IV.

STUDIES ON PHYSICAL METHODS FOR OVERCOMING DELAYED GERMINATION.

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D. / ..

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A.

The influence of outdoor treatments and of various temperatures, with and without controlled humidity, including tests on the effects of heat and alternating temperatures.

That certain temperature conditions may be very effective for the promotion of germination of seeds which are in a state of delayed germination, is a well-known fact. This was also established early in these investigations in a preliminary study in which seeds were kept in a sealed atmosphere at 40-42°C for two months : (a), without adjustment of humidity and (b), by saturating the atmosphere (free water surface). The seeds employed were the same 9 kinds listed on page . Two jars were used and all seeds treated together, the tests being started on the 12th of August, 1936.

Compared with their respective controls, only 4 of the 9 ecotypes were benefited by one or both of these treatments, as revealed by their germination capacity over the first 8 days' duration of the test. It is interesting to note that for 2 of these ecotypes both treatments gave about the same responses, whilst for the other 2 the dry atmosphere was of little or no benefit. In the case of the remaining 5 ecotypes the responses were negative or indifferent.

TABLE /..

TABLE 15: THE PERCENTAGE GERMINATION OF THE 4 ECO-TYPES (OUT OF THE NINE) WHICH WERE STIMULATED WHEN SUBJECTED TO 40 - 42°C IN A SEALED ATMOSPHERE, (a) WHEN THE HUMIDITY INSIDE WAS NOT ADJUSTED, AND (b) WHEN THE ATMOSPHERE INSIDE WAS KEPT SATURATED. THE DURATION OF GERMINATION TESTS WAS 8 DAYS.

Ecotypes	Treatment (a) %	Treatment (b) %	Control %
<u>Panicum</u> <u>minus</u> F.14	50.9	56.1	10.5
<u>Panicum</u> sp.C.79	47.5	54.3	16.8
<u>Panicum</u> <u>coloratum</u> (?) C.98	14.7	42.3	3.0
<u>Digitaria</u> seln. 24-3	4.3	57.5	3.5

(1) <u>Outdoor treatments, with and without humidity control.</u>

<u>Methods andMaterials.</u>

As any form of outdoor treatment would be an approach to natural methods of overcoming delayed germination and should offer a practical means, if successful, a series of such treatments were planned as follows :-

1. Seeds kept spread out on wire gauze trays placed on the bare ground, exposed to sun, rain etc.
2. Seeds kept in white muslin bags placed in a glass dish with glass cover, in sun, permitting air circulation, not rain water.
3. Seeds kept in muslin bags in sealed glass container in sun with 0% humidity.
4. Seeds kept in muslin bags in sealed glass container in sun with 50% humidity.
5. Seeds kept in muslin bags in sealed glass container in sun with 90% humidity.
6. Seeds kept in muslin bags placed in a jute bag, outside, but not exposed to rain.
7. Seeds kept in shade, outdoors, in muslin bags in sealed glass container with humidity 0.

8. / ..

8. Seeds kept in shade, outdoors, in muslin bags in sealed glass container, with humidity 50%. *swak.*
9. Seeds kept in shade, outdoors, in muslin bags in sealed glass container, with humidity 90%. *swak*
10. Seeds kept like No. 2, in shade. *Taamlik goed*
13. Seeds kept in sun, outdoors, in sealed tin (only opened for testing). *swakheid*
14. Seeds kept in sun, outdoors, in unsealed tin permitting air circulation. *red. goed*
15. Seeds placed in muslin bags kept in brown paper bag outside. *goed.*

<u>Materials.</u>

Humidity was controlled by means of solutions of sulphuric acid (Wilson 1921) which was periodically renewed. For the 0-humidity, concentrated sulphuric acid was employed, and for all such tests 3,000 c.c. jars with ground lids were used, the seeds being placed in white muslin bags and the acid in beakers. Test 5 had to be abandoned owing to condensation of moisture on the sides of the flask.

Test 14 was also abandoned after several months owing to rain water having found its way into the tin through the ventilation holes. Through unknown agents the jars of treatment 8 and 9 were accidentally knocked, spilling acid over part of the contents and some lines were unfortunately lost on this account while others were replaced. The kinds of seed employed are given below, and the monthly averages appear in the appendix. The following were the ecotypes of which the seeds could not be cleaned beforehand, (date of harvesting in brackets) :-

<u>Digitaria</u> ("Pretoria sandveld" ecotype) D.23 (16.2.7).
" ("Port Elizabeth" ecotype) A.23 (12.2.7).
" Selection 24-3 from "Inkruip" ecotype (20.1.7).
" Selection 8-1 " " " "
" " 27-9 " " " "
" " 12-8 " "Kuruman" " (21.1.7).
" ("Molopo" ecotype); from Rietondale, designated MX. (15.2.7).

Urochloa / ..

Urochloa ecotype C.74 (25.2.7).

Those of which the seeds could be cleaned beforehand were as follows :-

Panicum minus var. planifolium, B.7-11 (1.2.7).
P. (?) coloratum var. glaucum, C.99 (3.2.7).
P. (?) coloratum ecotype C.91 (11th, 14th and 16th Jan. 1937).
P. maximum ecotype designated APM (2.2.7).
Paspalum scrobiculatum, A.290 (4th and 24th March 1937).
Echinochloa pyramidalis, B.14-15 (12.3.37).
Setaria sphacelata, H.10 (27.1.7).
Brachiaria isachne Stapf., designated BW.(Annual weed) (27.1.7).

Discussion of results.

At the outset it should be stated that certain kinds exhibited prolonged delayed germination; viz. Digitaria ecotype "XM"; Digitaria selections 24-3, 27-9 and 8-1; Panicum ecotypes C.99 and C.91; and Urochloa ecotype C.74. They were also very unresponsive to the environments of the various treatments, with the exception of treatment 1, where this was applied. The erratic germination of the seed of Brachiaria isachne and to some extent of that of Digitaria ecotype D.23, often giving rise to irregularities in the daily germination curve, should be recorded. The cause of this phenomenon - under conditions which were seemingly uniform from test to test - remains obscure. These unforeseen and unavoidable difficulties, as well as the very variable response, rendered interpretation of results somewhat more difficult, but, several lines were employed for each treatment, though they were not all included in every treatment.

The data appear in the appendix and the results are graphically presented in figs. 1 - 12 for individual treatments, and figs. 13 - 21 for seed of individual lines. Not only did the treatments result in different responses, but the behaviour of the different kinds with the same treatment was also rather

different / ..

different. Where it was possible or appeared advisable, the treatments were conducted for 15 months and this was particularly useful from the viewpoint of storage considerations.

Treatment 1 (exposure in the open) was undoubtedly the most effective of all treatments for inducing quickest stimulation, although, apparently, the viability (? or vitality) of some strains was easily impaired, whilst others, e.g. Digitaria ecotype 24-3, required a much longer period of treatment to promote germination capacity. The harmful effects of such treatment would appear to set in with the high summer temperatures before maximum stimulation has been attained and it seems not unlikely that with reduced exposures - the period depending upon the strain - or with exposures not during the middle of summer, or by initiating the treatment after the proper age of the particular seed, better results could be secured with this treatment. Though this treatment may appear very severe, it does not seem that a decline in germination signifies loss of viability. This may, in certain cases at least, indicate an acquired (temporary) "dormancy". Not only is there support for such a view in the results of the treatment under consideration, viz. in the case of Digitaria 24-3, Panicum APM, and Digitaria 8-1 which registered a rise after the first drop in % germination, but in thesimilar treatment No.2, in which this behaviour was very marked. Unfortunately the treatment (No.1) could only be studied for 6 months, as exposure caused unavoidable losses through wind, the seed supplies having been very limited. It would seem that the effect involved is more that of heat than one of light. Direct and indirect evidence appear below.

Tests 2 and 6 (figs. 2, 4 and 5) were the next best treatments for improving germination capacity - although decline in germination of most of the well-stimulated ecotypes also set in in the middle of the summer, again before maximum

stimulation / ..

stimulation was only slightly benefited. In the case of treatment 2, these trends of the individual ecotypes were more definite than in the case of treatment 6. In both treatments, the Panicum B.7-11 was apparently not much affected by the high summer temperatures and in the case of treatment 2 the Digitaria selections 8-1 and 24-3, both with long after-maturation periods (and showing poor stimulation), seemed, however, to have clearly benefited from the more severe conditions which had been detrimental to the germination progress of the 3 early stimulated ecotypes A.290 (Paspalum), H.10 (Setaria) and APM (Panicum) which, apparently completely (or practically so), lost their viability (at a very striking rate) as a result of these unfavourable conditions. The extent and rate of loss of viability were less for the same kinds of seed with treatment 6.

Those ecotypes (treatment 2) which survived the summer conditions, appeared thereafter to have gradually declined in viability under the autumn and winter conditions following. This either did not happen in the case of treatment 6 or was not so obvious. In any case, the summer conditions in this latter treatment were not so harmful as in treatment 2, as may perhaps be expected, although decline set in about a month earlier. With treatment 2, Paspalum scrobiculatum A.290 showed a very rapid and marked stimulation, after the 5th month (giving approx. 90% germination), followed by an equally rapid and pronounced fall. On the whole, treatment 6 has given the highest and best increases in stimulation of the two.

A comparison can now be made of treatments 3 (fig.3) and 4 (fig.4) - the 0-humidity-lots and 50% humidity-lots respectively -, in which the seeds were exposed to direct sunlight in muslin bags. Interesting differences are observed. For the 8 ecotypes studied, absence of humidity had, when compared with room storage, no stimulation value with Digitaria

12-8 / ..

12-8, was of doubtful value to Digitaria 8-1, was harmful to Panicum B.7-11 and Setaria H.10, but favourable to Digitaria A.23. It is interesting to note that Digitaria A.23 which has fairly quick after-maturation, should be favourably influenced by a dry atmosphere, in direct sunlight, though not so favourably by a dry atmosphere in shade (test 7). Moreover, Setaria H.10 and Digitaria 8-1 showed very similar response, giving slight increases after 10 to 11 months. Digitaria 24-3 and P. scrobiculatum A.290 (not plotted) were under 4% during the 15 months. With 50% humidity, Digitaria 12-8, Setaria H.10 and Digitaria A.23 were well stimulated in the first 4 months, thereafter the former two showed a decline. However, the treatment appeared to have had a harmful effect on Panicum B.7-11, whilst digitarias XM and 8-1 were not clearly affected; Panicum APM apparently lost viability after 6 months, as happened to Paspalum A.290, which rose to 55% at 5 months. Digitaria 24-3 behaved as in test 3.

It would seem that outdoors, absence of humidity and very reduced aeration kept the germination very low, though it is not certain whether this signified preservation of viability. Under the conditions of the tests, it would further appear that a 90% humidity would have been very harmful (in the open), particularly when the results of test 9 are also considered.

The 0%-, 50%- and 90%-humidity treatments in shade outdoors (Nos.7, 8 and 9) were as unsatisfactory as Nos.3 and 4, the 90% showing distinctly harmful effects after a few months, apparently resulting in loss of viability. No.8 did not reveal the same harmful influence with prolonged treatment, as its counterpart, No.4, in direct sun, and it would appear that this humidity (under reasonable temperatures) might have storage value.

Treatment 10 (fig.9) has not resulted in any spectacular behaviour of any of the lines, in the course of 15 months

of / ..

of such treatment. In some cases, although in the shade, a decline set in after February, after 9 months of treatment, though an improvement appeared to follow again after May, after 12 months. On the whole, this treatment was of doubtful value though <u>Digitaria</u> A.23 clearly showed stimulation.

In the case of treatment 13 (inside a sealed tin in the open), the results (fig.10) were about the same as in the previous, though the response was less favourable, particularly in the case of <u>Panicum</u> B.7-11. The <u>Digitaria</u> D.23 curve showed rather pronounced depressions and rises. Treatment 14 (fig.11), conducted for 5 months, appeared to have had a beneficial effect on all the seed used in the test.

A comparison of tests 13 and 14 (fig.11) should provide information on the question of aeration in after-maturation and particularly so in nature. It would appear that with the <u>Digitaria</u> ecotypes A.23 and D.23 and seln.12-8, and the <u>Panicum</u> B.7-11, aeration is distinctly more favourable than non-aeration, though in the two kinds <u>Setaria</u> H.10 and <u>Panicum</u> APM, there is no clear difference in the results of the early months of treatment. It is not possible to differentiate between the relative roles of aeration and humidity in those treatments where both are involved, but to judge from the results of treatments 13 and 14, aeration would seem to be important.

Test 15 (fig.12), that of keeping seed in muslin bags placed in a brown paper bag in the sun, has proved to be about equal to No.6, in comparison with which it was found that 12-8 showed a rapid decline after the fourth month, whereas with No.6 this did not occur even after 5 months, by which time the seed in the test had been used up. The same happened to <u>Digitaria</u> ecotypes D.23 and XM (in test 15), after a lapse of 7 months. In test 6, the former also lost viability markedly after the same period, though rising again later on. Unfortunately the seed was used up after 9 months, but there would probably have

been / ..

been a rise again as the fall was not so low as in test 6. *Digitaria* ecotype XM was not included in this latter test. In test 15, *Panicum* B.7-11 and *Digitaria* 8-1 showed a rapid fall after the 11th month, with rapid rises the following month. In test 6, this decline was gradual, earlier, and somewhat prolonged. For *Setaria* H.10 there was no decline in test 15, as was obtained in No.6.

The differences in response of the same kind of seed to different treatments are very interesting and are well brought out in the graphs.

The seed of "Inkruip" 8-1 (*Digitaria* sp.) was subjected to about 6 treatments and appeared to be hard to stimulate, though sunlight treatment had a very favourable influence, giving 50% within 3 months, with a 20% drop after a further two months, and another rise in the following month, when it was discontinued through lack of seed. Except for treatment 3, which showed the poorest germination of all treatments, amounting to no stimulation, the other four treatments (2, 4, 6 and 15) resulted in very irregular curves of germination.

The seed of *Setaria sphacelata* H.10 received 11 outdoor treatments, showing interesting responses. The irregularities observed in the previous ecotype, were not noticeable here, the curves being much smoother. With everyone of these treatments, except 3 and 9, stimulation (as compared with room storage) was registered during at least the first four months and these seeds can be said to be fairly easily stimulated. On the whole, a decline in the rate of after-maturation was clearly evident at about the third month, and again at about the 8th to 9th month, after which the curves flattened out or dropped somewhat, though at this latter stage, test 6 responded in the opposite direction.

The selection 12-8 from "Kuruman" (*Digitaria* sp.) was subjected to about 11 outdoor treatments for only 6 months,

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when the seed was used up. All of these showed stimulation over the first 3 months' period as compared with room "storage", sunlight treatment giving excellent results after 2-3 months (about 60% increase over room storage).

Selection B7-11, Panicum minus var.(?) planifolium Stapf., received 9 outdoor treatments, 5 of which -2, 6, 10, 14 and 15 - showed distinct stimulation as compared with the room-stored seed, for the full period of 15 months. Treatments 3, 4, 7 and 13 showed little effect on after-maturation. On the whole, the curves showed a smooth course of after-maturation with practically all treatments. Sharp falls and rises were experienced with certain treatments after about 12 months.

Panicum maximum Jacq. APM received 8 outdoor treatments and, except in No.10, after-maturation proceeded smoothly. As in the last-mentioned kind, no.7 indicated no stimulation. The very interesting response exhibited with No.6 is perhaps an indication not to regard an almost identical decline as a sure sign of total loss of viability. One is forced to consider the possibility of induced "dormancy" in such behaviour.

"Pretoria Sandveld" D.23 (Digitaria sp.), though receiving 8 outdoor treatments, (the longest lasting 11 months), were well stimulated by all, in comparison with room "storage", with the possible exception of treatment 13 during the first three months. The sunlight treatment showed 2 peaks (an exception to other similar treatments), the first exhibiting about 50% in excess of room "storage" and the last peak reaching up to 95% germination after 6 months. The deep trough in the progress of after-maturation between the 2nd and 7th months of room storage is difficult to account for. About the 7th to 8th month, decline in germination occurred with most treatments, though in three out of five treatments - 6, 13 and 16 - rapid increases were registered immediately afterwards, No.2 showing an unabated fall.

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The "Port Elizabeth" A.23 ecotype (Digitaria sp.) is an exceptional ecotype, being not only easily stimulated, but is one of the few of the studied seeds with reasonably quick after-maturation. Subjected to 4 and 5 months of treatment, good stimulation was obtained with all but two treatments (7 and 13), as compared with room storage. The behaviour with treatment 9 (90% humidity in shade outdoors) was exceptional, as the curve in this instance cuts across 6 of the curves between the second and third months, although the progress was much slower during the first two months. Unfortunately the seed was used up after the third month. Decline set in after the 3rd or 4th months for all those treatments for which seed was still available.

Paspalum scrobiculatum A.290, a poor germinator, was subjected to 10 outdoor treatments. With the two 0-humidity treatments and the 50%-humidity in shade, no stimulation was exhibited, whereas the 50% humidity in sun gave fairly good and quick stimulation but equally quick loss of viability subsequently. Treatments 1, 2, 6 and 10 gave the same amount of stimulation, but the periods were very different.

In the case of Digitaria 24-3, subjected to all outdoor treatments, the results were very disappointing. Digitaria ecotype XM was no better. It is interesting to recall the behaviour of Digitaria 24-3 during the previous season, when, with outdoor exposure in a petridish, it showed 59% increase in germination after 6 months, as compared with 22% in the above tests. Moreover, in the former it further rose to 85% at the end of 9 months, but fell to 32% by the end of 12 months.

It would almost appear that the seed posesses some sort of a protective system which, presumably, ensures survival in nature. At other occasions, seed was also subjected to outdoor treatment. Thus, in fig. 1, germination curves of Setaria

B.3-3 / ..

B.3-3, harvested the 28th February, 1936, and placed in the sun on the 26th July, 1938, as well as that of Panicum sp.("Makarikari"), harvested January, 1938, and put in sun on the 2nd June, 1938, are given. The latter showed about 70% stimulation in less than 5 months. Panicum coloratum C.98 (of 27/1/37) of which the previous season's seed gave only 12% germination after one year, could be increased from 12% to 90% in less than 2 months.

At this stage it is perhaps necessary to consider whether concentrated H_2SO_4, used for the O-humidity lots, is harmful or not. In other words, whether the responses registered under this treatment are wholly or partly due to the absence of humidity or to the effects of the H_2SO_4. In the above results it is not possible to differentiate between effect of lack of humidity and that of H_2SO_4. In the case of Digitaria A.23 both O-humidity treatments were, however, better than the room storage, whereas in practically all other cases complete loss of viability was not suffered with these treatments. In this connection, the following comparison, obtained between calcium chloride and H_2SO_4, is interesting :-

TABLE 16 : THE COURSE OF GERMINATION OF Digitaria ECOTYPE A.96 of 3/2/41 WHEN PLACED OVER CONC. H_2SO_4 AND $CaCl_2$ RESPECTIVELY ON 10/8/41.

	on 10/9/41 %	on 21/10/41 %	on 28/11/41 %	on 30/12/41 %
with H_2SO_4	54.3	-	29.9	22.9
" $CaCl_2$	59.2	47.4	30.5	44.3
Control	57.3	55.1	42.5	64.3

The results show that the $CaCl_2$ treatment, though not as unfavourable as the H_2SO_4, was also harmful.

Nakajima (1925), working with rice varieties, found storage over H_2SO_4 harmful, as compared with $CaCl_2$. On the other / ..

other hand, Pickholz (1911) - cited by Lehmann and Aichele (1931) - shortened the after-maturation of Poa pratensis by the use of H_2SO_4. A few other workers have also reported results bearing on this matter.

It would appear that few authors have given attention to the effect of outdoor conditions, or sunlight, on the germination of seeds. Laurent (1902), using cereal, clover and other seeds which were apparently not in a condition of delayed germination, insolated these in test-tubes closed with cotton wool (in which the temperature did not exceed 43.5°C). He obtained only detrimental effects, the tests lasting about a month. He mentions Tammes (1900) who had made similar tests (with rice), with negative results, and Jodin (1902) who regarded the heat action of more importance than the light action. Reiling (1912) - cited by Lehmann and Aichele (1931) - reported quicker germination from Alopecurus pratensis and Holcus lanatus seed kept in sunlight than from that stored at room temperature.

On the whole, the above results indicate the possibilities of certain outdoor treatments, but the differences in response obtained with the various kinds of seed necessitate further experimentation with particular attention to period of treatment, to the question of moisture-content of seed, etc. in relation to the condition of seed-coats and embryo at various stages of the treatment, etc. Certain harmful influences are revealed. Nevertheless, the indications are that certain kinds of seed can perhaps not be stimulated by such methods. With the availability of larger supplies of seed of the more promising or useful grasses, further investigations can undoubtedly be conducted with advantage, along the above lines.

(a) Incubator tests at different temperatures, with and without controlled humidity.

Methods; even temperatures.

Employing the same kinds of seeds as in the last-mentioned series of outdoor treatments, a number of tests were undertaken to study the effect of various combinations of temperatures and humidities on the progress of delayed germination. Humidity was controlled as in the previous studies.

These tests, commenced on the same date as the outdoor series, were planned as follows :-

16\. Seeds kept in muslin bags placed in a paper bag indoors.

In a domestic refrigerator :

17\. Seeds kept in sealed glass container at humidity 0.

18\. " " " " " " " " 50%.

19\. " " " " " " " " 90%.

20\. " " " " " " with uncontrolled humidity (sealed after every monthly germination).

21\. Seeds kept in an open glass container (refrigerator atmosphere

In an incubator at ca. 25°C :

22\. Like 17 - humidity 0.

23\. " 18 - " 50%.

24\. " 19 - " 90%.

25\. " 20 with uncontrolled humidity (sealed after every monthly germination).

26\. Like 21 at incubator atmosphere.

In an incubator at ca. 35°C :

27\. Like 22 - humidity 0.

28\. " 23 - " 50%.

29\. " 24 - " 90%.

30\. " 25 with uncontrolled humidity (sealed after every monthly germination).

31\. Like 26 at incubator atmosphere.

In an incubator at ca.45°C :

32. Like 22 - humidity 0.

33. " 23 - " 50%.

34. " 24 - " 90%.

35. " 25 with uncontrolled humidity (sealed after every monthly germination).

36. Like 26 at free air circulation (incubator atmosphere).

46. At "atmospheric" humidity; 6 hours at 25°C and 18 hours at 45°C (in incubators).

47. At "atmospheric" humidity; 18 hours at 25°C and 6 hours at 45°C (in incubators).

Test 29 had to be abandoned owing to moisture condensation and tests 25 and 35 were omitted because of lack of space in the incubators. As it took many months to obtain a low temperature incubator from overseas, it was too late to include the 5 series also at 15°C., and tests with alternating temperatures of 15° and 45°C, as was also planned.

Discussion of results.

Graphs showing the results for individual treatments are presented in figs. 22 - 34, the data being tabulated in the appendix.

In domestic refrigerator -

The treatments 17-21 proved of little value for overcoming delayed germination and were discontinued after 7 months. In all these treatments, *Panicum* B.7-11 appeared to have suffered as compared with room storage, but the *Digitaria* ecotype XM and selns.8-1 and 12-8 were rather indifferent to these environments. On the other hand, *Digitaria* ecotypes A.23 and D.23 responded rather differently, although they were not appreciably benefited by any treatment. With the 0-humidity, *Digitaria* A.23 showed a marked fall after the third month. Although, apparently, little stimulation benefit might be expected with such low

temperatures / ..

temperatures, it is not unlikely that such a condition might prove very useful for the preservation of vitality. No clear evidence in favour of humidity control was shown at this temperature over 7 months of treatment, the individual response being very variable. It would have been interesting to have studied the progress of after-maturation after discontinuation of this series, but unfortunately no time was available. To some extent, however, this was done in another series to be reported on elsewhere.

At 25°C -

In this series - 22-26 - the results are more interesting. With the 0-humidity treatment, the seed of the better-germinating *Digitaria* ecotypes A.23 and D.23 showed a fairly rapid decline in germination after the first to the second months, the former registering under 10% after 5 months, which was in direct contrast to the similar outdoor treatment, so far as A.23 was concerned. *Panicum* B.7-11 was deleteriously affected only after the 6th month, after which time a very steady germination percentage was retained throughout the period of test (15 months). The poor-germinating seed of seln.12-8 (*Digitaria* sp.) was apparently not affected by complete lack of humidity.

The 50% humidity appeared not to have affected the two poor germinators, digitarias XM and 8-1, whilst *Digitaria* seln. 12-8 was perhaps slightly benefited. On the other hand, *Digitaria* ecotype A.23 was slightly improved, though a rapid decline was observed after the fifth month. The *Panicum* line B.7-11 was somewhat harmfully affected under these conditions. The germinability of seed of *Digitaria* ecotype D.23 remained more or less the same over the first 9 months, whereafter it declined somewhat. The 90%-humidity (No.24) induced stimulation of the seed of digitarias D.23, 12-8 and 8-1 over the first three months, that of *Panicum* B.7-11 and *Digitaria* 27-9 ap-

pearing / ..

pearing to be indifferent during this period. With the exception of the latter, all kinds showed extremely rapid decline after the third month, they having lost their germination capacity by the end of the fourth to fifth month. With uncontrolled humidity and free aeration (No.26), improvement in germination was clearly evident in the better-germinating kinds Digitaria ecotypes A.23 and D.23 and in Panicum B.7-11, over at least the first 9 months period for the latter two (3 months in the case of A.23) as compared with room storage. On the other hand, all the four poor-germinating kinds concerned in this test did not differ from their respective values under room-storage conditions. This was to be expected because a temperature of 25°C is about that of room temperatures in summer.

At 35°C -

The effects of the 0-humidity treatment (No.27) here, was very similar to those at 25°; if anything, it appeared to be slightly more harmful. On the other hand, the 50% humidity (No.28) seemed to be slightly more favourable than in the previous series, the curves showing the same trends in both tests. Though treatment 29 (90% humidity) was discontinued, it is not difficult to foretell what its effect would have been, considering what the results were with this humidity at 25° and 45°, the latter proving to be so harmful that no germination was registered for any line of seed. In the uncontrolled humidity but sealed atmosphere (test 30), one of the better-germinating ecotypes, Digitaria D.23, showed a better germination capacity than its counterpart at room temperature during approximately the first 10 months, but was not much different to that at 50% humidity. On the other hand, Echinochloa B.14-15 seed was better than at 50% humidity, whilst seed of Panicum B.7-11 and digitarias XM and 8-1 were not different to their respective values with room storage. B.14-15 germinated better that at

50 % humidity / ..

50% humidity, but the *Digitaria* seln.27-9 differed little from that at 50% humidity. However, with uncontrolled humidity and free aeration (test 31), the position was somewhat different. *Echinochloa* B.14-15, remaining on the 90% germination level for most of the time, germinated considerably better than in test 28 (50% humidity) or even test 30. On the other hand, *Digitaria* A.23 seed responded better than with room storage but the response was not appreciably different to tests 28 and 30. Also, *Panicum* B.7-11 and digitarias D.23 and 12-8 were a good deal better than at room storage, whilst *Digitaria* XM seed gave, if anything, only a slightly better germination than with room storage.

At 45°C -

At this temperature, the O-humidity (test 32) produced, if anything, a poorer response than its counterpart at 35°C and, except for the poor-germinating *Digitaria* XM seed, they were all inferior to room storage. The 50% humidity was, however, more interesting. At this temperature, in contrast to those in the two previous series, this humidity was quite harmful after two months duration, though stimulation was initially recorded during this period, at least in the case of the *Digitaria* A.23 and D.23 seed. After 4-5 months hardly any germination was registered. As mentioned above, the 90% humidity was so harmful that even after one month no germination was obtained. On the other hand, when the humidity and aeration were not controlled (test 36), the best stimulation so far was realized, though for some reason or other the curves of 3 out of the 4 kinds (*Digitaria* A.23, *Digitaria* D.23 and *Echinochloa* B.14-15) exhibited troughs at about the fourth to fifth months, while only *Panicum* B.7-11 showed such a depression at the thirteenth month. Though of little practical significance, the seed of the poor-germinating digitarias XM and 27-9 also exhibited fair stimulation.

Alternating / ..

A presentation of graphs grouped together for individual kinds appears in figs. 35-42.

Alternating temperatures -

By subjecting seeds to alternating temperatures of $25^{\circ}C$ and $45^{\circ}C$ (tests 46 and 47), there was found to be little difference between keeping seed at the higher temperature for longer hours than for shorter hours, so far as the poor-germinating seeds of digitarias XM and 24-3 are concerned. In the case of the better-germinating seeds of Echinochloa B.14-15 and Setaria H.10, there was little difference between the two tests, beyond the fact that with the less drastic treatment (No.47) the curve for the B.14-15 seed was far more irregular. However, more favourable response was registered with the seed of digitarias D.23 and 12-8 with treatment 47. In both tests Digitaria 24-3 showed a sharp rise after the 14th month.

In comparison with room storage, all of the seeds used except the poor-germinating kinds, evinced marked stimulation, but, compared with the results at constant temperature of $45^{\circ}C$ (test 36), the latter displayed, if anything, more favourable response. The graphs appear in figs. 43 and 44.

In another test with alternating temperatures of (a) 6 hours at ca. $65^{\circ}C$ plus 18 hours at ca. $28^{\circ}C$; (b) 2 hours at $65^{\circ}C$ plus 22 hours at ca. $28^{\circ}C$, in which Panicum minus, F.14, was used, there was little difference in total stimulation between treatments (a), (b) and even temperature at $65^{\circ}C$, the percentage germination rising from 45% to ca. 90% within 2 days in all cases. However, in the case of treatment (b) the curve showed a rapid and marked fall between the tenth and twentieth day, rising again to the original height within the next 16 days (vide fig.47).

Heat -

In addition to the above studies on the value of even and alternating / ..

ternating temperature, further studies were conducted on the effect of high temperatures on delayed germination. In these a temperature of ca. 65°C was employed for a period of about 2 months and several kinds of seed were under observation, the first test being started on 5/5/38 and the other a month later. The graphs for these appear in fig.46. In these studies, the kinds of seed used were :-

Setaria sp. B.3-1 (of 28/2/38)
do. B.3-3 (of 28/2/38)
Panicum sp."Makarikari" (of Jan.1937)
Digitaria sp. Seln.24-3 (of 3/3/36)
do. do. (of 19/3/36).

In all these seeds, viability was lost after about 66 days in spite of the fact that they were of different ages. The "makarikari" *Panicum* is stimulated least, the stimulation being a good deal higher in the second test when the seeds were a month older. The germination of the setarias and the digitarias were well promoted by this treatment, the former showing their maxima in 20 and 28 days respectively, the highest stimulation being about 45%, but in the case of the selection B.3-1 a second peak is exhibited about 25 days afterwards. The *Digitaria* 24-3 seed showed a very similar response for the 2 lots harvested at the two different dates. The maximum stimulation in this case was about 55%, realized after about 42 days' treatment.

(3) The effect of pre-treatment of fresh seeds at certain temperatures on the course of delayed germination with subsequent room storage.

Materials and methods.

In order to study the effect of different temperatures on the course of delayed germination of newly harvested seed, several kinds of seed were used, some of which were subjected to temperatures of 28, 40 and 50°C for diverse periods

directly / ..

directly after being harvested, whilst others were kept at 20°C for 10-29 days and only thereafter subjected for diverse periods to the same temperatures of 28°, 40° and 50°C respectively. The following seed, kept in open paper bags throughout the experiment, were studied :-

a) Chloris gayana ex Prinshof, harvested 3/2/41.
b) do. No.1, ex Rietondale, do.
c) Digitaria sp. A.720, "Zanghun Pan", harvested 11/2/41.
d) do. "N'Gami Lake", " do.
e) Setaria sp. A.287 " 25/1/41.
f) Panicum sp. "Makarikari"; seln.11/12 " 3/1/41.
g) Paspalum scrobiculatum A.386 " 27/2/41.
h) Paspalum notatum (not indigenous) A.401 " 14/3/41.

Germination tests were made at ca.28°C at the completion of every pre-treatment and thereafter 6- to 8-weekly tests were conducted. The results of this experiment are collated in table 17 below.

TABLE 17.

THE EFFECT OF PRETREATMENT OF DIFFERENT LINES OF FRESH SEED AT 28°, 40°, AND 50° RESPECTIVELY, ON THE COURSE OF DELAYED GERMINATION, DURING SUBSEQUENT ROOM STORAGE, AS REFLECTED BY CONSECUTIVE GERMINATION TESTS. (CONTROL PERCENTAGES ARE GIVEN IN BRACKETS.)

Particulars of seed and treatment.	First Test %	Second Test %	Third Test %	Fourth Test %	Fifth Test %
Rhodes Grass of 3/2/41 (Ex Prinshof).					
Directly for 38 days					
at 28°C (1)	3.0^{x}(5.3)	7.7^{x}(10.1)	14.5^{a}(26.0)	15.2^{b}(38.8)	30.7^{f}(62.6)
" 40°C (2)	- (do)	12.9 (do)	21.8 (do)	45.4 (do)	28.7 (do)
" 50°C (3)	2.0 (do)	23.3 (do)	54.9 (do)	59.8 (do)	55.7 (do)
First 10 days at 20°C thereafter for 38 days					
at 28°C (18)	5.1^{n}(do)	8.4^{x}(do)	23.2^{a}(do)	25.2^{b}(do)	26.2^{f}(do)
" 40°C(16)	3.6.(do)	14.6(do)	17.7(do)	21.5 (do)	38.1 (do)
" 50°C(17)	3.0 (do)	19.1(do)	26.6(do)	39.6(do)	54.1(do)
First 10 days at 20°C thereafter for 76 days					
at 28°C (31)	6.4^{e}(7)	39.0^{m}(do)	14.6^{a}(do)	22.4^{b}(do)	24.7^{f}(do)
" 40°C (32)	10.0 (do)	65.6 (do)	25.6 (do)	35.5 (do)	43.0 (do)
" 50°C (33)	12.5 (do)	79.7 (do)	47.9 (do)	37.0 (do)	41.1 (do)
Rhodes Grass No.1 of 3.2.41.					
18 days at 20°C thereafter for 30 days at 28°C(12)	14.1^{e}(12.1)	35.1^{x}(65.3)	63.4^{a}(40.2)	72.7^{b}(83.8)	81.6^{f}(76.2)
" 40°C(10)	17.2 (do)	59.9 (do)	60.3 (do)	79.7 (do)	88.9 (do)
" 50°C (11)	15.4 (do)	68.6 (do)	81.2 (do)	89.0 (do)	91.2 (do)
18 days at 20°C thereafter for 60 days					
at 28°C (40)	38.2^{n}(do)	47.2^{m}(do)	64.9^{c} (do)	62.3^{e}(do)	85.9^{f}(do)
" 40°C (41)	35.9 (do)	73.6 (do)	78.1 (do)	77.3 (do)	84.3 (do)
" 50°C (42)	60.5 (do)	73.2 (do)	89.4 (do)	86.6 (do)	87.4 (do)
Dig.Zanghun Pan A 720 of 11.2.41.					
Directly for 30 days					

Kind of grass and particulars of treatment.	First Test %	Second Test %	Third Test %	Fourth Test %	Fifth Test %
Directly for 30 days at 28°C (5)	0[x](0)	0.5[*](1.5)(3/5)	0.2[a](0.3)	0.0[b](0.5)	0.5 (1.1)
" 40°C (4)	0 (0)	0 (do)	0.1 (do)	0.5 (do)	0.7 (do)
" 50°C (6)	0 (0)	0 (do)	0.2 (do)	1.0 (do)	0.7 (do)
First 10 days at 20°C thereafter for 30 days at 28°C (15)	0[θ](0)	0.5[*] (do)	0.7[a] (do)	0.0[b](do)	1.4[f](do)
" 40°C (13)	0 (0)	0.5 (do)	1.2 (do)	0.0 (do)	0.4 (do)
" 50°C (14)	0 (0)	0.5 (do)	1.7 (do)	0.3 (do)	0.8 (do)
Dig.N'Gami Lake of 11.2.41. Directly for 30 days at 28°C (8)	0[x](0)	0[*](0.2)(3/5)	0.1[a](0.0)	0.0[b](0.0)	0.1[f](0.0)
" 40°C (7)	0 (0)	0 (do)	0.0 (do)	0.0 (do)	0.2 (do)
" 50°C (9)	0 (0)	0 (do)	0.5 (do)	2.7 (do)	1.2 (do)
First 10 days at 20°C, thereafter for 30 days at 28°C (21)	0[θ](0)	0[*] (do)	0.2[a](do)	0.0[b](do)	0.0[f](do)
40°C (19)	0 (0)	0 (do)	0.4 (do)	0.0 (do)	9.1 (do)
50°C (20)	0 (0)	0 (do)	2.7 (do)	0.2 (do)	0.1 (do)
Setaria A 287 of 25.1.1941. 19 days at 20°C thereafter for 40 days at 28°C (22)	26.8[θ](9.8)	43.6[*](27.3)	48.4[a](39.7)	60.5[b](39.0)	57.0[f](55.8)
40°C (23)	35.6 (do)	48.2 (do)	63.2 (do)	62.0 (do)	62.6 (do)
50°C (24)	17.0 (do)	46.9 (do)	56.8 (do)	61.4 (do)	61.0 (do)
29 days at 20°C thereafter for 40 days at 28°C (25)	27.3[r](± 15)	34.1[*](27.3)	50.3[a](39.7)	54.3[b](39.0)	52.2[f](55.8)
40°C (26)	37.8 (do)	49.8 (do)	54.8 (do)	56.7 (do)	64.7 (do)
50°C (27)	25.4 (do)	44.9 (do)	48.3 (do)	66.0 (do)	64.3 (do)
Pasp.scrobiculatum A.386 of 27.2.41. Directly for 37 days at 28°C (28)	0[r] -	0[m] -	0.0.[a] -	1.4[b] -	1.5[f] -
40°C (29)	0 -	0 -	0.8 -	0.4 -	2.0 -
50°C (30)	0 -	11.8 -	2.0 -	2.5 -	7.0

Particulars of seed and treatment.	First Test %	Second Test %	Third Test %	Fourth Test %	Fifth Test %
Pasp.notatum A.401 of 14.3.41					
10 days at 20°C thereafter for 30 days at					
28°C (34)	0[n] -	0[m]	0.0[c] -	0.0[e] -	8.0[f]
40°C (35)	0 -	1.2	1.7 -	6.6 -	44.7
50°C (36)	0 -	1.7	4.2 -	12.8 -	42.9
10 days at 20°C thereafter for 60 days at					
28°C (43)	0.1[q] -	0.1 -	0.0[e] -	10.0[f]	-
40°C (44)	1.7 -	6.9 -	31.1 -	63.0	-
50°C (45)	2.7 -	9.7 -	41.3 -	67.1	-
Panicum sp.: Makarikari 11/12 of 3.1.41.					
10 days at 20°C thereafter for 60 days at					
28°C (37)	0[n](0.3)	0.3[m](0.3)	0.1[c](-)	0.0[e](-)	0.4[f](0.75)
40°C (38)	1.4(do)	1.5 (do)	2.3 (")	3.8 (")	4.8 (do)
50°C (39)	2.4(do)	5.5 (do)	5.2 (")	10.0 (")	10.5 (do)

x - date of germination test 13/3/41
e - " " " " 24/3/41 and 25/3/41
r - " " " " " 7/4/41
n - " " " " 21/4/41 and 24/4/41
ж - " " " " 12/5/41
q - " " " " 24/5/41
m - " " " " 4/6/41
a - " " " " 23/7/41
b - " " " " 16/9/41
c - " " " " " 11/8/41
e - " " " " 29/9/41
f - " " " " 1/12/41

Discussion of results.

In the case of the two lines of *Chloris gayana* a marked difference in the delayed germination was noticeable, the one registering over double the percentage germination of that of the other. The quickest and highest stimulation was obtained with the poor-germinating line (ex Prinshof) which showed 80% germination at the second test (76 days at 50°C) being an increase of almost 70% over the control. However, it exhibited a decline immediately afterwards, as was also the case with the 40° treatment. Only a slight decline was registered by the other line (No.1) and then only after the third test. Also, in the former kind (ex Prinshof) it was observed that little, if any, benefit was to be drived from pre-treatment at 20°C. In fact, at the third and fourth tests the % germination with 50°C (test 3) was about double that in the corresponding test 17, not subjected to 20° pre-treatment. Moreover, it would even seem that for the same rhodesgrass seed temperatures of 28°C after harvesting was, if anything, harmful as compared with the higher temperatures and with the control. With the better-germinating line the 28° temperature was also somewhat harmful. At about the fourth test, the majority of the treatments were about equal to/or below their controls. For the poor-germinating rhodesgrass (ex Prinshof) a two months period was a much more favourable period of heat treatment than one month (particularly at the temperatures of 50° or 40°), but viability was apparently easily impaired. In the other kind there was not much to be gained by prolonging the treatment.

The treatments were of no value, up to this stage, to the seeds of the two digitarias, the *P.scrobiculatum* and the *Panicum*, but the *P. notatum* seed is showing the favourable effects of the 40° and 50°C clearly at the third test, but then

only / ..

only with the 2 months' period of treatment. In the case of the two digitarias there was no evidence of the value of pre-treatment at 20° up to the fifth test.

The *Setaria* showed a fair stimulation throughout the tests, but there was little in favour of the 50° and apparently little to choose between a 19-days and a 29-day pre-treatment at 20°C.

(4) Summary.

1. A preliminary test with a 2 months' heat treatment of 40-42°C indicated that the delayed germination of grass seed may be overcome to a very appreciable extent by such treatment, even when aeration and humidity were controlled. Of 9 eco-types used, 4 were stimulated by such treatment.

2. The results of a number of outdoor treatments, with and without controlled humidity, showed that non-afterripened seeds are very easily affected by the conditions of their environment, and under certain conditions delayed germination may be overcome to a large extent, though certain lines were hardly benefited at all.

3. The most effective stimulation outdoors was obtained with direct exposure (insolation) of seed spread out on wire gauze trays placed on the bare ground. The response varied with the line of seed, but the age of seed was found to be an important factor. Decline in germinability was, however, always obtained before complete stimulation could be realized, though such decline does not seem to signify loss of viability.

4. Incomplete exposure to sunlight, by subjecting seeds to sunlight in white muslin bags, as well as by placing seeds (contained in muslin bags) inside a jute bag, also resulted in almost as good stimulation as with insolation.

5. The control of humidity at 0 and 50% (using H_2SO_4), with incomplete exposure to sunlight (in white muslin bags, inside glass jars) and at 0-, 50- and 90%-humidity in shade outdoors, proved to be of very doubtful value, showing harmful results, particularly with the 90% humidity.

6. Aeration, in conjunction with outdoor exposure in tins, was distinctly beneficial to the majority of seed (lines) studied, but two lines were not clearly benefited.

7. By subjecting seed to conditions of controlled humidity (of 0%, 50% and 90%, respectively) and aeration, at temperatures of a domestic refrigerator, at 25°C, at 35°C and at 45°C respectively, fairly good indications were further obtained as to the requirements of seed with a view to overcoming delayed germination.

8. Temperature conditions inside a refrigerator were not conducive to the overcoming of delayed germination, and humidity control, at the levels employed, proved of little value for this purpose.

9. At 25°C, the 3 humidity levels were of very doubtful value, the 90% producing rapid decline of germinability after 3 months. Better results were, however, evident when humidity was not controlled (free aeration).

10. At 35°C, the doubtful value of humidity control was even more evident, the treatment with free aeration giving very good responses.

11. At 45°C, the 90% humidity was very harmful and though the 50% initially brought some stimulation, germinability was lost after 2 months. The 0-humidity was still of very doubtful value. In this incubator series, the best responses were secured with uncontrolled humidity (free aeration).

12. / ..

12. Subjecting seed to alternating temperatures of 25° and 45°C, for periods of months, did not result in any better responses than with even temperature at 45°C.

13. By subjecting seed of different lines and of different ages to a temperature of ca. 65°C, very good stimulation was obtained, but decline in germinability followed immediate- on maximum stimulation. The period needed to produce maximum stimulation varied with the line of seed and apparently with the condition of delayed germination, being 2 days in *Panicum* F.14 and about 3-6 weeks in the other seed employed. Germinability was lost after about 66 days.

14. Studies were made of the effects of subjecting fresh seed for varying periods to temperatures of 28°, 40° and 50°C, with a view to overcoming delayed germination, when subsequently stored at room temperature. In some cases, the seed was kept at 20°C for 19 - 29 days, before being subjected to the above temperatures.

15. A stimulation of 70% was secured (76 days at 50°C) with seed of the one *Chloris gayana* ecotype, about 3 months after treatment. An immediate decline followed. Temperatures of 28°C after harvesting appeared harmful. Other lines of seed exhibited little benefit from such treatment, except the *P. notatum* seed, in which improvement in germinability was clearly evident at 40° and 50°C, after the third test. With the *Setaria* seed the 50°C temperature appeared to be little better, if any, than the 40°C. Pre-treatment at 20°C was of very doubtful value.

B. / ..

B.

The Effect of various combinations of heat, cold and "sunlight".

Germination tests were made in the usual way at ca. 28°C. The *Panicum* and *Setaria* seeds were cleansed beforehand, but the *Digitaria* seed after completion of the test.

(1) Pre-heating at ca.65°C with subsequent room and outdoor "storage".

An experiment to ascertain the effect of pre-heating of seed at 65°C on the delayed germination with subsequent continuous outdoor (daytime) exposure and also on continuous room storage. Different lots of seed were exposed to 65°C for periods of 2 hours, 12 hours, 1 day, 2 days, 4 days, 6 days, 10 days, 20 days, 30 days, 40 days and 50 days, and thereafter one half of each lot was kept in open tins in the laboratory and the remaining half of each lot was spread out on tin plates which were placed on a lawn during the daytime, but brought in after sunset every day.

This experiment was commenced on 6/6/1938 and lasted 4 months. In the *Setaria* and *Panicum*, fortnightly, and in the *Digitaria*, monthly, germination tests were conducted. Three kinds of seed were included in the experiment, viz., *Setaria* sp.B.3-3 of 28/2/1938, *Panicum* sp."Makarikari" of January 1938, and *Digitaria* sp. seln. 24-3 of 19/3/1936. The individual lots of seed from the different periods of heat treatment were all released simultaneously from their respective treatments so that they were subsequently exposed to identical outdoor and indoor conditions.

The graphs of the results appear in figs.47 and 48. The curves of both the outdoor and indoor series display a

striking / ..

striking irregularity. Also, in both series greatest stimulation was realized with the "makarikari" ecotype, which, incidentally, had the lowest germination and was the least affected by heat treatment (see also fig.46).

The effect on room storage.

It is of interest first to direct attention to certain features of the heat treatment itself. It will be seed from the graphs that with the *Digitaria* seed, the 50-day period of heat treatment which, as such, was a less favourable treatment than the 40-day period, produced a far better increase in germination when released from the heat treatment, than the seed of the 40-day heat treatment. In other words, a decline in germination with such heat treatment is not necessarily due to a loss of viability. It is surprising that none of the shorter heat treatment periods could equal the 50-day increase with room storage. The 40-day curve exhibited a rapid decline after the heat treatment.

With the other two kinds of seed this phenomenon was also very noticeable. In the wase of the Setaria, the 50-day period of heat has reduced germination to well below the control, but after being placed at room temperature, there was a marked stimulation within a fortnight. In the outdoor series this was also clearly demonstrated.

In this (room) series best stimulation with the *Digitaria* seed was obtained throughout the 4 months with the 50-day period. With two exceptions - which do not seem genuine - all treatments with this kind of seed experienced a decline after the first month at room temperature, with subsequent rises, the falls and rises being far more marked for the 15- and 10-day periods than for the 30- and 40-day periods. The lower-period heat treatments are of doubtful

or / ..

or little value during the first three months of room storage.

With the Setaria seed, in which the optimum germination with the heat treatment alone was obtained a fortnight earlier than with Digitaria (see fig.46), the subsequent effect with room storage (fig.47) was in fair agreement therewith, as the three higher periods of heat treatment were not of the same value - as for instance the 20- and 15-day periods -, though during the first month of room storage the 40- and 30-day periods were of about the same value, but with subsequent rapid decline. The shorter periods showed about the same response as with the above kind (Digitaria), but the favourable effect appeared earlier. In an earlier experiment, the 15-day treatment had given 90% germination with Setaria B.3-1. Declines after the first 4 to 6 weeks at room temperature were also then experienced.

Where, in the case of the Panicum, the period of optimum germination with heat treatment lay between those of the above two kinds of seed, the best response in the room storage series was, likewise, with periods between those which gave best responses with the other lines of seed. The 40-, 30- and 20-day periods were distinctly better than the 50-day pre-treatment. The short-period heat treatments were not of the same value as with the Setaria seed. The 15-day period here showed two very deep troughs not experienced in the other two kinds or in any other treatment.

The effect on outdoor treatment. (Fig.48).

In two of the three lines of seed, the outdoor controls ultimately, after about 3 months, exhibited about the same increase in germination as obtained with the best heat treatments, though the latter were better at the earlier stages. In the case of the Digitaria seed (in which the response was rather different to the other two), the decline after the first month was a very regular one and, to judge from the two other

kinds / ..

kinds of seed used, this decline no doubt set in earlier. The rise after the second month was equally regular for the treatments below 15 days, but in the higher heat treatments the curves ran horizontally, rising after the third month. In all except the 50-day treatment, the maximum stimulation was not realized until 4 months outdoors, at which time there was little difference between the various treatments, they giving a good deal better germination than the room-stored seed.

With the Setaria, as with the Panicum, the curves were very irregular, though with the exception of the 50-day period (which was well below the outdoor control throughout the 4-month period) they were well above the control during the first 2 months outdoors, declines being registered after 1 to 2 months. Similar declines were not exhibited by any of the controls of the 3 kinds of seed. After 4 months all treatments above 10 days were germinating below the outdoor control, the others being distinctly better, recovery being shown by only the short-period treatments.

The Panicum seed showed somewhat more marked stimulation outdoors than indoors. In the longer period treatments this was obtained within the first fortnight, whilst in the shorter period treatments it occured after 6 weeks. All treatments exhibited distinct declines after 6 or 8 weeks, outdoors and thereafter recovery was only realized by the shorter-period treatments, which is in contrast to the room storage series in which subsequent increases were only realized with the longer-period treatments. Eventually, after 3½ months, the sun control was equal to or better than any of the treatments and particularly the longer-period treatments.

(2) Pre-cooling at ca.3°C with subsequent room and outdoor storage.

The aim of this experiment was similar to that above. Pre-cooling periods of 3 days and 1, 2, 3, 4 and 6 weeks were

tested / ..

tested out. The materials, methods, period and time of the experiment were the same as in the above experiment.

The results are presented in figs. 49 and 50. In contrast to the effect of heat and in accordance with expectation, there was no immediate influence of cold treatment noticeable, in view of which the direct response to cold was omitted in the graphs. The best stimulation in these series of room and outdoor storage was obtained with the <u>Digitaria</u> which registered over 60% increase in germination in the room-storage series. On the other hand, the <u>Panicum</u> showed no stimulation with room storage, whereas the <u>Setaria</u> seed fell in between them. There was in both room and outdoor series little to choose between the various periods of pre-cooling. The <u>Digitaria</u> seed showed stimulation only after the third month, the germination being below the control before this. In the case of the <u>Setaria</u> seed at room temperature, the response was a good deal less favourable though very regular.

In the outdoor series, the <u>Digitaria</u> did not show the same stimulation as in the room series, but the maximum was registered a month earlier, the increases being as rapid as the declines. The <u>Setaria</u> and <u>Panicum</u> seed both showed slight stimulation, the outdoor control of the latter exhibiting slightly superior germination to the treatments after 3½ months.

(3) <u>The effect of the alternation of various periods of heat (65°C) and sunlight.</u>

The alternations tested out were :-

2 hours at 65°C	:	2 days in sunlight.
2 days " "		7 " " "
2 " " "		14 " " "
2 " " "		30 " " "

The same <u>Panicum</u> seed was used but the <u>Setaria</u> was the line B.3-1 of 28/2/38 and the <u>Digitaria</u> line 24-3 of 3/3/36. In the latter, monthly, and in the other two, fortnightly germina-

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tion tests were conducted. The experiment was commenced on 5/5/38 and lasted 4 months. The results are plotted on the graphs appearing in fig. 51.

This treatment was very beneficial to the Digitaria seed, giving 70% stimulation over the room control, after 6 weeks. The 3 longer-period alternations were of equal value, but all registered an immediate decline thereafter. The Setaria and Panicum seed were also well stimulated in comparison with their room controls, but in the case of the latter line, there was no advantage, compared with its outdoor control, except in respect of time. The maximum stimulation obtained with Setaria seed in this series was, however, no better than its control at 65°C and, in fact, the longer-period treatments were below the stimulation realized with heat alone. In the case of the Digitaria, 3 of the 4 treatments were well above the heat control.

(4) Alternation of various periods of low temperature and sunlight.

The alternations tested out were :

6 hours	at	ca. 3°C	:	2½ days	sunlight.
2 days	"	"		7 "	"
2 "	"	"		14 "	"
2 "	"	"		30 "	"

~~Germination tests were conducted fortnightly.~~ The same seeds were used as in the previous experiment; the time and the period of treatment were also the same. Germination tests were conducted fortnightly. The data for this test are graphically presented in fig. 52.

It does not appear as if this alternation can be expected to give better germination than sunlight treatment by itself, or than sunlight with pre-cooling, although in comparison with room treatment marked stimulation was realized, particularly in the case of the Panicum. In this seed, for

instance / ..

instance, the same stimulation was eventually obtained with sunlight, as with the best combination used in this experiment.

(5) The alternation of various periods of cold (ca.3°C) and heat (ca.65°C).

The alternations tested out were :

2	hours	at 65°C	:	22	hours	at 3°C.
6	"	"		18	"	"
12	"	"		12	"	"
18	"	"		6	"	"
22	"	"		2	"	"

The kinds of seeds, period of treatment and date of commencement of the experiment were the same as in the previous. Germination tests were made fortnightly with the Setaria and Panicum and monthly with the Digitaria, the data being graphically presented in fig.53.

With the Digitaria and Setaria seed very good germination was obtained but for the Panicum, which showed good stimulation in three of the other four experiments, the lowest germinations were recorded with these treatments. These treatments appeared somewhat drastic, particularly to the Setaria in which the 0% mark was approached within $2\frac{1}{2}$ and 3 months. The severity was apparently largely determined by the length of the heat treatment. The maximum stimulation exhibited by the Digitaria (within $2\frac{1}{2}$ months) and Setaria (in $1\frac{1}{2}$ months) were not, however, obtained with the same treatments in the two lines. The stimulation with these two were well in excess of heat and cold treatments and controls separately. Those treatments which gave the quickest stimulation also showed the fastest and greatest falls in germination thereafter.

(6) Summary.

1. The effects of different periods of pre-heating seed (3 lines) at ca.65°C with subsequent room and outdoor storage respectively, were studied as a possible means of overcoming delayed germination.

2. Under these conditions, excellent stimulation was realized with all 3 lines, when the seed was stored at room temperature, being highest in the "Makarikari" Panicum, in which the maximum germination (approx. 60%) was registered after the first 14 days, at room temperature. The optimum period of heat treatment varied with the line of seed, being longest in the Digitaria and shortest in Setaria. The curves of all 3 kinds of seed exhibited marked falls and rises, the trends showing fairly close agreement. Marked differences in response were evident between the various periods of treatment.

3. Under the same conditions of pre-treatment, outdoor storage resulted in larger increases for the Panicum and Setaria, but these increases were about equalled by their outdoor controls after approx. 3 months, which, however, was not the case with the Digitaria, in which the treatments were well above the outdoor controls, after 4 months. Also here similar rises and falls were experienced and marked differences in response were evident between the different periods employed.

4. Employing pre-cooling in the same manner as in the above, the response with room storage were far less consistent than in the previous. No stimulation was realized with the Panicum, but excellent increases were obtained with the Digitaria, the responses with Setaria taking an intermediate position. The irregularities in the curves were not evident in this series, and little difference was exhibited between the different alternations.

5. With outdoor storage, pre-cooling was even less effective than the last-mentioned conditions, when compared with their outdoor controls, In contrast to the outdoor storage with pre-heating, the increases were realized much later, almost coinciding with those of the controls. Marked irregularities were not evident although all Digitaria curves exhibit a fall after their

peaks / ..

peaks at the third month. Little difference in response was exhibited between the different alternations.

6. The alternation of various periods of heat and sunlight resulted in highest increases being realized with the Digitaria (70% stimulation). With the Setaria and Panicum the stimulation did not equal those obtained in the pre-heating series and the tendency for the outdoor controls to come up to the levels of the treatments, was apparent. The different alternations responded somewhat differently.

7. The alternation of cold and sunlight proved to be of the least value in these series, though considerably better than room storage alone.

8. The alternations of heat and cold induced marked stimulation in the Digitaria (approx.70%) and the Setaria (approx.55%), when compared with room controls, but marked declines were exhibited with certain treatments. With the Panicum, this type of treatment, though giving up to 40% stimulation, was the poorest of all series. This kind of treatment is apparently severe, as complete loss of germinability followed with most of the treatments in which decline of germination was registered.

C.

Discussion of the results of temperature, humidity and sunlight, including a brief reference to the literature.

Many workers have given attention to the influence of temperature and of the related questions of desiccation and moisture-content of seeds on the germination of after-ripened as well as non-afterripened seeds. Lehmann and Aichele (1931) have reviewed the literature for the Gramineae and it is therefore unnecessary to refer to all here.

A number / ..

A number of workers, e.g., Hötter (1892), Hiltner (1901), - both cited by Harrington (1923) - Atterberg (1907), Kiessling (1911) - after Harrington (1923) -, Harrington and Crocker (1918), Stapledon and Adams (1919), Harrington (1923), Joseph (1929) and Poptzoff (1936) have reported on the favourable effects of drying on delayed germination. Whether these effects were directly or indirectly due to heat treatment or to reduction of moisture content of the seed (water withdrawal) or to both, must needs depend on the kind and condition of the seed under observation, as well as on the various external factors. Thus the views and ideas expressed on this subject have varied accordingly. Nevertheless, it appears that in some cases the beneficial effects were definitely associated with water withdrawal i.e., water-content, such as when dehydration agents (e.g., H_2SO_4 and $CaCl_2$) are used as was shown by Hiltner (1910) - cited by Lehmann and Aichele (1931) -, Harrington (1917), Steinbauer and Steinbauer (1932), etc. In other cases, however, temperature or heating, as such, was no doubt responsible, e.g. Hötter (1892) - cited by Lehmann and Aichele - found that after-ripening proceeded when water-content remained constant; Kiessling (1911) - cited by Harrington (1923) - attributed his results to temperature effects.

On the other hand, Harrington (1923 a), in connection with wheat sutdies, wrote : "There is no quantitative relation between water-content and germinability, after-ripening progressed at the same time as normal loss of water during curing of the grain, but not primarily as a result thereof." He (1923 b) also stated that the acceleration of after-ripening of Johnson grass seeds was more easily affected by heating than by lime or H_2SO_4.

Harrington (1917) found seeds of Johnson grass stored in definite humidities (using H_2SO_4) hastened delayed germination, ~~Some workers have found dry heat useful~~ but prolonged severe drying over H_2SO_4 reduced germination. Some workers

have / ..

have found dry heat useless; e.g. Burton (1938) reported no success with timothy seed dried at 50°C. Franck and Wieranga (1928), employing 5 - 7 days at 35°C for artificial after-ripening of various kinds of vegetable seeds, obtained both favourable and unfavourable results.

Hiltner and Kinzel (1906), Atterberg (1907), Franck (1925) - cited by Lehmann & Aichele -, Harrington (1923) and others, used about 30 - 50°C with favourable results and usually workers employed short periods, up to ten days. Though seeds can endure much higher temperatures than used in the present studies, viz. 45 - 65°C (for example, Dixon (1901, Harrington and Crocker (1918), Staker (1925), Joseph (1929), Spafford (1930)), water-content of the seeds at commencement is an important factor (e.g., Waggoner (1917), Harrington & Crocker (1918), Atanasoff and Johnson (1920), Lipscomb and Dowling (1926), Tincker and Jones (1927)).

A good deal of work has been done on suitable storage conditions for the preservation of viability, but these results are of no immediate concern to our discussion, as the question of delayed germination is usually not considered with this problem. Bihlmeier (1928) found that the germination of a number of species was improved by dry storage, the time required and the degree of improvement varying considerably with the various seeds.

Kiessling (1911) - cited by Harrington (1923) - reported favourable effects (with drying) on barley in early stages of after-maturation, but when this was completed, or nearly so, harmful effects were obtained. Harrington (1917) found that seeds of Johnson grass stored in definite humidities (H_2SO_4 solution), were hastened in their after-ripening, but prolonged severe drying over H_2SO_4 reduced germination. Toole (1921) reported that when dried quickly in the sun or when

desiccated / ..

desiccated over H_2SO_4, wheat may retain its dormant condition for a long time. Working with oats, Tincker and Jones (1927) found that the moisture-content of the grain was negatively correlated with the rate of germination. Borthwick and Robbins (1928) established that low temperature dry storage of lettuce seeds did not improve the germination as compared with laboratory-temperature stored seed. Giersbach and Crocker (1932) found wild plum seeds required a period of low temperature stratification or a period in a low temperature germinator for after-ripening, preparatory to germination, which are methods that have been found effective by many workers for the promotion of after-maturation, not only of the seeds of woody plants, but also of the non-woody kinds including those of the Gramineae, as already stated. This may, however, prove of little or no value (e.g., Ray and Stewart (1937), using dry and wet treatment at low temperatures with _Paspalum_ spp.), as also our own results show. Toole (1940) found higher temperatures for storage more successful for improving after-maturation than low temperatures (_Oryzopsis_).

Above attention has been directed to the importance of light for the germination of seeds and particularly during the condition of delayed germination, it being also pointed out that, apparently, little has been done on the value of light of different wavelength and of sunlight, on the course of delayed germination, particularly of dry seeds. The results of the present investigation show that sunlight treatment may produce very marked increases (see outdoor treatments, under A.(1) above), but when a closer examination of the phenomenon is attempted, as described below, under D (1), it would seem that temperature, directly or indirectly, perhaps plays a major role, though there appears to be a very distinct difference between certain filters in the case of _Setaria_. The inequality of age of the two kinds of seed is probably the

cause / ..

cause of the difference in response, as it is now known that the relative importance of the two controlling factors alters considerably with time. It must, however, be admitted that the results are somewhat puzzling and do not shed much light on the direct cause of the phenomenon and it is only with further experimentation that the question can be solved.

When one considers the experiments in which sunlight was used in conjunction with heat (expts. under B (1) and (2) above) one is again confronted with the differential response of the different kinds of seed. The value of sunlight is quite considerable, but when alternated with suitable periods of heat or when preceded by the correct heat treatment, the value of heat becomes evident and one wonders to what extent the effectiveness of sunlight is dependent upon the heat factor concerned, especially with the good results obtained when room storage - instead of outdoor storage - is used in combination with pre-heating. The value of heat is in fact very clearly shown in these series of heat - cold - sunlight combination. On the other hand, pre-cooling with room storage may produce very marked stimulation in contrast to the results secured with continuous low temperatures. At the same time, the harmful effects of pre-cooling and sunlight in contrast to pre-cooling plus room storage in the case of Digitaria 24-3 is recalled.

It is, moreover, interesting to note that the alternation of heat and cold is apparently a good deal more drastic than that of heat and sunlight, though accompanied by equally good stimulation effects; or even more drastic than cold and sunlight, although accompanied by better stimulation effects for the Panicum seed. Throughout, the differential response exhibited by the three kinds of seeds used in these series, is quite striking. It is furthermore apparent that heat or heat

and / ..

and cold, or even heat and sunlight, may produce the same reduction of delayed germination as sunlight, and usually sooner.

It would seem that the periods used in the various combinations of these series were fairly well chosen.

The value of temperature for the improvement of delayed germination is well demonstrated in the incubator series (under A (2), above). This is revealed by a comparison of the tests without humidity control, at the refrigerator temperature (No.21), with that at incubator temperature of 45°C and of 35°C, as well as alternating temperature treatment (Nos.46 and 47), but the maximum stimulation is not realized until after about 8 - 9 months and the curves are not always smooth, especially at the higher temperatures. The temperature of 45°C is apparently not always more favourable than the 35°C one, for maximum stimulation, though it may be so for quickest stimulation. Temperatures below 30 - 35°C are apparently not of much value compared with room storage for maximum stimulation.

The ineffectiveness of temperature to affect improvement in the delayed germination of certain resistant seeds (even after long periods) is not restricted to particular genera, as <u>Panicum</u>, <u>Urochloa</u> and <u>Digitaria</u> are concerned, and it would be interesting in future studies to ascertain to what extent changes in seed-coats and embryo are affected by the treatment. It is probable that temperature changes affect only the seed-coat or the embryo and the treatment may, therefore, appear ineffective, when in fact it may have been very effective for either the one or the other. The results in Chapter 1 have demonstrated the importance of these factors in the delayed germination of these seeds and it will thus not only be interesting, but also necessary to keep track of the changes in relative contribution of these factors, if any,

which / ..

which occur during the period of treatment as otherwise valuable information may be lost.

That the age of the seed, that is the condition of the embryo and seed-coats, must be an important factor with the in-effectiveness of any treatment, is evident. In the case of Chloris gayana it has been shown (Chapter 1) that delayed germination is almost entirely attributable to seed-coats a few weeks after harvesting, and it would, therefore, seem that the success of heat treatment of fresh seeds of the species (vide A (3) above) is probably entirely due to the effect of the treatment on the seed-coats. If this be so, the ineffectiveness of this treatment with certain kinds of seed (Urochloa, etc.) is readily explained.

The importance of aeration for certain kinds of seed during heat treatment is well illustrated by a comparison of treatments 30 and 31 (figs.31-32) at 35°C. This is well shown by the behaviour of the seed of Panicum B.7-11 and Echinochloa B.14-15. At refrigerator temperatures this is not at all apparent. Whether the favourable effects are due to aeration, per se, or to the effect of humidity, can only be ascertained by a consideration of the effects of humidity itself.

The interpretation of the effects of various humidities call for a certain amount of caution, in view of the possible unfavourable effects of conc. H_2SO_4 in the case of 0-humidity treatments. If the acid is deleterious, then it is not equally harmful to all kinds of seed and it does not cause complete loss of viability in the majority of tests, even over the 15 months' period. Above it has been shown that, apparently, H_2SO_4 does cause a somewhat quicker decline in germinability than $CaCl_2$, although dehydration by means of $CaCl_2$ ~~(xxxxxx)~~ is also unfavourable for the progress of delayed germination of this line of seed, as the limited results with

$CaCl_2$ (above) show. It would thus appear that the ill-effects resulting from the use of conc. H_2SO_4 for 0-humidity treatments are perhaps to be attributed more to the lack of humidity or dehydration of the seed than to the effects of the acid itself, particularly where stimulation is registered with some seeds in the initial stages and where favourable results have been reported by other workers, as noted above.

At low temperatures (refrigerator) the effects of the different humidities are not particularly noticeable, but with increase in treatment temperature, the humidity differences become more and more distinct and the regulation of humidity more harmful, with perhaps the exception of one or two kinds of seed in the case of the 50% humidity at 35°C. Judging from the results obtained with the three conditions of humidity, there seems to be little in favour of humidity control with heat treatment, for the promotion of delayed germination, especially when the favourable results of the uncontrolled humidity treatments are taken into consideration.

The low temperatures are probably not without value, as they would seem to be favourable for the preservation of viability, for good stimulation was realized (expt. under B (2) above), when pre-cooled seed was subsequently stored at room temperature.

D.

Miscellaneous Treatments.

Under this head will be discussed the various explorative attempts made to obtain information on the value of certain other physical methods of overcoming delayed germination.

(1) The use of "filters" in conjunction with sunlight.

As standardized "filters" were unavailable, except for the yellow filter used in ordinary darkrooms, plate glass of

various / ..

various colours were made use of with the hope of securing more information about the favourable effects previously obtained with sunlight. Comparisons were made of :-

a) Blue plate glass : transmission ') in wavelengths 4200 to 5200 and from 6800 upwards.

b) Red plate glass : transmission ') in wavelengths 6300 to 7700.

c) Green " " " " " 4600 to 6300, with peak at 5350.

d) Yellow glass : Ordinary yellow filter of darkroom used (only one <u>Setaria</u> used).

e) Plain (white).

f) Total darkness.

g) Continuous exposure to sunlight, rain, etc. (only one kind of seed used).

h) Continuous exposure to sunlight, but protection from rain.

The seeds were exposed in single layers in a shallow galvanized iron "tray", the bottom of which was jacketed to hold water which was kept cool by continuous circulation of running water from a tap. The tray was divided off into light-proof partitions, each of which was covered with a different filter, one of the compartments being covered with photographic (black) paper to exclude all light. Two compartments were used for treatments g) and h) respectively. The provision for the continuous circulation of running water from a tap was made with the idea of eliminating the temperature factor. All "filters" were slightly raised at the N. and S. sides to permit free air circulation.

These studies, made with <u>Setaria</u> seln.B.3-1 of 28/2/38 and <u>Digitaria</u> seln. 24-3 of 3/3/36, were commenced on 16/4/38. Germination tests were conducted fortnightly, for a period of 6 months, when the experiment was discontinued.

Discussion / ..

') Nutting spectro-photometer was used, its range being 4200 - 7700 A° (white electric light was employed).

Discussion of results.

A graphical presentation of the results appears in Fig.45. Unfortunately the seed of the controls lasted only 2½ months, as losses are unavoidable as a result of full exposure. During this period a precipitation of 0.66 inches was registered on 22/4/38 with very light daily showers before this date and two days thereafter, which, apparently, resulted in an immediate increase of over 20% in germination capacity of the *Setaria* seed (control g). The control h) of both kinds, as well as the control g) after the first month, exhibited the poorest germinability of all treatments. In both kinds the same trends were noticeable in the controls, which in the case of *Digitaria* also agreed with the behaviour of the other treatments.

For both lines of seed the red filter, though somewhat better than some of the other filters during the first 1½ to 2 months exposure, was the poorest treatment. The yellow "filter" (only used with the *Setaria* seed) appeared to be the best treatment, giving over 90% germination within 4½ months, although a 15% decline in germination was experienced directly afterwards - a drop which coincided with an equally marked fall in the case of green, blue and "darkness" treatments with this kind of seed. All of these treatments, however, showed a subsequent rise. Except for a minor peak after about 1½ to 2 months, which was also exhibited by the green and red (and all the curves of the *Digitaria*), the yellow showed a straight course over the first 4½ months.

With the *Setaria* seed the next best treatment was "darkness", which for *Digitaria* was, with the exception of red (and of course the control), the least beneficial treatment. Thereafter the best treatment for this kind was the plain glass, which happened to be the best treatment for the *Digitaria*,

though / ..

though the highest germination recoreded was only 40%. With both kinds of seeds the green and blue fell in between.

No curve exhibited a trend not displayed by one or more of the other curves. The first fall shown by the majority occured in the middle of winter, the other again in spring.

(2) Soaking and Soaking and drying.

In a preliminary test with several kinds of seed exposed on the seed-bed in petridishes, it was found that intermittent wetting and drying was of little or no value and it was, therefore, decided to plan a detailed experiment to test out the possibilities of this method. In this, seed of *Setaria* seln.B.3-4 of February 1938 was used. The seed was first soaked at 27°C, divided into three portions, one being dried at 45°C, the second one at 65°C and the third one in the sun. In the first series the alternation of 2 hours' soaking and 22 hours' drying was used and this was followed directly by another series of 6 hours' soaking and 18 hours' drying. The experiment was commenced on 8/6/38 and germination tests were made on the 3rd, 6th, 11th, 21st and 30th days. A fair stimulation was obtained as shown by the following data :-

TABLE 18 : THE PROGRESS OF DELAYED GERMINATION OF *Setaria* B.3 - 4 OF FEBR. 1938, WITH CONTINUED SOAKING AND DRYING, WHEN TWO ALTERNATIONS OF SOAKING AND DRYING WERE USED AND THREE METHODS OF DRYING. THE CONTROL DID NOT EXCEED 24% GERMINATION.

Number of test	Method of drying after soaking	Germination w. 2hrs.soaking & 22hrs.drying %	Germination w. 6hrs.soaking & 18 hrs.drying %
3rd day	in sun	14.2	15.1
	at 65°C	9.4	5.5
	at 45°C	19.0	34.2
6th day	in sun	10.5	24.2
	at 65°C	17.9	2.4
	at 45°C	14.9	50.2

11th day / ..

Number of test	Method of drying after soaking	Germination w. 2 hrs. soaking & 22 hrs. drying %	Germination w. 6 hrs. soaking & 18hrs. drying %
11th day	in sun	19.0	37.2
	at 65°C	15.0	0.0
	at 45°C	23.2	57.9
21st day	in sun	47.7	43.0
	at 65°C	-	0.2
	at 45°C	50.4	44.4
30th day	in sun	-	25.8
	at 65°C	-	-
	at 45°C	-	42.8

In the first series, with shorter hours of soaking, the method of drying had little effect on the germination and stimulation was only registered after the 11th day. In the series with longer hours of soaking, however, stimulation was already apparent after the third day, the maximum germination of 58% being realized about the 11th day, this amounting to a stimulation of about 34%. Drying at 65°C was most harmful, as already by the 3rd day a marked decrease in germination was exhibited. It is, however, not unlikely that this is only a case of secondary "dormancy".

Soaking *Paspalum scrobiculatum* and three ecotypes of *Digitaria* for 6, 18, 24, 48 and 96 hours in tap water, showed that in some cases a fair stimulation may be obtained, although it appeared that the shorter periods were, if anything, harmful. Best increases were obtained with those seeds in which delayed germination was probably entirely due to seed-coat restraint, although the maximum stimulation amounted only to about 22%. In three out of the four lines the most favourable period was 48 hours, whilst in the other kind (*Digitaria*) it appeared to be in the neighbourhood of about 24 hours.

Interesting / ..

Interesting also are the data tabulated below (table 19). Whereas soaking has produced excellent increases (up to 75%) in two of the lines, the third was not benefited in the least. The method of drying adopted was distinctly harmful. The optimum period of soaking appeared to be approximately 96 hours, perhaps more.

T A B L E 19 : A COMPARISON OF THE EFFECTS OF SOAKING SEED IN TAP WATER FOR DIFFERENT PERIODS, WITH THAT OBTAINED WHEN SEEDS WERE DRIED FOR 20 HOURS AT 40°C, AFTER EVERY SOAKING. *Panicum* "MAKARIKARI" 11/12/, *Digitaria* A.708 (MOBABI FLATS) AND *Paspalum notatum* A.240, ALL HARVESTED FEBR. 1941 AND SHOWING RESP. 5.0%, 3.4% and 0.3% GERMINATION. AT 28°C (CONTROLS) WERE EMPLOYED. TIME OF TEST JAN.1942.

period of soaking	% germination directly after soaking			% germination when seeds were dried at 40°C for 20hrs after the soaking		
	Panicum 11/12	*Digitaria* A.708	*Paspalum* A.240	*Panicum* 11/12	*Digitaria* A.708	*Paspalum* A.240
2 hours	17.3	6.7	0	5.5	4.8	0
6 "	44.7	8.4	0	16.5	6.2	0.3
18 "	54.0	10.0	0	12.0	3.3	0
24 "	62.3	13.0	0	15.6	8.3	0.3
48 "	79.4	42.3	0.3	44.7	26.3	0
96 "	80.5	68.3	0	64.8	41.3	0

Many workers have reported on the effect of soaking and in some quarters it has become a standard practice in testing. Hastening of delayed germination, by means of soaking or of wetting and drying is, however, far less frequent. Fisher (1918) improved the germination of timothy by alternate wetting and drying. Foy (1932), using *Paspalum* seed, found good results with 5 minutes soaking at 60°C or 18 - 24 hours at room temperature. Burton (1939), however, could not improve the germination of *Paspalum notatum* with 24 hours soaking, whereas Wengar (1941)

realized / ..

realized good increases with 2 - 4 days soaking of Buchloe dactyloides.

(3) Hotwater treatment and soaking and freezing.

Preliminary hot water (60°C) treatment varying from ½ minute to 60 minutes, employing Digitaria: line 24-3 and ecotype A.23, resulted in very different responses. Whereas the former is not affected, the latter showed, apparently, slight stimulation in the case of the short period treatments up to 2 minutes, as also in the case of the control soaked at 30°C. On the other hand, with 45 and 60 minutes treatment, the germination speed was impaired, the majority of seeds germinating only after the 6th day. Boiling water (95°C) for varying periods up to 60 seconds, gave negative results.

By soaking the refractory seed of Digitaria 24-3 of 19/3/36 in water for 1 hour and freezing at ca. 3°F. for periods of 10 minutes, ½, 1, 2, 5, 10, 24 and 36 hours, no improvement in germination could be secured, the seeds being dried in the sun before each germination test. In fact, when compared with the germination of dry seed or of seed soaked for 1 hour only, with and without subsequent drying, the freezing, particularly the longer periods, appeared to be harmful. The experiment was commenced on 28/5/38 when the majority of the embryos were probably ready for germination and one may perhaps conclude that this freezing treatment has had little effect on the seed-coats.

(4) Breaking of seed-coats.

From the results that have been recorded above (II), it will be apparent that once the "embryo" has become ready for germination, there will be no difficulty in inducing germination, provided the seed-coats were broken. To achieve this by chemical means, should entail no real difficulty, as has

indeed / ..

indeed been reported by a number of workers for other grass-seed, but from the viewpoint of practical application, such a method can hardly be expected to be a success or, at best, can find only a limited practical application. The only means then is one of mechanical injury of the coats. It was hoped to achieve this by such means as freezing or hotwater, but, as reported immediately above, this did not prove a very hopeful line of attack.

Employing a spunge rubber pad on very fine emery paper, the germination of rhodesgrass A.245 could be increased by rubbing, from 8-72%. In a similar way also the germination capacity of _Digitaria_ line 24-3 could be increased by over 90%. In the latter case, however, the effect was more that of bruising, as in most fruits only the glumes were removed, the caryopses remaining enclosed in the remaining coverings (bracts).

When, however, it comes to the practical application of this method, it would seem that this will be a difficult, if not insuperable, task, as the majority of the seed of indigenous grasses, is so small, and the caryopses so tightly enclosed by the coverings, that the development of suitable machines to break the seed-coats will be most difficult. It is possible that with the larger-seeded kinds this might be successful, although experience has shown that in several of these (e.g., _Themeda_ and _Setaria_) the embryos are easily injured, once the caryopses are set free.

(5) Ultraviolet light and radium oxide treatment.

For testing out the value of ultra-violet light, a quartz-mercury vapour arc lamp, working at atmospheric pressure with an alternating current of 240 volts - 50 cycles, was employed. Seed of _Setaria_ B.3-1 of 28/2/38 was used and this was spread out in front of the light source at an average distance of about 10 inches, all other sources of light being eliminated by enclosing the whole in a carton paper box of thick material / ..

material. A control was also enclosed.

The apparatus was run continuously from 30/4/38 for 15 weeks and weekly germination tests were made. The results are presented in graphical form in fig.45 . Stimulation was registered over the first 6 weeks, followed by an immediate decline of about 25%.

Thereafter a quick increase followed, the germination rising to the previous height, a direct fall being again experienced.

For the radium oxide treatment, Digitaria seln.24-3 of 3/3/36 was utilized, the fruits being very lightly rubbed to remove the hairy glumes and thereafter mixed with the oxide, in which it was kept for 4½ months. The results showed that rubbing, though executed with the greatest care, inflicted so much "bruising" that an immediate rise of about 30% in germination resulted.

For the first 3½ months the treated seed remained well below, or was about equal to, the control but thereafter a sharp rise is shown, bringing the germination above the control. With the first germination test, 16 days after commencement, followed by 4 monthly tests, the treatment and control percentages were respectively 50.9 and 54.9; 39.3 and 52.6; 45.8 and 40.9; 33.2 and 45.8; 61.8 and 50.9. The results were disappointing and, apparently, few workers have studied the effects of this kind of radiation on the delayed germination of seeds. Pietruscynski (1926) found 15 minutes treatment with ultraviolet light had a favourable influence on seeds not fully after-ripened. Kamensky and Orekhova (1937) obtained favourable results with ultraviolet light on not fully after-ripened wheat and barley seeds under certain conditions; but not for certain other seeds.

(6) Oxygen pressures.

The effect of different O_2 pressures on the germinability

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of seed in a state of delayed germination was also studied. For this purpose fresh seed of <u>Sporobolus</u> ecotype A.228 and of 1 year old seed of <u>Digitaria</u> ecotype A.720 were employed. In both cases the seed was used in the conditon of (a) intact fruits, (b) intact caryopses and (c) scratched caryopses. Pressures of resp. 10, 2 0 and 60 atmospheres, each for one- and four-hour periods, were tested out, the results being tabulated below.

<u>T A B L E 20</u> : THE EFFECT OF DIFFERENT OXYGEN PRESSURES ON THE % GERMINATION OF FRESH SEED OF A <u>Sporobolus</u> ECOTYPE AND OF 1 YEAR OLD SEED OF A <u>Digitaria</u> ECOTYPE WHEN THE SEEDS WERE TREATED AS, (a) INTACT FRUITS , (b) CARYOPSES REMOVED FROM THEIR BRACTS and (c) AS FREED CARYOPSES, WITH SEED-COATS BROKEN. 2 x 25 AND 1 x 50 SEEDS WERE USED . TIME OF TEST JANUARY 1942.

Kind of seed and its pre-treatment	10 atmospheres		20 atmospheres		60 atmospheres		Control
	1 hr %	4hrs %	1 hr %	4hrs %	1 hr %	4hrs %	%
<u>Sporobolus</u> :							
(a) intact fruits	0	2	2	0	0	0	2
(b) " caryopses	0	34	0	22	2	2	4
(c) scratched "	4	6	12	4	4	10	5
<u>Digitaria</u> :							
(a) intact fruits	2	28	6	2	2	4	8
(b) " caryopses	24	34	36	26	44	28	24
(c) scratched "	70	74	62	64	52	54	64

In the case of the <u>Sporobolus</u>, in which practically all embryos and seed-coats were inhibiting germination, as shown by the controls, the intact caryopses were benefited in comparison with scratched caryopses, at the 4 hour periods of 10 and 20 atmospheres. This response is not easily accounted for. The results with the <u>Digitaria</u> would appear to indicate that also

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in this ecotype "embryo" inhibition may partly be overcome by O_2 pressures.
