCOPIC MOISTURE IN SOILS

SOIL TYPE	STRATUM	Percent Water
Marshall	Surface, 0-9 inches	4.599
Marshall	Subsurface, 9-18 inches	4.104
Marshall	Subsoil, 18-36 inches	2.775
Rosebud	Surface, 0-9 inches	4.213
Rosebud	Subsurface, 9-18 inches	4.442
Rosebud	Subsoil, 18-36 inches	4.047
Pierre	Surface, 0-9 inches	5.019
Pierre	Subsurface, 9-18 inches	5.006
Pierre	Subsoil, 18-36 inches	6.026

The 24 pots, prepared as described, were transferred to the glass laboratory. Here weighed quantities of water were applied to each pot in order to bring the moisture content of the soil to the desired percentage of dry soil. The pots were then arranged in series corresponding to the soil types. Each series was again subdivided into four sets of pots, each set composed of two pots. Each set of two pots constituted a pair of duplicates containing the same quantity of water or percentage moisture content of the soil. Table 3, following, illustrates the arrangement of pots:

TABLE 3.
ARRANGEMENT OF POTS IN SERIES

SOIL TYPE		Marshall		Rosebud		Pierre	
Percent Water*		Pot Number					
1915-1	All Others						
18	9	A-1	A-2	A-1	A-2	A-1	A-2
22	11	B-1	B-2	B-1	B-2	B-1	B-2
26	13	C-1	C-2	C-1	C-2	C-1	C-2
32	16	D-1	D-2	D-1	D-2	D-1	D-2

*The higher percentages were maintained only during the growth of the first crop, under glass.

The first crop was started thus under glass, in December 1914. This was done by planting three germinated seeds per pot, and after a perfect stand was assured in each pot, all but one plant was removed. Thus a single plant was grown in each pot. The first crop was cut about June 20, 1915. At this time it was determined to reduce the moisture content of the soil in each set of pots by one-half, on account of the absence of any indications of limitation of growth under the existing high moisture content of the soil. Further, it was determined, on account of the high summer temperatures that would prevail under glass, to provide a screened inclosure outside the building to which the pots might be removed. This was accordingly done.

OUTDOOR SCREENED INCLOSURE OR "CAGE"

The screened inclosure referred to above consisted of a wooden platform, 8 by 24 feet, surmounted by a frame work of iron piping which was covered with galvanized screening with four meshes to the linear inch. The platform was at an average height above the ground of about 24 inches throughout the balance of the work. The "cage" was eight feet in height. This screened inclosure served to protect the plants from hail and birds. It also reduced the solar radiation. The quantity of the reduction was not measured, but Briggs and Shantz (1914) have noted under similar conditions that this may amount to 20 percent. During the entire period of work it was necessary to move this "cage" once on account of build-

ing operations on the campus. However, the new exposure was very similar to the old one, and the general liabilities to meteorological influences were the same. The second crop of 1915, the mixed crop of 1916, and the crop of 1917 were obtained in the old position; the crop of 1918 and the one of 1919 were obtained in the new position. The pots were thus at an elevation above the surface, and so subjected theoretically, at least to a higher rate of transpiration. It has already been noted that a screened inclosure will reduce the solar radiation. Briggs and Shantz (1914) also state that such shelter also reduced the water requirement, in the case of their measurements this amounted to about 22 percent, when compared to plants outside the shelter. Compared to plants outside the shelter, but set in a pit, the water requirement in the shelter was 10 percent higher (in the case of wheat). Kiesselbach and Montgomery have shown that, in the open, an elevation of six feet (somewhat greater than the height of the tops of the pots in our inclosure) increased the evaporation from a free water surface about 52.6 percent as compared with the surface of the earth (Kiesselbach and Montgomery, 1911). Thus it may be seen, that while the balance is not exact, the effect of reduced solar radiation does in a large measure counteract the effect of elevation. It also seems highly probable that the wire screen would materially reduce wind velocity, thus also tending to balance the effect of elevation. However accepting whatever increase there was in water requirement and other factors as due to this position, it remains to be proven that the difference was not constant for all pots, and that they are not therefore comparable among themselves. Since it was the purpose of the work to study the relative water relationships of sweet clover and the soils employed, the results are therefore comparable and conclusions should be confidently drawn, unless it can be shown that within an area of 192 square feet at a constant elevation and under conditions of uniform exposure to the meteorological elements, measurable variations in evaporation and transpiration can obtain, at different points in the area, simultaneously.

GROWING THE PLANTS

The method of growing the plants for the first crop in 1915 has been described. The second crop of 1915, obtained in the outdoor inclosure was of course the second growth from these same plants. Subsequent crops were obtained by starting a number of seedlings in the glass house early in the spring and selecting 24 uniform plants therefrom at the time of transplanting into the large pots. After the transplants

were sufficiently large the cover openings were usually closed by means of oilcloth fitted about the stems, thus largely excluding rain and preventing evaporation. This applies to the crops of 1916, 1917 and 1918. In 1919, with the new type of cover, already described, the openings were waxed as soon as the covers were put on after transplanting, and surgeon's adhesive tape was used to seal the seams between covers and pots. Thus the exclusion of rain and loss by evaporation was reduced to the minimum. Except in the case of the 1919 crop, one plant was grown in each pot. In 1919, three plants were grown. The object of this replication was the elimination as far as possible of the individual variation. This difference has been taken into consideration in compiling the tables.

WEIGHING POTS AND SUPPLYING WATER

Throughout each period in which the work was conducted the pots were weighed daily, or as often as was necessary to maintain the moisture content of the pot at the given percentage. At the time each pot was weighed the loss in moisture content as indicated by loss in weight was made up,—using at all times soft water, pumped from rain-water cistern,—and the weight recorded. For weighing the pots, platform scales, reading in the metric system were used. The sensitivity of the scales was 0.1 kilogram. During the first six weeks of the growth of the first crop (1915) the loss in water was made up by supplying the water through the side-tubes to the bottoms of the pots. Thereafter, it was determined to apply all water-loss renewals to the surfacing of the pot. When water was originally applied to the pots to bring them up to their determined moisture contents, a portion of the water was applied to the surface of the soil, while the balance was applied to the bottom through the side tubes. The reduction in the moisture content of each pot to one-half the original percentage, which was done after the first crop, 1915, was cut, was accomplished by removal of the covers and allowing both transpiration and evaporation to reduce the water content of each pot.

RECORDING THE DATA OBTAINED

Certain measurements, in addition to the daily record of the water supplied each pot, were made upon each plant at the time the crop was cut. Certain other measurements were necessarily made at a later time, such as the dry or air-dry weights and the leaf surface measurements. The following outline indicates the heads under which the data obtained has been grouped and recorded.

1. Total quantity of water utilized, kilograms; (Quantity of water supplied plus or minus any deficiency or excess in weight at beginning or end of the period of growth.)
2. Total weight of dry or air-dry matter, grams; (exclusive of roots, and two-inch stubble.)
3. Water Requirement: (The ratio between water utilized and dry or air-dry weight produced.)
4. Maximum height of plant, centimeters;
5. Mean length of main stems, centimeters;
6. Number of main stems from plant crown;
7. Mean length of branches, cms.
8. Mean number of branches per stem;
9. Green weight of leaves and of stems and branches, grams. (weight when cut.);
10. Dry or air-dry weight of leaves and of stems and branches, grams. (Dry weight at 105° C.);
11. Number of leaves in 15 grams green leaves;
12. Area of 15 grams green leaves, sq. cms.;
13. Calculated number of leaves on plant;
14. Calculated area of leaves on plant, sq. cms.;
15. Mean area per leaf, sq. cms.;
16. Leaf area per unit of dry or air dry matter produced, sq. cms.;
17. Leaf area per unit of water utilized; sq. cms.

From a study of the data obtained, either by direct measurements, or from calculations made therefrom, it would be expected to be able to show the effect of the quantity of water and the soil type upon the performance of sweet clover. As indicated under (11) and (12) above, actual measurements of leaf areas and counts of the actual number of leaves were made upon 15 gram portions of the green leaves. This was accomplished as follows. The leaves were rapidly stripped from the plant at the time of harvest, and placed in a covered can. There they were thoroughly mixed, duplicate 15 gram samples or aliquots were weighed out and as rapidly as possible laid out upon a large printing frame, such as is used by engineers in making "blueprints." In like manner, the sensitized paper was laid over the leaves and the "print" made and developed in the usual manner. After drying and pressing, the outlines of the leaves on the paper were easily traced with a polar planimeter, thus giving the area of the leaves so "printed", and from this area the total area of the plant was calculated from the number of 15 gram aliquots contained in the total weight of green leaves. These measurements were made but twice during the progress of the work. They

were made on the first crop, grown under glass and at the higher moisture content of the soil, and again on the second year growth of the crop of 1918. These measurements involved the measurement of 32,638 leaves, on fifty-two sheets, averaging about 628 leaves per sheet. In the case of the crop of 1918, but a single sheet representing a given plant was measured. In the case of the crop of 1915, however, all duplicate sheets were measured which covered the plants on the Marshall series, and all but three of the Rosebud series. The balance of measurements for this crop was confined to a single sheet. The following tabulation shows the relationship between duplicate prints:

No. pairs duplicates measured	13
Mean Difference in No. leaves between duplicates	53.2
Average No. leaves per print	627
Percent. = Mean Diff. ÷ Mean No. Leaves	8.48

PERIODS OF WORK

The work has naturally divided itself into periods corresponding to the growing periods and life of the sweet clover plant. Five crops were harvested, which consisted of sweet clover alone; and one crop (1916) which consisted partly of sweet clover from transplanted second year plants and partly of corn (Z. Mays) where like transplantings failed. The following outline shows the periods into which work falls:

1. 1915: First crop from first year plants, grown under glass, at moisture content range: 18% to 32% of the weight of dry soil.

   1915: Second crop from first year plants, grown in inclosure, at moisture content range: 9% to 16% of the weight of dry soil.

2. 1916: Transplanted second year plants, from field; 33 1-3% survived transplanting. (Plants used 1915 winter killed.) Corn was substituted for sweet clover where transplants failed.

3. 1917: First year plants from seedlings started under glass and transplanted to pots in April. One crop harvested.

   1918: Second year growth of plants from 1917; certain plants failed to survive wintering, chiefly those on pots with moisture content of soil between 9% and 11%. One crop harvested.

4. 1919: First year plants from seedlings as in 1917. Three plants grown per pot. One crop harvested.

For the purposes of this report, the crop of 1916 has little value. In the following pages, however, will be found a summary of the data of this crop, which is here given for whatever value may attach to it. The crops of 1917, 1918 and 1919 were started in the outdoor inclosure usually about the first week in May. The crops were harvested usually in July or August. The data from each of the seasons' crops have been summarized in tables further on in this bulletin. In all data presented the averages of the duplicates has been taken and tabulated for the purposes of discussion. In some cases the differences between the duplicates have been quite wide, but in most cases the difference has been within the limit of error. The nature of the growth of the plant is responsible largely for variations in certain measurements, e. g., number of main stems and branches, their length, etc. Variations in water requirement between duplicates also is in a large measure probably due to plant type, especially where plants are grown, as they were in 1915, from bulk seed.

From the experience of that season, where the seed used was of unknown origin, it was early seen that uniform growth was not to be expected. For this reason, seed used in 1917 and the following seasons was obtained from one of the plants grown in the inclosure in 1916. By so much selection a very uniform set of plants was obtained which materially improved the quality of results. A comparison of the plants grown in 1915 with those in 1918 as shown in Plates I and II, will indicate some of the difficulties experienced in handling this plant.

DISCUSSION OF THE RESULTS

In a series of 19 tables following will be found the tabulation of the results of the project. As before stated, these tabulations represent the averages of the duplicate pots. In making comparison of the effect of the soil type and of the moisture content upon the growth of the sweet clover plant, there has been employed a system of cross-averaging by which all pots of one series (without regard to moisture content of the soil) have been averaged to show the relative influence of the soil type upon the growth of the plant. In like manner, all pots of the same moisture content, regardless of soil type, have been averaged to show the relative effect of moisture content of the soil, upon the growth of the plant. While it may be contended that such a system of cross-averaging will give nothing but purely arbitrary values from which to draw conclusions, it appears to the writers that this is the only logical system by means of which the large mass of data may be concisely presented to show the definite effects

which differences in soil type and the moisture content produce upon the growth of sweet clover. This, it will be remembered, is the stated object of the investigation. In addition to these summaries, there is also presented the summary of each crop grown, and from these also it will be seen that the conclusions reached are quite the same as from the system of cross-averages.

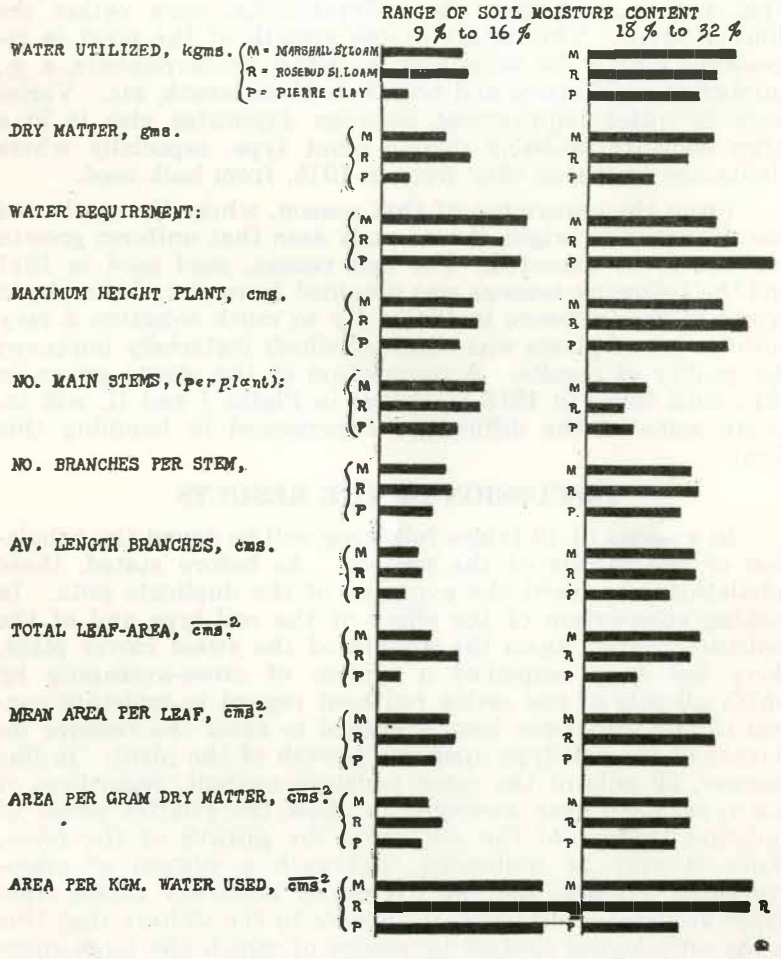

Fig. 2. Effect of Soil Type on the Growth of White Sweet Clover.

In each table the data is presented for each crop grown, and the averages for all comparable crops are also given. The summary of each measurement is given relative to the soil type and to the moisture content of the soil. It will be recalled that in 1915, the first crop was grown at percentages of moisture ranging from 18 percent to 32 percent, and that all subsequent crops were grown at moisture contents of exactly one-half of these. Figures 2 and 3 also present graphically the summarized data of all the crops grown.

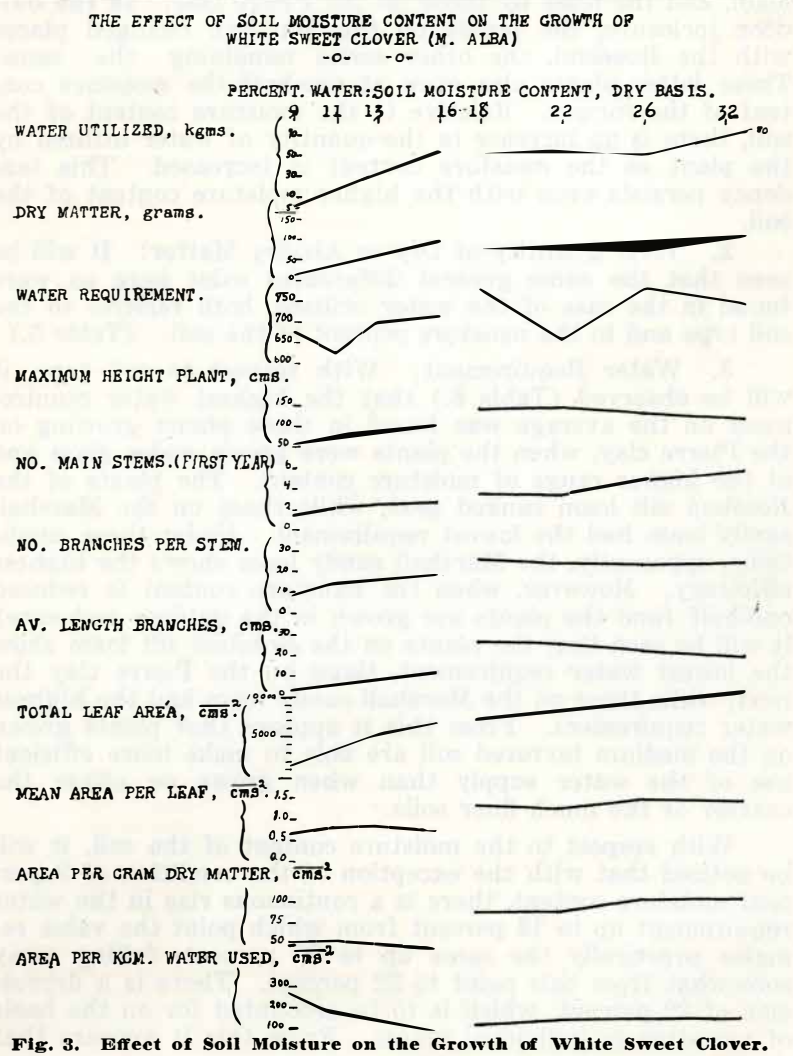

Fig. 3. Effect of Soil Moisture on the Growth of White Sweet Clover.

An examination of the tables thus presented yields the following:

1. Total Quantity of Water Utilized: The total quantity of water utilized by the plant (Table 4) varies with the type of soil and with the moisture content of the soil. Under glass and at percentages from 18 percent to 32 percent the largest quantity of water utilized was that by the plants on the Marshall sandy loam, next by those on the Rosebud silt loam, and the least by those on the Pierre clay. In the outdoor inclosure, the plants on the Marshall changed places with the Rosebud, the other series remaining the same. These latter plants also grew at one-half the moisture content of the former. Relative to the moisture content of the soil, there is an increase in the quantity of water utilized by the plant as the moisture content is increased. This tendency persists even with the higher moisture content of the soil.

2. Total Quantity of Dry or Air-dry Matter: It will be seen that the same general differences exist here as were found in the case of the water utilized, both relative to the soil type and to the moisture content of the soil. (Table 5.)

3. Water Requirement: With respect to soil type, it will be observed (Table 6.) that the highest water requirement on the average was found in those plants growing on the Pierre clay, when the plants were grown under glass and at the higher range of moisture content. The plants of the Rosebud silt loam ranked next, while those on the Marshall sandy loam had the lowest requirement. Under these conditions, apparently, the Marshall sandy loam shows the highest efficiency. However, when the moisture content is reduced one-half (and the plants are grown in the outdoor inclosure) it will be seen that the plants on the Rosebud silt loam show the lowest water requirement, those on the Pierre clay the next, while those on the Marshall sandy loam had the highest water requirement. From this it appears that plants grown on the medium textured soil are able to make more efficient use of the water supply than when grown on either the coarser or the much finer soils.

With respect to the moisture content of the soil, it will be noticed that with the exception of the condition of 9 percent moisture content, there is a continuous rise in the water requirement up to 18 percent from which point the value remains practically the same up to 26 percent, falling away somewhat from this point to 32 percent. There is a depression of 22 percent, which is to be accounted for on the basis of variation in individual plants. From this it appears that

the water requirement is increased with the increase in moisture content between the limits of 11 percent and 26 percent of the dry weight of the soil.

4. Maximum Height of Plant: The maximum height of the plant is taken as the length of the tallest main stem. From table 7 it will be seen that, relative to soil type, the greatest maximum height was attained by the plants grown on the Rosebud silt loam, both at the lower as well as the higher range of moisture content of the soil. Relative to the moisture content of the soil, the maximum height of the plant increases from 9 percent up to and including 22 percent, while from the latter point it steadily decreases. It would be expected that the height of plant might be affected by the number of stems and branches which the plant produces.

TABLE 4.
TOTAL QUANTITY OF WATER UTILIZED RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL.

(a) Relative to Soil Type (Kilograms Water)

SEASON	Mean of All Percentages Soil Types		
	Marshall	Rosebud	Pierre
1915 First*	70.47	60.94	52.71
1915 Second**	39.90	36.61	13.27
1917 1st Year	39.93	49.06	15.69
1918 2nd Year	34.53	36.37	13.30
1919 1st Year	39.16	38.77	9.075
Average, Type***	38.38	40.20	12.834

*First crop, 1915, grown under glass at higher moisture contents than succeeding crops.

**Second crop, 1915, grown in screened inclosure at constantly diminishing moisture content, until one-half the former content was obtained. It required from one-third to one-half the growing period for the moisture content of the pots to fall to their respective levels.

***Excludes first crop, 1915, (Av. of 1917-19; M = 37.87; R = 41.40; P = 12.688).

(b) Relative to Moisture Content (Kilograms Water)

SEASON	Mean of All Soil Types Percent Moisture Content of Soils							
	9	11	13	16	18	22	26	32
1915 First	.....	.....	.....	.....	54.43	58.21	54.80	79.05
1915 Second	12.66	19.68	34.06	53.30	.....	.....	.....	.....
1917 1st year.	3.83	18.30	47.91	69.53	.....	.....	.....	.....
1918 2nd year.	5.70	17.40	29.78	43.24	.....	.....	.....	.....
1919 1st year.	4.28	14.65	36.05	61.03	.....	.....	.....	.....
Av. per cent.	6.62	17.51	36.95	56.78	54.43	58.21	54.80	79.05

From data to be discussed presently covering the relationship of stems and branches produced it will be seen that there is a continuous increase, both in the number of stems and of branches, as the water content of the soil increases. A comparison of this latter data with the maximum height of the plant would seem to indicate that the increase in the amount of vegetative growth of the plant there is a corresponding increase in the height of the plant up to a certain point, beyond which further vegetative growth is made at the sacrifice of length of the main stems and height of plant.

5. Mean Length of Main Stems: The mean length of main stems is the average length of all the main stems produced on the plant. From the data given in Table 8 it will be

TABLE 5.

TOTAL QUANTITY OF AIR-DRY OR DRY MATTER PRODUCED RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

GRAMS PER PLANT

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 First crop*	119.00	95.31	62.69
1915 Second crop**	44.35	64.91	21.95
1917 1st year***	30.44	48.04	14.12
1918 2nd year***	93.21	129.88	47.87
1919 1st year***	63.44	75.21	14.92
Av. dry basis	62.36	84.71	25.63

*High Percents. Air dry.
**Low Percents. Air dry.
***Dry basis.

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop*	.....	.....	.....	.....	82.75	91.58	78.50	116.33
1915 2nd crop*	25.66	32.60	53.68	62.86	.....	.....	.....	.....
1917 1st year†	3.58	16.33	42.42	61.16	.....	.....	.....	.....
1918 2nd year†	29.60	56.97	93.54	127.66	.....	.....	.....	.....
1919 1st year†	7.25	29.38	63.05	105.08	.....	.....	.....	.....
Av. dry basis.	13.48	34.22	66.33	97.96	.....	.....	.....	.....
Av. air-dry ..	25.66	32.60	53.68	62.86	82.75	91.58	78.50	116.33

*Work of 1915 on air dry basis.
†Work of 1917-1919, inc., on dry basis.

seen that the same conclusions apply here as in the consideration of the maximum height of the plant. The relationship is obvious.

6. Mean Number of Main Stems Per Plant: The number of main stems growing from the crown of the plant varies with the age of the plant. Plants growing the first year usually have fewer than those growing the second year. The like applies when more than one crop is grown in a season. The data covering the plants observed is shown in Table 9. Relative to soil type, we find that the plants grown on the Marshall sandy loam produced more main stems than those grown on the other types. Relative to the moisture content of the soil it will be seen that the mean number of main stems increased as the moisture content of the soil increased.

TABLE 6.

WATER REQUIREMENT OF M. ALBA RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop*	621	721	899
1915 2nd crop†	866	582	677
1917 1st year†	1229	1003	1066
1918 2nd year†	354	283	278
1919 1st year†	603	486	648
Av. 1917 and 1918 (2 years)	791	643	672
Av. 1915-1919 (4 crops)	703	588	667

*High percents. †Low percent.

(b) Relative To Moisture Content of Soil

SEASON	Moisture Content Percent							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	789	662	788	748
1915 2nd crop.	596	641	773	822	.....	.....	.....	.....
1917 1st year.	1266	1009	1151	1138	.....	.....	.....	.....
1918 2nd year.	192	306	316	352	.....	.....	.....	.....
1919 1st year.	647	553	564	550	.....	.....	.....	.....
Av. 1917 & 1918	729	657	733	745	.....	.....	.....	.....
Av. 1915-1919.	675	627	701	713	.....	.....	.....	.....
Av. All Crops	675	627	701	713	789	662	788	748

7. Mean Number of Branches: (a) per plant (b) per main stem.

(a) Relative to soil type, the plants of the Marshall series produced the largest number of branches per plant, except in 1918. The number of branches per plant appears to bear a direct relation to the number of main stems. Relative to moisture content there was an increase in the number of branches per plant with increased moisture content of the soil. (Table 10.)

(b) Relative to soil type, the plants grown on the Rosebud silt loam produced on the average a larger number of branches per stem. This series of plants also grew the tallest, i. e., had the greatest maximum height and mean length of main stem. The relationship between length of main stem and number of branches per stem is apparent. Relative to

TABLE 7.
MAXIMUM HEIGHT (CMS.) OF M. ALBA PLANTS, RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	129.88	156.86	136.48
1915 2nd crop	80.12	89.37	73.62
1917 1st year	103.43	108.12	95.12
1918 2nd year	111.74	126.22	105.25
1919 1st year	57.97	54.66	34.73
Av. Biennium 1917-1918	108.59	117.18	100.19
Av. 4 years 1915-1919	88.32	94.59	77.18

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture Content							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	146.36	147.93	138.61	129.73
1915 2nd crop.	74.00	83.66	77.00	87.83	.....	.....	.....	.....
1917 1st year.	58.25	96.00	120.66	134.00	.....	.....	.....	.....
1918 2nd year.	67.80	102.10	119.20	127.20	.....	.....	.....	.....
1919 1st year.	29.81	46.11	57.60	64.96	.....	.....	.....	.....
Av. 1917 & 1918	63.03	99.05	119.93	130.60	.....	.....	.....	.....
Av. All crops.	57.46	81.97	93.62	103.49	146.36	147.93	138.61	129.73

moisture content of the soil, the number of branches per stem increased with the increase in the soil moisture supply. (Table II.)

8. Mean Length of Branches. Relative to soil type, the maximum length of branches is found on the plants grown on the Rosebud silt loam. (Table 12.) This apparently correlates with height of plant or length of main stem and also with the number of branches per stem. Relative to moisture content of the soil, it will be seen that the length of branches increased with moisture content up to 18-22 percent, but decreased from that point to 32 percent. This tendency to decrease beyond a certain moisture content was also noted in regard to the height of the plant or length of main stem.

TABLE 8.

MEAN LENGTH OF MAIN STEMS OF M. ALBA; (a) RELATIVE TO SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	117.87	143.80	123.92
1915 2nd crop (no data)	.....	.....	.....
1917 1st year	96.27	96.72	81.95
1918 2nd year	79.35	96.57	70.55
1919 1st year	52.15	48.97	31.96
Av. 1917-1918	87.81	96.65	76.25
Av. 1915; 2-'19	75.92	80.75	61.48

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915, 1st crop.	.....	.....	.....	.....	134.46	135.98	130.11	118.05
1915, 2nd crop*	.....	.....	.....	.....	.....	.....	.....	.....
1917 1st year.	54.96	89.25	105.91	116.46	.....	.....	.....	.....
1918 2nd year.	48.40	72.20	86.10	91.26	.....	.....	.....	.....
1919 1st year.	27.20	38.55	52.15	59.38	.....	.....	.....	.....
Av. 1917-1918.	51.68	80.73	96.00	103.86	.....	.....	.....	.....
Av. All crops.	43.52	66.66	81.38	89.03	134.46	135.98	130.11	118.05

*No data.

9. Mean Number and Area of Leaves Contained in Fifteen Grams, Green Weight: The number of leaves and their total area contained in 15 grams, green weight, will depend upon the relative thickness and density of the individual leaves, and thus upon the mean thickness and density. No measurements were made of the density of the leaves, and the measurement of the thickness of from 100 to 200 leaves per plant on several plants in 1918 did not indicate that any defi-

TABLE 9.

MEAN NUMBER OF MAIN STEMS PER PLANT, RELATIVE TO (a) SOIL TYPE AND (b) WATER CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	5.9	3.5	4.5
1915 2nd crop	13.6	11.6	8.9
1917 1st year	2.2	2.1	2.3
1918 2nd year	24.1	23.2	15.7
1919 1st year	2.4	2.5	2.0
Av. 1917-1918	13.15	12.65	9.00
Av. 1915; 2-1919	10.57	9.85	7.45
Av. 1st (yr) crops	2.3	2.3	2.15
Av. 2nd (yr) crops	18.85	17.4	12.3

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	3.6	3.6	5.2	6.0
1915 2nd crop.	10.3	11.0	11.0	13.2	.....	.....	.....	.....
1917 1st year.	1.3	1.8	2.8	3.0	.....	.....	.....	.....
1918 2nd year.	12.00	15.5	24.2	26.0	.....	.....	.....	.....
1919 1st year.	1.8	2.5	2.3	2.6	.....	.....	.....	.....
Av. 1917-1918.	6.65	8.65	13.50	14.50	.....	.....	.....	.....
Av. 1915:2-1919	6.35	7.70	10.07	11.20	3.6	3.6	5.2	6.0
Av. 1st (yr) crops	1.55	2.15	2.59	2.80	3.6	3.6	5.2	6.0
Av. 2nd (yr) crops	11.15	13.3	17.6	19.6	.....	.....	.....	.....

nite information could be gained in that manner without involving more time and labor than was available. From Tables 13 to 15 inclusive, it will be seen that noticeable differences exist between the two crops on which leaf measurements were made. In 1915, (the crop grown under glass and at higher range of moisture content of soil), it will be seen that there was, in general, a smaller number of leaves in 15 grams than in the case of the 1918 crop. It will be remembered that the crop of 1918 was grown from seed from the same mother plant, and that there was therefore greater uniformity among the plants than among those grown in 1915. Confining our attention to the crop of 1918 we find that, relative to the soil

TABLE 10.

MEAN TOTAL NUMBER OF BRANCHES PER PLANT, RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	114.7	88.5	93.7
1915 2nd crop (no data)	.....	.....	.....
1917 1st year	42.4	38.1	40.0
1918 2nd year	285.8	376.0	185.6
1919 1st year*	105.6	92.6	33.5
1919 1st year**	35.2	30.86	11.2

* and **Three plants were grown in each pot in 1919. * gives the total number branches on the three plants, ** gives the average per plant. It will be seen from the quantity of water utilized, the dry matter produced, and various other data already given, that the three plants per pot functioned approximately as one plant, i. e. three plants did not utilize three times as much water nor produce three times as much dry matter as one plant under like environment in other years.

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	82.5	85.8	73.6	146.8
1915 2nd crop.	.. (no data) ..		.....	.....	.....	.....	.....	.....
1917 1st year.	19.0	34.0	46.6	61.0	.....	.....	.....	.....
1918 2nd year.	71.0	204.7	321.6	350.6	.....	.....	.....	.....
1919 1st year*	18.6	68.0	103.5	118.8	.....	.....	.....	.....
1919 2nd year**	6.2	22.6	34.5	39.6	.....	.....	.....	.....

* and **(See note above.)

type, the largest number of leaves and greatest area of leaves in 15 grams, and also the largest mean area per leaf, occur on plants of the Rosebud series. The smallest values for these factors are found on the plants of the Pierre series. It would appear from this that the soil type affected these functions of the plant. As may be anticipated, we find that the calculated total number of leaves on the plant and total leaf-area of the plant correlate with the number of leaves and area of leaves in 15 grams green weight. (See tables 16 and 17; and Figures 2 and 3.)

Relative to soil moisture content, we find, in general, that the number of leaves in the 15 grams noticeably decreases while the area of the leaves slightly increases with the increase in the moisture content; also that the mean area per leaf increases with the increase in moisture content.

TABLE 11.
MEAN NUMBER OF BRANCHES PER MAIN STEM, RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	25.62	27.31	23.03
1915 2nd crop (no data)			
1917 1st year	20.16	18.09	16.75
1918 2nd year	14.86	20.35	15.17
1919 1st year	14.56	13.74	6.04
Av. 1917-1918	17.51	19.22	15.96
Av. 1917-1919	16.53	17.39	12.65

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.					26.38	25.18	24.00	25.71
1915 2nd crop*								
1917 1st year.	14.33	19.46	16.83	22.70				
1918 2nd year.	7.90	16.32	16.62	17.96				
1919 1st year.	5.58	9.20	15.20	15.80				
Av. 1917-1918.	11.11	17.89	16.73	20.33				
Av. 1915-1919.	9.27	14.99	16.22	18.82	26.38	25.18	24.00	25.71

*No data.

However, the calculated total number of leaves and total leaf area of the plant both increase as the moisture content of the soil increases.

While these conclusions are based upon the 1918 data alone, it is indirectly supported by other data available for 1917 and 1919 which correlates with the leaf area and number of leaves, namely: dry matter, height of plant, number of stems and branches, etc., considered above. These conclusions thus apply to the 9 percent to 16 percent moisture range, only. The wide variations between the individual plants in 1915 apparently submerged indications of general tendencies induced by the moisture content of the soil or by the soil type.

10. Leaf Area of Plant Per Gram of Dry Matter: In Table 18 is given the calculated values for the ratio:

$$\frac{\text{Total leaf area}}{\text{Total wt. dry matter}}.$$

TABLE 12.

MEAN LENGTH OF BRANCHES (CMS.) RELATIVE TO (a) SOIL TYPE AND (b) MOISTURE CONTENT OF SOIL

(a) Relative to Soil Types.

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	26.15	26.80	20.15
1915 2nd crop (no data)	.....	.....	.....
1917 1st year (no data)	.....	.....	.....
1918 2nd year	7.47	9.25	7.25
1919 1st year	12.42	11.57	5.10
Av. 1918-1919	9.95	10.41	6.18

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	26.85	26.10	23.45	20.40
1915 2nd crop.	.....	.....	.....	.....	.....	.....	.....	.....
1917 1st year.	.....	.....	.....	.....	.....	.....	.....	.....
1918 2nd year.	3.20	8.00	7.80	8.82	.....	.....	.....	.....
1919 1st year.	4.40	6.65	12.25	15.43	.....	.....	.....	.....
Av. 1915-1919	3.80	7.33	10.03	12.13	26.85	26.10	23.45	20.40

Again, considering the values for the 1918 crop only, we find that the largest leaf area per unit of dry matter occurred in the case of the plants on the Rosebud series; the smallest on those of the Pierre series. Relative to moisture content, there is a slight increase from 9 percent to 11 percent, but a continuous decrease from that point to 16 percent.

11. Leaf Area per Kilogram of Water Utilized: In Table 19 is given the calculated values for the ratio:

$$\frac{\text{Total leaf area}}{\text{Total wt. water utilized}}.$$

TABLE 13.
MEAN NUMBER OF LEAVES IN 15 GRAMS GREEN WEIGHT.

(a) Relative to Soil Type.

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	587	500	609
1918 2nd year	703	765	863

(b) Relative to Moisture Content of Soil

SEASON	Percent Water in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	569	595	561	537
1918 2nd year.	910	828	765	795	.....	.....	.....	.....

TABLE 14
MEAN AREA (CMS^2) LEAVES IN 15 GRAMS GREEN WEIGHT

(a) Relative to Soil Type.

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	837.24	752.39	736.59
1918 2nd year	657.49	706.65	611.34

(b) Relative to Moisture Content of Soil

SEASON	Percent Water in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	766.01	817.06	797.23	789.69
1918 2nd crop.	624.32	676.47	668.35	640.52	.....	.....	.....	.....

Again, the greatest leaf area per unit of water utilized is found on the Rosebud series, and the lowest area on the Pierre series, although the Marshall series is but a small amount in excess of the Pierre. Relative to moisture content, we find that with the increase in the moisture content, there is a marked decrease in the area produced per unit of water utilized.

TABLE 15
MEAN AREA PER LEAF (CMS.²)

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	1.53	1.55	1.245
1918 2nd year	0.86	0.94	0.71

(b) Relative to Moisture Content of Soil

SEASON	Percent Water in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	1.38	1.32	1.546	1.52
1918 2nd crop.	0.68	0.84	0.89	0.826	.....	.....	.....	.....

TABLE 16
MEAN NUMBER OF LEAVES ON PLANT (CALCULATED)
(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	8271	6533	4511
1918 2nd year	5418	7549	3050

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	5376	6720	5613	8011
1918 2nd year.	2281	3845	5366	7167	.....	.....	.....	.....

TABLE 17
MEAN LEAF AREA PER PLANT (CMS.²)

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	11,637	10,387	5,336
1918 2nd year	4,753	7,989	2,194

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	7350.1	8185.7	8858.4	10753.2
1918 2nd year.	1,565	3,162	5,169	6,788	.....	.....	.....	.....

TABLE 18.
LEAF AREA PER GRAM DRY (OR AIR-DRY) MATTER (CMS²)

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	101.64	106.24	88.91
1918 2nd year	51.72	61.35	43.62

(b) Relative to Moisture Content of Soils

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	91.79	92.69	106.32	107.39
1918 2nd year.	52.84	55.62	51.98	49.35	.....	.....	.....	.....

TABLE 19.
LEAF AREA PER KILOGRAM WATER UTILIZED (CMS²)

(a) Relative to Soil Type

SEASON	Soil Types		
	Marshall	Rosebud	Pierre
1915 1st crop	164.40	160.73	104.52
1918 2nd year	161.26	210.48	160.91

(b) Relative to Moisture Content of Soil

SEASON	Percent Moisture in Soil							
	9	11	13	16	18	22	26	32
1915 1st crop.	.....	.....	.....	.....	125.98	140.06	151.96	154.67
1918 2nd year.	274.59	182.25	169.79	112.06	.....	.....	.....	.....

SUMMARY TABLE "A"

SUMMARY OF FIRST CROP, 1915. GROWN UNDER GLASS DECEMBER 1, 1914—JUNE 29, 1915

Results Given as the Mean of Measurements on Duplicate Plants.

SERIES 1, MARSHALL SANDY LOAM

Percent, water in pots	18	22	26	32
Water utilized, kgms.	60.95	76.15	52.80	92.00
Airdry matters, gms.	117.75	123.00	77.25	158.00
Water requirement	586	638	683	578
Maximum height plant, cms.	140.40	120.60	117.80	140.75
Av. length main stems, cms.	134.80	119.70	99.45	122.60
Number of main stems	2.5	3	9	9
Length branches, cms.	34.60	30.15	21.45	36.80
No. branches per stem	28.75	27.45	21.15	25.15
Total wt. green leaves, gms.	158.00	223.00	175.00	261.40
No. 15 gm. aliquots in total	10.54	14.87	11.67	17.43
Area 15 gms. green leaves, cms^2	807.99	773.43	826.48	941.06
No. leaves in 15 gms.	609.70	757.00	398.50	583.25
Area per leaf, cms^2	1.42	1.02	2.075	1.62
No. leaves per plant	7265.	11164.	4636.	10019.
Leaf-area of plant, cms^2	8868.3	11406.9	9972.6	16300.4
Area per gm. a. d. matter, cm^2	82.91	97.16	123.25	102.74
Area per kgm. water used, cm^2	142.6	152.9	180.3	181.8

SERIES 2, ROSEBUD SILT LOAM

Percent, water in pots	18	22	26	32
Water utilized, kgms.	53.95	47.55	68.20	79.05
Airdry matter, gms.	76.50	59.00	119.50	126.00
Water requirement	861	739	569	653
Maximum height plant, cms.	156.05	160.55	174.45	136.40
Av. length main stems, cms.	141.50	147.50	158.15	128.15
Number of main stems	3.0	2.5	4.0	4.5
Length branches, cms.	21.80	26.90	29.65	28.85
No. branches per stem	29.75	25.25	26.50	27.75
Total wt. green leaves, gms.	160.6	124.1	229.6	285.5
No. 15 gm. aliquots in total	10.705	8.275	15.305	19.035
Area 15 g. green leaves, cms^2	702.86	683.22	864.94	758.55
No. leaves in 15 gms.	516.25	440.25	622.0	424.0
Area per leaf, cms^2	1.37	1.59	1.438	1.793
Total No. leaves on plant	5428.	3525.	9008.	8189.
Leaf-area of plant, cms^2	8215.5	5645.5	13205.7	14482.1
Area per gm. a. d. matter, cms^2	103.03	96.59	109.23	119.6
Area per. kgm. water used, cms^2	132.29	131.70	195.79	183.14

SERIES 3, PIERRE CLAY

Percent, water in pots	18	22	26	32
Water utilized, kgms.	45.40	55.95	43.40	66.10
Airdry matter, gms.	53.75	92.75	39.75	65.00
Water requirement	872.	609.	1100.	1015.
Maximum height plant, cms.	142.65	162.65	128.60	112.05
Av. length main stems, cms.	127.10	145.95	119.25	103.40
Number main stems	5.5	5.5	2.5	4.5
Length branches, cms.	24.10	21.25	21.25	13.95
No. branches per stem	20.65	22.85	24.35	24.25
Total wt. green leaves, gms.	91.50	142.5	72.75	145.25
No. 15 g. aliquots in total	6.10	9.50	4.85	9.685
Area 15 g. green leaves, cms^2	782.18	794.47	700.27	669.47
No. leaves in 15 g.	582.	589.	661.	604.
Area per leaf, cms^2	1.35	1.36	1.125	1.145
Total No. leaves on plant	3535.	5472.	3212.	5826.
Leaf-area of plant, cms^2	4966.58	7504.7	3396.88	6477.29
Area per gm. a. d. matter, cms^2	89.45	83.84	86.49	99.845
Area per kgm. water used, cms^2	103.05	136.08	79.88	99.07

SUMMARY TABLE "B"

SUMMARY OF SECOND CROP, 1915, GROWN IN SCREENED INCLOSURE JUNE 29—OCTOBER 20.

Results Given as the Mean of Measurement on Duplicate Plants.

SERIES 1, MARSHALL SANDY LOAM

Percent, water in soil	9	11	13	16
Water utilized, kgms.	14.20	29.55	38.25	77.50
Airdry matter, gms.	34.00	35.40	38.10	70.00
Water requirement	422.	862.	1050.	1123.
Maximum height plants, cms.	77.0	83.0	69.0	91.5
No. main stems	8.5	13.	14.	19.

SERIES 2, ROSEBUD SILT LOAM

Percent water in soil	9	11	13	16
Water utilized, kgms.	13.45	19.40	50.40	63.20
Airdry matter, gms.	30.5	35.75	106.25	87.15
Water requirement	482.	653.	478.	717.
Maximum height plant, cms.	69.5	96.0	95.5	96.5
No. main stems	12.	7.	14.	13.5

SERIES 3, PIERRE CLAY

Percent water in soil	9	11	13	16
Water utilized, kgms.	10.35	10.10	13.45	19.20
Airdry matter, gms.	12.80	27.25	16.7	31.35
Water Requirement	880.	391.	792.	626.
Maximum height plant, cms.	75.5	72.0	66.5	80.5
No. Main stems	10.5	13.	5.	4.5

SUMMARY TABLE "C"

CROP GROWN IN SCREENED INCLOSURE SUMMARY OF MIXED CROP, 1916

Certain pots grew transplanted second year M. Alba plants; the balance contained plants of Z. mays. These crops are indicated below.

SERIES 1 MARSHALL SANDY LOAM

Percent, water	9	9	11	11	13	13	16	16
Pot No.	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
Crop Grown	M. Alba	M. alba	Z. mays	Z. mays	Z. mays	Z. mays	M. alba	Z. mays
No. main stems	2	4	.....	.....	.....	.....	3	.....
No. plants	.....	.....	2	2	2	2	.....	2
No. branches	42	40	.....	.....	.....	.....	45	.....
Max. Height, cms.	76.5	86.6	107.2	102.4	129.7	120.2	65.0	95.9
Total a. d. wt. gs.	12.6	20.1	51.3	44.2	78.9	74.3	18.3	33.7
Water requirement	603	502	294	242	267	204	732	576
Water utilized	7.6	10.1	15.1	10.7	21.1	15.2	13.4	17.5

SERIES 2 ROSEBUD SILT LOAM

Percent, water	9	9	11	11	13	13	16	16
Pot No.	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
Crop grown	M. alba	Z. mays	Z. mays	M. alba	Z. mays	Z. mays	M. alba	Z. mays
No. main stems	2	.....	.....	2	.....	.....	2	.....
No. plants	.....	2	2	.....	2	2	.....	2
No. branches	35	.....	.....	38	.....	.....	30	.....
Maximum height, cms.	74.5	122.5	133.4	117.0	131.0	124.5	62.4	142.3
Total a. d. wt. gs.	14.0	56.5	75.7	20.9	77.0	62.7	6.0	94.5
Water requirement	650	327	222	627	274	343	1000	266
Water utilized	9.1	18.5	16.8	13.1	21.1	21.5	6.0	25.2

SERIES 3, PIERRE CLAY

Percent, water	9	9	11	11	13	13	16	16
Pot No.	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
Crop Grown	M. Alba	M. alba	Z. mays	Z. mays	Z. mays	Z. mays	Z. mays	Z. mays
No. main stems	3	2	.....	.....	.....	.....	.....	.....
No. plants	.....	.....	2	2	2	2	2	2
No. branches	45	45	.....	.....	.....	.....	.....	.....
Max. height, cms.	45.3	124.6	85.7	85.5	87.6	95.2	86.3	108.0
Total a. d. wt., gs.	9.08	19.9	18.2	18.9	21.3	25.2	22.3	35.2
Water requirement	715	351	593	428	704	377	376	301
Water utilized	6.5	7.0	10.8	8.1	15.0	9.5	8.4	10.6

NOTE: One plant of M. alba was grown in each pot indicated above. Two plants of Z. mays were grown in each pot where indicated in table.

SUMMARY TABLE "D"

SUMMARY OF FIRST YEAR CROP, 1917, GROWN IN SCREENED INCLOSURE, APRIL 13—OCTOBER 5.

Results Given as Mean of Measurements on Duplicate Plants.

SERIES 1, MARSHALL SANDY LOAM

Percent, water in soil	9	11	13	16
Water utilized, kgms.	5.6	25.5	58.85	69.8
Dry matter, gms.	6.25	21.75	41.50	52.25
Water requirement	937.	1212.	1431.	1338.
Maximum height plants, cms.	70.3	91.5	115.0	137.0
Av. length main stems, cms.	60.4	90.6	97.1	137.0
Number of main stems	2	2	4	1
No. branches per stem	14.	21.2	19.5	26.

SERIES 2, ROSEBUD SILT LOAM

Percent, water in soil	9	11	13	16
Water utilized, kgms.	2.9	18.45	68.95	105.95
Dry matter, gms.	2.75	16.0	70.5	103.0
Water requirement	1245.	1216.	978.	1025.
Maximum height plant, cms.	60.5	83.0	141.0	148.0
Av. length main stems	60.5	73.3	126.0	127.1
Number of main stems	1.	2.	2.5	3.
No. branches per stems	15.5	18.0	26.5	25.6

SERIES 3, PIERRE CLAY

Percent, water in soil	9	11	13	16
Water utilized, kgms.	3.0	10.95	15.95	32.85
Dry matter, gms.	1.75	11.25	15.25	28.25
Water requirement	1616.	1051.	1045.	1052.
Maximum height plant, cms.	44.0	113.5	106.0	117.0
Av. length main stems	44.0	103.9	94.7	85.3
Number of main stems	1.	1.5	2.	5.
No. branches per stem	13.5	19.3	17.7	16.5

SUMMARY TABLE "E"

SUMMARY OF SECOND YEAR CROP, 1918, GROWN IN SCREENED INCLOSURE, MAY 7—SEPT. 3.

Results Given as the Mean Measurements on Duplicate Plants.

SERIES 1, MARSALL SANDY LOAM

Percent water in pots	9	11	13	16
Water utilized, kgms.	5.70	19.80	44.95	53.25
Dry matter, gms.	29.60	60.40	130.20	120.90
Water requirement	192.	328.	345.	440.
Maximum height plant, cms.	67.80	97.95	129.80	129.50
Av. length main stems, cms.	52.80	61.10	92.60	95.00
Number of main stems	12.	19.	29.	22.
Length of branches, cms.	3.24	7.32	7.84	9.45
No. branches per stem	7.9	14.2	15.9	17.9
Wt. green leaves (total) gms.	37.6	74.15	152.15	134.45
No. 15 g. aliquots in total	2.507	4.94	10.143	8.963
Area 15 g. green leaves, cms.^{2}	624.32	678.49	673.85	636.73
No. leaves in 15 gms.	910.	864.	634.	811.
Area per leaf, cms.^{2}	.68	.82	1.065	.78
Total No. leaves on plant	2281.	4296.	6315.	7213.
Total leaf-area plant, cms^2	1565.17	3354.88	6764.62	5734.53
Area per gm. dry matter, cms^2	52.84	55.45	51.63	47.49
Area per kgm. water used, cms^2	274.59	169.32	150.04	107.78

SERIES 2, ROSEBUD SILT LOAM

Percent water in pots	9(a)	11(b)	13(c)	16(d)
Water utilized, kgms.		15.00	42.30	73.20
Dry matter, gms.		53.50	149.10	236.30
Water requirement		286.	283.	278.
Maximum height plant, cms.		106.30	145.50	147.00
Av. length main stems, cms.		83.30	100.50	119.20
Number of main stems		12.5	27.	42.
Length branches, cms.		8.67	9.61	9.84
No. branches per stem		18.5	21.9	22.6
Wt. green leaves (total) gms.		65.9	186.4	306.1
No. 15 g. aliquots in total		4.393	12.427	20.407
Area 15 g. green leaves, cms^2		674.43	774.85	702.88
No. leaves in 15 gms.		792.5	836.	638.
Area per leaf, cms^2		.86	.926	1.115
Total No. leaves on plant		3394.	10388.	13019.
Total leaf-area plant, cms^2		2969.21	9629.06	16384.37
Area per gm. dry matter, cms^2		55.75	64.58	69.33
Area per kgm. water used, cms^2		195.18	227.63	223.96

SERIES 3, PIERRE CLAY

Percent water in pots	9	11	13(c)	16(d)
Water utilized, kgms.			8.35	18.25
Dry matter, gms.			29.2	66.6
Water requirement			304.	252.
Maximum height plant, cms.			95.5	115.3
Av. length main stems, cms.			67.5	71.0
Number of main stems			12.	18.
Length of branches, cms.			6.89	7.66
No. branches per stem			14.7	15.7
Wt. green leaves (total) gms.			33.0	72.65
No. 15 g. aliquots in total			2.20	4.843
Area 15 g. green leaves, cms^2			609.6	613.13
No. leaves in 15 gms.			869.	857.
Area per leaf, cms^2			.705	.715
Total no. leaves on plant			1807.	4144.
Total leaf-area plant, cms^2			1344.88	3041.88
Area per gm. dry matter, cms^2			46.03	41.20
Area per kgm. water used, cms^2			160.62	161.19

SUMMARY TABLE "F"

SUMMARY OF FIRST YEAR CROP, 1919. GROWN IN SCREENED INCLOSURE, APRIL 30—AUGUST 19.

Results are Given as the Mean of Measurements on Duplicate Plants.

SERIES 1, MARSHALL SANDY LOAM

Percent water in soil	9	11	13	16
Water utilized, kgms.	7.25	24.85	51.70	72.95
Dry matter, gms.	12.60	40.90	83.25	117.00
Water requirement	564.	607.	621.	622.
Maximum height plant, cms.	40.15	52.6	70.3	68.85
Av. length main stems, cms.	37.1	46.85	63.3	61.35
Number main stems	4.5	8.5	6.5	10.0
Length branches, cms.	6.35	8.85	17.05	17.45
No. branches per stem	9.55	13.15	18.05	17.75

SERIES 2, ROSEBUD SILT LOAM

Percent water in soil	9	11	13	16
Water utilized, kgms.	2.90	11.45	48.00	87.75
Dry matter, gms.	6.05	43.20	90.05	161.55
Water requirement	485.	384.	535.	543.
Maximum height plant, cms.	26.45	55.05	60.50	76.65
Av. length main stems, cms.	22.85	46.60	52.20	71.25
Number of main stems	6.5	8.	8.5	7.
Length of branches, cms.	3.00	9.20	13.30	21.00
No. branches per stem	4.2	13.2	18.2	19.35

SERIES 3, PIERRE CLAY

Percent water in soil	9	11	13	16
Water utilized, kgms.	2.80	2.65	8.45	22.40
Dry matter, gms.	3.10	4.05	15.85	36.70
Water requirement	892.	676.	538.	485.
Maximum height plant, cms.	22.85	24.70	42.00	49.40
Av. length main stems, cms.	21.65	22.20	37.95	40.55
Number of main stems	5.	6.	6.	7.
Length of branches, cms.	3.85	1.9	6.4	8.25
No. branches per stem	3.	1.5	9.35	10.3

Note: In 1919, three plants were grown per pot. The Mean Number of Main Stems given in the above table is mean number **per pot**; to obtain the mean number **per plant** the figures given should be divided by 3. A comparison of this crop with the crop of 1917 will show that the three plants grown in 1919 functioned practically as one plant with respect to "water utilized", "dry matter," etc., excepting only the "number of main stems" to which attention has already been called.

SUMMARY TABLE "G"

EFFECT OF SOIL TYPE ON GROWTH OF M. ALBA WITH VARIED RANGES OF SOIL MOISTURE CONTENT

A. Soil Moisture Content Range: 18% to 32%, Dry Weight of Soil;
B. Soil Moisture Content Range: 9% to 16%, Dry Weight of Soil.

A. SOIL MOISTURE CONTENT RANGE, 18% to 32%, DRY WEIGHT OF SOIL. AVERAGE OF DUPLICATES, SEASON 1915, 1st CROP.

SOIL TYPE	Marshall Sandy Loam	Rosebud Silt Loam	Pierre Clay
Water utilized, kgms.	70.47	60.94	52.71
Dry (a. d.) matter, gms.	119.00	95.31	63.69
Water requirement	621	721	899
Max. height plant, cms.	129.88	156.86	136.48
Av. length main stems, cms.	117.87	143.80	123.92
Number of main stems	5.9	3.5	4.5
Length of branches, cms.	26.15	26.80	20.15
No. branches per stem	25.62	27.31	23.03
Total leaf-area, cms²	11637.	10387.	5586.
Mean area per leaf, cms²	1.53	1.55	1.246
Total number leaves	8271.	6533.	4511.
Area per gm. dry matter	101.64	106.24	89.90
Area per kgm. water used	164.40	160.73	93.497

B. SOIL MOISTURE CONTENT RANGE: 9% to 16%, DRY WEIGHT OF SOIL. AVERAGE OF DUPLICATES, 1915-1919, 4 CROPS.

SOIL TYPE	Marshall Sandy Loam	Rosebud Silt Loam	Pierre Clay
Water utilized, kgms.	38.38	40.20	12.83
†Dry matter, gms.	62.36	84.71	25.63
Water requirement	703	588	667
Max. height plant, cms.	88.32	94.59	77.18
†Av. length main stems, cms.	75.92	80.75	61.48
Number of main stems	10.57	9.85	7.45
§Length branches, cms.	9.95	10.41	6.18
†No. branches, per stem	16.53	17.39	12.65
*Total leaf area, cms²	4753.	7989.	2194.
*Mean area per leaf, cms²	.86	.94	.71
*Total No. leaves	5418.	7549.	3050.
*Area per gm. dry matter	51.72	61.35	43.62
*Area per kgm. water used	161.26	210.48	160.91

†Average for 1917-1919, 3 crops.
§Average for 1918-1919, 2 crops.
*Average for 1918, 2nd year crop only.
All other data represents average for 1915, 2nd crop, to and including 1919, 1st year crop.

Note: Crop: supplying data under "A", was grown under glass, 1915. All other crops supplying data for "B", were grown in outdoor screened inclosure, 1915-1919, inclusive.

SUMMARY TABLE "H"

EFFECT OF WATER CONTENT OF SOIL ON GROWTH OF M. ALBA, SUMMARY OF ALL SOIL TYPES

A. WATER CONTENT 18% to 32%, CROP GROWN UNDER GLASS. AVERAGE OF DUPLICATES OF ALL SOIL TYPES.

Percent water in soil	18	22	26	32
Water utilized, kgms.	54.43	58.21	54.80	79.05
Dry (a. d.) matter, gms.	82.75	91.58	78.50	116.33
Water requirement	789	662	788	749
Max. height plant, cms.	146.36	147.93	138.61	129.73
Av. length main stems, cms.	134.46	135.98	130.11	118.05
Number main stems (1st year)	3.6	3.6	5.2	6.0
Length of branches, cms.	26.85	26.10	23.45	20.40
Number branches per stem	26.38	25.18	24.00	25.71
Total leaf-area, cms^2	7350.12	8185.70	8858.40	10753.20
Mean area per leaf, cms^2	1.38	1.32	1.55	1.52
Total no. leaves	5376.	6720.	5613.	8011.
Area per gm. dry (a. d.) matter	91.79	92.69	106.32	107.39
Area per kgm. water used	125.98	140.06	151.96	154.67

B. WATER CONTENT 9% to 16%, CROPS GROWN IN OUTDOOR INCLOSURE. AVERAGE OF DUPLICATES OF ALL SOIL TYPES.

Percent water in soil	9	11	13	16
Water utilized, kgms.	6.62	17.51	36.95	56.78
†Dry matter, gms.	13.48	34.22	66.33	97.96
Water requirement	675	627	701	713
Max. height plant, cms.	57.46	81.97	93.62	103.49
†Av. length main stems, cms.	43.52	66.66	81.38	89.03
Number of main stems, (1st year)	1.55	2.15	2.55	2.85
Number main stems, (2nd year)	11.15	13.13	17.6	19.6
§Length of branches, cms.	3.8	7.33	10.03	12.13
†Number branches per stem	9.27	14.99	16.22	18.82
*Total leaf area, cms^2	1565.	3162.	5169.	6788.
*Mean area per leaf, cms^2	.68	.84	.89	.82
*Total no. leaves	2281.	3845.	5366.	7167.
*Area per gm. dry matter	52.84	55.62	51.98	49.35
*Area per kgm. water used	274.59	182.25	169.79	112.06

†Averages for 1917-1919, 3 crops.
§Averages for 1918-1919, 2 crops.
*Average for 1918, 2nd year crop, only.

All other data represents average for 1915, 2nd crop, to and including 1919, 1st year crop.

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WATER REQUIREMENT OF VARIOUS CROPS AND WEEDS: (AFTER BRIGGS AND SHANTZ, 1911-1913, AT AKRON, COLORADO)*

(Figures given are averages for the crop indicated).

CROP	WR
Proso	293
Millet	310
Sorghum	322
Corn	368
Wheat	513
Barley	534
Oats	597
Rye, spring	685
Flax	905
Sugar beets	397
Potatoes	636
Navy beans	682
Can. field peas	788
Red clover	789
Crimson clover	797
Alfalfa, Grimm	844
Alfalfa Yellow flower	865
Brome grass	1016
Wheat grass	705
Sweet clover	770

WEEDS	WR
Tumble weed	277
Pigweed	297
Russian thistle	336
Lamb's quarters	801
Sunflower	683
Ragweed	948
Western wheat grass	1076

*See Journal of Agricultural Research, Vol. 3, No. 1; Oct. 1914., pp. 58-60.

ANNUAL RAINFALL BY MONTHS AT THE SEVERAL STATIONS

BROOKINGS

	1905	1906	1907	1908	1909	1910	1911
Jan.	0.22	0.17	1.06	0.26	1.20	1.07	0.61
Feb.	1.00	0.02	0.28	1.80	1.57	0.40	0.53
Mch.	0.68	0.58	0.55	1.16	0.37	0.35	0.53
Apr.	1.01	1.40	1.67	2.10	1.16	2.34	1.62
May	6.14	3.51	2.36	6.46	4.85	0.87	1.90
June	6.09	4.89	5.65	6.35	2.29	1.85	3.78
July	0.98	1.86	3.77	4.69	2.44	1.68	3.32
Aug.	4.54	4.28	1.41	2.37	3.39	2.46	3.81
Sept.	2.16	5.13	1.28	3.89	1.67	0.96	3.08
Oct.	1.50	3.01	0.96	1.43	1.71	0.38	5.12
Nov.	2.45	0.89	0.10	1.30	0.65	0.17	0.23
Dec.	T	0.52	1.12	0.42	1.14	0.10	0.42
Total	22.77	26.26	20.21	32.17	22.44	12.63	24.95

BROOKINGS

	1912	1913	1914	1915	1916	1917	1918	1919
Jan.	0.28	0.02	0.22	0.18	1.47	1.54	0.19	0.07
Feb.	0.24	0.09	0.40	1.12	0.32	0.47	0.14	0.63
Mch.	0.26	0.45	0.42	0.18	0.50	1.09	0.44	0.73
Apr.	3.36	2.24	1.64	2.03	2.95	3.09	1.28	1.90
May	6.98	3.60	4.16	2.12	3.72	3.08	3.40	3.87
June	2.09	1.96	6.67	3.28	4.27	3.49	1.85	9.30
July	2.52	2.99	1.62	3.04	0.40	2.03	3.95	5.60
Aug.	4.68	1.33	3.16	3.52	2.03	1.20	4.19	1.48
Sept.	1.61	1.55	3.32	2.68	0.84	2.89	0.72	1.69
Oct.	0.96	1.18	2.21	1.37	0.45	0.12	1.56	1.14
Nov.	0.00	0.81	T	0.28	0.03	0.04	1.61	1.35
Dec.	0.20	0.09	0.33	0.62	0.36	0.31	1.09	0.10
Total	23.18	16.31	24.15	20.42	17.34	19.35	20.42	27.86

COTTONWOOD

	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Jan.	0.66	T	0.17	0.16	0.03	0.39	0.04	0.45	0.32	0.04
Feb.	0.97	0.15	0.05	0.10	1.18	1.57	0.02	1.50	1.50	0.29
Mch.	0.76	T	3.00	0.43	0.35	0.46	0.04	0.31	0.34	0.71
Apr.	1.06	0.85	3.32	1.15	2.26	2.80	0.81	0.80	2.27	3.57
May	2.54	1.10	1.18	2.95	2.35	6.61	3.87	3.30	2.78	1.29
June	1.30	0.64	0.95	0.59	1.64	4.79	1.83	0.62	1.37	4.97
July	1.11	0.59	2.42	0.81	1.04	4.58	1.80	0.90	2.29	2.05
Aug.	0.48	2.41	3.42	1.84	1.88	2.51	2.22	2.00	3.43	0.20
Sept.	0.82	3.59	1.30	1.15	1.19	2.42	0.18	1.17	1.43	0.25
Oct.	0.32	1.15	0.11	0.76	2.23	0.90	0.57	0.14	0.28	2.03
Nov.	0.53	0.20	T	0.14	0.02	T	0.15	0.39	0.11	0.71
Dec.	3.00	0.42	0.12	0.38	0.84	0.10	0.14	0.50	0.25	0.20
Total	12.65	11.10	16.04	10.46	15.28	27.31	11.67	12.08	16.37	16.31

EUREKA

	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Jan.	0.10	0.60	0.50	0.25	0.10	0.22	0.90	0.79	0.40	0.14	0.07
Feb.	0.45	1.70	0.73	0.40	0.03	0.05	1.08	0.13	0.20	0.50	1.04
Mch.	0.14	1.23	0.62	1.05	0.09	0.13	0.23	1.78	1.46	0.58	0.52
Apr.	0.50	0.82	2.24	1.29	0.68	2.07	1.83	0.88	2.18	1.98	1.28
May	2.65	0.42	0.97	3.37	1.97	2.20	2.58	3.57	1.30	1.97	3.68
June	3.35	3.80	1.29	1.50	2.91	4.28	4.66	4.16	1.61	0.93	2.29
July	2.21	0.53	0.43	2.19	2.16	1.25	3.38	—	1.04	1.03	4.08
Aug.	1.39	2.60	3.27	3.27	1.53	2.11	2.47	4.62	0.93	1.77	0.77
Sept.	1.25	3.65	1.15	1.43	0.54	0.70	3.74	1.05	0.67	0.36	0.04
Oct.	0.17	0.18	0.61	0.07	1.52	0.87	3.10	0.29	0.06	0.55	1.13
Nov.	0.60	T	0.88	T	0.06	T	0.56	0.14	2.00	0.53	0.12
Dec.	2.40	0.25	0.80	0.11	0.52	0.53	0.36	0.06	0.75	0.20	0.32
Total	15.21	15.78	13.79	14.93	12.11	14.41	24.89	17.47	12.60	10.54	15.34

HIGHMORE

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Jan.	T	0.26	0.82	0.11	0.13	0.05	0.13	0.43	1.40	1.12	0.60	0.10
Feb.	0.53	0.34	0.19	0.39	0.11	0.30	0.62	1.28	0.27	0.52	0.25	1.35
Mch.	0.00	0.13	0.58	2.54	0.27	0.87	0.45	0.37	0.74	1.27	0.45	1.24
Apr.	1.35	0.30	1.40	0.32	1.05	1.27	3.65	2.50	0.89	2.79	2.57	1.96
May	2.68	4.72	0.94	2.31	2.20	4.56	2.23	3.48	4.15	2.04	3.57	6.63
June	5.78	1.69	3.74	0.09	1.31	0.97	4.09	4.87	4.54	2.04	1.59	1.95
July	2.49	1.81	0.85	2.69	1.44	1.79	2.01	5.55	2.10	1.91	5.26	2.65
Aug.	3.53	3.74	0.66	2.52	3.39	1.20	1.16	0.78	4.10	0.68	1.88	0.82
Sept.	0.62	1.70	0.89	3.06	0.71	0.53	1.01	2.36	2.75	2.03	0.62	0.54
Oct.	2.19	1.04	0.24	1.05	0.20	0.61	1.92	1.15	0.58	0.06	0.49	2.16
Nov.	1.39	0.71	0.40	0.35	0.00	0.03	—	0.32	0.13	0.07	1.10	1.80
Dec.	0.31	1.41	0.44	0.44	0.35	0.28	0.25	0.20	0.47	0.27	0.86	0.15
Total	28.87	17.85	9.05	15.87	12.00	12.46	17.52	23.29	22.12	14.80	19.24	21.35

VIVIAN

	1915	1916	1917	1918	1919
Jan.	0.50	1.00	1.35	1.10	0.00
Feb.	1.77	0.04	0.18	0.50	3.25
Mch.	1.19	0.29	1.00	0.50	0.66
Apr.	2.62	1.08	2.38	3.92	4.14
May	3.02	3.46	5.20	3.33	3.23
June	4.31	4.49	1.18	1.70	5.01
July	6.76	3.53	1.02	2.07	4.00
Aug.	1.12	3.52	2.01	3.32	0.94
Sept.	3.16	0.90	2.64	0.75	1.70
Oct.	1.12	0.57	0.00	0.82	1.95
Nov.	0.38	0.12	—	0.22	1.91
Dec.	0.03	0.04	0.32	0.90	0.13
Total	25.98	19.04	17.28	19.13	23.99

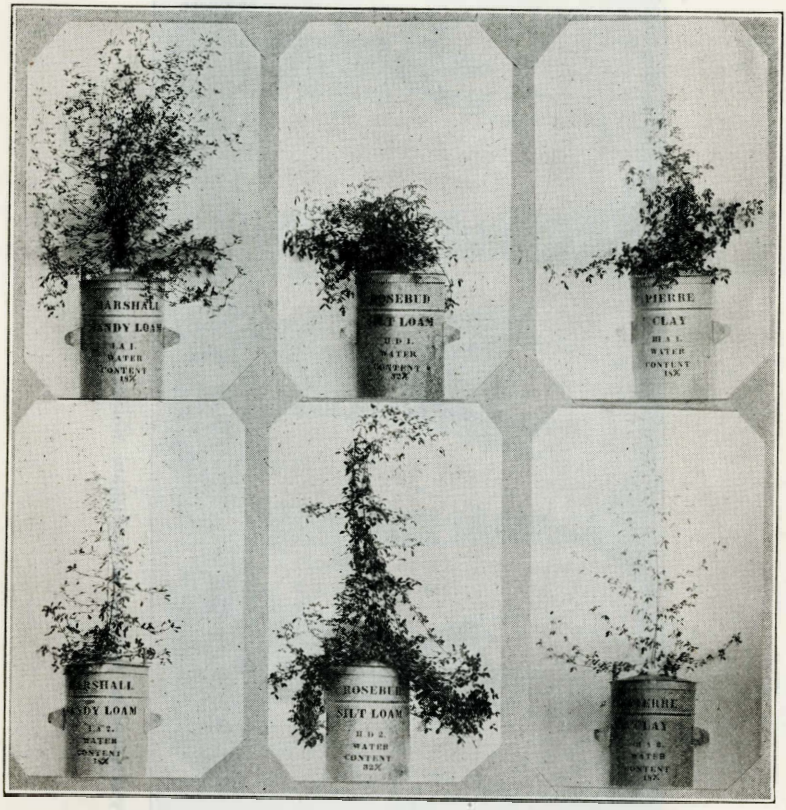

Plate I. Variation in Soil Type May Cause Variation in Water Requirement.

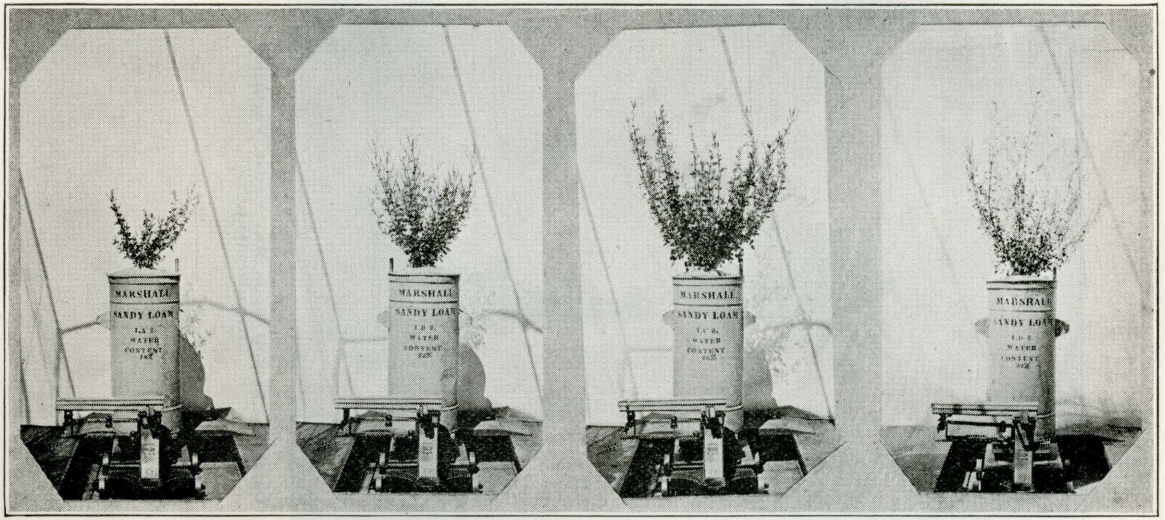

Plate II. Variation in Amount of Available Moisture on the Same Soil Type