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The Influence Of Light On The Respiration Of Germinating Barley And Wheat

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MEETING OF THE SOCIETY,

Thursday, April 12, 1894.

Dr. WILLIAM CRAIG, Vice-President, in the Chair.

The presentation to the Society of a copy of Goode-nough's *Algae*, by Mr. G. W. TRAILL, was announced.

Miss MADDEN exhibited a twig in flower of *Stauntonia latifolia* from a plant grown at Royal Terrace, Edinburgh.

Surgeon-Major H. H. JOHNSTON exhibited specimens of cultures of *Bacteria* from water, and pointed out the inadequacy of most filters to prevent the passage of *Bacteria*.

Mr. CAMPBELL sent from his open garden at Ledaig, blooms of *Acacia linearifolia*, *Orchis mascula*, *Erica mediterranea*, and *Pyrus communis*.

The following Papers were read:—

THE INFLUENCE OF LIGHT ON THE RESPIRATION OF GERMINATING BARLEY AND WHEAT. By T. CUTHBERT DAY.

INTRODUCTION.

Though this paper was written as long ago as 1886, still, as far as I am aware, the work is new. I have not come across any communication on the subject since, and the paper I have the honour of bringing before your notice to-night has not been read before any society as yet. The fact is I hardly knew what to do with it. I did not think it suitable for the Chemical Society, as not being nearly chemical enough, though there is a fair amount of chemical work in it. As the paper is fairly in the domain of vege-

table physiology, I thought it might interest the members of this Society, and I trust you may find at least some matter worthy of your attention in it.

From a practical point of view the importance of the subject is really almost nil, but in almost every book on malting the influence of light on germination is mentioned, and in regard to it some fearful and wonderful statements are sometimes put forward. Some maltsters, as I have seen in various places, have adopted blue glass for the windows of the malting floors, under the impression that by admitting the actinic rays of light they favour in some way the germination of the grain, apparently losing sight of the fact that their operations are practically carried on in the dark, as far as germination is concerned, seeing that it is only the upper layer of corns that is exposed to the light. Some other maltsters, prefer having their floors altogether dark, which is often an advantage, because direct sunlight is excluded, and the consequent undue elevation of temperature is avoided, which, of course, would affect the germinative activity to a considerable extent.

Many experiments have been recorded at different times by various authors in connection with the influence of light on the germination of seeds, but the results arrived at have been very conflicting.

The state of uncertainty in which this question still remains has induced me to make a series of experiments, using every means which I could devise to avoid the interference of outside influences, in order to arrive, if possible, at a definite solution of the problem as to whether light retards or accelerates the respiratory functions of such seeds as barley and wheat during the process of germination. My chief purpose in making this communication is rather to place on record the methods employed and their result, than to put forward any particular conclusions that might be deduced from the experiments.

Among the experimenters who have worked on this subject, the following names may be mentioned. They are collected from the historical record of the subject, with references, given by M. A. Pauchon in his memoir, to be alluded to again :—

Miesse (*Expériences sur l'Influence de la Lumière sur les Plantes*.—*Journal de Physique de Rozier*, T. 6, Dec. 1775) considered that light has little or no influence on germination.

Sénebier (*Memoires Physico-Chimiques*, 1782) concluded that light was hurtful to the germination of seeds.

Ingenhousz held the same opinion as Sénebier as to the action of light (*Expériences sur la Végétation*, 1787–89).

The Abbe Bertholon (*Journal de Physique de Rozier*, Dec. 1789) criticises previous experiments on the subject, laying special stress on the necessity of equality in the degree of humidity of the seeds experimented upon.

Sénebier (*Physiologie Végétale*, 1800) in subsequent experiments, called forth by the remarks of the Abbe Bertholon, and taking care to adopt the precautions suggested by the latter, is led to the same conclusion as formerly.

E. Lefébure performed many experiments on the action of light, especially with regard to the action of coloured rays. In the latter inquiry he does not arrive at any definite result. He discovers a retardation of germination under the influence of white light. The experiments were made without regard to small differences of temperature, though considerable trouble was taken to secure similarity in the conditions of moisture (*Expériences sur la Germination des Plantes*, 1800).

Th. de Saussure (*Recherches Chimiques sur la Végétation*, 1804) regarded the action of direct sunlight as hurtful to the seeds on account of the heat which accompanies it, but in diffused light, when every precaution was taken to ensure similarity in the conditions of temperature and moisture, he does not perceive any difference in the progress of germination.

A. P. de Candolle (*Phys. Végét.*, 1832) thinks that light has no action on the germinative activity.

Ch. Morren (*An. Sc. Nat.*, 1832) considers that obscurity favours the first period of germination.

Mayen (*Neues System der Pflanzen-physiologie*, 1837) made experiments with seeds of six different genera of plants, observing equal conditions of heat and moisture

He noticed that the appearance of the radicle and the development of the cotyledons were the same in light as in darkness.

G. Ville (*Revue de Cours Scientif.*, 1865) considers that the action of light is inconsiderable.

M. Faivre (1879), experimenting with seeds of *Tragopogon porrifolius*, noticed that the seeds developed chlorophyll and sap more rapidly under the influence of yellow light than under the influence of blue light.

It will be readily seen, from a perusal of the foregoing resumé, that there is no real concordance in the results obtained by the different experimenters.

There are two serious defects in the methods of experiment followed. The first is a failure to secure *real* identity in the conditions under which the seeds were germinated in light and darkness. Similarity in temperature and moisture is of the most paramount importance; and though at first sight it might appear easy to secure identity in this respect, it is in reality a matter of considerable difficulty. The material used as a shield from the light to one of the vessels containing the seeds operated upon, must make a difference in the amount of heat absorbed or radiated, especially if the vessels are surrounded by air, or if they are situated far apart. If similarity of moisture is secured, in the first place, by steeping the seeds for the same length of time in water at the same temperature, this similarity is destroyed during the experiment if the surface of one of the containing vessels becomes colder than the other; because, in that case, though moisture is condensed on the inner surface of both vessels, the coldest vessel will have the greatest amount of condensation, and the moisture so condensed is derived from the seeds, unless special provision is made to keep the contained air saturated with moisture. The second defect alluded to is the method of judging the progress in germination. The usual plan is to note with as much accuracy as possible the development of the radicle in dicotyledonous seeds, or of the radicle and plumule in monocotyledons. This method is, of course, very crude and uncertain, and much of the variation in the results obtained may be attributed to the employment of it.

In 1880, Dr. A. Pauchon published a memoir (*Rôle de la Lumière dans la Germination*) in which he criticises closely all foregoing experiments on the subject, showing their defects. He performed many experiments, with proper precautions, but judging of the germinative progress in the way above mentioned, in order to show that only doubtful results could be so obtained. He then suggests, as a measure of germinative progress, the amount of oxygen absorbed by the seeds during germination. This method is a decided improvement, since it substitutes a precise and easily observed measurement, for a rough estimation by which an approximate result can hardly be arrived at even with much trouble.

Dr. Pauchon's apparatus consisted of two wide tubes of glass, one of which was covered with folds of black paper to exclude light, the other being left clear. The two tubes were placed upright, side by side, during an experiment, the lower ends being closed by corks pushed in to a certain distance. Above the cork in each tube was placed a small vessel containing concentrated potassa solution, and above

Fig. 1.

this was supported another vessel containing a pad of cotton wool saturated with water, on which the seeds were placed. A narrow tube, bent twice at right angles, issued from the upper end of each of the two wide tubes, and its open extremity was immersed in mercury. The limb of the narrow tube, above the mercury, was graduated into cubic centimetres and parts of a cubic centimetre, and the absorption in each tube was observed by the movement of the mercury column. Fig. 1 gives the appearance of one of the tubes as fitted up.

The seeds absorbed oxygen and exhaled carbonic anhydride, which was at once fixed by the solution of potassa, producing a partial vacuum; the mercury then rose in the narrow tube, and the absorption of oxygen was measured by taking an observation and making proper allowance for temperature, pressure, and tension of aqueous vapour, and the volume of the solid and liquid contents of each apparatus. An account was also taken of the visible progress

in germination made by the seeds during an experiment. The seeds experimented upon were chiefly oleaginous and leguminous, with the exception of Indian corn, which was the only seed which approached in composition the seeds of wheat or barley.

Dr. Pauchon concludes from his experiments:—

1. That light accelerates in a constant manner the absorption of oxygen by germinating seeds in all cases.
2. That a relation exists between the degree of illumination and the quantity of oxygen absorbed.
3. That the respiratory acceleration, exercised by light, persists in obscurity for some hours.
4. That the differences between the amounts of oxygen absorbed in light and in darkness are more considerable at a low than at a high temperature.

According to the experimental record, the first conclusion seems to be well established, and in that case the second would follow almost as a matter of course. The two last conclusions do not appear to me at all clearly warranted, after a careful perusal of the experiments.

There are three possible sources of error in Dr. Pauchon's experiments. The first consists in placing the seeds on a pad of cotton saturated with water. In this case some of the rootlets may come in contact with the pad before others, and this would cause, by itself, a considerable irregularity in germination by the stimulating action of the moisture absorbed. The second source of error is the irregularity in germination caused by selecting seeds, for experiment, in which the radicle has not already burst the seed coats. The third source of error is the manner of securing similarity of temperature. The two glass vessels containing the seeds, one clear and the other covered with black paper, were placed side by side, in the air, with a thermometer between them. It does not seem to me at all certain that the thermometer indicates the actual temperature of the interior of each vessel, for the radiating powers of clear glass and black

paper are by no means the same; and any difference in the temperature of the surrounding air, or of near objects, would destroy, if only in a small degree, the equilibrium of temperature in the two vessels, which would affect the germinative activity of the seeds, and vitiate the absorption observations by unequal expansion or contraction of the enclosed air.

If the problem be considered in the light of what we already know of the active influence of light on the green parts of plants in the presence of small quantities of carbonic anhydride, one would be inclined to think that light would probably have an *apparently* retarding effect on the respiratory function of seeds. In this way,—If the seed coats be at all pervious to light, chlorophyll would be developed in the young plumula, and by the action of the light on this substance, in presence of the carbonic anhydride evolved during germination, a portion of the carbonic anhydride would disappear, and the actual quantity produced during germination would be diminished in proportion to the activity of the light. This indirect effect of light could not take place if the carbonic anhydride evolved by the seeds was removed as soon as formed. It will be seen to what extent this idea is confirmed by the test of experiment.

Method of experiment.—In my first series of experiments I made use of an apparatus similar to the one employed in former experiments on germination, and fully described in a previous paper (Chem. Soc. J., Sept. 1880). The only modification introduced is in the form of the vessel containing the seeds experimented upon. This consisted of a piece of combustion tube, worked into

Fig. 2.

the form shown in the figure (Fig. 2). The internal diameter was 13 M.M., and the length, between the

two bends, 190 M.M. A tube this size will hold about 3 grams of barley loosely disposed all along the interior. Two tubes of the kind described were used in each experiment, and the rest of the apparatus was in duplicate. The two tubes were placed side by side in a glass trough

filled with water, one of the tubes being closely covered with two or three folds of tinfoil, to exclude the light, while the other was left clear. The carbonic anhydride, evolved in each tube, was collected by absorption in the potash bulbs and weighed.

A few remarks on the respiration of germinating barley will not be out of place at this point.

During germination oxygen is absorbed and carbonic anhydride excreted, the amount of the latter gas produced being very slightly less in volume than that of the oxygen absorbed, showing that a small quantity of oxygen is retained by the corns, and is probably used up in other changes. A certain quantity of water is also produced by respiration; and I have found that a fairly definite relation exists between the weights of the carbonic anhydride and the water. The numbers obtained indicate pretty plainly the splitting up of a carbohydrate by oxidation. The carbohydrate may belong to the cane sugar group represented by the formula $C_{12} H_{22} O_{11}$, the grape sugar group $C_{12} H_{24} O_{12}$, or the starch group, $n (C_6 H_{10} O_5)$.

The oxidation by respiration of these carbohydrates may be represented by the following equations, and it will be observed that no more oxygen is required than is sufficient to convert the carbon into carbonic anhydride:—

1. Cane Sugar. $C_{12} H_{22} O_{11} + 24 O = 12 CO_2 + 11 OH_2$
2. Glucose. $C_{12} H_{24} O_{12} + 24 O = 12 CO_2 + 12 OH_2$
3. Starch. $C_6 H_{10} O_5 + 12 O = 6 CO_2 + 5 OH_2$

The relation of the carbonic anhydride to the water will be made simpler by taking the molecular weight of carbonic anhydride 44, as a basis, then the ratios will be:—

		CO_2	OH_2
With Cane Sugar	.	44·0	16·5
„ Glucose	.	44·0	18·0
„ Starch	.	44·0	15·0

In one set of experiments on this point, the results of which appeared in the paper referred to above, a ratio of 44 : 18·28 was obtained, while in a later series of experiments, with a different barley, the ratio was 44 : 14·43. The first result points to the splitting up of a glucose, and the last to a splitting up of a starch.

In selecting corns for experiment, a small sample was taken, and all doubtful-looking corns carefully removed. From this, two lots of identical weight, about 3 grams each, were taken, one for each tube. They were steeped in water in small beakers, at the same temperature, for the same length of time, and were again weighed before being introduced into their respective tubes. The amount of moisture absorbed during steep was about 1.7 grams in most cases, and did not vary more than 0.02 grams in each duplicate experiment. The glass trough containing the germination tubes was placed as close as possible to a window having a clear look-out to the north. During the experiment, air saturated with moisture was slowly aspirated through the apparatus, so that the corns might be continually surrounded with fresh air. The germination was usually allowed to proceed for ten days, or until the acrospire had nearly reached the end of the corns. The temperature during the whole course of the experiments ranged between $14^{\circ}2$ C. and $20^{\circ}8$ C., and was regulated by means of a thermostat. During the greater number of the experiments the temperature only varied between $15^{\circ}5$ C. and $16^{\circ}6$ C.

The potash bulbs were weighed after germination had proceeded for three days, again after another interval of three days, and finally after another interval of four days. The other parts of the apparatus, including the germination tubes, were also weighed at the same time, to show that no moisture was lost or gained by the seeds experimented upon.

[Continued on next page.

I will now give the results of seven double experiments, made during March, April, and May 1881:—

Exposed to Light.			In Obscurity.			Result in favour of Light or Obscurity.
Experiment.	Days.	CO ₂ C.C.	Experiment.	Days.	CO ₂ C.C.	
1A. Saale Barley, 3·014 grams,	3 6 10	25·67 34·50 41·50	1B. Saale Barley, 3·022 grams,	3 6 10	29·27 34·95 44·85	C.C. CO ₂ . Obscurity, 3·60 Do. 0·45 Do. 3·35
Total,	..	101·67	Total,	..	109·07	Obscurity, 7·40
2A. Saale Barley, 3·037 grams,	3 6 10	40·79 43·48 47·18	2B. Saale Barley, 3·037 grams,	3 6 10	42·06 44·24 49·87	Obscurity, 1·27 Do. 0·76 Do. 2·74
Total,	..	131·40	Total,	..	136·17	Obscurity, 4·77
3A. Saale Barley, 3·040 grams,	3 6 10	40·23 41·70 47·94	3B. Saale Barley, 3·052 grams,	3 6 10	41·04 42·31 49·41	Obscurity, 0·31 Do. 0·61 Do. 1·47
Total,	..	129·87	Total,	..	132·76	Obscurity, 2·89
4A. Saale Barley, 3·029 grams,	3 6 10	43·78 41·75 52·10	4B. Saale Barley, 3·028 grams,	3 6 10	*42·46 *40·28 53·17	Light, . 1·32 Do. . 1·47 Obscurity, 1·07
Total,	..	137·63	Total,	..	135·91	Light, . 1·72
5A. Saale Barley, 3·010 grams,	3 6 10	41·95 41·14 45·56	5B. Saale Barley, 3·018 grams,	3 6 10	40·74 41·29 48·30	Light, . 1·21 Obscurity, 0·15 Do. 2·74
Total,	..	128·65	Total,	..	130·33	Obscurity, 1·63
6A. Saale Barley, 2·956 grams,	3 6 10	41·80 38·76 47·23	6B. Saale Barley, 2·936 grams,	3 6 10	41·40 40·03 46·62	Light, . 0·40 Obscurity, 1·27 Light, . 0·61
Total,	..	127·79	Total,	..	128·05	Obscurity, 0·26
7A. Saale Barley, 3·011 grams,	3 6 10	49·72 46·87 49·31	7B. Saale Barley, 3·094 grams,	3 6 10	50·63 45·81 50·12	Obscurity, 0·91 Light, . 1·06 Obscurity, 0·81
Total,	..	145·90	Total,	..	146·56	Obscurity, 0·66

Taking the totals in each double experiment, the result is as follows:—

Experiment.	Total CO ₂ produced.		Excess of CO ₂ in favour of	
	Light.	Obscurity.	Light.	Obscurity.
1.	101·67 c.c.	109·07 c.c.	...	7·40 c.c.
2.	131·40 "	136·17 "	...	4·77 "
3.	129·87 "	132·76 "	...	2·89 "
4.	137·63 "	135·91 "	1·72 c.c.	...
5.	128·65 "	130·33 "	...	1·68 "
6.	127·79 "	128·05 "	...	0·26 "
7.	145·90 "	146·56 "	...	0·66 "
Totals,	902·91 c.c.	918·85 c.c.	1·72 c.c.	17·66 c.c.

Total excess of carbonic anhydride produced in favour of obscurity is 15·94 c.c., or an increase in favour of obscurity

of 1.75 per cent. on the mean of the total quantity of carbonic anhydride produced.

Of the seven double experiments, six show an increase in respiration in favour of obscurity, and one only in favour of light.

Out of the twenty-one separate observations made during the course of these experiments, fifteen show the greatest activity in obscurity, and the remaining six point to light as being a stimulating agent. I must remark here that two of the observations recorded in experiment 4B, and marked with an asterisk, are probably vitiated by a leakage which was found at one of the joints in apparatus, which would have the effect of diminishing somewhat the current of air which passed over the germinating barley, and the quantity of carbonic anhydride collected would be lessened in consequence.

Though, as a rule, there appears to be more carbonic anhydride evolved in darkness during germination, yet the increase, as shown by the foregoing experiments, is exceedingly variable in amount, and is altogether so slight that it is more than doubtful whether one is justified in taking the arithmetical mean of so few as seven experiments to express the truth. That identity in the conditions of moisture and temperature were secured in each double experiment can hardly be doubted. The only source of variation which remains is the difference in the samples of barley and in the constitution of individual corns, a difference which it is impossible to detect, much more to avoid. This difference in the samples of barley used, if not great, say about equal in effect at the most, to the retarding influence of light would in some experiments exaggerate the results in favour of obscurity and in others tend to neutralise them altogether, the results varying with the degree of difference between the samples of barley.

At the end of each experiment the corns were all carefully examined. I did not meet with any still or dead corns during all the experiments. There was little or no difference in the outward appearance of two samples, one grown in darkness and the other in strong diffused light, at the end of ten days; but on dissecting the corns it was found that while the interior of the primitive sheath of the

plumula was of a pale yellow colour in the corns grown in obscurity, the colour of the same part in the corns grown under the influence of light was a dark green.

Not being satisfied with the results already obtained, I resolved to try a different method of experiment. I thought that if the observations could be made volumetrically as to the amount of carbonic anhydride produced, greater accuracy might be attained. With this object in view I devised and fitted up an apparatus similar in principle to that employed by Dr. Pauchon, and alluded to on a previous page. There is, however, considerable difference in the details and in the manner of experiment.

Fig. 3.

DESCRIPTION OF THE APPARATUS, Fig. 3.—A, a large strong glass tube (about 140 c.c. capacity) closed at one end. The open end of the tube is closed by an india-rubber cork, C. This cork is always pushed in to the same distance, shown by marks scratched on the glass tube. The cork has three perforations to carry three tubes, D, E, and F. D has an internal diameter of 8 m.m., and is bent in the form shown in the figure. It is graduated on both limbs from 0 to 90 m.m. E and F are two capillary tubes; F reaches nearly to the end of the tube A, while E is terminated level with the inner surface of the cork. The upper ends of both these tubes are closed by stoppers covered by a water joint. Their use is for replenishing the air in the large tube as often as it is considered necessary. B and B¹ are two porcelain spoon boats; B contains a measured quantity (about 1.3 c.c.) of distilled water, and B¹ about the same amount of potassa solution. The corns experimented upon are placed near the closed end of the tube.

A duplicate to this piece of apparatus, similar in every respect, was prepared, but light was excluded from its interior by an external coating of very thin sheet brass. The two tubes were fixed in an appropriate holder, and the whole was immersed under the surface of water, with only the open upper ends of the graduated tubes and the water joints protruding. The trough itself was placed in strong diffused light in a small greenhouse facing the north. Both pieces of apparatus were carefully calibrated.

METHOD OF EXPERIMENT.—A sample of the corn, about 50 grams of barley or wheat, was taken and placed in a beaker. The corn was covered with water from thirty-six to seventy-five hours, changing the water at intervals. The water was then drained off the seeds, and they were placed in a glazed earthenware jar, covered with an opaque plate, and allowed to germinate for periods varying from two to eight days. At the stage fixed on for experiment the jar was opened and the sample turned out. Thirty corns, or thereabout, were then selected for each tube, the greatest pains being taken to ensure similarity in the size, weight, and progress in germination of the two samples. It was hoped by employing this method of selecting the corns to eliminate in some degree the variations caused by differences in the samples employed for experiment. After being weighed, the samples were introduced into their separate tubes, as shown in the figure, and the apparatus was immersed. After a short interval, to establish equilibrium of temperature, readings were taken on the limbs of the tube D, which is half filled with quicksilver, and the volume of the enclosed air was deduced after allowing for temperature, pressure, tension of aqueous vapour, and the volume of the seeds, as well as that of the two boats with their liquid contents. The volume occupied by the corns was ascertained by finding the specific gravity of a separate portion of the same sample. The readings were repeated at suitable intervals. The reduction in volume between each observation gave the amount of oxygen absorbed by the seeds, the carbonic anhydride produced being absorbed, as soon as formed, by the potassa solution in the boat B¹. When it was required to change the air in the tubes, which was usually done immediately after an observation of the

absorption, the stoppers of the tubes E and F were removed; F was connected with an aspirator, and E with an apparatus for purifying the air and saturating it with moisture. About 1 litre of air was drawn through each tube at one time, the operation occupying about ten minutes. The stoppers were then replaced, and the volume of the contained air immediately ascertained.

Fig. 4.

The quantity of carbonic anhydride, produced by the seeds, was found at the end of the experiment in the following way:—The contents of the two boats B and B¹, from each of the two tubes, were washed into two small flasks, like A in Fig. 4, with distilled water.

Each flask was, in turn, fitted with an indiarubber cork, B, perforated by the wide tube C, which was connected with a Sprengel's mercury pump. A tap funnel, E, containing recently boiled dilute sulphuric acid tinged with litmus communicated with the interior of the flask by the narrow tube, D, which passes down the axis of the broad tube C. As soon as a vacuum had been obtained, the acid solution in the funnel was *cautiously* run into the flask till the contents were pink in colour. The pump was then worked, and the flask exhausted as far as possible, the carbonic anhydride being collected in a tube over mercury. Gentle heat was then applied to the liquid, which caused it to boil briskly. It was found very advantageous to put a small piece of platinum foil, previously ignited, into the flask to prevent bumping. The source of heat was then withdrawn, and the pump worked till a vacuum was again produced, at which stage heat was applied once more, and the pump was set in action as previously. This operation was repeated until a vacuum was obtained within a few seconds after boiling the liquid. By proper attention to these details, the carbonic anhydride expelled from the liquid can be obtained nearly free from water in the collecting

tube. The gas, which consists of carbonic anhydride, with a slight admixture of air, was analysed in the usual way in a Frankland's gas apparatus. A deduction was made from the quantity of carbonic anhydride found, to allow for that which was originally present in the potassa solution employed. The quantity of carbonic anhydride found, subtracted from the total quantity of oxygen absorbed during an experiment, gave the amount of oxygen absorbed and retained by the seeds.

These experiments were conducted at intervals during 1883, 1884, and 1885. Three blank experiments were tried with the apparatus placed in a *dark* room, and fitted up as described. The results thus obtained are tabulated on the next page.

EXPERIMENT.	Observations during Germination.				Total Carbonic Anhydride produced.			Total Oxygen absorbed and retained.			
	Temperature.	Interval.	Oxygen utilised.		A. Clear Tube.	B. Covered Tube.	Excess in favour of	A. Clear Tube.	B. Covered Tube.	Excess in favour of	
1A. and 1B. White Hungarian Barley, 1882. Weight—{1A, 1·87 grams. {1B, 1·84 " 80 Corns each. Germinated 4 days. Steeped 70 hours.	15·1 to 21·7 °C.	Hours. 22½ 22½ 24 24½ 23½	A. Clear Tube. C.C. 5·52 4·86 4·86 4·52 4·11	B. Covered Tube. C.C. 5·65 5·03 4·62 4·35 3·83	Excess in favour of C.C. Covered, . 0·13 Do. . 0·17 Uncovered, 0·24 Do. . 0·17 Do. . 0·28	23·06	22·08	Covered, 0·02	1·81	1·40	Uncovered, 0·41
2A. and 2B. Yellow English Barley, 1882. Weight—{2A, 2·32 grams. {2B, 2·33 " 30 Corns each. Steeped 68 hours. Germinated 8 days.	14·5 to 16·5	22½ 23½ 24½	7·22 5·89 7·27	7·31 6·09 7·47	Covered, . 0·09 Do. . 0·20 Do. . 0·20	19·76	20·11	Covered, 0·35	0·62	0·76	Covered, 0·14
3A. and 3B. Yellow English Barley, 1882. Weight—{3A, 2·14 grams. {3B, 2·14 " 30 Corns each. Steeped 66 hours. Germinated 4 days.	14·3 to 16·0	22 23½ 23½ 23½ 24½	6·61 6·26 5·84 4·78 5·08	6·80 6·38 5·78 4·56 4·96	Covered, . 0·19 Do. . 0·12 Clear, . 0·06 Do. . 0·22 Do. . 0·12	25·75	25·91	Covered, 0·16	2·82	2·57	Clear, 0·25

A glance at the preceding Table shows that there is not much difference in the results obtained in the two tubes, when the whole apparatus is kept in the dark. In the case of "Oxygen utilised," the differences are pretty equally distributed in favour of either tube; but in the case of "Carbonic Anhydride produced" there appears to be a slight increase in favour of the covered tube in each experiment. These results may be more clearly seen by collecting the totals as before:—

Experiment.	Total Oxygen utilised.		Excess in favour of	
	Clear Tube.	Covered Tube.	Clear Tube.	Covered Tube.
1.	23·87 c.c.	23·48 c.c.	0·39 c.c.	...
2.	20·88 "	20·87 "	...	0·49 c.c.
3.	28·57 "	28·48 "	0·09 "	...
Totals,	<u>72·82 c.c.</u>	<u>72·83 c.c.</u>	<u>...</u>	<u>0·01 c.c.</u>

Experiment.	Total CO ₂ produced.		Excess in favour of	
	Clear Tube.	Covered Tube.	Clear Tube.	Covered Tube.
1.	22·06 c.c.	22·08 c.c.	0·02 c.c.	...
2.	19·76 "	20·11 "	0·35 "	...
3.	25·75 "	25·91 "	0·16 "	...
Totals,	<u>67·57 c.c.</u>	<u>68·10 c.c.</u>	<u>0·53 c.c.</u>	<u>...</u>

The total quantity of oxygen utilised by the seeds in the three experiments is nearly identical in both tubes. The totals of carbonic anhydride produced show a small increase of 0·53 c.c. in favour of the covered tube, equal to 0·78 per cent. on the mean of the total quantity of carbonic anhydride formed. There is hardly any doubt that this increase would be considerably lowered if the mean of a larger number of experiments were taken.

Considering these results as a sufficient test of the efficiency of the apparatus, I may now give, in a tabular form, the results obtained when strong diffused light was admitted to the clear tube.

TABLE OF EXPERIMENTAL RESULTS.

EXPERIMENT.	Observations during Germination.					Total Carbonic Anhydride produced.			Total Oxygen absorbed and retained.			
	Temperature. °C.	Interval.	Oxygen utilised.			Excess in favour of C.C.	A. Light.	B. Obscurity.	Excess in favour of C.C.	A. Light.	B. Obscurity.	Excess in favour of C.C.
			A. Light.	B. Obscurity.	Excess in favour of C.C.							
1A. and 1B. Saale Barley, 1880. Weight—{1A., 3.78 grams, 1B., 3.71 " } 60 Corns each. Steeped 62 hours. Germinated 1 day.	12.0 to 19.5	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		12 $\frac{1}{2}$	...	3.70	...	...	...	...	...	...	...	...
		34 $\frac{1}{2}$	...	1.02	...	...	...	...	...	...	...	...
		65 $\frac{1}{2}$	...	2.78	...	...	...	...	...	...	...	...
		13 $\frac{1}{2}$	...	5.51	...	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	12.0 to 19.5	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		12 $\frac{1}{2}$	...	4.27	...	...	...	...	...	...	...	...
		6	...	5.72	...	...	...	...	...	...	...	...
		12 $\frac{1}{2}$	...	1.84	...	...	...	...	...	...	...	...
		4	...	2.51	...	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	12.0 to 19.5	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		23.36	...	29.36	...	...	...	...	...	...	...	...
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		11 $\frac{1}{2}$	2.23	2.27	Obscurity, 0.04	...	...	...	...	...	...	...
		23.23	2.26	2.26	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		6	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
		8	1.89	1.80	Obscurity, 0.04	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	2.23	2.27	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		23.23	2.26	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		23.23	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
		8	1.89	1.80	Obscurity, 0.04	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		11 $\frac{1}{2}$	2.23	2.27	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		23.23	2.26	2.26	Do. . 0.16	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		6	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
		8	1.89	1.80	Obscurity, 0.04	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	2.23	2.27	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		23.23	2.26	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		23.23	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
		8	1.89	1.80	Obscurity, 0.04	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		11 $\frac{1}{2}$	2.23	2.27	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		23.23	2.26	2.26	Do. . 0.16	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		6	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4	0.94	0.99	Light, . 0.09	...	...	...	...	...	...	...
		8	1.89	1.80	Obscurity, 0.04	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	2.23	2.27	Light, . 0.20 Do. . 0.13	...	...	...	...	...	...	...
		23.23	2.26	2.26	Do. . 0.16	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		4 $\frac{1}{2}$	1.99	1.86	Do. . 0.16	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	2.42	2.26	Do. . 0.16	...	...	...	...	...	...	...
		11 $\frac{1}{2}$	0.93	0.85	Do. . 0.08	...	...	...	...	...	...	...
		23.23	1.54	1.37	Do. . 0.17	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		13	2.60	2.45	Do. . 0.15	...	...	...	...	...	...	...
		4 $\frac{1}{2}$	1.11	1.00	Do. . 0.11	...	...	...	...	...	...	...
		7 $\frac{1}{2}$	1.78	1.64	Do. . 0.14	...	...	...	...	...	...	...
		23.65	23.65	22.02	Light, . 1.63	...	...	...	...	...	...	...
2A. and 2 B. English Barley, 1882. Weight—{A., 1.97 grams, B., 1.97 " } 30 Corns each. Steeped 70 hours. Germinated 8 days.	11.9 to 18.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		9	2.49	2.22	Light, . 0.27 Do. . 0.22	...	...	...	...	...	...	...
		10 $\frac{1}{2}$	2.47	2.25	Obscurity, 0.05	...	...	...	...	...	...	...
		4	0.94	0.99	Light, . 0.09	...	...	...	...</			

TABLE OF EXPERIMENTAL RESULTS—continued.

EXPERIMENT.	Observations during Germination.				Total Carbonic Anhydride produced.			Total Oxygen absorbed and retained.			
	Temperature. °C.	Interval.	Oxygen utilised.		Excess in favour of	A. Light.	B. Obscurity.	Excess in favour of	A. Light.	B. Obscurity.	Excess in favour of
			A. Light.	B. Obscurity.							
3A. and 3B. English Barley, 1882. Weight— {A., 2.18 grams. {B., 2.11 " 30 corns each. Steeped 72 hours. Germinated 4 days.	12.5 to 19.6	Hours.									
		7½	C.C.	C.C.	C.C.	Light, . 0.21					
		11½	3.75	3.54	2.95	Do. . 0.18					
		4½	3.13	2.95	1.26	Obscurity, . 0.05					
		7½	2.12	1.98	1.98	Light, . 0.14					
		11½	2.88	2.95	2.95	Obscurity, . 0.07					
		4½	1.13	1.09	1.09	Light, . 0.04					
		8½	2.51	2.33	2.33	Do. . 0.18					
		10½	2.94	2.84	2.84	Do. . 0.10					
		5	1.27	1.26	Do. . 0.01						
6	1.94	1.75	Do. . 0.19								
		22.88	21.95	Light, . 0.93							
4A. and 4B. English Barley, 1882. Weight— {A., 2.12 grams. {B., 2.03 " 30 Corns each. Steeped 70 hours. Germinated 5 days.	13.3 to 19.8	12½	3.81	3.73	Light, . 0.08						
		10	3.18	3.00	Do. . 0.18						
		15½	3.47	3.40	Do. . 0.07						
		10½	2.60	2.55	Do. . 0.05						
		12	2.13	2.28	Obscurity, . 0.17						
		8½	2.34	2.27	Light, . 0.07						
		11½	2.36	2.38	Obscurity, . 0.02						
		6½	1.48	1.48	Equal.						
			21.37	21.09	Light, . 0.28						
							20.76	20.52	Light, 0.24	0.61	0.57

TABLE OF EXPERIMENTAL RESULTS—continued.

EXPERIMENT.	Observations during Germination.				Total Carbonic Anhydride produced.			Total Oxygen absorbed and retained.		
	Temperature.	Interval.	Oxygen utilised.		A. Light.	B. Obscurity.	Excess in favour of	A. Light.	B. Obscurity.	Excess in favour of
			A. Light.	B. Obscurity.						
5A. and 5B. English Barley, 1882. Weight—{A., 2.28 grams. {B., 2.19 " 30 Corns each. Slept 72 hours. Germinated 3 days.	12.8 to 21.0	Hours.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.
		12	4.71	4.60	Light,	Do.	0.11			
		94	3.93	3.82	Do.	Do.	0.11			
		134	4.88	4.66	Do.	Do.	0.22			
		134	3.07	2.89	Do.	Do.	0.18	25.85	24.11	Light,
		134	2.99	2.79	Do.	Do.	0.20			1.74
	12.8 to 21.0	74	2.12	1.80	Do.	Do.	0.32			
		144	3.48	3.24	Do.	Do.	0.24			
		10	3.04	2.95	Do.	Do.	0.09			
			28.22	26.75	Light,	Light,	1.47			
					Obscurity,	Obscurity,				
					Light,	Light,				
6A. and 6B. English Barley, 1882. Weight—{A., 2.05 grams. {B., 2.10 " 30 Corns each. Slept 72 hours. Germinated 6½ days.	12.5 to 21.2	124	2.96	3.00	Obscurity,	Obscurity,	0.04			
		94	2.18	1.96	Light,	Light,	0.22			
		144	2.65	2.41	Do.	Do.	0.24			
		134	2.79	2.78	Do.	Do.	0.01			
		15	2.40	2.38	Do.	Do.	0.02	21.74	21.58	Light,
		234	4.05	4.21	Obscurity,	Obscurity,	0.16			0.16
	12.5 to 21.2	25	5.90	5.69	Light,	Light,	0.21			
			22.93	22.43	Light,	Light,	0.50			
					Obscurity,	Obscurity,				
					Light,	Light,				
					Do.	Do.				
					Equal.	Equal.				
7A. and 7B. Austrian Barley, 1882. Weight—{A., 2.11 grams. {B., 2.06 " 30 Corns each. Slept 72 hours. Germinated 3 days.	18.5 to 20.6	164	6.33	6.25	Light,	Light,	0.08			
		224	7.73	7.46	Do.	Do.	0.27			
		244	6.79	6.71	Do.	Do.	0.08	25.27	25.12	Light,
		23	5.69	5.69	Equal.	Equal.				0.15
			26.54	26.11	Light,	Light,	0.43			
					Obscurity,	Obscurity,				

In these experiments on different kinds of barley, the large majority of the observations, during germination, as to the amount of oxygen utilised by the corns, points to a small but variable increased activity under the influence of strong diffused light. Of the sixty-six observations recorded on this point, fifty-six are in favour of light, eight in favour of obscurity, and two show an equality.

Of the total quantity of oxygen utilised in each experiment, the results show a small variable increase in favour of light in every case:—

Experiment.	Total Quantity of Oxygen utilised.		Excess in favour of
	Light.	Obscurity.	Light.
2.	23·65 c.c.	22·02 c.c.	1·63 c.c.
3.	22·88 "	21·95 "	0·93 "
4.	21·37 "	21·09 "	0·28 "
5.	28·22 "	26·75 "	1·47 "
6.	22·93 "	22·43 "	0·50 "
7.	26·54 "	26·11 "	0·43 "
8.	27·39 "	26·17 "	1·22 "
9.	22·71 "	21·41 "	1·30 "
10.	26·97 "	25·50 "	1·47 "
11.	26·81 "	24·52 "	2·29 "
Totals,	<u>249·47 c.c.</u>	<u>237·95 c.c.</u>	<u>11·52 c.c.</u>

The *total* excess of oxygen utilised, in favour of light, in all the experiments amounts to 11·52 c.c., or an increase of 4·73 per cent. on the mean of the total quantity of oxygen utilised, 243·71 c.c.

Of the ten experiments in which the carbonic anhydride produced was determined, all show a small variable increase in favour of the corns grown under the influence of light.

Experiment.	Carbonic Anhydride produced.		Excess in favour of
	Light.	Obscurity.	Light.
1.	27·59 c.c.	26·53 c.c.	1·06 c.c.
2.	19·72 "	19·46 "	1·26 "
3.	20·77 "	20·05 "	0·72 "
4.	20·76 "	20·52 "	0·24 "
5.	25·85 "	24·11 "	1·74 "
6.	21·74 "	21·58 "	0·16 "
7.	25·27 "	25·12 "	0·15 "
8.	25·02 "	23·80 "	1·22 "
10.	26·13 "	24·66 "	1·47 "
11.	25·16 "	22·78 "	2·38 "
Totals,	<u>238·01 c.c.</u>	<u>228·61 c.c.</u>	<u>9·40 c.c.</u>

The *total* excess of carbonic anhydride produced, in favour of light, in all the experiments is 9·40 c.c., or an increase of 4·03 per cent. on the mean of the total quantity of carbonic anhydride produced, *i.e.* 233·31 c.c.

The amount of oxygen *absorbed* and *retained* by the seeds varied very much, and indefinitely, in the different experiments. Of the nine double results recorded, five are in favour of light, two in favour of obscurity, and in two equality was observed.

Experiment.	Oxygen absorbed and retained.		Excess in favour of	
	Light.	Obscurity.	Light.	Obscurity.
2.	3.98 c.c.	2.56 c.c.	1.37 c.c.	...
3.	2.11 "	1.90 "	0.21 "	...
4.	0.61 "	0.57 "	0.04 "	...
5.	2.37 "	2.64 "	...	0.27 c.c.
6.	1.19 "	0.85 "	0.34 "	...
7.	1.27 "	0.99 "	0.28 "	...
8.	2.37 "	2.37 "	Equal	
10.	0.84 "	0.84 "	Equal	
11.	1.65 "	1.74 "	...	0.09 c.c.

On comparing the mean rate of increase in the carbonic anhydride produced in favour of light, as determined by this series of experiments, with the rate obtained in the first series of experiments (where the carbonic anhydride was weighed), it will be at once seen that it is rather more than twice as great, and is, moreover, in the opposite direction. That is to say, in the first series of experiments an excess of carbonic anhydride was produced in favour of obscurity, and in the second series a greater excess of carbonic anhydride was produced in favour of light. I can only account for this discrepancy in the results in the following way:—

In the first series of experiments a larger number of seeds was employed; these were confined in a narrow tube, through which air was slowly aspirated. It is evident that the air present in the tube must be contaminated to a small extent with the carbonic anhydride produced by the germinating seeds. On calculating the amount of this contamination, from the quantities of air aspirated and carbonic anhydride excreted, it was found to vary from 0.58 per cent. to 1.26 per cent. during the different experiments. It is possible that the influence of light on the seeds in the exposed tube, in presence of this small quantity of carbonic anhydride, may have tended, by its partial decomposition, to diminish the observed amount of carbonic anhydride excreted, though the results, when compared with the degree of contamination in each experiment, do not show any corresponding variation in the

quantity of carbonic anhydride excreted. If this variation exists, it was overshadowed by the effect of unavoidable differences in the samples of barley, or by some other unknown cause. The main fact remains, that all the experiments show a slight increase of germinative respiration in the samples of barley grown in obscurity.

In the second series of experiments (in which the carbonic anhydride was measured volumetrically) the seeds were placed in a large tube with about 120 c.c. of air, and potassa solution was present in the tube, to absorb the carbonic anhydride as it was produced. The average quantity of carbonic anhydride produced in twenty-four hours throughout the experiments would be about 6 c.c. (varying from 4 to 8 c.c.), which would give 0.25 c.c. per hour, and there can be no doubt that the greater part of this quantity would be absorbed by the potassa solution in the same time, *i.e.* one hour. It is evident, therefore, that the contamination of the air by the presence of unabsorbed carbonic anhydride must be very slight indeed, and far below that which obtained in the first series of experiments, and also that the disturbing effect of such contamination on the results would be absent in the second series.

In order to test this theory, I performed a few additional experiments with the same apparatus used in the second series, but instead of absorbing the carbonic anhydride as it was formed, I allowed it to remain in contact with the seeds. At the end of each experiment, a portion of the air was withdrawn from each tube, and a measured quantity analysed, to determine the quantity of carbonic anhydride produced in each tube. The following are the results obtained in this way:—

EXPERIMENT.	Carbonic Anhydride produced.		Excess in favour of
	A. Light.	B. Obscurity.	
1A. and 1B. Yellow English Barley, 1882. Weight— {A., 2·11 grams. {B., 2·08 " 30 Corns each. " Steeped 72 hours. Germinated 4 days.	C.C. 15·24	C.C. 15·50	C.C. Obscurity, 0·26
2A. and 2B. Yellow English Barley, 1882. Weight— {A., 2·23 grams. {B., 2·26 " 30 Corns each. " Steeped 72 hours. Germinated 8 days.	11·33	11·01	Light, . 0·32
3A. and 3B. Yellow English Barley, 1882. Weight— {A., 2·34 grams. {B., 2·37 " 30 Corns each. " Steeped 72 hours. Germinated 8 days.	18·16	18·97	Obscurity, 0·81
4A. and 4B. Yellow English Barley, 1882. Weight— {A., 2·20 grams. {B., 2·14 " 30 Corns each. " Steeped 72 hours. Germinated 6 days.	18·85	19·40	Obscurity, 0·55
5A. and 5B. Saale Barley, 1880. Weight— {A., 2·08 grams. {B., 2·09 " 30 Corns each. " Steeped 72 hours. Germinated 4 days.	17·62	17·24	Light, . 0·38
6A. and 6B. Saale Barley, 1880. Weight— {A., 2·10 grams. {B., 2·14 " 30 Corns each. " Steeped 72 hours. Germinated 8 days.	18·76	18·33	Light, . 0·43
7A and 7B. Yellow English Barley, 1882. Weight— {A., 2·20 grams. {B., 2·17 " 30 Corns each. " Steeped 70 hours. Germinated 5 days.	14·86	14·74	Light, . 0·12
8A. and 8B. Yellow English Barley, 1882. Weight— {A., 2·10 grams. {B., 2·17 " 30 Corns each. " Steeped 70 hours. Germinated 11 days.	12·93	14·03	Obscurity, 1·10
Totals,	127·75	129·22	Obscurity, 1·47

In these experiments four results are recorded in favour of light and four in favour of obscurity; though the excess in favour of obscurity is rather more than twice as great as that recorded in favour of light.

This leaves a total excess of carbonic anhydride produced in favour of obscurity of 1.47 C.C., or 1.14 per cent. on the mean of the total quantity of carbonic anhydride produced in all the experiments.

The rate of increased activity in favour of obscurity, thus obtained, approaches in amount that found in the first series of experiments.

This result, if considered trustworthy, seems to bear out the explanation given above of the considerable discrepancy between the evidence afforded by the results of the first and second series of experiments as to the influence of light on the respiration of germinating barley.

A noteworthy point in this third series of experiments is the fact that although the contamination of the air by carbonic anhydride is much greater than it was in the first series, yet its effect in masking the stimulating action of light is not increased, as might reasonably be expected would be the case. The only part of the seed which would probably have the power of decomposing carbonic anhydride in presence of light is the young plumula, and the quantity of this gas which it would be able to decompose would certainly be very small, so it might happen that when the amount of carbonic anhydride present in the air is above a certain point it ceases to have an increased effect in diminishing the observed quantity of the gas which is produced by the seeds when germinated under the influence of light.

It seems fair to conclude from a consideration of all the results obtained that light has probably a small stimulating action on the respiration of germinating barley, resulting in an increase of between 3 and 4 per cent. in the quantity of carbonic anhydride excreted; and that this increased activity is lost sight of when the air surrounding the seeds is contaminated, even in a small degree, by carbonic anhydride.

I made a few experiments to ascertain the influence of light on the respiration of germinating wheat, employing

for the purpose the same apparatus that was used in the second and third series of experiments on barley.

In the six following experiments, the carbonic anhydride was absorbed by potassa solution as soon as formed, and the absorption of oxygen by the seeds was noted from time to time, as in the second series of experiments with barley:—

TABLE OF EXPERIMENTAL RESULTS.

EXPERIMENT.	Observations during Germination.					Total Carbonic Anhydride produced.		
	Temperature. °C.	Interval. Hrs.	Oxygen utilised.			A. Light. C.C.	B. Obscurity C.C.	Excess in favour of C.C.
			A. Light. C.C.	B. Obscurity C.C.	Excess in favour of C.C.			
1A. and 1B. White Wheat, 1882. Weight— {A., 2.04 grams. {B., 2.01 " 20 Corns each. " Steeped 50 hours. Germinated 3 days.	19.6 to 22.3	17½ 23½ 24 22½	5.91 7.24 7.28 7.49	6.15 7.27 6.64 6.03	Obscurity, 0.24 Do. 0.03 Light, . 0.64 Do. 0.14	28.50	27.17	Light, 1.33
2A. and 2B. White Wheat, 1883. Weight— {A., 1.47 grams. {B., 1.53 " 20 Corns each. " Steeped 50 hours. Germinated 2½ days.	16.3 to 18.3	25 28½ 18½ 27½ 13½	6.40 6.27 4.09 5.99 3.03	6.61 6.27 4.08 5.75 2.73	Obscurity, 0.21 Equal Obscurity, 0.01 Light, . 0.24 Do. 0.30	25.69	25.70	Obscurity, 0.01
3A. and 3B. White Wheat, 1883. Weight— {A., 1.41 grams. {B., 1.48 " 20 Corns each. " Steeped 37 hours. Germinated 3 days.	19.3 to 22.6	16 24½ 24	3.72 4.95 4.77	3.68 4.84 4.29	Light, . 0.04 Do. 0.11 Do. 0.48	12.57	Lost	Light (?)
4A. and 4B. White Wheat, 1883. Weight— {A., 1.43 grams. {B., 1.34 " 20 Corns each. " Steeped 24 hours. Germinated 3½ days.	18.5 to 20.6	17½ 23½ 23½ 24	3.20 3.54 3.98 3.45	3.03 3.01 3.17 2.77	Light, . 0.17 Do. 0.53 Do. 0.81 Do. 0.68	Lost	12.20	Light (?)
5A. and 5B. Red Wheat, 1884. Weight— {A., 1.54 grams. {B., 1.49 " 20 Corns each. " Steeped 36 hours. Germinated 4 days.	14.3 to 18.1	24½ 18 30½ 16½	4.37 2.98 4.12 2.91	4.41 2.71 4.08 2.94	Obscurity, 0.04 Do. 0.33 Light, . 0.04 Obscurity, 0.03	13.67	14.60	Obscurity, 0.93
6A. and 6B. Red Wheat, 1884. Weight— {A., 1.47 grams. {B., 1.46 " 20 Corns each. " Steeped 37 hours. Germinated 4 days.	10.5 to 14.0	24½ 24½ 48	3.61 2.69 5.56	3.50 2.76 5.47	Light, . 0.11 Obscurity, 0.07 Light, . 0.09	12.71	13.11	Obscurity, 0.40
			11.86	11.73	Light, . 0.13			

The results obtained in this rather imperfect series of experiments are too few in number to justify taking an average. They show, broadly, for white wheat an increased activity in the respiration under the influence of light; but in the case of red wheat, in the two experiments recorded, there appears to be a small increase in the oxygen absorbed and carbonic anhydride excreted in favour of the samples grown in darkness.

These experiments, though they can hardly be considered decisive as to the action of light, bring to notice a peculiarity in the respiration of wheat which I have never met with in barley, that is, the volume of carbonic anhydride excreted generally exceeds in volume the amount of oxygen absorbed by the seeds. In the case of barley there is always more oxygen absorbed than carbonic anhydride excreted. This peculiarity of wheat certainly deserves further study.

It is more than probable that a portion at least of the oxygen absorbed by germinating wheat is retained, and does not appear again as carbonic anhydride, as is the case with germinating barley. If this is so, a considerable percentage of the carbonic anhydride excreted by germinating wheat cannot be accounted for as derived from the splitting up of a carbohydrate, and we must look to more complicated bodies, probably some of the nitrogenous compounds, for its source.

As with barley, I made a few experiments to determine the action of light on the respiration of germinating wheat, when the carbonic anhydride excreted was allowed to remain in contact with the seeds. Contrary to expectation, white wheat still showed an increased activity in respiration under the influence of light, and red wheat still showed a little in favour of obscurity:—

EXPERIMENT.	Carbonic Anhydride produced.		Excess in favour of
	A. Light.	B. Obscurity.	
1A. and 1B. White Wheat, 1888. Weight— {A., 1.40 grams. {B., 1.44 " 20 Corns each. Steeped 24 hours. Germinated 4 days.	c.c. 12.36	c.c. 11.79	c.c. Light, . 0.57

EXPERIMENT.	Carbonic Anhydride produced.		Excess in favour of
	A. Light.	B. Obscurity.	
2A. and 2B. White Wheat, 1883. Weight— {A, 1.44 grams. {B, 1.36 ,, 20 Corns each. Steeped 24 hours. Germinated $4\frac{1}{2}$ days.	C.C. 13.76	C.C. 12.59	C.C. Light, . 1.17
3A. and 3B. Red Wheat, 1884. Weight— {A, 1.47 grams. {B, 1.45 ,, 20 Corns each. Steeped 47 hours. Germinated 5 days.	7.75	7.37	Light, . 0.38
4A. and 4B. Red Wheat, 1884. Weight— {A, 1.47 grams. {B, 1.49 ,, 20 Corns each. Steeped 38 hours. Germinated 6 days.	7.67	8.27	Obscurity, 0.60

If these experiments on wheat were considerably multiplied, using rather larger quantities of the seed, no doubt a more decided result might be obtained.

ON ACROSIPHONIA TRAILLII, A NEW BRITISH ALGA. By
EDWARD A. L. BATTERS, B.A., LL.B., F.L.S.

(With Plate II.)

Acrosiphonia Traillii, J. G. Ag. (Batt. in Herb.).—Filaments slender, one or two inches long, tufted and densely matted at base, becoming free and divergent above; colour at first dark green, but soon becoming brownish olive; tufts composed of numerous separate bundles; branches near the base rhizoidal, recurved, and interlaced; upper branches erect, opposite, or subsecund; main axis distinct, composed of one or two long branches beset with opposite or scattered ramuli; the ultimate branches of two kinds, the one having apices drawn out with a long slender point, the other of nearly equal diameter throughout, with very obtuse apices. The spiny branches greatly outnumber the blunt ones, but both kinds are sometimes found side by side. Hooked branches are present, but in very small numbers. Fertile cells $1-2\frac{1}{2}$ times as long as broad. Average width of filaments $110\ \mu$.