EBERSOL

Water as a Factor
in Plant Growth

Science
B. A.

1902

Learning and Labor.

LIBRARY

OF THE

University of Illinois.

CLASS.

BOOK.

VOLUME.

1902 Eb3

Accession No.

Water as a Factor in Plant Growth

. BY .

ELMER TRYON EBERSOL

THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

IN THE

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

1902

1902
163
87 May '03 H. H. H.

UNIVERSITY OF ILLINOIS

May 30, 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Elmer Tryon Ebersol

ENTITLED "Water as a Factor in Plant Growth"

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Arts in the College of Science

HEAD OF DEPARTMENT OF

Chas. F. Hottes
Approved, H. Burrill
Botany

Water as a Factor in Plant Growth.

The rôle of water and aqueous salt solutions in the germination of seeds has been but little studied. The best and most comprehensive work along these lines is the Handbuch der Samenkunde, by Nobbe, published in 1876. Many of the statements made by Nobbe have not been generally accepted and it was my purpose to verify or to prove as wrong, some of this former work.

At the outset of the work the course was outlined in a general way, but with the idea of turning aside into the most desirable lines of work as necessity and the work would lead.

Many times it was desired to proceed along certain definite lines but, as all related lines of work could not be investigated, my time was devoted almost exclusively to the rate and amount of absorption in seeds soaked in different solutions; the effect of soaking in these solutions on the per cent and time of germination; and some little work on absorption of water by roots of growing plants under different conditions of temperature.

Digitized by the Internet Archive
in 2013

<http://archive.org/details/waterasfactorinp00eber>

What work is recorded in these few pages has been done with the greatest care but in some few cases, as indicated in the text, there was not time to perform a sufficiently large number of experiments to warrant the forming of conclusions. In those cases where sufficient data was secured conclusions are drawn and though they agree or disagree with the conclusions of others working along the same lines, I am confident of my facts and figures here given warranting such deductions.

In the Botanical Gazette (1896) there is an article on "The Toxic Action of Dissolved Salts" by Kahlenberg and True, which shows that some salts including weak NaCl solutions, give an acceleration while certain other solutions give a retardation. It is also stated that the per cent of seeds germinating is decreased by the stronger solutions. The results of my experiments, where solutions of sodium chloride and also of ammonium alum were used, are given in this paper.

The brief comment, on the vitality of the spores of *Marsilia quadrifolia*, by Barnes, in the Botanical Gazette (1895) page 229, suggested the experiments on the effect of soaking seeds in various grades of alcohol; i.e. the effect on the rate and amount of increase in weight, and the effect on time and per cent of germination.

If this paper, though quite unsatisfactory to me, should offer some suggestion that might lead to further investigation on the part of some reader, it will be well. The work done has opened up new fields of thought, shown new problems needing solution, and widened the horizon of scientific investigation in me.

Maximum Amount of Water.

The results of experiments conducted by R. Hoffmann to determine the maximum amount of water certain seeds are capable of absorbing are given in Versuchs-Stationen Bd.VII z.50. In the work named it is stated that corn will absorb 44 % of its air dry weight of water, peas 106.8 %, bean 96.1 %, &c, and considers this the maximum. Johnson, in his work, "How Crops Grow", accepts the statement of Hoffmann.

During my preliminary experiments I did not continue the soaking of corn until it had taken up all the water it was capable of absorbing. In fact, no corn was soaked in either distilled or tap water longer than twenty four hours, while in salt solutions some had been continued for thirty six hours.

In these preliminary experiments the corn gained rapidly in weight up to the limit, 44 % , as given by Hoffmann and Johnson. From this it is but fair to suppose, that by more prolonged soaking, a far higher per cent is capable of absorption. The series of experiments next described, supports this supposition.

Three varieties of corn with the following characteristics were used in these experiments:- No.1. White Flint, small ears grains extremely hard, short, and with smooth rounded surface. No.2. White Dent: larger ears than the other, grains of medium

length, medium in hardness and with dent in the surface of the outer end. No.3. Perry's Golden Eagle; a large yellow corn with very long deeply indented, and much softer grains than either of the others. This corn had been grown on the University farm and was stored in the same dry room in the University granary, until shortly before its use.

For the experiment an equal number of grains of each variety were taken, carefully weighed, placed in a separate bottle of distilled water, and kept under exactly similar conditions. From time to time the corn was taken from the water, wiped dry, weighed and replaced in the water. This was continued until ninety five and one half hours had elapsed. During the last period of soaking there was a slight gain in weight, but it was thought best to discontinue the experiment.

The results are here given in tabulated form, and from the per cent gain, the accompanying curves have been constructed. See tables 1,2,&3, and curves of the page following table 3.

Amount and Time for Saturation.

White Flint.

Hours.	Weight.	Gain.	% gain.	Gain per hr.	% gain per hr.
0	2.090	0	0	0	0
24.	2.815	.725	34.68	.0302	1.445
31.	2.885	.795	38.03	.0256	1.227
46.	2.965	.875	41.38	.0190	.899
71.	3.060	.970	46.41	.0137	.653
79.5	3.095	1.005	48.09	.0126	.604
95.5	3.130	1.040	49.76	.0109	.521

White Dent.

0	1.805	0	0	0	0
24.	2.515	.710	39.44	.0295	1.642
31.	2.535	.730	40.55	.0235	1.308
46.	2.570	.765	42.50	.0166	.924
71.	2.620	.815	45.28	.0114	.637
79.5	2.650	.845	46.94	.0106	.591
95.5	2.690	.885	49.16	.0092	.514

Golden Eagle.

Table 2.

Hours.	Weight.	Gain.	% gain.	Gain per hour	% gain per hr.
0	1.945	0	0	0	0
24.	2.765	.820	42.27	.0342	1.761
31.	2.830	.885	45.62	.0285	1.473
46.	2.870	.925	47.62	.0201	1.036
71.	2.930	.985	50.77	.0139	.715
79.5	2.980	1.035	53.35	.0130	.671
95.5	3.025	1.080	55.67	.0113	.583

Amount of Water corn is capable

Table 4.

of absorbing and time of germination.

	Wt. dry.	Wt. 24hrs.	Gain.	% gain.	Av. time germ.
High Protein.	1.65555	2.15254	.49799	30.72	2.8
Low Protein.	1.54537	2.09520	.53983	35.59	2.8
High Oil.	1.73017	2.28945	.55928	32.31	3.6
Low Oil.	2.12521	2.85500	.72979	30.04	3.8

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

A glance at the tabulated results will show that the White Flint had absorbed more than 44% in seventy one hours - a shorter time than that given by Hoffmann, and had gained 49.76% in ninety five and one half hours. The White Dent had also passed the limit, as given by Hoffmann and Johnson, in seventy one hours, and, in the course of the experiment, reached a gain of 49.16%. The Golden Eagle went beyond the stated limit in less than thirty one hours and at the close of the experiment had absorbed 55.67% of its dry weight of water.

From my experiments it is very evident that corn is capable of taking up more than 44% of water, and the difference between my results and those of Hoffmann are due, either to a difference in the variety of corn used, or to a difference in the conditions, for example, temperature, under which the experiments were carried on. I find no statement of the temperature at which Hoffmann's were conducted, but there is a statement which indicates that all experiments were carried on for seventy two hours. A glance at the table shows that all of the varieties I used, absorbed a higher per cent in the same time (72 hours.) than that reported by Hoffmann.

In another series of experiments, corn bred by the Agricultural Station for high and low protein, high and low oil was used to determine the relations of chemical composition to

water absorbed. The results (table 4) show that the chemical composition has little or none effect on the amount of water absorbed.

Rate of Absorption.

The tables 1 - 4 in the preceeding experiment incidentally show the rate of absorption of corn. This is more fully investigated under the present head, and peas and lupines were taken for comparison.

Corn, peas, and lupines were weighed and placed in separate bottles (five seeds per bottle) containing cistern water. Two sets were treated alike except one set was started to soak at 6:00 P.M. and the other just twelve hours later. When the second set had been in the water four hours all seeds were wiped dry and weighed; this gave the weight and the gain after sixteen hours immersion. Four hours later all were weighed again, which gave the gain in twenty, and in eight hours. Four hours later the gain in twenty four, and in twelve hours was determined. This process, this far, gives results equal to taking only one set and weighing every four hours during a complete day of twenty four hours. The weighing was done at 10:00 A.M. 2:00 P.M., and at 6:00 P.M. each day. It must be stated here that those seeds which were placed in water first were at a lower temperature during their first twelve hours of soaking

than those placed in water twelve hours later. After the second set was placed in water all were under identical conditions.

In tabulating the results (tables 5&6) it was found that the combined results gave a generally uniform increase in weight. However, there was a fluctuation with the different sets; those which were at a higher temperature during the first twelve hours of the soaking had gained more than the others. This is clearly seen in the curves immediately following the tables, in which the broken line represents the space that would have been occupied by the unbroken line of the other curve had the two sets of seeds given one uniform curve.

Three complete experiments with each kind of seed were carried on simultaneously as will be seen from the tables. The mean per cent gain is calculated from the average weights for the three experiments, and the average dry weights of the same seeds.

In the curves ordinates represent mean per cent gain and abscissas the time of soaking, in hours.

In the tables the numbers in horizontal rows close together are the dry weights: the upper row of those weighed after sixteen, twenty and twenty four hours soaking; the lower row gives those weighed after four, eight, and twelve hours soaking.

Experiment to determine

12

Rate of Absorption in Water.

Time.	Corn.		Av. % g.		Lupine.		Av. % g.	
	1.85	1.79	1.77	1.80	.71	.65	.73	.70
0.	1.83	1.85	1.86	1.85	.69	.64	.74	.70
4.	2.18	2.19	2.18	21.1	.70	.87	.85	15.7
8.	2.36	2.36	2.32	30.5	.72	1.03	1.01	31.4
12.	2.49	2.48	2.43	37.2	.87	1.11	1.16	50.0
16.	2.38	2.38	2.37	29.5	.87	1.11	1.03	45.7
20.	2.46	2.48	2.44	33.9	.92	1.12	1.05	47.1
24.	2.53	2.56	2.50	38.9	1.03	1.12	1.17	58.5
28.	2.68	2.68	2.62	47.7	1.41	1.12	1.30	82.8
32.	2.70	2.72	2.66	50.0	1.41	1.13	1.30	82.9
36.	2.73	2.74	2.69	51.1	1.40	1.13	1.39	87.1
40.	2.66	2.73	2.62	45.0	1.05	1.12	1.19	60.0
44.	2.67	2.76	2.65	47.7	1.06	1.11	1.19	60.0
48.	2.69	2.79	2.67	48.9	1.05	1.10	1.18	58.5
52.	2.80	2.82	2.78	55.0	1.38	1.12	1.27	80.0
56.	2.80	2.83	2.79	56.0	1.37	1.11	1.27	78.5
60.	2.82	2.87	2.83	57.0	1.37	1.11	1.27	78.5
64.	2.74	2.85	2.72	49.0	1.03	1.09	1.17	42.8
68.	2.76	2.85	2.73	50.0	1.04	1.09	1.17	42.9
72.	2.79	2.88	2.75	52.0	1.04	1.10	1.17	42.9

Time.	Peas.			Av. % g.
0.	1.79 1.77	1.83 1.72	1.79 1.76	1.81 1.75
4.	3.05	2.85	2.89	62.2
8.	3.38	3.20	3.23	81.1
12.	3.46	3.32	3.38	87.7
16.	3.43	3.48	3.48	100.0
20.	3.45	3.52	3.50	102.3
24.	3.48	3.53	3.51	100.0
28.	3.51	3.38	3.47	91.1
32.	3.51	3.40	3.48	91.2
36.	3.51	3.42	3.48	91.1
40.	3.52	3.58	3.53	105.2
44.	3.52	3.58	3.51	105.2
48.	3.52	3.58	3.51	105.2
52.	3.47	3.41	3.45	90.0
56.	3.47	3.42	3.45	90.1
60.	3.47	3.44	3.46	91.2
64.	3.52	3.58	3.52	102.3
68.	3.52	3.58	3.52	102.3
72.	3.52	3.58	3.51	102.3

Time.	0 hr.	1 hr.	2 hr.	3 hr.	4 hr.	5 hr.
Wts.	1.69	2.13	2.30	2.60	2.76	2.91
% g.	0.	26.03	36.09	53.84	63.31	72.18

Rate of Absorption in Water.

Corn. Curve B.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

Rate of Absorption in Water.

Lupine. Curve D.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

While the rate of absorption in corn, peas, and lupines is very different, it is, nevertheless in each case, most rapid during the first few hours. About eighty per cent of the total amount absorbed by the corn is taken up in the first twenty four hours. In the same time the peas take up one hundred, and the lupines ninety five per cent of the maximum amount. In the corn, from twenty hours to seventy hours soaking there is a continually diminishing rate of increase in weight. During the last period of four hours ending with the seventy second hour of the soaking process, there is still water taken up by the corn. The corn also shows a gain of fifty seven per cent as early as the sixtieth hour of the soaking. During the first four hours the corn increased in weight twenty per cent, lupines eighteen per cent, and the peas sixty three per cent.

Since the increase in the peas is so great an experiment was conducted, covering the first five hours, in which experiment the weights were taken every hour. The results appear at the bottom of table 6. The lupines reached the maximum, with some irregularities, after soaking forty hours; later there was a considerable loss in weight. The marked loss in weight in the lupines and the slight variations in the weight of the peas after twenty hours in the water is probably due, as Nobbe states, to the solution of some of the substances of the seeds. The great variation in the lupine seems to result from a dif-

ference in the individuality of the seeds.

All of these peculiarities of the rate of absorption may be seen at a glance by turning to the curves on these experiments. However the phenomenon of variation in the lupine claims our special attention.

Nobbe shows by his work on the effect of soaking seeds that of the same variety some may take up water readily while others receive water only after a long period of immersion. This investigator placed two thousand clover - *Trifolium pratense* - seeds in water and at a constant temperature of 18° - 21° C. 92% of the seeds were swollen in twenty four hours. The experiment was continued for one hundred fifty six days during which time twenty four records were made of the number of newly swollen seeds. Each time there were some but only a few. At the end of the experiment there were forty seeds still which had not taken up water. Nobbe says that clover seed may germinate after lying inactive for three years with conditions favorable for immediate germination of a large majority of the seeds sown. He gives a number of such illustrations, but we will now consider the lupine.

Seeds of *Lupinus luteus* were placed in a vessel of distilled water and a temperature of about 22° C. was maintained. After twenty four hours soaking they were taken from the water and wiped dry. Ten of the seeds were swollen and were placed

in a saw-dust germinator by themselves. At the same time seven of those seeds remaining unswollen were also placed in the germinator. The remaining fourteen of the unswollen seeds were placed in two groups of seven seeds each and after the seed coat of each seed in one set had been cut through the two sets were weighed. They were placed in separate bottles of water. At intervals of two hours the seeds were taken out, wiped dry, and weighed. The results are shown below.

	Time:-9:20	11:20	1:20	3:20
Set 1. cut	.75	.98	1.47	1.55
Set 2. entire	.83	.83	.83	.83

It will be observed that Set 1. gained more than 100% in these six hours while Set 2 had not taken up any water. Both sets were now placed in the germinator. The temperature of the germinator was very near 25° C. and the saw-dust kept quite moist; probably too wet, for after twenty six days the seeds were dug up and all seeds which were swollen when placed in the germinator were rotten. One seed of Set 2 was large, heavy, and soft from the water absorbed, while all other seeds, unswollen when placed in the germinator, were still in the same condition, unaltered by the amount of moisture which, probably caused the destruction of those which, had previously absorbed water.

From this experiment it is evident that the individuality of the lupine results from the different character of the seed coats of the different seeds as regards the permeability.

This will offer an explanation for peculiarities later to be discussed.

Least Amount of Water necessary for Germination.

From Experiments 1 & 2 we learn that corn is capable of absorbing forty nine to fifty nine per cent of water in sixty hours. In this experiment it was my object to determine the least amount of water necessary for germination.

The desired end was sought by experiment in the following manner:- Seeds of each kind, and of known dry weights were placed in distilled water of the temperature of the laboratory at intervals such that when removed from the water they had soaked 0, 1, 2, ----- 10 hours. Of the corn - Perry's Golden Eagle - and the peas - Large White Marrowfat - ten seeds were used in each of eleven sets..

As soon as the seeds were taken from the water they were wiped dry, weighed, and placed in a germinator made as follows:- A four quart granite-ware pan containing one quart of water had a piece of cheese cloth stretched over the top and firmly held by a wire band just below the rim of the pan. Upon this stretched cloth were strips of tin, one half inch wide, standing on edge and bent so as to form one inch squares into which

the several sets of seeds were placed, and records kept. Over this a similar vessel, lined with filter paper, was inverted.

The seeds were taken from the germinator from time to time and weighed and these weights, together with number germinated, recorded as shown in the tables 7, 8, & 9. In these tables the first column gives the number of the set; the second the dry weight; the third the number of hours they were soaked; then the weight superficially dried. In the columns marked Wt. followed by a number we have the weight and the number of days since the beginning of the experiment, and in the column marked G. is given the number of seeds germinated since the last time given. The last column gives the average time of germination.

From a study of these tables it would appear that absorption of water in corn and peas varies with the time they are immersed in water. In every case those seeds which had taken up the most water decreased in weight after being placed in the germinator and those having the least amount of water increased in weight i.e. there was a general tendency toward uniformity in the amount of water absorbed. The amount of water in the corn and peas became quite uniform. Peas were able to take up nearly all that they are capable of absorbing in the short interval of six hours and those sets from 7 - 11 inclusive were first to germinate a large percentage of their seeds. The least amount contained by any set of peas when some seeds germinated

Least amount of Water necessary for Germination of Corn.

22

No.	Wt.	Hr.	Wt.	Wt.2	G.	Wt.4	G.	Wt.5	G.	Wt.7	G.
1.	4.1	0	4.1	4.5	0	4.7	0	4.8	0	4.9	0
2.	4.1	1	4.4	4.6	0	4.7	0	4.8	0	4.9	0
3.	4.1	2	4.6	4.7	0	4.8	0	4.9	0	4.9	0
4.	4.1	3	4.9	4.9	0	4.9	0	4.9	0	4.9	1
5.	4.1	4	4.9	4.9	0	4.9	0	5.0	1	5.0	0
6.	4.1	5	5.0	5.0	0	5.0	1	5.1	0	5.1	2
7.	4.1	6	5.0	5.0	0	5.0	0	5.1	0	5.1	1
8.	4.1	7	5.1	5.0	1	5.0	0	5.1	1	5.1	2
9.	4.1	8	5.1	5.0	0	5.0	0	5.1	0	5.1	0
10.	4.1	9	5.2	5.0	1	5.0	0	5.1	1	5.1	3
11.	4.1	10	5.2	5.0	0	5.0	1	5.1	0	5.1	1

No.	Wt.9	G.	Wt.11	G.	Wt.15	G.	18d.	21d.	23d.	Rot'd	Av.T.
1.	4.8	2	5.5	0	5.2	3	1	2	0	2	15.6
2.	4.8	0	5.0	0	5.0	3	3	3	0	1	20.2
3.	4.9	0	5.0	2	5.1	1	1	1	2	3	17.4
4.	4.9	0	5.0	1	5.1	2	2	0	0	4	14.0
5.	4.9	1	5.1	3	5.2	4	1	0	0	0	12.5
6.	4.9	4	5.2	2	5.1	1	0	0	0	0	9.1
8.	5.0	1	5.2	1	5.2	4	1	2	0	0	14.1
8.	4.9	1	5.2	3	5.0	2	0	0	0	0	9.3
9.	4.9	1	5.0	1	5.0	1	1	1	2	3	14.3
10.	4.9	2	5.1	2	5.1	1	0	0	0	0	8.3
11.	5.0	1	5.2	3	5.2	3	0	1	0	0	11.9

Least Amount of Water necessary for Germination of Corn. No. 2

No.	Wt.	Hr.	Wt.	Wt.	Wt.	Wt.3	G.	Wt.5	G.	Wt.7	G.
1.	4.1	0	4.1	4.4	4.7	4.9	0	5.0	0	5.2	3
2.	4.1	1	4.4	4.5	4.7	4.8	0	5.0	2	5.2	5
3.	4.1	2	4.5	4.6	4.7	4.9	0	5.0	2	5.1	2
4.	4.1	3	4.6	4.7	4.7	4.9	0	5.0	1	5.1	1
5.	4.1	4	4.7	4.7	4.7	4.9	1	5.0	1	5.1	3
6.	4.1	5	4.8	4.8	4.8	4.9	0	5.1	2	5.2	2
7.	4.1	6	5.0	4.9	5.0	5.0	0	5.1	2	5.2	2
8.	4.1	7	5.0	4.9	4.9	5.0	0	5.1	0	5.1	0
9.	4.1	8	5.1	5.0	5.0	5.0	1	5.1	3	5.1	2
10.	4.1	9	5.2	5.1	5.0	5.1	0	5.1	2	5.1	1
11.	4.1	10	5.3	5.2	5.1	5.1	1	5.1	3	5.0	1
No.	Wt.9	G.	Wt.10	G.	12da.	14da.	16da.	19da.	22da.	Av.T.	
1.	5.2	1	5.3	3	3	3	0	0	0	9.6	
2.	5.3	2	5.5	1	0	0	0	0	0	7.3	
3.	5.2	2	5.3	2	1	0	0	1	1	9.3	
4.	5.1	0	5.1	1	1	0	1	2	2	14.6	
5.	5.2	2	5.3	1	0	0	1	0	1	9.7	
6.	5.3	3	5.4	2	1	0	0	0	0	8.3	
7.	5.3	2	5.4	2	1	0	0	1	0	9.3	
8.	5.1	2	5.2	2	2	2	1	1	0	12.5	
9.	5.0	2	5.0	0	1	0	0	1	0	8.1	
10.	4.9	1	4.9	0	0	0	1	1	3	12.0	
11.	4.9	2	4.9	1	0	2	0	0	0	8.3	

Least Amount of Water necessary for Germination of Peas.

24

1 day %

No.	Wt.	Hr.	Wt.	Wt.1	G.	Wt.2	G.	Wt.4	G.	Wt.6	G.
1.	2.1	0	2.1	2.4	0	2.7	0	3.0	0	3.3	0
2.	2.1	1	2.4	2.7	0	2.7	0	2.9	0	3.0	0
3.	2.1	2	2.4	2.6	0	2.8	0	3.0	0	3.1	0
4.	2.1	3	2.8	2.9	0	2.9	0	3.1	0	3.2	0
5.	2.1	4	3.3	3.3	0	3.3	0	3.7	2	3.8	6
6.	2.1	5	3.7	3.7	0	3.6	1	3.8	0	3.7	6
7.	2.1	6	4.0	3.8	6	3.7	1	3.8	0	3.7	2
8.	2.1	7	4.0	3.8	5	3.7	0	3.7	0	3.5	1
9.	2.1	8	4.1	3.9	2	3.8	1	3.8	2	3.6	0
10.	2.1	9	4.1	3.8	3	3.8	0	3.9	2	3.8	3
11.	2.1	10	4.0	3.5	2	3.8	2	3.9	6	3.8	0

No.	8 da.	G.	10 da.	12 da.	14 da.	Av. T.
1.	3.7	1	6	1	0	10.0
2.	3.3	0	1	6	1	12.0
3.	3.3	0	0	2	0	13.15
4.	3.6	0	4	4	0	11.1
5.	4.0	2	0	0	0	6.0
6.	3.9	3	0	0	0	6.7
7.	3.8	1	0	0	0	2.6
8.	3.3	0	2	1	0	5.0
9.	3.7	0	1	2	2	7.4
10.	3.8	1	1	0	0	4.4
11.	0	0	0	0	0	3.0

Least Amount of Water necessary for germination of *Vicia faba*.

No.	Wt.	Hr.	Wt.	Wt.	Wt.	Wt.	Wt.
1	2.1	0	2.1	3.1	3.4	3.5	3.7
2	2.1	1	2.4	3.2	3.4	3.6	3.7
3	2.1	2	2.5	3.0	3.2	3.3	3.3
4	2.1	3	2.5	2.6	2.7	2.9	3.2
5	2.1	4	2.5	2.8	3.1	3.3	3.4
6	2.1	5	3.0	3.4	3.6	3.6	3.6
7	2.1	6	3.1	3.5	3.7	3.6	3.6
8	2.1	7	3.2	3.4	3.5	3.6	3.9
9	2.1	8	3.9	3.8	3.8	3.8	3.9
10	2.1	9	4.0	3.9	3.8	3.4	3.2
11	2.1	10	4.5	4.3	3.7	3.4	3.2

After twenty days none have germinated: nearly all have become very mouldy. Probably none of them had absorbed sufficient water.

LIBRARY
OF
UNIVERSITY OF TORONTO

was 62% of the dry weight and the majority germinated after having absorbed 86 % of water. The least amount absorbed by any set of corn was 17.1% but the largest number germinated after having taken up 24.4% of water.

A set of curves is also given showing the average time of germination for the two tables of corn, tables 7 & 8, and the one of peas, table 9, together with the amount of water, in grams, at the average time of germination of the corn. It will be observed that the abscissa gives the number of the set given in the tables and the ordinate gives the average time, in days, of germination, and also represents amount, in grams, when considering the lower curve.

We have presented to us a set of curves difficult of interpretation and it seems that much work must be done along this line in order to draw conclusions. In general, it may be said that the more water taken up the sooner the germination, of course, within certain limits.

Effect of Temperature

on Rate and Amount of Absorption.

From the results of the last experiment it seems that usually there is a slight variation in the rate of absorption even where the temperature remains the same.

In order to secure information regarding the part temperature plays in the rate and amount of absorption a series of experiments was conducted. The seeds used were corn, peas, and lupines (*Lupinus luteus*). Five seeds of each kind were placed together in each of five bottles containing distilled water and one bottle placed in each of the following temperatures which remained constant during the experiment 12, 19, 35, 37, and 56 degrees. The first accompanying table (table 10) gives the actual weights of each set of each kind of seeds at the intervals indicated at the head of the column. Table 11 gives the percentage of gain relative to the dry weight of those seeds and presents some very interesting results. At the close of the first four hours the corn showed an amount absorbed which (with one exception: 19°) stood in direct relation to the temperatures; There is a difference of 16% between the extremes of temperature. After forty four hours of soaking the amount taken up still increases with the temperature with only one exception and that now at 37 degrees. It will also be noted

on Rate and Amount of Absorption.

Kind.	Dry.	4hr.	8hr.	12hr.	24hr.	28hr.	32hr.	44hr.
12°								
Corn	1.62	1.95	2.07	2.15	2.27	2.28	2.32	2.32
Peas	1.80	2.02	3.23	3.43	3.47	3.48	3.48	0
Lupine	.62	.64	.73	.75	.77	.81	.88	.91
19°								
Corn	1.63	1.92	2.08	2.19	2.31	2.33	2.33	2.37
Peas	1.70	2.94	3.27	3.36	3.36	3.37	3.35	0
Lupine	.70	.83	.89	.93	1.28	1.34	1.37	1.37
35°								
Corn	1.63	2.05	2.22	2.33	2.45	2.51	2.53	2.52
Peas	1.74	3.15	3.36	3.39	3.31	0	0	0
Lupine	.73	.85	.90	.90	1.11	1.11	1.10	1.14
37°								
Corn	1.61	2.08	2.19	2.29	2.37	2.42	2.43	2.45
Peas	1.65	3.01	3.17	3.19	3.12	0	0	0
Lupine	.60	.74	.95	1.06	1.09	1.08	1.08	1.18
56°								
Corn	1.86	2.47	2.70	2.82	2.91	2.94	2.98	2.98
Peas	1.72	3.20	3.22	3.21	3.18	0	0	0
Lupine	.67	.68	.90	1.11	1.17	1.16	1.16	1.14

Percentage Rate of Absorption

in Various Temperatures.

Temp.	0hr.	4hr.	8hr.	12hr.	24hr.	28hr.	32hr.	44hr.
Corn.								
12°	0	20.3	27.8	32.7	40.1	40.8	43.2	43.2
19°	0	17.8	27.6	34.3	41.7	42.9	42.9	45.4
35°	0	25.8	36.9	42.9	50.3	53.9	55.2	54.5
37°	0	29.2	36.3	42.2	47.2	50.3	50.6	51.2
56°	0	36.0	45.1	51.6	56.4	58.1	60.2	60.2
Peas.								
12°	0	67.8	79.4	90.6	93.0	93.3	93.3	0
19°	0	72.9	81.7	86.6	86.6	86.8	86.5	0
35°	0	81.0	92.6	94.8	90.3	0	0	0
37°	0	82.4	92.1	93.3	89.1	0	0	0
56°	0	86.0	87.2	86.6	84.9	0	0	0
Lupine.								
12°	0	3.2	17.7	20.9	24.2	30.6	41.9	46.8
19°	0	18.8	27.1	32.9	82.9	91.4	95.7	95.7
35°	0	16.4	23.3	23.3	52.1	52.1	49.9	56.1
37°	0	23.3	58.3	76.7	81.7	80.0	80.0	96.6
56°	0	1.5	34.3	65.7	74.7	73.1	73.1	70.1

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Lupine.

Percentage Rate of Absorption in Various Temperatures, Curve H.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

that the maximum occurs at the 56 degree temperature and is greater in thirty two hours than it was in the experiment on "Maximum Amount" at the temperature of the laboratory in ninety five hours. At the end of four hours the peas show a gain relative to temperature but at the end of twenty four hours the order is almost completely reversed. This is due to decomposition of the peas in the highest and next highest temperatures after eight and twelve hours respectively. Lupines are very peculiar: the individual character of the seeds being a more powerful factor in the rate of absorption than temperature of the surrounding medium. Again there is a loss in weight in those seeds in the highest temperature after twenty four hours.

The accompanying curves F, G, and H show at a glance the relative rates of absorption and the peculiarities. From these experiments we may conclude that corn and peas, in a general way, are influenced, in their absorption of water by the temperature of the surrounding medium but that characteristics of the seeds manifest themselves. The same is true of the lupine but here temperature exerts a less influence and individual characters a greater. In fact the influence of the individual characters is so great as to nearly obliterate the evidence of the influence of temperature.

Absorption of Water not effected

by Amount or Kind of Gas contained in the Water.

As the former experiments were conducted with the use of water containing such an amount of air as water will naturally absorb from the atmosphere it was thought there might be different results with a different amount of air - less or more - in the water, or that other gases might have a perceptible effect on the amount and rate of absorption quite different from that ordinarily contained. In order to secure the facts, corn and peas were soaked in cold boiled distilled water. Previous to the soaking, however, a quantity of such prepared water was saturated with carbon dioxide, a part with hydrogen, a part contained no gas, another portion saturated with air, and with these, a check in which the water contained such as it naturally contains.

The results of the two complete experiments are given in the following tables 12 & 13, and give rise to the following conclusions:-

Corn and peas may be soaked in water containing no air, small or large quantities of air, hydrogen, or carbon dioxide, and, in all these conditions the same rate and amount of absorption results. From this, imbibition can hardly be looked upon as a vital activity. This is Nobbe's conclusion.

Water saturated with CO₂, H, Air, & Gas free.

Exp.		Wt. D	12hr.	24hr.	%g 12	%g 24
CO ₂	1. Corn	1.59	2.22	2.38	39.61	49.67
	Peas	1.66	3.09	3.27	86.14	90.00
	2. Corn	1.66	2.10	2.28	26.50	37.50
	Peas	1.51	2.60	2.77	72.20	84.10
H	1. Corn	1.61	1.98	2.14	23.00	32.92
	Peas	1.44	2.84	2.91	97.22	102.08
	2. Corn	1.80	2.31	2.41	28.40	34.20
	Peas	1.51	2.94	3.01	94.70	99.90
Air	1. Corn	1.77	2.41	2.52	36.16	42.37
	Peas	1.57	3.05	3.09	94.26	96.81
	2. Corn	1.76	2.88	2.46	33.30	39.10
	Peas	1.49	2.88	2.90	93.30	95.10
Gas free	1. Corn	1.77	2.41	2.52	36.16	42.37
	Peas	1.51	2.95	2.91	95.36	92.64
	2. Corn	1.67	2.21	2.36	32.30	41.30
	Peas	1.52	2.93	2.96	92.70	94.60

Summary. Exp. 1 & 2.

Table II.

	Av. %g. 12 hr.	Av. %g. 24 hr.		Av. %g. 12 hr.	Av. %g. 24 hr.
Corn.			Peas.		
Tap H ₂ O	37.2	38.9	Tap H ₂ O	87.7	100.0
CO ₂ H ₂ O	33.1	43.5	CO ₂ H ₂ O	79.1	90.5
H H ₂ O	25.7	33.6	H H ₂ O	95.9	100.9
Air H ₂ O	35.1	41.2	Air H ₂ O	93.8	96.1
Gas free	34.2	41.6	Gas free	94.0	93.6

Resistance to Drought.

Corn that had been soaked, some twelve, and some thirty six hours, in salt solutions 1 - 12 for a previous experiment, was used. These were placed in a constant moisture germinator, and when the radicles were from 1 - 10 mm. in length, forty grains were placed in a drawer of the desk, where they were kept three days. At the end of this time they were thoroughly dry. Now they were placed in a saw-dust germinator, where in forty eight hours all had grown well. The plumules ranged in length from 1 - 30 mm. and the radicles from 1 - 33 mm. Average length of plumule was 8 mm. while the average for the radicles was 10 mm.

The average weight per ten grains before soaking was 4.5 grams; weight at the time they were taken from the constant moisture germinator was 5.6 grams per ten grains, and the weight per ten grains when taken from saw-dust germinator was 7.2 grams.

Twenty of the above were replaced in germinator and grew vigorously but were placed in a drying box at the end of twenty four hours. After drying they did not germinate when replaced in germinator. The other twenty were dried and replaced in germinator but only two started.

Resistance to draught.

Perry's Golden Eagle corn was soaked in city water twenty four hours and placed in sawdust germinator. When they had germinated, i.e. in two days, six divisions were made on basis of length of radicle. 100% of the seeds germinated.

Division I.

Length of Seeds, pl. (mm) rad.			Days dried in germ.		germinated. stem. root.		Length of stem (mm) root.	
4	0	1	3	4	3	3	8-15	2-20
4	0	1	7	4	4	1	10	12
4	0	1	11	4	4	3	12-25	12-90
4	0	1	15	5	2	1	8-50	135
4	0	1	20	6	2	2	35	60
4	0	1	26	4	2	0	12	0
4	0	1	30	4	3	3	12-15	7-15

Division II.

Length of Seeds, pl. (mm) rad.			Days dried in germ.		germinated. stem. root.		Length of stem (mm) root.	
4	0	5	3	4	2	1	8-15	28
4	0	5	7	4	1	0	12	0
4	0	5	11	4	1	0	8	0
4	0	5	15	5	0	0	0	0

Division III.

Length of Seeds.pl.(mm)rad.			Days dried.in germ.		Germinated. stem. root.		Length of stem(mm)root.	
4	2	11	3	4	1	0	6	0
4	2	11	7	4	0	0	0	0
4	2	11	11	4	1	0	8	0
4	2	11	15	5	0	0	0	0

Division IV.

Length of Seeds.pl.(mm)rad.			Days dried.in germ.		Germinated. stem. root.		Length of stem(mm)root.	
4	8	20	3	4	2	0	10	0
4	8	20	7	4	0	0	0	0
4	8	20	11	4	0	0	0	0
4	8	20	15	5	0	0	0	0

Division V.

Length of Seeds.pl.(mm)rad.			Days dried.in germ.		Germinated. stem. root.		Length of stem(mm)root.	
4	15	40	3	4	0	0	0	0
4	15	40	7	4	0	0	0	0
4	15	40	11	4	0	0	0	0
4	15	40	15	5	0	0	0	0

Division VI.

No grains of this division germinated.

Each division in the preceeding pages shows the number of seeds planted each time, the length of radicle and plumèule, the number of days they were dried, the number of days they remained in the germinator; in the germination, the number and length of stem and root.

Conclusion:- Corn may be thoroughly dried after the radicle has developed to so great a degree as to project one millimeter beyond the seed coat and still grow if the proper conditions are reestablished. 75% to 100% if the dry period does not extend longer than twelve days and 50% to 75% will revive if the dry period is from twelve to thirty days in length. Evidently the time could be much extended and at least 50% would revive under proper conditions but my experiments were continued for thirty days only.

When the radicle has once grown to a length of five millimeters the time of drying must not extend over more than eleven days or none will revive, and only 50% will grow after only drying three days. If the radicle has once attained a length of eleven millimeters 25% will revive during the first eleven days of drying but will not revive after that time. With the radicle having grown to a length of twenty millimeters, no grains will start again after drying more than three days. However, it is possible for 50% of those dried not more than three days to revive. Should the radicle be longer than twenty

millimeters there is no hope of any growth even under the most favorable conditions.

In the soil corn would not become so thoroughly dried, nor so quickly, as under the conditions of these experiments and would probably revive after a much longer period and in cases where growth had proceeded to a greater degree than given above.

Volume Increase in Swelling Seeds.

Since all seeds which take up water experience a change in volume, experiments were conducted to determine this change. A priori it appears self-evident, that with the taking up of a certain amount of water by a body capable of increasing, a corresponding volume increase must result. Persons who have made observations differ in their conclusions. Some like Payen, maintain that the weight of the absorbed water really exceeded the increase in volume of the seeds. Wiesner and others believe that a condensation takes place in the seed when water is taken up. Wiesner has determined by means of a series of well conducted investigations, that heat develops in soaking seeds, earlier than carbon dioxide is formed. From these facts Wiesner concludes that the increase of heat in seeds taking up water, results from a condensation of the water in the tissue of the seeds and a liberation of heat follows. Heat increases rapidly at first but later carbon dioxide being produced, the heat ceases to increase farther.

I used one hundred fifty grams each of Perry's Golden Eagle corn, Ferry's Large White Marrowfat peas, *Lupinus luteus*, *Phaseolus multiflorus*, and *Phaseolus vulgaris*. Each kind of seed was placed in a large bottle filled with water, and immediately closed by an absolutely close fitting cork from which extended vertically, a long glass tube having an inside diameter of

Change of Volume of Seeds in Water.

100 grams of each kind of seed were used.

Table 14.

Time.	Corn.	Peas.	Lupine.	B. bean.	W. bean.	H O
6:00	0	0	0	0	0	0
7:02	0	0	0	0	-.59	0
7:15	0	0	0	.62	-2.82	0
7:23	0	.93	0	0	-3.82	0
7:30	.39	1.37	0	.79	-4.52	0
7:45	.51	1.48	0	0	-5.06	0
8:00	.59	1.21	0	0	-5.06	0
8:15	.70	.83	0	0	-4.82	0
8:30	.76	.58	0	0	-4.41	0
8:45	.87	.24	0	0	-3.94	0
9:00	0	.03	0	0	-3.53	.06
9:15	.82	-.14	0	0	-3.12	0
9:30	.76	-.21	0	0	-2.88	0
9:45	.68	-.27	0	.91	-2.76	.15
10:00	0	0	0	0	0	.19
10:15	0	-.17	0	0	0	0
10:30	.78	0	0	0	0	.25

Time.	Corn.	Peas.	Lupine.	B.bean.	W.bean.	H O
10:45	0	.14	0	0	0	0
11:00	.84	.34	1.48	0	0	.31
11:30	0	.51	1.56	0	0	.37
12:00	.87	1.37	0	1.08	-2.41	.44
12:30	1.04	2.03	1.50	1.16	-2.12	.50
1:00	1.16	2.62	1.36	1.46	-1.71	.56
1:30	1.38	3.00	1.22	1.79	-1.29	.62
2:00	1.66	3.38	1.08	2.16	-.61	.69
3:00	2.33	4.34	.92	2.87	1.12	.78
4:00	2.76	5.49	.64	3.39	2.70	.78
5:00	2.93	6.38	.40	0	4.09	.69
6:00	0	7.07	.08	3.21	5.00	.58
7:00	2.91	7.76	-.16	3.21	5.94	.39
8:00	0	8.07	-.44	0	6.67	.28

Change of Volume in Soaking. Measured in c.c. Curve I.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

six millimeters. Immediately upon closing the bottle the surface of the water in the tube stood at a considerable distance above the cork; this position was marked as the starting point of the experiment. As the water rose or fell in the tubes the readings were taken every few minutes as given in Table 14. As a control for determining the rise and fall in the tube due to changes in temperature only, one bottle contained no seeds.

The numbers given in the table represent the change of volume in cubic centimeters. The numbers preceded by the sign-- show that the volume is less than at the beginning of the experiment; all other numbers represent the increase over the first reading. These tabulated results are represented in the form of curves. See curve I.

Whatever change of volume occurs in the vessel containing water only must be due to a change in temperature and the change in temperature would not be less in the other vessels.

A glance at the table or curves shows that no increase in the volume of the water took place within the first two hours. During the next six hours there was a slow but constant increase, the maximum being .78 cc. After this there was a decrease. In the corn, peas, and black beans there was an increase from the first but in the peas there was a change after thirty minutes. There was no change in the lupines for a considerable time and in the first four hours the increase amount-

ed to only 1.48 cc. The white beans decreased rapidly in volume, reaching the minimum, - 2.88 cc. in two and one half hours. After this there was an increase but the volume did not equal that at the beginning of the experiment until four and one half hours later, or seven hours after the first reading. The increase was very rapid towards the close of the experiment which was continued for thirteen hours.

While there is quite a similarity in the curves representing the volume change as determined by Nobbe and myself there are the following differences: I find the maximum and minimum points to be reached much sooner than Nobbe. This is probably due to a higher temperature (22°C). After two and three fourths hours my minimum is below the volume at the beginning while the corresponding low point in Nobbe's experiment is reached after four hours and remains a considerable above the original volume. After four hours soaking I find a constant increase to the end of the experiment. Nobbe finds an increase during the first three hours of the corresponding period and then a slight decrease. Nobbe finds in the beans a very rapid increase in the first ten minutes and then a rapid decrease, reaching - 13 cc in two hours and reaching the minimum after eight hours soaking. There is shown a slight increase following this lowest point. I find no increase at first, but a decrease in volume which reaches the minimum (- 5 cc) in the first forty five

minutes; then follows quite a constant increase to the close of the experiment at which time the volume of the contents of the bottle was 6.8 cc greater than at the beginning of the experiment. It is probably true that the beans Nobbe used were not of the same variety as used in my experiments.

Nobbe says that the conclusions of Payen and Wiesner, given above, are not to be denied or neglected, but considers that an intermediate product may arise because of the liberation of heat; this would come before the production of carbon dioxide. Later, perhaps, the process of diffusion, as well as the accompanying evident dissolving and increase in size might exert an influence on the temperature of the seeds and the medium in which they lie. Nobbe's experiments agree with the conclusions of Payen, in that the change of volume is greater than the change in weight. Since there is sometimes a decrease in size it seems indisputable that the figures derived from such experiments express ⁱⁿ exactly the change of relation between volume and amount of water taken up.

Rate and Amount of Absorption in Alcohol.

Experiments were conducted in which corn, peas, and lupines were soaked in alcohol of the following per cents: Absolute, 95 %, 75 %, 50 %, 30 %, 20 %, 10 %, and distilled water. Tables 15 and 16 give the weights of the seeds in the different per cents of alcohol at intervals of twenty four hours. Tables 17, 18, and 19 give the per cent gain and the mean per cent gain for corn, peas and lupines respectively. Accompanying these tables are sets of curves, J and K representing the average per cent gain in corn and peas respectfully. Because of the lack of uniformity in the lupines I have thought best to give curves L and M, representing the mean per cent gain for experiments 1 and 2 and N represents the average per cent gain of these experiments.

The results show that corn, peas, and lupines may increase in weight when soaked in absolute alcohol and that in general, the lower the per cent of alcohol the greater the amount of gain in a given time. The variations from this general rule must find their explanation in the facts and conclusions given in the paragraph concerning the lupines, which follows.

Experiment No 1.

Table 15.

	Abs.	95%.	75%.	50%.	30%.	20%.	10%.	H ₂ O.
0 hrs.								
Corn.	1.70	1.60	1.57	1.53	1.57	1.76	1.61	1.66
Peas.	1.61	1.64	1.62	1.68	1.63	1.65	1.64	1.63
Lupine	.76	.72	.70	.75	.70	.71	.70	.72
24 hrs.								
Corn.	1.73	1.67	2.01	2.07	2.24	2.42	2.24	2.42
Peas.	1.64	1.69	1.90	2.37	2.65	2.81	3.04	3.24
Lupine	.77	.73	.77	.75	.71	.83	.89	.84
48 hrs.								
Corn.	1.73	1.70	2.13	2.19	2.32	2.56	2.30	2.53
Peas.	1.65	1.73	2.00	2.45	2.68	2.80	3.04	3.27
Lupine	.77	.74	.80	.75	.71	.99	1.00	.82
72 hrs.								
Corn.	1.74	1.73	2.20	2.23	2.37	2.64	2.34	2.56
Peas.	1.66	1.75	2.05	2.47	2.69	2.81	3.03	3.27
Lupine	.77	.74	.81	.75	.82	1.00	1.23	.91
96 hrs.								
Corn.	1.75	1.74	2.22	2.26	2.38	2.67	2.37	2.58
Peas.	1.68	1.76	2.08	2.48	2.70	2.81	3.02	3.27
Lupine	.77	.74	.82	.75	.85	1.17	1.24	.91
120 hrs.								
Corn.	1.76	1.75	2.23	2.27	2.38	2.66	2.40	2.59
Peas.	1.68	1.77	2.09	2.49	2.70	2.82	3.01	3.31
Lupine	.77	.74	.82	.76	.85	1.42	1.23	.90

Experiment No. 2.

Table 16.

	Abs.	95%.	75%.	50%.	30%.	20%.	10%.	H ₂ O.
0 hrs.								
Corn.	1.92	1.96	1.92	1.96	1.97	1.98	1.96	1.97
Peas.	1.61	1.63	1.68	1.62	1.63	1.61	1.61	1.60
Lupine	.62	.64	.66	.62	.62	.65	.77	.63
24 hrs.								
Corn.	1.94	2.04	2.40	2.61	2.69	2.74	2.71	2.64
Peas.	1.63	1.74	2.03	2.30	2.61	2.83	3.02	3.15
Lupine	.62	.64	.67	.69	.62	.65	.77	.78
48 hrs.								
Corn.	1.94	2.07	2.52	2.77	2.87	2.84	2.88	2.77
Peas.	1.64	1.76	2.10	2.39	2.64	2.83	3.01	3.16
Lupine	.62	.64	.67	.69	.62	.65	.84	.78
72 hrs.								
Corn.	1.95	2.11	2.60	2.86	2.96	2.89	2.97	2.86
Peas.	1.65	1.77	2.13	2.40	2.64	2.84	2.99	3.15
Lupine	.62	.64	.67	.69	.62	.65	.90	.77
96 hrs.								
Corn.	1.95	2.13	2.65	2.92	2.96	2.92	3.01	2.89
Peas.	1.66	1.78	2.15	2.41	2.64	2.86	2.94	3.13
Lupine	.62	.64	.67	.79	.62	.75	.89	.88
120 hrs.								
Corn.	1.95	2.14	2.67	2.96	2.96	2.94	3.02	2.90
Peas.	1.66	1.78	2.16	2.41	2.64	2.84	2.93	3.12
Lupine	.62	.64	.67	.69	.62	.80	.89	.91

Percentage Gain in Alcohols.

721-16

53

Corn, Exp. 1.	Abs.	24hr. 1.8	48hr. 1.9	72hr. 2.3	96hr. 2.9	120hr. 3.5
	95%.	4.4	6.3	8.1	8.7	9.3
	75%.	28.0	35.7	40.1	41.4	42.0
	50%.	35.3	43.1	45.4	47.7	48.3
	30%.	42.7	47.8	50.9	51.6	51.6
	20%.	31.3	45.5	50.0	51.8	51.2
	10%.	37.2	42.8	45.3	47.2	49.1
	H ₂ O.	45.8	52.4	54.2	55.4	56.0
Exp. 2.	Abs.	1.0	1.0	1.5	1.5	1.5
	95%.	4.1	5.6	7.6	8.6	9.2
	75%.	24.5	31.3	35.4	35.6	35.7
	50%.	32.2	41.3	45.9	49.0	51.0
	30%.	36.5	45.7	50.2	50.2	50.2
	20%.	38.4	43.4	45.9	47.6	48.5
	10%.	38.2	46.9	51.5	53.5	54.0
	H ₂ O.	34.0	40.6	45.1	46.6	47.2
Mean.	Abs.	1.4	1.4	1.9	2.2	2.5
	95%.	4.2	5.9	7.8	8.6	9.2
	75%.	26.2	33.5	37.7	38.5	38.8
	50%.	33.7	42.2	45.6	48.3	49.6
	30%.	39.6	46.7	50.5	50.9	50.9
	20%.	34.8	44.4	47.9	49.7	49.8
	10%.	37.7	44.8	48.4	50.3	51.5
	H ₂ O.	39.9	46.5	49.6	48.0	51.6

Percentage Gain in Alcohols.

54

		Time / %				
Peas,		24hr.	48hr.	72hr.	96hr.	120hr.
Exp. 1.	Abs.	1.9	2.5	3.1	4.3	4.3
	95%.	3.1	5.4	6.6	7.3	7.9
	75%.	11.1	23.5	26.5	28.4	29.7
	50%.	41.1	45.8	47.0	47.6	48.2
	30%.	62.5	64.4	65.0	65.6	65.6
	20%.	70.3	70.1	70.3	70.3	70.8
	10%.	85.3	85.3	84.7	84.1	83.5
	H ₂ O.	98.7	100.6	100.6	100.6	103.1
Exp. 2.	Abs.	1.2	1.9	2.5	3.1	3.1
	95%.	6.8	7.9	8.6	9.2	9.2
	75%.	20.9	25.0	26.8	28.5	28.7
	50%.	41.9	47.5	48.2	48.8	48.8
	30%.	60.1	61.9	61.9	61.9	61.9
	20%.	75.7	75.7	76.3	78.3	78.3
	10%.	87.5	86.9	85.7	82.7	81.9
	H ₂ O.	96.9	97.5	96.9	95.6	95.0
Mean.	Abs.	1.5	2.2	2.8	3.7	3.7
	95%.	4.9	6.6	7.6	8.2	8.5
	75%.	15.6	24.2	26.6	28.4	29.2
	50%.	41.5	46.6	47.6	48.2	48.5
	30%.	61.3	63.1	63.4	63.7	63.7
	20%.	73.0	72.9	73.3	74.3	74.5
	10%.	86.4	86.1	85.2	83.4	82.7
	H ₂ O.	97.8	99.0	98.7	98.1	99.0

Lupine.		24hr.	48hr.	72hr.	96hr.	120hr.
Exp. 1.	Abs.	1.3	1.3	1.3	1.3	1.3
	95%.	1.3	2.7	2.7	2.7	2.7
	75%.	10.0	14.2	15.7	17.1	17.1
	50%.	0.	0.	0.	0.	0.
	30%.	1.4	1.4	17.1	21.4	21.4
	20%.	30.9	39.4	40.8	64.8	100.0
	10%.	26.8	42.8	75.7	77.1	75.7
	H ₂ O.	16.6	18.9	26.4	26.4	25.0
Exp. 2.	Abs.	0.0	0.0	0.0	0.0	0.0
	95%.	0.0	0.0	0.0	0.0	0.0
	75%.	1.5	1.5	1.5	1.5	1.5
	50%.	11.3	11.3	11.3	11.3	11.3
	30%.	0.0	0.0	0.0	0.0	0.0
	20%.	0.0	0.0	0.0	15.4	23.0
	10%.	22.2	33.3	42.8	41.2	41.2
	H ₂ O.	23.8	25.8	22.2	41.2	44.4
Mean.	Abs.	.6	.6	.6	.6	.6
	95%.	.6	1.3	1.4	1.4	1.4
	75%.	5.7	7.9	8.6	9.3	9.3
	50%.	5.6	5.6	5.6	5.6	5.6
	30%.	.7	.7	.8	10.7	10.7
	20%.	15.5	19.7	20.4	40.1	61.5
	10%.	24.5	38.1	59.7	59.2	58.5
	H ₂ O.	20.2	23.8	24.3	33.8	34.7

Percentage Gain in Alkohol. Corn. Av. of Exp. 1 & 2. Curve J.

LIBRARY
OF THE
UNIVERSITY OF TORONTO

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Percentage Gain in Alcohol, Lupine. Exp. I. Curve L.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Percentage Gain in Alcohol. Lupine. Exp. 2. Curve M.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Judging from the results of many experiments there are many seeds which show a more or less marked peculiarity in the rate of absorption. We have already considered the clover seed, we have noted a slight variation in corn and peas, and have considered briefly the same, but more marked differences and peculiarities of the lupines. In this experiment the lupines show extremely peculiar properties with regard to absorption. By reference to table 19, it will be seen that in Exp.1 these seeds increased in weight when soaked in all solutions - except 50 %: (even including the absolute alcohol.) In Exp.2, on the other hand seeds soaked one hundred twenty hours in 30 % alcohol do not gain in weight, while those in 20 % fail to absorb anything until between seventy two and ninety six hours. Another peculiar behavior of some seeds is shown in Exp.2. In the 50 % alcohol the seeds gained 11.3 grams during the first twenty four hours, and fail to increase thereafter.

The results of this and former experiments indicate that the constitution of the seed coat of some seeds is of such a nature that it will not allow water to penetrate it readily. However, if water does find an entrance to the embryo, or endosperm, this swells rapidly and by so doing stretches the seed coat. The stretching of the seed coat produces a change in its structure which permits quite free admission of water.

Effect of Alcohols on Germination.

In order to determine the effect of soaking corn, peas, and lupines in alcohols of various strengths the following per cents were used: Absolute, 95 %, 75 %, 50 %, 30 %, 20 %, 10 %, and distilled water. Into each of these grades of alcohol one hundred seeds of each kind were placed. Five seeds of each kind were taken from the respective alcohols after soaking for the time indicated in table 20, and planted in a saw-dust germinator. The time was extended much longer than indicated in the table but as no seeds germinated the table was not made to include that part of the experiment.

The table shows that some seeds soaked in absolute alcohol will grow even after six or seven days soaking. More seeds of the peas and lupines grow after soaking in absolute alcohol than when soaked in water and other wise treated in the same manner. Thirty four per cent of the peas soaked in 95 % and six per cent of corn soaked in 10 per cent alcohol germinated. There are occasional ones germinating in all alcohols except 30 % and 20 %. The time for germination, after removal from alcohol is, on the average twenty four hours less, in case of the water soaked seeds than in case of absolute alcohol immersed seeds of the same kind. Peas retain their vitality much longer in absolute alcohol than in water.

Effect of Alcohols on Germination. *Table 2.*

Alc.	Kind.	Length of time the seeds soaked.								
		12hr.	1da.	2da.	3da.	4da.	5da.	6da.	7da.	11da.
100 %	corn.	5	3	1	1	0	0	0	0	0
	peas.	5	2	2	2	0	2	1	1	0
	lup.	1	0	1	0	0	1	1	0	0
95 %	corn.	0	1	0	0	0	0	0	0	0
	peas.	0	1	4	1	4	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0
75 %	corn.	0	0	0	0	0	0	0	0	0
	peas.	0	2	1	1	0	0	1	0	0
	lup.	0	0	0	1	0	0	0	0	0
50 %	corn.	0	0	0	0	0	0	0	0	0
	peas.	0	0	0	0	0	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0
30 %	corn.	0	0	0	0	0	0	0	0	0
	peas.	0	0	0	0	0	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0
20 %	corn.	0	0	0	0	0	0	0	0	0
	peas.	0	0	0	0	0	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0
10 %	corn.	4	1	1	1	0	0	0	0	0
	peas.	0	0	1	0	0	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0

Table continued on next page.

H ₂ O {	corn.	4	4	3	4	2	1	1	0	0
	peas.	1	0	1	0	0	0	0	0	0
	lup.	0	0	0	0	0	0	0	0	0

the same is true of those in 95 % alcohol. Corn retains its vitality longer in water than in absolute alcohol; also better in 10 % than in 95 % alcohol. This indicates that some seeds possess certain properties which enable them to successfully withstand conditions injurious to other seeds. The experiment further shows that seeds of the same kind possess individual differences. Some seeds of peas and lupines germinated after soaking in 75 % and 50 % alcohol, while no corn germinated.

In the two sets of experiments, next to be given and discussed, the effects of soaking corn and peas in a complete series of NaCl solutions are given. The amount of gain in weight during the soaking process and the effect of absorption of these solutions on the time and per cent of germination will be considered. The corn and peas used in the two following experiments were the same as used in the preceeding two experiments. These four experiments give results which may easily be compared.

It has been considered that salt solutions of certain strengths produce an accelerating effect, while other solutions produce a retarding effect in the process of germination; still others inhibit germination. These points will receive attention later.

A table of the solutions used in all experiments with NaCl solutions will be found on the following page.

By referring to table 5 it will be seen that corn increases in weight 39 % in twenty four hours and 51 % in thirty six hours. Table 6 shows that peas gain 82 % in nine hours and 93 % in fourteen hours.

Isotonic Solutions.

Isotonic NaCl solutions as follows were used in which to soak the corn. The numbers given correspond to the strength of the solution throughout the experiments.

One hundred cubic centimeters of distilled water were used with the given weights of NaCl in grams. First the number is given; then the calculated weight of NaCl required; and third the weight as actually used.

No 30 NaCl solution is a saturated solution.

No.	Cal.	Wt.	Act.	Wt.	No.	Cal.	Wt.	Act.	Wt.	No.	Cal.	Wt.	Act.	Wt.
1	1.17		1.2		13	15.21		15.2		25	29.25		29.2	
2	2.34		2.3		14	16.38		16.4		26	30.42		30.4	
3	3.51		3.5		15	17.55		17.6		27	31.59		31.6	
4	4.68		4.7		16	18.72		18.7		28	32.76		32.8	
5	5.85		5.8		17	19.89		19.9		29	35.93		33.9	
6	7.02		7.0		18	21.06		21.1		30	35.10		35.1	
7	8.19		8.2		19	22.23		22.2		31	36.27		36.3	
8	9.36		9.4		20	23.40		23.4		32	37.44		37.4	
9	10.53		10.5		21	24.57		24.6		33	38.61		38.6	
10	11.70		11.7		22	25.74		25.7		34	39.78		39.8	
11	12.87		12.9		23	26.91		26.9		35	41.05		41.1	
12	14.04		14.0		24	28.05		28.1						

Absorption in NaCl solutions.

Corn and peas were weighed and placed in the entire series of solutions at such times as would permit their being taken from the solution at the same time. It was desired to have one set of corn and one set of peas nearly saturated; hence, as previous experiments had indicated, thirty six and fourteen hours was the time selected. Twenty four and nine hours was the time of soaking for the other sets of corn and peas respectfully.

When the seeds were taken from the solutions they were wiped dry with cheese cloth, and immediately weighed. The dry weight and the weight after soaking for the given time, together with the actual gain for that time, and the percent gain, are all given opposite each solution in the following tables. See tables 21, 22, 23, & 24.

Perry's Golden Eagle Corn.

Table 21.

Time of soaking 24 hours.

Five grains per set.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.
1	1.6	2.1	.5	31.25
2	1.7	2.1	.4	23.53
3	1.9	2.4	.5	26.32
4	1.9	2.3	.4	21.05
5	2.0	2.5	.5	25.00
6	1.8	2.1	.3	16.66
7	1.8	2.4	.6	33.33
8	1.7	2.0	.3	17.64
9	1.7	2.1	.4	23.53
10	2.0	2.5	.5	25.00
11	1.8	2.3	.5	27.77
12	2.0	2.2	.2	10.00
13	1.8	2.0	.2	11.11
14	1.7	2.0	.3	17.64
15	2.0	2.3	.3	15.00
16	1.9	2.2	.3	15.26
17	1.7	1.9	.2	11.76
18	1.8	2.1	.3	16.66
19	1.7	1.9	.2	11.76
20	1.9	2.2	.3	15.26

21	1.9	2.1	.2	10.52
22	1.9	2.1	.2	10.52
23	1.7	1.9	.2	11.76
24	1.7	1.9	.2	11.76
25	1.7	1.9	.2	11.76
26	1.8	2.1	.3	16.66
27	1.8	2.1	.3	16.66
28	1.7	1.9	.2	11.76
29	1.6	1.8	.2	12.50
30	1.7	1.9	.2	11.76

Perry's Golden Eagle Corn.

Table 22.

Time of soaking 36 hours.

Five grains per set.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.
1	1.8	2.5	.7	38.88
2	1.7	2.3	.6	35.29
3	2.0	2.4	.4	20.00
4	1.8	2.2	.4	22.22
5	1.8	2.2	.4	22.22
6	1.9	2.3	.4	21.05
7	1.7	2.0	.3	17.64
8	1.9	2.4	.5	26.32
9	1.9	2.1	.2	10.52
10	1.8	2.2	.4	22.22

11	1.8	2.1	.3	16.66
12	1.8	2.0	.2	11.11
13	1.7	2.0	.3	17.64
14	1.6	2.0	.4	25.00
15	1.8	2.2	.4	22.22
16	1.9	2.2	.3	15.26
17	1.8	2.0	.2	11.11
18	1.6	1.9	.3	18.75
19	1.8	2.1	.3	16.66
20	1.7	1.9	.2	11.76
21	1.8	2.0	.2	11.11
22	1.8	2.1	.3	16.66
23	1.9	2.1	.2	10.52
24	2.0	2.1	.1	5.00
25	1.8	2.0	.2	11.11
26	1.7	1.9	.2	11.76
27	1.8	2.0	.2	11.11
28	1.8	2.0	.2	11.11
29	1.7	2.0	.3	17.64
30	1.7	1.9	.2	11.76

Absorption in NaCl solutions.

White Marrowfat Peas.

Table 23.

Time of soaking 9 hours.

Five peas per set.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.
1	1.7	3.0	1.3	74.46
2	1.4	2.2	.8	57.14
3	1.6	2.5	.9	56.25
4	1.5	2.3	.8	53.33
5	1.5	2.2	.7	46.66
6	1.5	2.4	.9	60.00
7	1.5	2.3	.8	53.33
8	1.5	2.2	.7	46.66
9	1.5	2.2	.7	46.66
10	1.5	2.2	.7	46.66
11	1.5	2.3	.8	53.33
12	1.8	2.6	.8	44.44
13	1.7	2.7	1.0	58.82
14	1.5	2.2	.7	46.66
15	1.5	2.1	.6	40.00
16	1.5	2.0	.5	33.33
17	1.4	2.1	.7	50.00
18	1.5	2.2	.7	46.66
19	1.6	2.4	.8	50.00
20	1.6	2.4	.8	50.00

21	1.5	2.1	.6	40.00
22	1.5	2.3	.8	53.33
23	1.5	2.1	.6	40.00
24	1.5	2.3	.8	53.33
25	1.4	1.8	.4	28.57
26	1.6	2.1	.5	31.25
27	1.6	2.2	.6	37.50
28	1.4	2.1	.7	50.00
29	1.6	2.2	.6	37.50
30	1.5	1.9	.4	26.66

White Marrowfat Peas.

Table 24.

Time of soaking 14 hours.

Five peas per set.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.
1	1.6	2.8	1.2	75.00
2	1.6	2.6	1.0	62.50
3	1.5	2.4	.9	60.00
4	1.5	2.3	.8	53.33
5	1.5	2.3	.8	53.33
6	1.6	2.6	1.0	62.50
7	1.5	2.2	.7	46.66
8	1.5	2.2	.7	46.66
9	1.5	2.3	.8	53.33
10	1.5	2.2	.7	46.66

11	1.7	2.8	1.1	64.70
12	1.6	2.3	.7	43.75
13	1.7	2.6	.9	52.97
14	1.5	2.2	.7	46.66
15	1.5	2.2	.7	46.66
16	1.5	2.1	.6	40.00
17	1.5	2.0	.5	33.33
18	1.4	2.3	.9	64.28
19	1.4	2.2	.8	57.14
20	1.6	2.4	.8	50.00
21	1.5	2.4	.9	60.00
22	1.6	2.5	.9	56.25
23	1.5	2.2	.7	46.66
24	1.7	2.4	.7	41.18
25	1.5	1.9	.4	26.66
26	1.6	2.3	.7	43.75
27	1.6	2.2	.6	37.50
28	1.5	1.9	.4	26.66
29	1.6	2.0	.4	25.00
30	1.5	2.1	.6	40.00

The maxima and minima in these experiments are given below:

		Max.	Min.
Corn.	24 hours.	33%	10%
Corn.	36 hours.	39%	10% (1 except.)
Peas.	9 hours.	74%	26%
Peas.	14 hours.	75%	26%

From these results it is evident that less gain in weight occurs in salt solutions and in alcoholic solutions than in distilled water. See tables 17 and 18.

While the amount absorbed, in general, decreases with the higher solutions there is a marked variation and irregularity in the amount taken up. The two sets of curves, O and P, on the two following pages clearly represent the amount of absorption for the whole series of solutions and also the irregularities.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Germination of Corn soaked in NaCl solutions.

The amount of absorption is discussed in the preceeding experiment. The present is a continuation of amount of absorption but here special stress is given to time and per cent of germination.

The corn used for these experiments was the hard flinty variety used in experiment No.1. This corn gave a germination test of 97 %. After the corn of these experiments was soaked in the series, or part of the complete series, of salt solutions for the time indicated at the head of each table, they were weighed and placed in the constant moisture germinator, already described. The seeds were weighed from time to time, the last weighing being when the first seed coat was actually ruptured and the radicle pushing through. While the weights did not remain constant in the germinator it remained fairly so. A record of the time of germination was kept as follows.

Germination of Corn

after soaking 24 hours in NaCl solutions. *Table 34.*

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. 1st. germ.
1	5.1	6.3	1.2	23.6	6.1
2	5.2	6.3	1.1	21.4	6.6
3	5.1	6.2	1.1	21.6	6.5
4	5.2	6.1	1.0	19.2	6.5
5	5.1	6.0	1.0	19.6	6.3
6	5.1	5.9	.8	15.7	6.1
7	5.2	6.1	.9	17.3	6.3
8	5.0	5.7	.7	14.0	6.2
9	5.1	5.8	.7	13.7	6.3
10	5.1	5.8	.7	13.7	6.4
11	5.1	5.8	.7	13.7	6.5
12	5.3	5.9	.6	11.3	6.7
13	5.2	5.8	.6	11.5	6.7
14	5.2	5.8	.6	11.5	6.8
15	5.1	5.7	.6	11.7	6.7
16	5.2	5.8	.6	11.5	6.7
17	5.1	5.6	.5	9.8	6.5
18	5.0	5.5	.5	10.0	6.6
19	4.9	5.4	.5	10.2	6.4
20	4.9	5.3	.4	8.2	6.5
21	5.0	5.5	.5	10.0	6.6
22	4.9	5.3	.4	8.2	6.3

23	5.1	5.5	.4	7.8	6.5	79
24	4.9	5.3	.4	8.2	6.7	
25	4.6	5.0	.4	8.7	5.7	
26	4.7	5.1	.4	8.5	5.7	
27	4.6	5.1	.5	10.8	5.7	
28	4.7	5.1	.4	8.5	5.6	
29	4.8	5.2	.4	8.3	6.0	
30	4.4	4.7	.3	6.6	5.5	
31	4.7	5.0	.3	6.3	5.8	
32	4.6	4.9	.3	6.5	5.7	
33	4.5	4.9	.4	8.8	5.7	
34	4.6	5.0	.4	8.6	5.6	
35	4.5	4.9	.4	8.8	5.5	
Dis. H O.	5.0	6.6	1.6	32.0	6.5	
Tap H O.	4.9	6.5	1.6	32.6	6.4	

Germination of seeds. *Table 25*
 No. 7da. 10da. 12da. 14da. 16da. 17da. 18da. 35da. Mean.

1	0	2	0	1	4	0	3	0	15.2
2	3	1	0	2	3	1	0	0	12.1
3	4	5	1	0	0	0	0	0	9.1
4	0	6	1	1	1	1	0	0	11.9
5	0	2	0	5	2	0	1	0	14.0
6	0	0	3	3	2	0	2	0	14.6
7	0	0	3	1	4	0	0	0	14.2
8	0	2	3	3	2	0	0	0	13.0
9	0	2	2	3	3	0	0	0	13.4
10	0	7	3	0	0	0	0	0	10.6

11	0	10	0	0	0	0	0	0	10.0
12	0	3	3	4	0	0	0	0	12.2
13	0	2	0	2	4	2	0	0	14.6
14	0	4	1	1	2	0	0	0	10.2
15	0	1	3	0	3	1	0	0	11.1
16	0	3	0	3	2	0	0	0	13.0
17	0	0	0	0	8	1	1	0	16.3
18	0	4	1	1	1	1	0	0	12.4
19	0	5	4	1	0	0	0	0	11.2
20	0	2	1	6	1	0	0	0	13.2
21	0	0	3	0	4	0	1	0	14.5
22	0	0	0	2	2	4	0	0	16.0
23	0	0	0	4	3	0	2	0	15.5
24	0	2	0	5	2	0	0	0	13.5

18da. 20da. 22da. 26da. 27da. 31da. 33da. 35da.

25	2	4	4	0	0	0	0	0	20.4
26	1	3	3	2	0	0	0	1	23.2
27	0	0	3	3	0	4	0	0	26.8
28	0	0	0	0	3	6	0	0	29.6
29	0	0	6	3	1	0	0	0	23.7
30	0	0	2	1	1	0	1	3	29.4
31	0	0	2	1	1	4	0	0	27.6
32	0	0	6	2	0	0	0	0	23.0
33	2	0	6	0	0	0	0	0	21.0
34	0	0	4	4	1	0	0	1	24.0
35	0	0	4	0	1	0	0	2	26.4

Dis. H ₂ O	3	2	3	2	0	10.2
Tap H ₂ O	2	2	2	3	1	11.4

Germination of Corn

after soaking 36 hours in NaCl solutions. *Tab 10 26.*

No.	Dry Wt.	Soaked Wt.	Gain.	%gain.	Wt. 1st. germ.
13	4.4	5.0	.6	13.63	5.4
14	4.3	4.9	.6	13.95	5.4
15	4.1	4.7	.6	14.63	5.0
16	4.3	4.8	.5	11.63	5.3
17	4.5	5.0	.5	11.11	5.4
18	4.3	4.8	.5	11.63	5.4
19	4.2	4.6	.4	9.52	5.1
20	4.5	5.0	.5	11.11	5.6
21	4.5	5.0	.5	11.11	5.5
22	4.7	5.0	.3	6.38	5.7
23	4.4	4.8	.4	9.09	5.0
24	4.4	4.8	.4	9.09	5.4

Germination of above seeds. *Tab 10 26'*

No.	17da.	19da.	21da.	23da.	28da.	30da.	32da.	35da.	Mean.
13	1	0	3	1	1	2	0	0	23.9
14	0	0	0	0	0	4	2	2	31.7
15	0	0	0	0	0	1	3	2	33.0
16	0	0	1	1	3	0	2	1	28.4
17	0	1	1	0	0	0	3	1	28.5

18	2	2	2	1	0	1	0	0	23.9	82
19	2	0	2	2	1	0	0	0	21.4	
20.	0	1	2	0	2	0	0	0	23.4	
21	1	0	2	2	0	1	0	2	25.6	
22	0	2	1	2	2	1	0	0	23.9	
23	0	0	0	0	1	0	0	0	24.0	
24	1	0	0	0	1	1	2	0	27.8	

Germination of Corn after soaking 36 hours

in NaCl solutions. *Table 21*

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. 1st. germ.
1	4.3	5.5	1.2	27.90	5.4
2	4.6	5.7	1.1	23.91	5.8
3	4.6	5.7	1.1	23.91	5.7
4	4.5	5.5	1.0	22.22	5.6
5	4.7	5.7	1.0	21.27	6.0
6	4.5	5.4	.9	20.00	5.6
7	4.7	5.6	.9	19.15	5.8
8	4.3	5.1	.8	18.60	5.4
9	4.5	5.3	.8	17.77	5.7
10	4.6	5.4	.8	17.34	5.7
11	4.5	5.2	.7	15.55	5.6
12	4.5	5.2	.7	15.55	5.6

Germination of above seeds. *Table 22*

No.	5da.	7da.	10da.	12da.	14da.	15da.	17da.	20da.	Mean.
1	10	0	0	0	0	0	0	0	5.0

2	9	1	0	0	0	0	0	0	5.2
3	3	3	3	0	0	1	0	0	8.1
4	3	2	3	2	0	0	0	0	8.3
5	7	3	0	0	0	0	0	0	5.6
6	0	3	3	0	0	4	0	0	11.1
7	1	0	4	2	0	2	1	0	11.6
8	1	4	3	1	0	0	0	0	8.3
9	0	3	5	0	2	0	0	0	9.9
10	0	1	0	0	1	2	0	0	12.7
11	0	3	4	2	0	0	0	0	9.4
12	0	1	2	5	0	1	0	0	11.3

Germination of Corn

after soaking 12 hours in NaCl solutions. *Table 28.*

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. ist. germ.
1	4.7	5.6	.9	19.14	5.8
2	4.7	5.5	.8	17.21	5.8
3	4.4	5.2	.8	18.18	5.3
4	4.6	5.3	.7	15.22	5.8
5	4.5	5.1	.6	13.33	5.6
6	4.5	5.1	.6	13.33	5.6
7	4.5	5.1	.6	13.33	5.5
8	4.6	5.3	.7	15.22	5.6
9	4.5	5.1	.6	13.33	5.5
10	4.3	4.9	.6	13.95	5.3
11	4.5	5.1	.6	13.33	5.6
12	4.8	5.3	.5	10.42	5.8

Germination of above seeds.

Table 25.

84

No.	5da.	7da.	10da.	12da.	14da.	15da.	17da.	20da.	28da.	Mean.
1	3	2	5	0	0	0	0	0	0	7.9
2	4	6	0	0	0	0	0	0	0	6.2
3	0	1	4	3	2	0	0	0	0	11.1
4	2	4	3	1	0	0	0	0	0	8.0
5	1	1	6	1	0	1	0	0	0	9.9
6	0	0	4	0	1	2	0	2	1	15.2
7	0	1	4	3	1	1	0	0	0	11.2
8	0	4	1	1	0	2	0	1	0	11.1
9	0	0	4	0	0	3	0	3	0	14.5
10	1	2	7	0	0	0	0	0	0	8.9
11	0	1	4	4	0	0	0	0	0	10.5
12	0	1	1	3	0	2	1	2	0	14.0

Germination of Corn

after soaking 24 hours in NaCl solutions.

Table 27.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. 1st. germ.
13	4.3	4.8	.5	11.63	5.4
14	4.3	4.8	.5	11.63	5.5
15	4.3	4.8	.5	11.63	4.9
16	3.9	4.5	.6	15.38	4.6
17	4.4	4.8	.4	9.09	5.4
18	4.3	4.7	.4	9.30	5.3
19	4.4	4.8	.4	9.09	5.4
20	4.4	4.8	.4	9.09	5.4

21	4.4	4.8	.4	9.09	5.5	85
22	4.3	4.6	.3	6.97	5.3	
23	4.3 ,	4.6	.3	6.97	5.3	
24	4.3	4.6	.3	6.97	5.3	

Germination of above seeds. *Table 27.*

No.	17da.	19da.	21da.	23da.	28da.	30da.	32da.	35da.	Mean.
13	0	0	4	3	1	1	0	0	23.4
14	0	0	1	3	0	5	1	0	27.2
15	0	0	0	1	0	1	3	2	31.3
16	0	0	0	1	0	0	0	1	29.0
17	5	1	0	2	1	0	1	0	21.0
18	6	2	1	0	0	0	0	0	17.9
19	0	4	3	1	1	0	0	0	21.1
20	1	0	5	0	2	0	0	0	22.3
21	0	0	2	1	4	0	0	3	28.2
22	1	1	3	0	2	0	0	0	22.2
23	3	0	0	1	3	0	1	0	23.7
24	0	1	1	0	1	2	1	0	26.6

Germination of Corn

after soaking 48 hours in NaCl solutions.

Table 20.

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. 1st. germ.
1	4.0	5.2	1.2	30.00	5.1
2	4.3	5.4	1.1	25.58	5.3
3	4.0	4.9	.9	22.50	4.8
4	4.0	4.8	.8	20.00	5.0
5	4.1	5.1	1.0	24.39	5.1
6	4.2	5.1	.9	21.43	5.1
7	4.2	5.0	.8	19.05	5.2
8	4.4	5.2	.8	18.18	5.4
9	4.6	5.4	.8	17.39	5.7
10	4.3	5.0	.7	16.28	5.3
11	4.3	5.0	.7	16.28	5.4
12	4.4	5.1	.7	15.91	5.4

Germination of above seeds.

Table 20.

No. 12da. 15da. 17da. 19da. 21da. 23da. 28da. 32da. Mean.

1	3	5	2	0	0	0	0	0	14.5
2	0	2	6	0	2	0	0	0	17.4
3	0	0	0	0	1	4	3	2	26.1
4	0	0	0	0	0	0	0	10	32.0
5	0	0	0	0	0	1	0	8	31.0

6	0	0	1	0	0	4	3	0	24.1
7	0	2	2	0	3	3	0	0	19.6
8	0	3	2	0	5	0	0	0	18.4
9	0	2	4	2	1	1	0	0	18.0
10	0	2	3	1	3	1	0	0	18.6
11	0	1	5	1	3	0	0	0	18.2
12	0	0	2	0	0	3	5	0	24.3

Germination of Corn

after soaking 72 hours in NaCl solutions. *Table 26.*

No.	Dry Wt.	Soaked Wt.	Gain.	% gain.	Wt. 1st. germ.
1	4.0	5.3	1.3	32.50	4.9
2	4.1	5.3	1.2	29.27	5.0
3	4.2	5.4	1.2	28.57	5.2
4	4.1	5.2	1.1	26.83	5.2
5	4.1	5.1	1.0	24.39	5.1
6	4.1	5.0	.9	21.95	5.0
7	4.0	4.8	.8	20.00	5.0
8	4.3	5.2	.9	20.93	5.5
9	4.0	4.8	.8	20.00	5.1
10	4.3	5.0	.7	16.28	5.4
11	4.3	5.0	.7	16.28	5.5
12	4.3	5.0	.7	16.28	5.3

Germination of above seeds.

Table 21.

No.	12da.	15da.	17da.	19da.	21da.	23da.	28da.	30da.	32da.	Mean.
1	3	3	4	0	0	0	0	0	0	14.9
2	1	1	3	0	2	2	0	0	0	16.5
3	0	0	1	2	2	1	2	0	1	23.1
4	0	0	0	0	0	0	0	3	6	31.4
5	0	0	0	0	0	2	4	2	2	28.2
6	0	0	1	0	0	2	5	0	0	25.4
7	0	0	1	2	1	6	0	0	0	21.4
8	0	3	4	0	2	0	1	0	0	18.3
9	0	1	6	1	2	0	0	0	0	17.8
10	0	0	4	1	1	3	0	0	0	17.4
11	0	4	4	2	0	0	0	0	0	16.6
12	0	0	0	1	0	1	8	0	0	26.6

Effect of NaCl sol. on Germination of Corn, 24 hrs. — % gain in 36 hr. --- Mean time of Germ Curve Q.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

Iso. Sol.
 Effect of NaCl. 48 hrs. --- Mean time.
 105 11.7 12.9 14.0
 % gain

12 2.3 3.5 4.7 5.8 7.0 8.2 9.4 10.5 11.7 12.9 14.0
 72 hrs. --- Mean time. Curve S.
 % gain

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Lga. Lot.

Effect of NaCl, 12 hrs — % gain, --- Meantime.

15.2 16.4 17.6 18.7 19.9 21.1 22.2 23.4 24.6 26.7 26.9 28.1

24 hrs — % gain, --- Meantime, Curve T.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

Some of the above tables are incomplete, because of conditions we could not control.

Soaking in salt solutions of whatever strength and for any length of time up to seventy two hours does not lower the per cent of germination although the stronger solutions do retard germination.

Each table is followed by a corresponding set of curves. The tables are placed together and the curves in another group for convenience of comparison.

A study of the tables and curves shows a very sudden increase in the mean time of germination. This sudden and marked retardation occurs nearer to the time of beginning the soaking of the seeds as the time of soaking is lengthened. There is a general tendency toward lengthening the mean time of germination as the strength of the solution increases, but always with peculiar variations. The amount of water taken up decreases as the strength of the solutions increases; the variation in the amount of water in the seeds accounts for the general lengthening of the mean time of germination. The sudden great increase in the mean time of germination I cannot understand. It may be due to some peculiar relation existing between the corn and a certain amount of NaCl absorbed with the water. Salt is actually found in all portions of the grains after soaking for twenty four hours in 20 % salt solutions as I proved by chem-

ical test. When a certain amount enters a certain part, the germ, probably, germination is retarded. I offer this as a suggestion only. Much more work should be done along this line.

Effect of Ammonium Alum on Corn.

A hard white variety of corn, bred at the Agricultural Experiment Station for high and low protein and high and low oil was used in this experiment. An equal number of grains of each was placed in each of the following solutions of Ammonium Alum: .1 %, .2 %, .3 %, .4 %, .5 %, .6 %, .7 %, and .8 %. The corn was allowed to soak in these solutions twenty hours. The tables here given, represent the dry weight, weight after the soaking, gain and percent gain together with the average time of germination. In these experiments every grain germinated.

The percentage of gain is not different from that when the corn is soaked for a like period in distilled water. The amount absorbed varies with the different chemical compositions of the same variety of corn but the strength of the solution has no effect in this regard. Thus more absorption takes place in the low protein than in the high and more in the high and low oil than in the high and low protein. In general the more concentrated the solution, within the limits of my experiments, the longer is the average time of germination: i.e. germination is retarded.

Effect of Ammonium Alum on Germination of Corn.

High Protein.

Solution.	Wt. dry.	Wt. in 20hr.	Gain.	% gain.	Av. T. of g.
.1%	1.785	2.295	.510	28.7	3.6
.2%	1.885	2.495	.610	32.4	3.4
.3%	1.850	2.430	.580	31.3	2.6
.4%	1.965	2.560	.595	30.4	3.6
.5%	1.895	2.500	.605	32.0	4.8
.6%	1.725	2.305	.580	32.5	5.4
.7%	1.860	2.465	.605	32.5	5.6
.8%	1.810	2.375	.565	31.2	3.8

Low Protein.

Solution.	Wt. dry.	Wt. in 20hr.	Gain.	% gain	Av. T. of g.
.1%	1.580	2.095	.510	32.3	2.2
.2%	1.616	2.145	.529	32.8	3.2
.3%	1.735	2.335	.600	34.6	4.0
.4%	1.499	1.985	.486	32.4	4.2
.5%	1.850	2.480	.630	34.0	4.6
.6%	1.605	2.105	.500	31.2	4.0
.7%	1.690	2.275	.585	34.0	4.0
.8%	1.840	2.460	.620	33.7	4.0

Effect of Ammonium Alum on Germination of Corn.

High Oil.

Solution.	Wt. dry.	Wt. in 20hr.	Gain	% gain	Av. T. of g.
.1%	1.875	2.480	.605	32.5	2.4
.2%	1.805	2.400	.595	33.0	3.0
.3%	2.075	2.720	.645	31.1	3.2
.4%	1.885	2.350	.465	24.3	3.0
.5%	1.785	2.385	.600	33.7	4.0
.6%	1.985	2.713	.728	37.1	4.8
.7%	1.645	2.185	.540	32.9	6.2
.8%	1.775	2.370	.585	33.0	4.2

Low Oil.

Solution.	Wt. dry.	Wt. in 20hr.	Gain.	% gain.	Av. T. of g.
.1%	1.985	2.670	.665	33.5	3.2
.2%	1.985	2.660	.675	33.7	3.5
.3%	2.036	2.770	.734	36.1	3.6
.4%	2.025	2.730	.705	34.7	3.8
.5%	1.920	2.620	.700	36.4	4.0
.6%	2.000	2.655	.655	32.3	5.2
.7%	1.995	2.780	.785	39.1	4.0
.8%	2.295	3.050	.755	32.9	5.2

Sol. 1% GENE DIETZGEN 2% CHICAGO 3% 4% 5% 6% 7% 8%
Percentage increase in Ammonium Alum Solutions. Curve U.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Mean Time in Tenths of Days.

100
96
92
88
84
80
76
72
70
65
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0

H Pro
L Oil
H.O.I
L Pro } Means.

L Oil.
H.O.I
L Pro.
H. Pro.

Sol. 0 1% 2% 3% 4% 5% 6% 7% 8%
Mean Time of Germination, CORN, Ammonium Alum. CURVE V.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Action of Coleus.

On February 13, '02, I carried Coleus from the University greenhouse to the greenhouse of the Department of Botany. The plants had been grown where a day temperature of 66 degrees F. was maintained. Although the temperature was 6 degrees F. below freezing, the plants experienced no change of temperature in the transfer, because of the double box in which they were carried. The temperature was taken before and after the trip by the same thermometer. Most of the pots were placed on a greenhouse bench. Three were carefully taken from pots with dirt undisturbed and placed in wide mouthed bottles filled with water, and, as the dirt soaked, it fell to the bottom of the bottle and left the roots free in the water. Twelve hours later they were greatly wilted. Two were placed under bell-jars, with constantly saturated atmosphere, to prevent transpiration: the other on table in the greenhouse: wilting continued and leaves fell from lower part of stem. February 18, '02 still much wilted. A fresh plant was then taken and its roots, dirt, pot and all immersed in water to its lowest leaves: In thirty six hours the plant was much wilted so that the lower leaves fell off. The plant continued in this wilted condition. Another one was gradually (during three days) watered until finally immersed to first leaves. Wilted in 24 hrs. after immersion: lower leaves fell; continued wilted.

Absorption of Water by Roots of Plants.

In work done along this line it has always been necessary to use apparatus which had to be hermetically sealed. This is frequently inconvenient and for that reason something new was sought with which to secure results in a series of experiments on absorption of water. The following described piece of apparatus was constructed and gave excellent satisfaction. Under conditions in which the neck of the bottle is small it is sensitive to one tenth of a cubic centimeter.

Description of Apparatus.

The glass tube A Plate 1 is about forty centimeters long and has a diameter of thirteen and one half millimeters. The lower end of this tube is closed by a tight fitting cork into which the S shaped, six millimeter glass tube extends. This S tube ends flush with the inner end of the cork. The longer end of the tube S passes through a cork C and extends some distance below the other end of the S. The large cork through which the crooked tube passes has a portion cut away so as to leave the opening O for the plant when the stopper is in position. The upper end of the tube A is also closed with a cork through which a glass tube of six millimeters diameter extends. This glass tube T has its lower end about one centimeter above

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.

the cork in the lower end of the tube A, and its upper end is drawn into a capillary tube to regulate the rate of inflow of air as water passes from the tube A, into bottle B, as the plant roots absorb the water from the bottle. It is necessary to have the bottle B, and tubes S and A filled with water at the beginning of the experiment, and then, with a pipette, draw off water from the bottle until a bubble of air passes from tube T into tube A. Now, as the plant takes up water by means of its roots and the surface of the water in B sinks below a level with the lower end of T, water will flow from A into B through S and air will pass through the capillary end of T and rise from the lower end of T in single bubbles and at regular intervals - the time between bubbles depending alone on the rapidity of absorption of water by the roots of the plant. The tube A has a scale, graduated to half cubic centimeters etched on its surface by means of which readings can be made.

By means of this piece of apparatus the same constant level of water is maintained in the vessel containing the plants. The evaporation from the surface of the water through the opening O is reduced to a minimum by stopping the opening around the stem of the plant with cotton.

It was intended that considerable work would be done with the use of this apparatus on the absorption of water by the

roots of Coleus, but, as stated before, these plants would not continue vigorous when transferred from soil to water. Consequently only the following two experiments - one with corn and one with a rooted cutting of Coleus - were conducted. The tables and curves are here given but for lack of comparative data no comments given. They may be suggestive.

Experiment to determine Rate of

Absorption of Water by roots of corn.

February 12, '02 four growing stalks of corn accustomed to growing in water were placed in apparatus shown on the preceding page.

Temperature.	Time.	Amt. Abs'd.
23 C.	24 hrs.	9.3 cc.
21 C.	24 hrs.	9.8 cc.
4 C.	24 hrs.	5.4 cc.
15 C.	24 hrs.	5.5 cc.
21 C.	24 hrs.	5.1 cc.

Plants apparently dying during last hours. After several days the plants revived somewhat and lived for more than a month.

On 6th. and 7th. of March, '02 the amount of absorption in 24 hours was again up to 7.1 cc.

Rate of Absorption of Water
by Roots of Coleus.

The plant was a cutting rooted in water and had eight well developed leaves.

		cc.	cc. per hr. from read. to read.	
March 15	3:45 P.M.	8.5	0.0	
March 16	8:45 A.M.	10.5	.119	
March 17	5:00 P.M.	14.0	.472	
March 18	8:15 A.M.	15.1	.073	
March 18	1:40 P.M.	15.8	.115	
March 19	11:20 A.M.	17.0	.057	
March 20	8:40 A.M.	17.8	.080	
March 20	9:00 A.M.	0.0	clear	.0
March 20	6:00 P.M.	8.6	clear	.955
March 21	8:30 A.M.	12.2	cloudy	.248
March 21	5:30 P.M.	15.3	cloudy	.344
March 22	7:30 A.M.	16.9	cloudy	.114
March 22	11:00 A.M.	17.2	clear	.085
March 22	5:00 P.M.	22.6	clear	.900
March 23	7:00 A.M.	30.4	clear	.557
March 23	6:00 P.M.	36.0	clear	.509
March 24	9:00 A.M.	43.9	cloudy	.526

Temperature 23 - 26 C.

Amount per hour in hundredths of cubic centimeters.

Absorption of Water by Roots of Coleus.

Curve N.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS.