STUDIES ON THE SEED-SETTING AND ON THE GERMINATION OF THE SEED, OF INDIGENOUS GRASSES, WITH PARTICULAR REFERENCE TO METHODS FOR OVERCOMING DELAYED GERMINATION.

BY

LOUIS CHRISTIAN CRONJE LIEBENBERG.

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C O N T E N T S

INTRODUCTION.

The main objective of the present studies was to investigate the potentialities of the assembled indigenous grasses from the viewpoint of their propagation by seed, when the necessity arose for their appropriate utilization in pasture development programmes. The first requirement was to give attention to seeding habits and germinability.

The work was commenced in June 1935 and was continued till the present day, with the exception of a year's interruption as a result of the writer's transfer in 1939. Being a virgin field, the prosecution of these studies were naturally attended with difficulties. The studies were pursued along lines which entertained the greatest chances of ensuring quickest results. The outcome was that a study of the causes of the delayed germination of the seed which should, logically, have been undertaken first, was only recently taken in hand.

Many researchers have given attention to the development of the seed, its physiology, histology and anatomy, and much valuable information has been accumulated on post-fertilization events, but we are still much in the dark about certain of these events, the course of which is seemingly readily influenced by environmental conditions, both external and internal. About the complex problem of embryo unpreparedness, including that of associated factors, there is even less agreement, though numerous investigators have made contributions towards the elucidation of the basic aspects of both the physiology of germination and of delayed germination. The problem is thus not only a vexed one, but, apparently, one of which the solution will depend upon the progress of our knowledge re-

garding / ..

garding the basic aspects of growth. The scope of the problem of delayed germination is an immense one, embracing the majority of the fundamental problems of plant physiology.

As only a few authors, such as Nilsson-Ehle (1909 and 1914), Deming and Robertson (1933) and Johnson (1935), have given attention to the question of the inheritance of delayed germination and allied phenomena, there is a great gap in our knowledge, but one cannot help thinking that such inheritance plays a major role and that along the line of breeding and/or selection, there is much scope for improvement. This should be borne in mind.

I.

SEED-SETTING AND GERMINATION.

A large number of native grasses have for years been assembled at the Prinshof and Rietondale stations, at Pretoria. Since it was believed that a majority of these types were low seed-setters and germinated unsatisfactorily, vegetative means were in the first instance employed in their propagation.

Slow progress was shown with this method of propagation and it became evident that it was not destined to play an important role in the development of artificial pastures, particularly when a number of promising grasses did not lend themselves to this method of propagation. As a consequence, vegetative propagation was condemned by many, an attitude which should, however, be challenged, since the slow progress was perhaps not entirely due ?? to the non-availability of seed but to a lack of knowledge regarding the correct methods of vegetative propagation.

Thus / ..

Thus far only about 10% of the indigenous genera have proved of value, or have exhibited potential economic value. These are : *Digitaria* '), *Panicum* '), *Setaria*, *Themeda*, *Cenchrus*, *Urochloa*, *Chloris*, *Paspalum*, *Brachiaria*, *Acroceras*, *Echinochloa*, *Cynodon*, *Melinis*, *Hemarthria* and *Ehrharta*. In each of the genera *Cenchrus*, *Acroceras*, *Themeda*, *Echinochloa*, *Cynodon*, *Melinis*, *Ehrharta*, *Hemarthria* and *Chloris* only about one species is concerned, whereas in each of the others several species are involved.

Seed-Setting Ability.

A good indication of the extent and variation in seed setting was first secured in a study on self-fertilization, open-fertilization and seed-setting of a number of *Digitaria* selections. In these studies, muslin sleeves were employed to cover individual heads with, these (just after flowering and before shedding) being enclosed by wire, the whole being held in a position by a dropper driven into the ground. The results are summarized in table 1.

Seed-setting, expressed as a ~~%~~ percentage of total florets, varied in the 26 selections, as shown in Table 1, from 0.16% to 37.4% and showed wide variations for the individuals of the same open-fertilized progeny. Thus, for three individuals of the progeny of Inkruip 24-3, one of the best *Digitaria* selections, the ~~%~~ percentage seed setting ~~were~~ was ± 11%, 15.9% and 37.4% under open-fertilized conditions. In the second case, however, ergot was recorded. In several instances the average number of seeds per head was larger for the self-fertilized than in the case

of / ..

') These genera require revision and as a consequence the species involved cannot be precisely defined.

of the open-fertilized heads of the same selection.

The low values for seed-setting are rather striking even though some of the best seeding ecotypes were under observation. Possibly it was too late in the season to obtain an indication of normal seed-setting because it appears to be markedly influenced by seasonal conditions, even if the disease factor be ignored. The majority of digitarias are attacked by a *Claviceps* sp. (Ergot) and they generally suffer severely towards the end of the growing season. A *Cerebella* sp. often inflicts heavy losses on *Urochloa* while another fungus ') may be responsible for a high percentage of seed infection in *Cenchrus ciliaris*.

In the 1940-41 season further studies were undertaken on the seed-yielding ability of some grasses in which were included certain selections of a *Panicum* sp. and of *Digitaria Smutsii*; of a number of ecotypes of *Digitaria*, (mainly from the N'Gamiland region), of *Chloris gayana* and of *Cenchrus ciliaris*.

TABLE 1: THE % SEED SETTING IN CERTAIN *Digitaria* SELECTIONS UNDER OPEN-FERTILIZED CONDITIONS : END 1936-37 SEASON.

Strain		No. of heads under observation	Total hermaphrodite fls. on all heads	Total seeds on enclosed heads	% seed-setting.	Average No. of seeds per head.
"Port Elizabeth"	45 - 1	4	4331	511	12.8	138
D. Smutsii	3 - 8	2	2802	55	1.96	27
do.	2 - 2	4	4167	153	3.7	38
do.	2 - 1	5	-	56	-	11
"Umflozi"	1 - 1	1	1358	16	1.2	16
do.	3 - 5	3	4189	103	2.5	34
do.	3 - 6	5	5615	252	4.60	50

"Inkruip" / ..

') The *Sphaeralcia* stage of a *Claviceps* sp.

Strain	No. of heads under observation	Total hermaphrodite fls. on all heads	Total seeds on enclosed heads	% seed-setting.	Average No. of seeds per head.
"Inkruip" 1 - 7	4	2431	24	0.85	6
do.	4	1574	38	2.1	9
31- 5 / 2 - 4	3	1294	21	1.6	7
do. 2 - 8	4	4296	21	0.5	5
do. 2 -10	3	1370	49	3.6	16
D 24 / 1	2	1796	37	2.1	18
31- 2 / 1 - 4	3	1735	40	2.3	13
15- 7 / 1 - 9	2	1436	227	15.8	113
15- 7 / 1 - 2	4	2150	244	11.6	61
15- 7 / 1 - 5	1	ca.600	119	ca.20	119
31-16 / 1 - 5	2	1253	60	0.5	30
31-16 / 1 - 3	4	2071	17	0.8	4
"Port Elizabeth" 39 - 14	7	4507	107	2.4	15
do. 45 - 2	3	1233	3	0.2	1
do. 37 - 10	4	4052	594	14.7	148
24- 3 / 2 - 1	1	1082	405	37.4	405
do. 2 - 4	2	1612	256	15.9	128
do. 2 - 12	4	1218	330	ca.11.2	82
D. 24 / 2	3	1574	57	3.6	19

Methods and Materials.

In the case of the panicums, which ordinarily shed their seeds long before the last flowers have opened, heads were enclosed as described above but soon after flowering had started and were shaken every day. This method was also adopted in the case of the D. Smutsii selections. In the remaining grasses small gauze bags were slipped over the heads after the last flowers had opened and before any shedding had occurred, the open ends being tied up to prevent the escape of seeds. The bags were not supported by wire; they were left on until the seeds were mature. This method worked very well with these

genera / ..

genera, allowing of the normal course of pollination and fertilization and facilitated normal development of caryopses.

All florets (spikelets in the case of Chloris and Cenchrus) and all seeds were counted and the number of seeds expressed as a percentage of the florets in Digitaria and Panicum and as a percentage of the spikelets in Cenchrus and Chloris as in the latter two the spikelet is composed of 2 or more florets which makes calculations on a "floret" basis impracticable. The results of these studies are recorded in table 2.

T A B L E 2 : THE PERCENTAGE SEED-SETTING OF A NUMBER OF ECO-TYPES AND SELECTIONS OF GRASSES: 1940-41 Season

Kind of Grass and/ or no (ecotype or selection).	No. of heads covered.	Range (in %) of seed-setting ability	Ave. % seed setting	Stand. Deviation.	Coeff. of variation.
Panicum Sp. ("makarikari") selections :					
14 - 17	4	45.7 - 54.8	50.0	3.98	7.88
1 - 6	4	56.8 - 84.0	71.2	11.86	16,67
2 - 14	3	21.6 - 36.0	31.3	4.87	15.55
14 - 11	5	9.8 - 18.4	13.7	4.3	31.43
2 - 23	5	60.8 - 79.3	69.3	6.75	9.73
13 - 12	4	26.7 - 42.8	35.2	7.25	20.61
11 - 4	2	41.8 - 46.6	44.2	3.39	7.68
11 - 11	5	8.0 - 22.8	15.9	5.31	33.37
15 - 5	5	15.5 - 21.6	17.6	2.44	13.88
15 - 9	4	5.0 - 12.1	7.4	3.19	42.94
12 - 6	5	0.5 - 1.6	0.8	-	-
12 - 1	1	-	48.7	-	-
Digitaria Smutsii selections :					
1 - 5/7	16	9.9 - 37.6	24.0 ')	10.75	44.75 ')
1 - 5/2		17.5 - 37.9	30.9 ')	6.27	20.27 ')

Digitaria Smutsii / ..

') These values represent results from two separate individuals in the same clone.

Kind of Grass and/or no (ecotype or selection).	No. of heads covered.	Range (in %) of seed-setting ability	Ave. % seed setting	Stand. Deviation	Coeff. of variation.
<u>Digitaria Smutsii selections: (cont.)</u>					
1 - 6	14	9.8 - 38.5	21.6	-	-
1 - 9 ")	14	13.9 - 36.6	27.5	-	-
3 - 3 ")	21	19.0 - 46.6	31.7	-	-
7 - 4 ")	9	27.7 - 39.2	32.7	-	-
13 - 14 ")	12	16.7 - 51.1	31.7	-	-
13 - 12 ")	13	22.4 - 59.6	33.8	-	-
15 - 12 ")	19	20.3 - 54.4	37.9	-	-
16 - 6 ")	16	39.5 - 54.3	47.1	-	-
16 - 12 ")	14	29.2 - 55.7	44.6	-	-
8 - 7 ")	12	25.1 - 46.7	34.7	-	-
<u>Digitaria</u> spp.:					
Mobabi Flats A.708	6	0.9 - 12.4	5.7	4.07	71.4
Zanghunpan A.616	6	63.0 - 83.8	76.5	7.29	9.52
Gomoti R. No.1 A.615	6	26.1 - 50.3	42.4	10.63	25.07
Kwaai No. 11 A.598	6	47.6 - 83.0	65.5	11.66	17.80
Nkoana Pits 5 A.594	6	5.6 - 13.3	8.3	3.46	41.68
Ngami Lake A.687	7	4.5 - 72.6	39.8	30.23	75.9
Molopo No.1 A. 38	6	10.5 - 57.3	30.1	16.73	55.58
Mobabi Flats A.717	6	19.0 - 44.6	30.8	8.88	28.83
Chobi R. A.701	7	21.4 - 84.7	49.9	22.73	45.55
Gomoti R. A.699	6	25.1 - 72.2	41.2	18.16	44.07
Gomoti No.23 A.685	5	52.3 - 90.1	68.7	16.97	24.70
Zanghunpan A.720	6	42.8 - 63.6	48.8	8.42	17.25
Rakops No.6 A.597	4	55.3 - 94.7	82.4	18.16	22.03
Kwaai No.23 A.601	6	45.2 - 81.7	68.4	12.6	18.42
Zanghunpan A.730	6	37.7 - 62.6	46.4	8.42	17.68
Rakops No. 5 A.591	6	55.9 - 82.6	71.7	9.8	13.99
Zanghunpan No.2 A.614	6	33.1 - 71.3	52.9	15.03	28.41
Umflozi, seln. 3/5	7	7.2 - 22.8	15.4	10.77	69.93
do. 3/6	6	5.1 - 14.6	11.1	10.86	97.83
do. 1/1	8	9.8 - 40.4	19.8	9.11	46.01

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<u>Chloris gayana</u> / ..

") In all these selections anything from 1 to 6 heads were enclosed in the same bag, the material from each such bag being counted together. Standard deviations could therefore not be computed for individual heads.

Kind of Grass and/or no (ecotype or selection).		No. of heads covered.	Range (in %) of seed-setting ability	Ave. % seed setting	Stand. Deviation.	Coeff. of variation
<u>Chloris gayana</u> : "')						
Et.Elim Hospital	A.367	9	10.4 - 39.8	18.1	9.16	50.6
R. No. 1 seln.	A.172	9	44.1 - 98.3	68.9	17.37	25.21
Olifants Riv.	A.202	9	61.4 - 91.7	78.6	9.79	12.45
R. No. 2 Seln.	A.174	10	40.2 - 93.2	79.4	16.5	20.88
Zebediela	A.167	9	48.1 - 90.8	73.8	19.31	26.16
"Commercial"	A.168	9	74.7 - 99.1	88.2	7.87	8.92
Greytown	A.224	10	22.2 - 72.2	52.1	17.01	32.62
Umflozi	A.245	6	44.1 - 76.3	60.0	16.01	26.66
Lorenzo Marques	A.169	8	69.1 -104.5	89.9	12.56	20.93
Nursery	A. 83	9	75.4 - 91.4	84.48	5.56	6.58
<u>Cenchrus ciliaris</u> : "')						
Hartjies Veld	A.456	9	5.1 - 41.7	20.6	12.72	61.75
Mt. Elgon	119	7	14.8 - 82.4	54.8	30.64	55.9
Groot Marico	A.557	12	37.7 - 72.4	52.5	10.72	20.41
Nursery No.12		9	12.2 - 75.4	34.7	16.85	48.55
" " 334		10	14.0 - 50.8	29.7	15.68	52.83
" " 338		10	24.2 - 73.4	39.6	15.09	38.1
" " 388		9	19.0 - 76.7	46.9	22.49	47.99
" " 339		15	1.9 - 45.2	15.4	13.52	87.79
Dodoma " 118		8	26.9 -123.0	61.5	33.45	54.39
"	A.291	7	45.2 - 94.4	68.2	17.69	25.93
Hartjies Veld	A.265	9	6.9 - 23.9	13.2	7,07	53.6
Wylliespoort	A.467	9	35.5 -129.0	64.2	31.38	48.87
Springbok Vlakte	A.211	9	14.6 - 53.2	29.0	15.49	53.26
Marico		8	49.7 -105.2	85.1	19.28	22.66
Nursery 344		8	0.0 - 19.3	8.0	7.93	99.12
" 325		9	9.1 - 40.0	21.0	17.26	82.19
" 76		8	31.0 - 86.2	58.3	19.77	33.91
Marico Seln.		7	56.8 -138.5	88.5	25.23	28.51
Nursery No.75		8	43.0 - 96.4	63.0	21.09	33.47
" " 292		8	71.6 - 95.4	80.5	7.60	9.44
<u>Brachiaria brizantha</u> :						
Weenen	A.495	9	27.3 - 47.2	37.0	7.47	20.17
Rustenburg	A.246	6	11.8 - 45.7	31.5	12.52	39.80

Discussion / ..

"') The seed-setting was computed on a spikelet basis and not on a floret basis.

Discussion.:

The *Panicum* selections exhibited a very wide range of seed-setting, which is in great contrast to the values secured for their delayed germination, as recorded below. In the case of the *D. Smutsii* selections, however, the values ~~are~~ were much lower and consequently the scope for improvement of seed production seems to be more limited.

The *Digitaria* ecotypes, on the other hand, offer good possibilities for improvement in the direction of better seeding capacity. The *C. gayana* ecotypes are, with one exception, quite good seed-setters and are on the whole appreciably better than commercial seed obtained in the trade, as revealed by our analyses. Yet if one considers that the majority of the spikelets contain 2 - 3 fertile florets, there would appear to be ample room for improvement.

The *C. ciliaris* ecotypes are somewhat disappointing, though a few of them are fairly good.

A notable feature of the results is the great variability registered in the majority, particularly in the *Cenchrus* and *Digitaria* groups. This was anticipated as preliminary studies had revealed such a condition, though it is not very clear why it should be so unless it be due to the small size of the plots and the consequent poorer chances for effective pollination. However, anthesis often appeared to be somewhat irregular on individual plants. The results nevertheless indicate that great possibilities for improvement in this respect exist.

As regards the other panicums, in general, observations indicate that, on the whole, they shed their seeds very readily and seed-setting of the various species and ecotypes vary probably fully as much as obtained in the above selections. Disease may, however, cause much loss during the latter part of the season. In connection with the digitarias , on the other

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hand, the position is a good deal less favourable than indicated by the N'Gamiland ecotypes, the performance of which, as a group, is quite unusual. The majority of the balance of the digitarias are poor seeders and from some ecotypes no seed have so far been obtained. A few have shown fair seed-setting, viz., "Port Elizabeth", "Inkruip", "Kuruman", "North Rhodesia", "Matabele Location" and Digitaria longiflora A65.

Though no actual studies were made on Acroceras macrum , the experience so far indicates that the available ecotypes of this species are very poor, with perhaps one exception and that shedding takes place soon, as with Ehrharta calycina . Similarly Paspalum scrobiculatum ecotypes appear to be fairly good seeders and this applies, on the whole, to the Urochloa spp. and ecotypes. Echinochloa and Setaria ecotypes in our possession are, in the main, very poor. Some Themeda ecotypes are fair seeders. Amongst the Sporobolus and Eragrostis spp., some of which are also attracting attention in conservation work, good seeders are to be found.

Some of the annuals, such as Urochloa helopus, Dactyloctenium aegypticum, Brachiaria isachne, Panicum laevifolium, which are pioneers under certain conditions, are quite good seeders.

Germination.

Investigations on any phase ? of germination are of little or no value unless the number of seeds used in the tests are known, as otherwise the percentage germination cannot be ascertained. A good deal of time was initially devoted to methods of cleaning seeds; that is, separating bracts (coverings) devoid of caryopses and/or removing the coverings themselves and so setting the caryopses free. An improvised blower, constructed for this purpose, proved very effective, but could only be

used / ..

used for the cleaning of seeds of grasses like <u>Panicum</u>, whereas seeds (fruit) of the digitarias, setarias etc., possessing hairs and setae could not be cleaned in this way and had therefore to be germinated in the uncleaned condition, the cleaning being accomplished on the completion of the germination test and after drying of the seeds. For this purpose a suitable method of cleaning (i.e. for removing the coverings) of the seeds had to be evolved, the procedure developed for this purpose consisting of the rubbing of the fruits between rubber surfaces to release the caryopses.

The use of transmitted light for the separation of fertile and unfertile spikelets appeared unserviceable. It was found that Concn. H_2SO_4 could be used for removal of the hairs and that after washing and drying the separation of the spikelets devoid of caryopses could be effected by blower, but though this proved useful for certain work, it could hardly be considered safe for all purposes. Even if suitable means of removing the coverings (bracts) mechanically could be found, there would still be the possibility of injury to a percentage of the caryopses.

<u>Methods employed in the germination tests.</u>

It is customary in germination tests to count out the seeds for a test, beforehand and then to place these on the particular substratum for germination. As explained immediately above, however, no satisfactory means of precleaning the seed of many of these grasses has until now been evolved. For this reason the general procedure adopted was to take a quantity of "seed" to furnish at least about 400 caryopses per test. This necessitated that a rough estimation of the seed content of every sample of seed employed should be made. On the whole, the number of caryopses used was in excess of 500. Germination

tests / ..

tests were not replicated for the majority of the studies reported; recently, however, replication was introduced. It is appreciated that without replication one has no real check on the uniformity of germination but under the circumstances this appeared to be impracticable, and, moreover, large numbers of seeds were employed. Throughout the germination tests were made in petridishes, using clean, heat-sterilized quartz sand, distilled water and filter paper as the substrate. The quantities of sand and water were measured, in order to control the moisture contents at the start. The petridishes were always placed together in the same incubator held at a constant temperature of 28°C (initially 30°C). Counts were made daily* and the moisture content adjusted at this occasion, when necessary. Before entering the tests, all lots of seed were treated with Tillitine R. Electrically controlled incubators were used throughout and for all temperatures reported a fluctuation of about 1°C above or below is to be understood. The abbreviation ca. for "circa" is therefore prefixed. Results were always based on short-period germination tests of about 10 - 14 days, according to the kind of seed employed. This was done to eliminate, as far as possible, secondary influences arising out of an extended stay on the seed-bed.

Temperatures of 28 - 30°C were employed, because too low or too high temperatures often are unfit for the majority of seeds, whilst alternating temperatures stimulate germination. Moreover, preliminary tests indicated that this range was quite satisfactory which subsequent studies have confirmed, as discussed elsewhere.

The influence of various conditions or treatments on the germination of seeds in a state of delayed germination is discussed below.

Even / ..

* This provided a reasonable check on the uniformity of germination

control?

Even and alternating temperatures.

In 1936 tests were carried out with even and alternating temperatures on about 30 kinds of seed. After employing 7 - 8 days of even temperature at ca. 30°C, the combination of 6 hours at 40°C + 17-18 hours at 30°C was introduced for 4 days. In comparison with the former conditions, the latter produced marked stimulation (table W in appendix) in the case of Sporobolus sp. G37, Dig. milanjiana D36 and Panicum sp. "makarikari" C79. Of the balance, 18 kinds showed no stimulation and the others varying amounts. After introducing the combination 6 hours at room temperature plus 18 hours at 30°C, Panicum "Makarikari" C80 showed more stimulation than C79; the rest of the kinds exhibited little or no response. After a further 4 days the combination was altered to room temperature during the day and 40 - 42°C during the night, under which conditions C80 again showed more stimulation. C79 and P. minus F14, derived more benefit than at any previous occasion. This was true of also a few other Panicum ecotypes which had not shown any stimulation previously. When, after 4 days under these conditions, 6 hours at room temperature (daytime) and 18 hours at 40°C were substituted, only D36 yielded a very distinct response.

In the following test, 6 weeks afterwards, the same combination as previously was introduced after 8 days of even temperature, giving the same response as previously, except that D36, which had now registered a much higher germination during the even temperature period (table X, appendix), did not yield the same amount of stimulation as in the previous test. For the rest, the responses were essentially the same as in the previous test and this was also true when 6 hours at room (during the day) plus 18 hours at 30°C was thereafter substituted. When, after 4 days, this was replaced by 6 hours

at / ..

at room and 18 hours at 40°, D36 did not, as in the previous monthly test, show stimulation, but F14 and G37 were now slightly benefited.

In the subsequent test, 6 weeks afterwards, C80 showed no stimulation (table Y, appendix), where in the previous tests it had shown a fair increase after substitution of the first combination of alternating temperatures. Otherwise the responses were essentially the same with this combination.

Favourable alternating temperatures during germination often yield a very marked stimulation as compared with even temperatures. Thus, for example, 1½ months after harvesting <u>Panicum</u> sp. C80 showed a 70% increase over the germination at even temperature, whereas about 6 months after harvesting the increase under the same conditions was 95%. Apparently the effect of any combination of temperatures will vary according to the stage of delayed germination. <u>Paspalum virgatum</u>, on the other hand, gave no germination during the even temperature period at 30° or the subsequent 4 days at 6 hours laboratory temperature plus 18 hours at 30°, but when this was followed by the combination 6 hours in laboratory (daytime) plus 18 hours at 40°, the delayed germination was broken to the extent of 97% within a few days.

At other times, however, little or no stimulation can be secured by alternating temperatures. Thus, for example, <u>Urochloa</u> A.182 (of 4/3/41), when set out at 20°, at 40° and at 20 - 40°, 3 months after harvesting, gave no germination. Also, <u>Digitaria</u> "Kwaai" 11 (of 30/1/41) subjected to the same conditions, 5 months after harvesting, could not be stimulated at all even though at least 50% of the embryos in the latter were ready for germination. In the former, apparently, no embryos were ready for germination, as will be observed below. It would then seem that the application of alternating temperatures, like in the case of soil, is capable of overcoming, to some extent at least,

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the seed-coat and "embryo" restrictions of only certain kinds of seed.

In studies on suitable conditions for the testing of Chloris gayana seeds, it was found that the most favourable germination, in comparison with greenhouse soil tests, was realized with a combination of 20 - 30°C at the usual periods.

Low temperatures.

Though other workers have often found prechilling and low temperatures stratification or even low temperature germination effective or partly so, even with the Gramineae, the method has so far not proved to be of much use in the present studies thus far.

Digitaria Lake N'Gami of 11/2/41 was germinated in sterilized sand of three different moisture contents viz: 70%, 50%, 40% (expressed in terms of the waterholding capacity) at 10°C, but no definite response was realized even when the petri-dishes were subsequently transferred to the 28°C incubator.

Along the same lines as immediately above, an experiment was undertaken on 7 September, 1941 with Panicum NK36 of 27/1/41 and Urochloa N183 of 24/1/41. The seeds were kept at 5°C in moist sand of varying moisture-contents for different periods and thereafter germinated at 28°C. The moisture-contents employed were 75, 100 & 125% as expressed in terms of the water-holding capacity of the sand. The data are tabulated below.

TABLE 3: SHOWING THE EFFECT OF KEEPING SEEDS OF Panicum and Urochloa AT 5°C IN STERILIZED SAND OF DIFFERENT MOISTURE-CONTENTS AND FOR VARIOUS PERIODS ON THE COURSE OF THEIR DELAYED GERMINATION. GERMINATION TESTS TEN DAYS AT 28°C.

% Germination/..

	% Germination with various periods of treatment at 5°C							
	6hrs	12hrs	24hrs	2days	7dys	14dys	4wks	6wks
			75% moisture-content:					
Panicum N36	2	4	7	32	36	55	27	
Urochloa	0	0	1	0	0	1	0	
			100% moisture-content :					
Panicum N36	0	6	8	13	40	41	13	
Urochloa	2	0	0	1	1	0	0	
			125% moisture-content :					
Panicum N36	13	5	4	23	46	44	26	
Urochloa	1	1	3	0	3	3	1	

It would appear that moisture content between 75 and 125% had little, if any, effect on the course of delayed germination of either of the two kinds of seed used. The period of low temperature treatment was, however, an important factor and it would seem that a 14 days period was quite adequate to induce the greatest stimulation under these conditions. The controls for the Panicum and Urochloa were respectively 3.5 and 0%, thus giving a maximum stimulation of about 50% with the former.

Light.

The effect of light on germination has received much attention and that it may be an important factor in germination in isolated cases, is revealed by the undermentioned studies.

Panicum coloratum C99, was observed to respond well to conditions in front of a west-facing laboratory window, after the usual germination at ca.30°C in a dark incubator. As light seemed to be responsible for this favourable influence, seed of this ecotype was subjected to alternate light and dark treatments (where A = the petridish started off with light treatment and B = the petridish started off with dark treatment, black photographic paper being used to obtain darkness). The test

was / ..

was conducted in front of the same window, giving the following germination percentages :-

TABLE 4 : THE EFFECT OF ALTERNATING LIGHT AND DARK TREATMENTS (DURING THE PERIOD OF GERMINATION) ON THE GERMINATION OF *Panicum* ECOTYPE C99 OF 6/3/36.

	First 12 days	subsequent 12 days	subsequent 16 days	Foll. 13 days	Next 5 days	Total %
in light:	A 6.2%	B 21.8%	1.8%	A 10.4%	B 0.5%	A65.7%
in dark :	B47.2%	A 40.5%	4.3%	B 2.1%	A 4.3%	B73.4%

Darkness was better than 'light' to the extent of approximately 40% (first 12 days results), the latter, contrary to expectation, almost completely inhibiting germination. Incidentally the control in the incubator also gave ca.40%, which would appear to indicate that the illumination received during the periods when daily counts were made, had little, if any, effect on the germination capacity. The original favourable response was most probably due to temperature fluctuations.

The results further show the sensitivity of seeds to such influence, particularly when on the seedbed and whilst in the condition of delayed germination. An attempt is always made to expose seeds (in the petridishes) as little as possible, when seedlings are counted out, in order to obviate light and temperature influences as much as possible.

Light and KNO_3.

Owing to the need for more information about light influence on the seed of native grasses, further tests with several kinds of seed were undertaken the results of which appear in the table below.

TABLE 5/..

T A B L E 5 : THE EFFECT OF LIGHT AND KNO_3 (0.2%) ON THE GERMINATION OF VARIOUS KINDS OF SEED WHEN KEPT AT ROOM TEMPERATURE IN FRONT OF A SOUTH-FACING WINDOW. "DARK" DISHES WERE NOT OPENED UNTIL COMPLETION OF THE TEST. (The values in brackets are those obtained a fortnight earlier when the seeds were germinated in the greenhouse and the "dark" dishes were opened 3 times for counting during the test). 2 x 100 SEEDS PER TEST WERE USED ; DATE OF TEST 4/10/41.

Kind of grass; plot no; date of harvesting	Control at 28°C	Light plus Water	Dark plus Water	Light plus KNO_3	Dark plus KNO_3
<u>Panicum</u> <u>leavifolium</u>	- 4	18.5	36.0	63.3	20.5
N.K. 36; 3/2/41		(22.3)	(41.3)	(68.3)	(14.6)
<u>Panicum</u> sp.	- 6	18.8	43.0	14.5	31.3
A 146; 24/1/41		(21.3)	(44.8)	(41.5)	(24.6)
<u>P. scrobiculatum</u>	- 0	1.31	23.3	19.0	29.3
A 275; 25/1/41		(1.8)	(26.6)	(19.0)	(25.3)
<u>P. notatum</u>	1 -	-	-	-	-
A 240; 27/1/41		(0)	(0)	(5.0)	(10.6)
<u>Brachiaria</u> <u>brizantha</u>	0.5	-	-	-	-
A 259; 24/1/41		(0)	(0)	(0)	(0)
<u>Urochloa</u> sp.	0.75	-	-	-	-
N.K. 85; 24/1/41		(0)	(2.8)	(8.3)	(2.5)

The above results obtained under room and glasshouse conditions indicate that illumination may play an important role, in the germination of seeds which exhibit delayed germination...On a sand-water seedbed (in petridishes), darkness increases the germination of three out of the six kinds very appreciably or, in other words, light reduces or partly inhibits germination. It is, therefore, not unlikely that the phenomenon is widespread in the seed of our native grasses. The more

extreme/ ..

extreme conditions in the greenhouse, in respect to temperature range, have apparently slightly increased germination, even for the dark treatments, which, if anything, should have shown lower values because they were opened three times for counting.

With a sand - KNO_3 seedbed the position is very different and the response no longer consistent. P. laevifolium now shows about the same germination in the dark as with water in light, whereas with light the germinability rises over 43%. That means, KNO_3 is harmful in dark and stimulating in light. With the Panicum A146, KNO_3 is harmful in both light and dark but more so with the former, though not so harmful as with light and water. With P. scrobiculatum , on the other hand, KNO_3 in dark is about equal to water plus dark, but with light it is not as harmful as is water plus light. The above differences obtained for P.laevifolium and Panicum sp.A146 were later (three months afterwards) found to be largely obliterated when the seed-coats were broken before the application of the same treatment.

In order to find out whether soaking in water and subsequent germination in KNO_3, or soaking in KNO_3 and germination in water will have any value for seeds which are in the condition of delayed germination, 2 ecotypes of Digitaria were soaked for 2, 6, 12 and 24 hours in both of the above series and thereafter germinated in the two respective media. The outcome of this experiment was that there was little in favour of any of the treatments for the promotion of germination of either of the ecotypes.

The breaking of seed-coats was studied in relation to light-, darkness-, water-, KNO_3- treatment, using P. maximum N.K.122 of 18/1/41 and P. laevifolium N.K.36 of 3/2/41. The comparison was made in October 1941 and January 1942 respectively. The controls at 28°C were 8.5% and 11.5% respectively.

T A B L E 6/ ..

TABLE 6: THE EFFECT OF BREAKING OF SEED-COATS ON THE GERMINATION OF P. maximum N.K.122 AND P. laevifolium, N.K.36 WITH LIGHT-DARK AND KNO_3-WATER TREATMENTS.

		Light Water	Dark Water	Light KNO_3	Dark KNO_3
P. maximum;	seed-coats broken	15.0	8.0	4.5	23.0
do	normal fruits	18.5	25.0	19.0	11.0
P. laevifolium;	seed-coats broken	78.0	82.0	90.0	74.0
do.	normal fruits	10.0	10.0	40.0	26.0
	previous exp.	18.5	36.0	63.3	20.5

With the seed of the N.K.122 ecotype, tested at room temperature, breaking of the seed-coats was apparently harmful with dark plus water and light plus KNO_3; but favourable with dark plus KNO_3. On the other hand, with the seed of the N.K.36 ecotype, tested at 28°C, all treatments were favourable with breaking of the seed-coats, the best one appearing to be light plus KNO_3. In the latter line of seed there was a tendency for the differences shown with the germination of normal fruits to become obliterated by the breaking of the seed-coats. In this case the delayed germination was largely due to the restrictions imposed by the seed-coats. In the other line of seed, however, the 'embryo' factor was the main cause of the delay and here the responses were not in the same direction. proof?

From the above it would appear that illumination employed in these studies, may be an important factor in the germination of the seed of indigenous grasses, and is a factor to be reckoned with in any studies on the problem and condition of delayed germination, in order to obviate any unwarranted conclusions.

Light and other salts.

The value of $MgCl_2$, $MgSO_4$ and $NaNO_3$ as media in concentrations /

concentrations of 0.2% (solutions) was studied with seed of Brachiaria brizantha A.259 of 24/1/41, and Urochloa A.183 of 27/1/41. In all but the Setaria, the controls with water in dark registered under 1%. The Setaria showed in the dark with water, $MgSO_4$, $NaNO_3$ and $MgCl_2$ resp. 52.5, 49.75, 34.0 and 51.5%, whilst in light the values were resp. 68.0, 60.75, 69.5 and 69.25%. These results would tend to indicate that light was more favourable than dark, for this kind of seed, not only when water was used as a medium, but also in the case of the salts employed, but that in light $NaNO_3$ was distinctly harmful. The salts are therefore no better than water. The experiment was conducted over the period October-November 1941.

The influence of seed-coverings on germination.

In Chapter 2 the influence of coverings in relation to the breaking of the seed-coats will receive attention and it only remains to note the effects of the removal of the coverings (paleae, etc.) on the immediate course of germination. As the caryopses of Chloris gayana are not tightly enclosed by their coverings and therefore easily removed without injury, the experiment was conducted with seeds of this species, the result being that the immediate effect brought an increase in germination of about 11% with this ecotype.

The removal of coverings was also attempted for other genera, but owing to the difficulty of removing caryopses without injuring the seed-coats, these results cannot be considered as reliable, although large increases were registered in a few cases. However, at other occasions, Chloris gayana ecotypes showed differences of 23% in favour of the removal of caryopses, whilst Sporobolus ecotypes, in which caryopses are readily set free without injury, 4% was the maximum difference registered.

S u m m a r y .

The following is a summary of the above studies :-

1. Seed-setting was studied in a number of ecotypes and selections by enclosing individual heads and not by harvesting of individual plots, as the latter was impracticable It was computed as a percentage of the number of spikelets per head, so that where there is only one floret per spikelet (e.g. Digitaria), the values are on a floret basis.

2. Great variation in seed-setting ~~is~~ exhibited (in certain groups studied,more than in others) not only within the same exotype, but also within the same species and within the genus (between spp. of the same genus). Climatological influences would appear to be important in seed-setting.

3. Excellent seed-setting ~~is~~ exhibited by certain of the Digitaria ecotypes studied, as also by certain of the selections of the 'Makarikari' ecotype of Panicum coloratum and by certain ecotypes of Chloris gayana and Cenchrus ciliaris.

4. Good seed-setting ~~is~~ not always associated with the best growth habits, but from a practical standpoint, there is, on the whole, good scope for improvement.

5. The effects of various treatments and conditions on the germination of non-afterripened seed were studied.

6. All even temperatures so far studied, were ineffective to bring about anywhere near complete germination of seed in the condition of delayed germination and at best only presented an evaluation of the condition of delayed germination.

7. On the other hand, alternating temperatures may bring about

a marked / ..

- 24 -

a marked increase in germination of such seed, in some cases almost amounting to complete germination. The requirements in this respect varied for different kinds of seed.

8. Low temperatures of 15 or 20°C were so far not found to be effective for inducing germination, though it may be useful for cereals, etc. Even when the moisture content of the seed-bed (sand) was varied at the former temperature, the conditions were ineffective.

9. Precooling at 5°C, for definite periods, appears to be a much more effective method of inducing germination, though that may only be true of the seed of certain lines. The moisture content of the seed-bed would appear to have little or no effect on the course of germination.

10. Light has a very important effect on the germination of, apparently, an appreciable percentage of the seeds of indigenous grasses, the majority, however, appearing not to be much affected by light or darkness. The sensitivity varied according to the ecotype, some being sensitive to light, others to dark.

11. KNO_3 and, to some extent, other salts, may have a very favourable effect on germination, but such effects may be influenced by light and dark.

12. Breaking of the seed-coats tends to obliterate the differential effects of light-dark and KNO_3-water treatments in the one line of seed used, but not in the other.

13. The influence of seed-coverings (bracts) on the course of germination is reported, it being shown that this may [illegible] about appreciable differences.

II. / ..

II .

THE PROBLEM OF DELAYED GERMINATION AND THE EXTENT AND DISTRIBUTION OF THE PHENOMENA ASSOCIATED THEREWITH IN INDIGENOUS GRASSES.

The scope / ..

The Scope of the Problem as revealed by the Literature.

The literature on germination is a voluminous one. That part dealing with the Gramineae has received attention from Lehmann and Aichele in an excellent treatise published in 1931, in which the literature was very fully dealt with. Despite the results of numerous investigations, the story of the development of seed from a condition of rest or inactivity into one of activity, and so into a seedling, is as yet an incoherent one. So early as 1908 Ewart (in referring to longevity) stated that probably few sections of human knowledge contain a larger percentage of contradictory, incorrect and misleading observations, than are to be found in the works dealing with seed longevity. Perhaps he was overcritical, yet after a lapse of over thirty years the position in regard to the various phases of the subject is little different and botanical science is still unable to present a coherent story. Whether this must be interpreted as signifying that in different kinds of seed different patterns or orders of complex activities are or are not involved, or whether the pattern is, within the group of seed plants, essentially the same, differing only in the lesser features, will still have to be elucidated. One fact, however, is apparent : a seed is a very sensitive organism, readily reacting to, and influenced by, environmental conditions, not only during its period of dependence but also during its independent existence. This being so, it is only natural that our efforts to learn more about the biology of seeds, tend to be confused by external factors.

By delayed germination is implied the inability of seeds to germinate naturally when vegetative maturity has been attained. Other terms employed are : aftermaturation, after-

ripening / ..

ripening, dormancy, rest period; in German :"Nachreife", "Keimruhe" and "Samenruhe". But any term implying a degree of ripeness or "Reife" or that of rest must be, in a sense, inappropriate and therefore the general term of delayed germination, is here adopted.

The occurence of delayed germination in cultivated and wild species.

Delayed germination is ordinarily not a serious problem with agricultural seeds but it is nevertheless present in varying degrees in most, if not all, crop seeds under certain conditions and has received the attention of workers in all parts of the world. Lehmann and Aichele (1931) have catalogued this information for individual cultivated genera belonging to the Gramineae. In the case of other cultivated genera, fruit trees and forest trees, one can mention studies by such workers as Lakon (1911, *Fraxinus* and *Pinus*), Davis and Rose (1912, *Crataegus*), Rose (1915, *Delphinium*, snapdragon), Larsen (1925, white pine), Joseph (1929, *Betula*), Davis (1930, *Ambrosia*), Crocker and Barton (1931, rosaceous seeds), Borthwick (1931, carrots), Flemion (1931, *Sorbus*), Giersbach and Crocker (1932, wild plum), Haut (1932, apple, peach and cherry), Kearns and Toole (1932, *Festuca* spp.), Steinbauer (1932, artichokes), Steinbauer and Steinbauer (1932, elm), Barton (1934, *Tilia*), Flemion (1934, *Symphoricarpus*), Schroeder (1935, *Benzoin*), Simpson (1935, cotton), Thompson (1935, lettuce), Flemion (1937, grape seeds), Odland (1938, cucurbits), Watts (1938, cucumber), Riccharia and Dhodapkar (1939, *Sesamum*), Smith (1939, *Humulus*), Choate (1940, *Echinocystis*).

That delayed germination probably has an important role to fulfill in nature, can not be disputed and where breeding methods have tended to eliminate it entirely, it has led to such phenomena as after-harvest sprouting. With apparently a

few / ..

few exceptions, the seeds of wild species always show some degree of delayed germination, which may take several years to overcome and the behaviour of our indigeneous grasses in this respect is therefore, unfortunately for our pasture development, no exception. In America the results of investigations by Howard (1915), Dahlberg (1917), Mitchell (1926), Adams (1927), Jackson (1928), Fivaz (1931), Nichols (1934), Ransom (1935), Blake (1935), Barton (1936), Griswold (1936), Wilkinson and Stoddart (1938), Burton (1939), Toole (1939), Pladeck (1940), Toole (1940), Toole and Toole (1940), Toole (1941), Wengar (1941) and some others; in Europe, those of Wiesner (1894) and (1898), Niethammer (1927), Bihlmeier (1928), Niethammer (1929), Dörfel (1930) and others, have demonstrated the wide-spread nature of the phenomenon of delayed germination.

In South Africa little work has been done on germination in general and on that of wild species. Henrici (1935) and (1939) has reported on the germination of Karroo-bush seeds, including a number of species of compositae in which after-ripening was recorded for all species, being very prolonged in some cases. Levyns (1935) studied 3 spp., recording after-ripening in *Elytropappus rhinocerotis*, and delayed germination in *Anthospermum aethiopicum* and *Relhania genistaefolia*. Gill (1931) has reported on the now well-known delayed germination in *Paspalum dilatatum*.

The 'hard seed' problem.

In connection with 'hard' seeds in the Leguminosae, a phenomenon which is responsible for delayed germination, an extensive literature has accumulated and it is interesting to note that here, where the delay in germination is apparently a very simple one, viz., the impermeability of the seed-coat to water, there is no agreement on the fundamental cause thereof, though some very

good/

good papers have been published on the subject, the results of which have an important bearing on the major problem of the present studies. Harrington (1916) summarized the occurrence of hard seeds in cultivated species.

The factors of importance are :- to what is the impermeability of the testa to be attributed; by what means can this be overcome or lessened; what conditions, after harvesting, bring about, reduce, intensify or tend to intensify hardness ; and, finally, how can this knowledge be applied to the problem under discussion.

To the general question of permeability and semi-permeability attention will be given further on; here it may be stated that the structure of the testa of leguminous plant has received attention from such workers as Malpigh (1687), Pammel (1899), Bergtheil and Day (1907), Ewart (in collaboration with Miss White, 1908), Coe and Martin (1922), Lute (1928), Zimmermann (1937) who quotes: Sempolowski (1874), Beck (1878), Mattirolo and Buscalioni (1892), Möller-Griebel (1928) and Netolitzky (1926). From outside inwards the normal cross-section of a leguminous seed shows a cuticle, a cuticular layer, a palisade layer or Malpighian layer, an osteosclerid cell layer the whole combination constituting the testa, which is underlaid by parenchyma cells (nutrient layer). The developmental history of the strophiolum has received little attention, though Zimmermann (1937) studied that of 4 species belonging to the 4 genera Lathyrus, Phaseolus, Melilotus and Lupinus. This, as well as the anatomic studies of 19 other spp. revealed 6 types o anatomic differences, but a relation between anatomic structure of the strophiole and hardness could not be established. Also, testa thickness was investigated for 19 spp. and a relationship traced between thickness and hardness. Three types of anatomic differences of the palisade layer were evident. Though in the

24 spp. / ..

24 spp. (14 genera) of Papilionatae studied by him, one type was always associated with soft seeds, the other two types included both permeable and impermeable seeds.

Ippolito (1905) and Hiltner and Kinzel (1906), according to Zimmermann (1937), regarded the light-line of the Malpighian cells as the seat of impermeability. Similarly, Coe and Martin (1922) and Martin (1922) attributed impermeability to this region, though the work of Junowicz (1877), as reported by Zimmermann (1937), of Kühn (1925) and of Lute (1928) tend to discredit this view. The latter worker, studying Lupinus angustifolius, found the impermeable region to be located in the lower parts of the palisade cells. Lute (1928) similarly traced the cause (in lucérne) to the Malpighian cells. Nelson (1924) thought that hardness was due to a varnish-like deposition on the seed surface produced within and by the pod. Schmidt (1925) likewise believed the cause to be that of the outer covering of the coat, which he thought was a waxy substance, one layer in lucerne and 2 layers in sweet clover. Bergtheil and Day (1907) working with Indigofera arrecta traced the impermeability to the cuticle and (according to Zimmermann) this view was held by Wübbena (1899). Ewart (in collaboration with Miss White, 1908) found in a large number of seeds that a thin membrane was always present and that it contained a material known as 'cutiole', which material may also be laid down in the walls of the palisade cells. This 'cuticle' (Rees 1910) is "believed to be formed by the laying down of particles of waxy or fatty substances in the already existing cell wall".

Von Höhnel (1875) - according to Zimmermann (1937) - found a higher concentration of silicic acid in the palisade layer of hard seeds. Physical factors were, however, held responsible by Lakon (1914). Puchner (1915) and Nilsson (1926), as cited by Zimmermann. Thus, through dessication of the seed-coats the palisade cells would press against each other so strongly that water can not pass through. Kühn (1925) found in the lower parts of the palisade cells abundant pectin which he considered with drying out to assume a condition in which swelling was impossible. Zimmermann (1937) also noted this pectin accumulation in 13 spp. studied and he thought that with drying this colloidal pectin falls out and so could cause difficulty of swelling. Hamly (1932) studied the testa of <u>Melilotus</u> michrochemically and found that the impermeable region was due to a layer of tightly appressed suberin caps.

Hamly (1932) reported softseededness in <u>Melilotus alba</u> to be irreversible, the permeability occuring through the opening of a cleft at the strophiole. This cleft could be produced mechanically or by moderate heating. Contrary to this view, is that of Behrens (1934), Esdorn (1930) and Stutz (after Zimmermann) (1933), of the reversibility of hardseededness of the material and conditions under which they worked.

Many treatments have been tried for hard seeds. Scratching or breaking the seed coat is always effective and therefore mechanical scarification is, as far as possible always adopted. Chemically this is generally accomplished by sulphuric acid, though Rees (1910) claims that the waxy material of the cuticle was effectively removed by chloroform, whilst Gehlsen (1931) found HCl and H_2O_2 in several concentrations, efficient. As regards physical means, many methods have been found useful. For example, Rivera et al (1937) found high hydrostatic pressure as a rule effective. Davies (1928) reported high pressure for 1 minute effective with <u>Medicago</u>. Midgley (1926) found dry or moist freezing or moist storage effective for lucerne; also Rodriguez (1924) found freezing (dry and wet) fairly effective for lucerne. Hiltner and Kinzel (1906), Schneider - Orelli (1910), also - according to Whitcomb(1931)- Stevens and Campbell (1912), Staker (1925), Stewart (1926), Jones (1928). Lute (1928) found heat, usually dry, an efficient means of overcoming impermeability, often to a very large extent. Boiling water treatment or live steam has been successfully employed by Stevens and Campbell (1912), Schmidt (1924) and others.

Many workers have studied the conditions which affect impermeability favourably or unfavourably. Thus Behrens (1934) established a rhythm in regard to hardness of seed-coat which followed more or less closely the periodic annual fluctuation of absolute air moisture. Bredemann (1931) found that in Lupinus luteus the seeds became hard after harvest, this being governed by absolute atmospheric moisture and temperature. Harrington (1916), Witte (1931), Gadd (1938) and others have found that seeds forming during favourable seasons contain 100% hard seeds. Gadd (1938) further found that heat favoured softening of lucerne seed whilst red clover seed softened better under conditions of cold, if not particularly moist. By freezing at the temperature of liquid air, Busse (1930) made sweet clover and lucerne permeable. Zenari (1928) found impermeability to be influenced by climate and soil.

The problem of permeability.

The problem of delayed germination in seeds, apart from that of legumes, is one which assumes wide proportions, for not only is it one which is concerned with the much studied and vexed question of semipermeability of seed- and fruit-coats but also that of immaturity and growth inability of the embryo as well as the availability of nutrients; of activation or inactivation of reserves, including growth substances and enzymatic activity.

Giglioli / ..

Giglioli (1895) reported on vitality of lucerne and other seeds stored for over 16 years in alcohol, gases etc., whereby the selective permeability was demonstrated. Dixon (1901) confirmed this but A.J.Brown (1907) was the first to discover and study the semi-permeable membrane in barley etc., and this he found to be the spermoderm (remains of ovular integuments together with the outer layer of nucellar tissue). Schroeder (1911) confirmed this for wheat as far as penetration of chemicals was concerned. He suggested that absorption was exclusively at the embryo, with the subsequent spread within the semi-permeable envelope of the grain. Brown suspected the nucellus epidermis, Schroeder, however, found a typical cellulose reaction for it. "Später stellte er in Verbindung mit Koller(1921) fest, dass die nuzellarepidermis in gequollenem Zustand völlig permeabil ist. Dagegen wird das als kutinisiert erkannte innere Integument als semipermeable Membran angesprochen. Diese Meinung wurde auch durch weitere Untersuchungen immer bekräftigt." (Lehmann und Aichele). Atkins (1909) (after Shull 1913) failed to find selective permeability in the coat of the bean. Reichard (1912), studying the testa of barley, attributed much importance to tannin or tannin-rich compounds, which, under the influence of chemical agents, were considered to pass from a sol into gel condition and back under certain conditions. He stated that this is similar to the Lloyd concept of a tannin-colloid complex. Becquerel (1907) (after Shull 1913), showed that thoroughly dried seed-coats of certain plants were impervious to various gases and to such penetrating substances as absolute alcohol, ether and chloroform. Shull (1913) gave a list of species he reported as possessing semi-permeable membrames. Studying <u>Xanthium</u> seed, he could confirm Becquerel's results; the dry seed-coats have a selective semipermeability, no evidence being, however, obtained for the diffusion of O_2 through absolute dry seed-coats. Selective acti-

vity / ..

vity, as was found by Brown and Schroeder, was not determined by any living substance in the coat. The testa, 3 layers thick, had an inner layer of nearly pure cellulose, unsuberized, perhaps containing tannin, but the middle one containing more tannin. Semi-permeability was demonstrated for seed-coats of plants in 6 families and many dead membranes possessed this property. He (1914) has also shown that permeability to gases probably also plays a role, for by increasing O_2 pressure, increased absorption and immediate germination resulted.

Nilsson-Ehle (1914) found that germination of white and red varieties of wheat to be associated, in some way, with the pigment of the testa, red varieties being less permeable to water. He could establish that the testa consists of 2 independent membranes (derived from the inner integuments of which the inner one contains the pigment) which was later confirmed by Zeuschner (1926) and Krauss (1933).

Atwood (1914) in summing up his physiological study on the germination of Avena fatua, stated that the data seemed to point to an increased permeability of the seed-coat to oxygen, accompanied by an increased water-absorbing power of the embryo, as constituting afterripening. Verschaffelt (1912) studied the relative permeability to water and other liquids of different areas of the seed-coats of a large number of plants which produce impermeable seeds. Such a semi-permeable membrane was reported for rice by Valeton (1907) and Nagai (1916); also for maize by the latter author (after Lehmann and Aichele).

After investigating the velocity of water intake, Shull (1920) claimed that his results contradict those of Brown and Worley (1912) and moreover, believed that the results indicate that absorption involves both physical and chemical changes, the latter being mainly due to the colloids and that semi-permeability as such was thought not to be an important

factor / ..

factor. Denny (1917) studied the role of different substances in seed-coats in regulating their permeability to water. Employing various solvents to extract the membranes, the effect on permeability could be compared before and after such treatments. The results were most interesting. Extraction with hot lipoid solvents and acetone at room temperature resulted in an increased permeability of all seed-coats except that of grape-fruit seeds. Hot-water extraction increased permeability of peanut - the tannins and part of the lipoid materials being removed - and almond seed-coats, though that of grape-fruit and squash seeds were not measurably increased. $CaCl_2$ treatments increased permeability of the membranes. Permeability of membranes to water was determined by lipoids, tannins and pectic substances, though "suberized layers were not found to be significant". Denny (1917) also studied the permeability of several plant membranes (seed-coats) to water, including the effect of temperature, and, amongst others, found no evidence that either chemical or physical processes were exclusively involved in the passage of water.

Collins (1918), after studying the structure of the integumentary system of the barley grain, in relation to the localized water absorption and semi-permeability, came to the following very interesting and pertinent conclusion:- Only a small part of the water absorbed by the grain "when steeped in various solutions, enters by the general surface ....which is invested by 3 layers of cuticularized cell wall". Special spots for the entry of water (and this is true of the passage of the bulk of such solutes as iodine and acetic acid) occurred in the germinal region of the grain and "here must be sought the structure which is the seat of the remarkable selective permeability which keeps out mineral acids and most salts whilst passing water with considerable freedom". Further, "the

barley / ..

barley grain does not appear to possess perfect impermeability to any solute .... It is at the outer cuticularized wall of the tegmen that the recorded arrest of silver nitrate and sodium chloride penetration takes place. This cuticularized membrane is permeable to water and solutes only to the extent usually associated with the cuticle...... The initial uptake of water supplies the need of the embryo ...... The subsequent distribution of liquid in the endosperm is precisely the path of enzyme disintegration within the endosperm during the germination of the embryo. "

Harrington and Crocker (1923), studying the pericarp and integument of Johnson grass, found penetrant solutes entered much more readily at the proximal end of the caryopsis, probably through the hilar oriface, than elsewhere and spread laterally and distally under the seed-coat. The inner integument and various pericarp layers contained tannin compounds, all were highly suberized especially the inner wall of the inner integument which consisted of suberin impregnated with fats and to which resistance to chromic acid was due. They considered that these substances diminish extensibility of membranes and permeability to solutes. "Dormancy was due to pericarp and inner integument which, if broken, destroys sensitiveness to alternate temperatures".

Shull and Shull (1924) and Beeskow (1924) (after Tharp 1935) found that the diffusion of permeable solutes (iodine) through the vestments over the endosperm of the maize kernel was faster than any spread within. Orton (1927) observed that relative permeability of maize varieties differed for several mercurial solutes in aqueous solution. Freiberg (1931) - cited by Krauss (1933) - found water intake in maize to take place equally over the whole surface but swelling ability was higher at the micropyle end as compared with the chalaza

region / ..

region. Soaking rice in solutions of different salts, Masabuti (1927) noted that delay in germination was proportional to concentration of the salts, these and other results being interpreted upon the basis of the semi-permeable nature of the seed-coats.

Zeuschner (1926) studied the thickness of testa and pericarp of wheat varieties but found no correlation between coat thickness and germination speed or treatment sensitivity, though the layers of the inner integument formed a selective permeable membrane. Penetration was not the same at all points of the grain surface. Gurewitsch (1929) after studying the permeability of the selective membrane of the wheat grain, postulated the membrane as being a hydrophylic gel with micellar structure, electrolytes and water passing through the intermicellar spaces (the size depending upon the condition of swelling and thus upon ion composition and concentration), and organic dyes, etc. (which permeate readily), through the micellae themselves. The vestments of the grain were completely impermeable in the unswollen condition because of the cutin-free cellulose layer, which apparently only permits the intermicellar passage of substances.

Swanson (1928) reported on anatomic structure of the seed-coats of <u>Sorghum</u>. Andersen (1927) after studying the development of gametophyte and caryopsis of <u>Poa</u>, reported that the inner layer of the inner integument consists of a comparatively thin layer of suberin, the outer integument being represented by a thick layer of the same material.

R.Brown (1931), after investigating the absorption of water by <u>Lolium perenne</u> and other gramineae, found that the cuticular membranes of the seed retarded absorption of water but the permeability was increased by the stretching of the cuticle consequent upon swelling. The earliest absorption took place

through / ..

through the micropyle from where diffusion took place upwards to a certain extent, thus causing the endosperm to swell at this higher level, which in turn induced stretching and greater permeability of cuticular membranes. Thus there was a progressive extension upwards of the area of absorption. In 1932 the latter process was further reported for wheat, in which it was found that the semi-permeable region was composed of 2 cuticle-like membranes enclosing a single mucilaginous testa. Non-electrolytes with small molecules passed through but the passage of electrolytes and solutes with large molecules was retarded; after 60 hours, however, permeability increased suddenly. As absorption could be expressed by the Freundlich absorption equation, it was suggested that diffusion of electrolytes is retarded by processes of absorption and that when absorption is complete, the membranes become more freely permeable. Kisser and Lettmayr (1934) studied the absorption of certain salts by the separated seed-coats of wheat, the retention depending upon the salt and its concentration.

Pugh and Johan (1932) also studied the development of the caryopses of wheat, in relation to infection by <u>Gibberella saubinetti</u> and found the testa to completely envelop the seed except at the micropyle and at the groove region. The presence of suberin-like or cutin-like substances were indicated.

Krauss (1933) studied the developmental history of <u>Hordeum</u>, <u>Triticum</u>, <u>Bromus</u> and <u>Poa</u>, with special reference to their testa. Over the embryo of these grains the pericarp lacked the outer cuticle. "As found by Nilsson-Ehle (1914) for wheat, the testa showed no visible differences over the embryo and the rest of the caryopses. This also applies, according to our studies, for the greater part of the testa covering the embryo, with the exception of two points .... the micropyle

and / ..

and the hilar orifice". (Structural variations over the micropylar regions were recorded). It is stated that in agreement with the views of Collins (1918) and Harrington and Crocker (1923), regarding Gramineae caryopses and of Netolitzky (1926) of angiosperm seeds in general, she also is convinced, on the strength of the anatomic studies of the testa, that the abovementioned points are to be looked upon as preferred entrance spots. The results of Schroeder (1911), Nilsson Ehle (1914), Zeuschner (1926) and Scheibe (1930) on the faster penetration of water and iodine solution in the neighbourhood of the embryos of cereal grains, as well as that of Gassner (1915) for Chloris ciliata, is recalled by the author.

Tharp (1935) also investigated the developmental anatomy and permeability of barley seed-coats and found that "the selective semi-permeable envelope has been identified as the persistent, crushed and cutinised inner integument together with the suberized resistant tissue of the chalaza". The inner integument, the thickness of which varied at various parts of the grain, consisted of a thin inner cutin membrane and a much thicker outer cutin layer of variable thickness. The thickness of these membranes varied with the variety and so did the degree of permeability. A wet environment during maturation and premature harvesting tended to induce a decreased resistance to permeation. The heavier cutin layer and the heavier deposits of fat substances in the integument cells seemed to be correlated with decreased permeability. "It is entirely probable that not only is there an initial point of rapid permeation (the micropyle) but there is also a gradient of the seed-coats to permeation with the stretching and swelling resultant from the early basal absorption assisting in the progressive apicalward permeation and absorption by the grain". Johnson (1935) claimed that results obtained in the study of the physiology of delayed germination of *Avena fatua* point to the probability that the enveloping coats (pericarp and testa) of *Avena fatua* cause delayed germination by restricting O_2 supply to the embryo.

R. Brown (1940) investigated the seed-coat permeability of *Cucurbita pepo* to gases and established that the inner of the two seed-coat membranes controlled the gas exchange as the outer was perforated by the micropyle and that its permeability to gases was increased by absorption of water.

The role of seed-coats in delayed germination.

That the permeability of the seed-coverings play an important role in delayed germination may be further demonstrated by the following specific cases. Flemion (1931) reported that in *Sorbus aucuparia* seed-coats played a role in after-maturation of the embryos. Crocker (1907) found that the seed-coat played a part in the after-maturation of several water plants. Davis and Rose (1912) observed a similar state of affairs for *Crataegus mollis*. Davis (1925) found delayed germination of *Sphaeralcia remota* to be due to an impermeable cuticle. Flemion (1933-34) confirmed this for *Rhodotypos kerrioides* and *Symphoricarpus racemosus* seeds respectively. Also Giersbach and Crocker (1932, for wild plum seeds) and Giersbach (1934, for *Cotoneaster* spp.) established an additional seed-coat delay, whereas Spaeth (1934) found the water-impermeable testa a primary cause of dormancy in *Tilia* seeds, which was confirmed by Barton (1934). Stoddart and Wilkinson (1938) established that long delayed germination of *Oryzopsis hymenoides* was due to the firm seed-coats prohibiting germination.

Toole (1939), after studying *Danthonia spicata*, considered that the seed-coat was the only inhibiting factor in delayed germination, restricting gas exchange. Watts (1938) found the rest period of cucumber seed to be effectively broken by coat removal. Heinisch (1937) obtained complete germination

[illegible]

when fresh seed of barley, oats and wheat were decorticated. The results of Goika (1940) confirmed this for certain barleys.

That the encasing structures occasionally play a role besides those of restricting water intake or gas exchange, has been reported by certain workers. Crocker (1916) quoted Müller (1914) as having shown that the force of the expanding contents is not sufficient to rupture the coats. Crocker and Davis (1914) also claimed that in Alisma plantago the imbibitional and osmotic forces ~~are~~ were not large enough to break the testa. Rose (1919) considered that in Rubus after-ripening was probably due to the high breaking strength of the endocarp. Hart (1928) considered that studies on Celastrus scandens favoured the view that dormancy was partly due to mechanical restraint exerted by the seed-coat.

The role of the embryo in delayed germination.

Many cases in which the embryo has been found to be associated with delayed germination, in addition to those mentioned above, have been investigated. Goebel (1905), P.249, ~~makes~~ made reference to cases of incomplete embryos. Lakon (1911) found Fraxinus excelsior embryos were mature but undersized so that "Vorkeimung" ~~is~~ was necessary before germination ~~can~~ could take place, during which time the mucilagenous substances ~~are~~ were depleted (after Eckerson 1913). Fundeis (1917) and Steinbauer (1937) also established this for Fraxinus. Davis and Rose (1912) reported on studies made with Crataegus mollis, in which the hypocotyl ~~is~~ was responsible for delay. In 1919 Rose published similar results on the embryo of Tilia.

Harrington and Hite (1923, apple seeds), Davis (1930, Ambrosia trifida), Okada (1930, Euryale ferox), Borthwick (1931, most spp. of the Polygonaceae), Choate (1940, Echinocystis) and others have recorded the role of embryos in delayed

germination / ..

germination. In horticultural and forestry practice low temperature stratification is very often employed and this is generally done to overcome embryo resistance.

In many cases delayed germination has been studied but without any definite analysis as to the respective roles of seed-coats and other factors. Thus, may be mentioned, timothy (Fischer 1918); Festuca pratensis, Poa pratensis and Bromus inermis (Nazarenko and Djadjun, 1934); rye grass (Hyde 1932 ; Meadly 1936); Johnson's grass (Harrington 1917); Bermuda grass (Bryan 1918; Burton 1939); Paspalum spp. (Ray and Stewart 1937, Burton 1939); Buchloe dactyloides (Pladeck 1940); Dactylis (Sprague 1940); Panicum and Setaria (Toole 1940); Chloris spp. and Stenotaphrum (Gassner 1910). In most of the Gramineae seed-coats undoubtedly play an important role but there is not the slightest doubt that other causes, e.g. the embryo, may have a share in the delay of germination, at least for a certain period or in certain instances.

Breaking of 'dormancy' in plants, tubers, etc.

Much work has been done on the physiology of delayed germination and space does not permit a review of even a part of these investigations. In passing, however, reference should be made to work on dormant plants, tubers, etc. - work which may appear unrelated to our problem, yet which is considered to have a direct bearing and therefore deserves some mention. Many chemical agents have been used in these studies in which the potato was often the test object.

Johannsen (1983) presented the first evidence of the value of anaesthetics. McCallum (1909) found carbon tetrachloride fairly successful. Stuart (1909) obtained good results with ether and chloroform but such agents as ethyliodide, ethylbromide and ethylchloride as well as CCl_4, alcohol and acetone

were / ..

were also used with a certain amount of success, Jesenko (1911 and 1912) induced earlier growth of woody twigs by the use of alcohol and ether solutions as well as with baths of acid solutions.

Appleman (1914) could shorten the rest period of new potatoes by the use of H_2O_2. Howard (1915) reviewed the literature and conducted studies not only on the general question of the occurrence of the "rest period" in seeds, the effect of etherization, freezing and soaking but also on the physiological changes accompanying breaking of the rest period of woody cuttings. Chemical treatments like MNO_2 and ether gave best results. Curtis (1918) obtained good results with $KMNO_4$. Weber (1916) used acetylene, whilst Newton (1923) employed KNO_3 and Rosa (1923 and 1925) $NaNO_3$ and ethylene. Boresch (1926) secured shortening of the rest period of buds by injections of certain organic acids (such as lactic acid), of other organic compounds (such as acetaldehyde) and of baths and vapours of certain organic compounds.

Denny (1926) reported the trial of 224 chemicals on potatoes, ethylene chlorhydrin, thiourea, Na- and Kthiocyanate, dichlorethylene, trichlorethylene, CS_2, ethylene dichloride, xylol and ethylbromide ~~were~~ being found effective. Ethylene and propylene were used with good results by Vacha and Harvey (1927). Miller (1930, and 1933) added a number of sulphur compounds to these lists including H_2S and ammonium dithiocarbonate. Further studies, in addition to those of their colleagues at the Boyce Thompson Institute, have confirmed the value of these and were undertaken to obtain information on the physiological changes (enzyme activity, respiration, etc.) induced by such treatment. Other workers, like Kidd (1919), Loomis (1927), Thornton (1933), Zimmermann et al (1933), Thornton (1935 and 1939), Zimmermann and Hitchcock (1940), have given attention to CO, CO_2 and O_2,

particularly / ..

particularly to CO_2, whilst, workers such as Loomis (1927), Loomis and Evans (1928), Loomis (1934), Volz and Keyes (1934), have tested out the value of heat. Recently the value of growth substances for rootproduction have been demonstrated by workers such as Zimmerman and Hitchcock (1935), Zimmerman and Wilcox (1935), Laibach (1935), Hitchcock and Zimmerman (1936), Amlong (1936), Zimmerman et al (1936), Vegis (1937), Myers et al (1938), Zimmerman and Hitchcock (1939) and Hitchcock and Zimmerman (1940).

The significance of growth substances and their application.

The more direct phase of the subject, namely the presence and role of growth substances in seeds has also received consideration in recent years. According to Cholodny (1935), in the endosperm of maize, oats and other cereal grains a growth substance (possessing the properties of auxin) is formed in the starch-containing tissues of this organ from the very earliest stages of germination, with the slightest penetration of water into the endosperm. It is eagerly and completely absorbed by the embryo during the first 48 hours. Yet this hormone is completely independent of the viability of the seed.

From his results, as well as those of Dagys (1934) (that the endosperm extract from maize markedly stimulates yeast increase) the conclusion is made that the endosperm probably also secretes the cell-dividing hormone or meristin. He considers that the results of certain earlier workers support such a view. Brunner (1932), growing excised Pinus maritima embryos in artificial nutrients, concluded that the embryos needed definite hormone-like substances in the endosperm. The results of van Overbeek (1933) and Navez (1933) would indicate that young seedlings depend upon growth substance reserves of the endosperm or cotyledon. Schander (1934) has also shown

that / ..

that the grass embryo obtains germination-activating substances from the aleurone layer which Cholodny thinks were merely taken up from the endosperm. Yet von Veh and Söding (1937) wrote (Ruge 1939, entirely associating himself with this), that "Alle diese Beobachtungen zeigen klar, dass der Wuchstoff für die eigentliche Keimung, den Uebergang von Ruhe zum Wachstum nicht entscheidend ist":- growth substance did not play the role of a germination hormone in the kernels of fruit trees. Excised embryos germinated readily. Active growth substances were present in the endosperm as well as the embryo, but an immediate and important increase in growth substances concentration was not necessarily connected with germination. The results of Laibach and Meyer (1935) and Meyer (1936) (after Ruge 1936) would indicate that growth substances decrease rapidly during germination, the former having also shown the dependence of young seedlings on the growth substance in the endosperm. Also Pohl (1935)and 1936) reached the conclusion that the coleoptile tip (Avena) produced no growth substances, but its growth is governed by that in the endosperm which it activated. Voss (1937) showed that the auxin is inactivated in the maize scutellum during swelling of the grain. "The active growth substance in the endosperm comes into the scutellum , where it is inactive and again experiences activation in the coleoptile tip."

When, however, one considers the studies of the application of growth substances for the stimulation of germination, the results are not very encouraging. For example, Amlong and Naundorf (1937), treating old seeds with heteroauxin solutions, obtained better germination and increased yields. Davies et al (1937)found indole derivatives retarded germination, whilst Lustig and Wachtel (1938) observed that heteroauxin had no effect on germination of Cardamine seeds. Guthrie (1939) found

little / ..

little support for the idea that dormancy of potato tubers is regulated by increase or decrease of the auxin-like substances in the tissues. Ruge (1939) using B. indolylacetic acid solutions, varying from 10^{-2} to 10^{-10} normal, found only retardation of germination. He writes: "Aehnliches wie für das Auxin A scheint übrigens auch für das Auxin B zu gelten, das nach den Untersuchungen von Nielsen (1936), Dagys (1937) und Rippel (1937) in verschiedenen Samen zwar reichlich enthalten ist. Nielsen findet aber keine reellen Unterschiede in den Konzentrationen dieses Bio-Wuchsstoffes bei normal keimenden und nicht mehr keimfähigen Samen, wie man es erwarten sollte, wenn das Auxin B ein Keimungshormon darstellt." Borzini (1935), with "growth substance" obtained from Aspergillus amd Rhizopus, found no perceptible favourable influence on the germination of Triticum, Trifolium etc. Barton (1940) treating numerous dormant seeds with growth substances, found these of very little value.

Genuine germination-promoting and germination-retarding (or inhibiting) substances.

In recent years some light has been shed on a closely related aspect of the subject and one which had been neglected until then. This is the field of genuine germination-retarding or inhibiting substances and of germination-promoting substances. Wiesner (1894) could not germinate Trifolium, Lepidium and Linum on the mucilage of Viscum berries. The inhibition was (1897) attributed to viscin. Heinricher (1912 and 1916) - according to Ruge (1939) - could confirm the above observations but gave - perhaps correctly, viz. lack of a different interpretation. The conclusions of Oppenheimer (1922) - after Ruge -, of Fukaki (1930), of Reinhard (1933) and of Kookemann (1934), to the effect that germination of certain seeds were inhibited by the juices of fleshy fruits and that the latter, therefore, contain inhibiting substances, can

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perhaps be regarded as being of no immediate biological significance and von Veh (1936) has voiced a somewhat similar opinion. After conducting a number of tests he considered there were no inhibitors.

However, the results of other workers are of more direct interest to our problem, viz. about the substances present in the seed- and fruit-coats. Ruge writes : "Thus Magnus (1920), Peters (1924) and Böhmer (1928) could, from the seed-coats of *Phacelia tenacetifolia*, extract with water a photodynamic inhibiting substance which depressed the germination speed of the dark-loving seeds more in a light seedbed than in a dark seedbed ..... Kisser and Possing (1932) also report inhibiting substances for the seed-coats of *Vicia*, *Pisum* and *Cucurbita*." To these must be added the similar findings of Borriss (1936) with *Vaccaria pyramidata* and of Lehmann (1937) with buckwheat. The substances thought to be responsible were apparently different, where these were studied. In this connection the claims of Russian workers (Isip 1940, Jarkovai 1940) in regard to protective substances, are of interest.

That certain germination-inhibiting substances leach out from seeds during germination, has been shown directly and indirectly by a number of workers. Gümbel (1912), using light-demanding *Brassica*, and Shuck (1935) using lettuce seeds with similar demands, obtained, respectively, much lower and not germination on blotters than in soil or absorbent cotton (or water). Lehmann (1909), using *Ranunculus sceleratus*, found no dirrerence in germination in soil between dark and light soil seedbeds, whereas, when filterpaper was used, no germination resulted in the dark, indicating, like in the above, that light favoured diffusion of an inhibiting substance. Shuck stated " The increased germination of lettuce seeds in the light indicates that light may promote the diffusion of the substance

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from the seeds, and although light may accelerate the process, tests have shown that an inhibiting substance passes from the seeds in total darkness". Borriss (1936) also made some interesting observations on Vaccaria pyramidata, but he ~~finds~~ found complete germination in soil whereas on filter paper no germination occurred in either light or dark. He found the substance to be light volatile or of the nature of a gas. Axsentiev (1927) found the extract from Phacelia not specific. It would inhibit germination of one kind of seed, whereas another would be stimulated; in still others the effect would be neutral. Meadly (1936) reported that dormant seeds of wimmera ryegrass germinate better in sand than on filter paper. Finally the very interesting investigations of Ruge (1939) have shown that by germinating oats an inhibiting substance ~~is~~ was excreted in the seedbed, where it accumulated but which is afterwards inactivated if new seeds ~~are~~ were repeatedly set out in the same substratum. This inhibiting system ~~is~~ was not species-specific and, in contrast to soaked seeds, ~~is~~ was the only "system" found in dry seeds but the system ~~is~~ was transformed into a germination-accelerating one.

Ruge writes : "Es ist bekannt, dass während der Quellung und Keimung vieler Samen neben den bereits genannten keimungshemmenden Stoffen auch Farbstoffe (Gassner 1915), fluoreszierende Substanzen (Linsbauer 1929, Metzner 1930), wasserlösliche N_2-Verbindungen (Gassner und Franke 1935), Gerbstoffe (Tilly 1935) und wahrscheinlich noch viele andere mehr in das Keimbett ausgeschieden werden. "

Much less frequent are the references to genuine growth promoting substances. Zlatasoff (1926) - after Ruge (1939),- reported that the water extract of pears and potato seedlings stimulated seedlings of maize, barley etc. Davies et al (1937) and Hayes (1935) established that thiocyanic acid ~~is~~ was

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capable of significantly increasing germination (thiocyanate increases over 1000% during germination). Ruge (1939) found that a germination-accelerating system (mentioned above) was only formed in the later life of seedlings. Both systems may be demonstrated in the plumule, radicle, hypocotyl and cotyledon of young Helianthus seedlings. Finally, he puts forward an interesting and pertinent hypothesis for a biological system whereby an inhibiting substance (cyanic acid) could be transformed into a germination-accelerating one (thiocyanic acid) during imbibition (with the assistance of the findings of Gemeinhardt (1938), Lang (1933) and Laibach und Keil (1937)).

To review the results of the many studies on methods of overcoming delayed germination of seeds, or for the stimulation of germination, will be beyond the scope of this paper, except for the fields covered and these will receive attention under the appropriate heads. Many contributions in this field deal with temperature. Not only is it employed for dicotyledonous seeds (kept moist) as reported by Davis and Rose (1912) for Crataegus and by a number of later contributors, but it is also commonly employed in seedtesting practice for cereals etc. (Harrington (1923), Toole (1923), Gadd (1939) etc.etc.). However, the value of such methods is somewhat limited for practical purposes, as they are applied during the period of germination and not as pretreatment of dry seeds.

The results on the utilization of chemical agents for the promotion of germination form an extensive chapter in our knowledge of the physiology of germination, yet none has proved to be of value for general application in the matter of breaking delayed germination.

There is little doubt that a better understanding of the processes and changes accompanying after-maturation will simplify the task of finding suitable means for the elimination

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of after-maturation, but not until more consistent indications have become available, to guide our attack on the problem, than heretofore. The many contributions in this connection would strongly point to the close resemblance of the basic factors involved in the delayed germination of various types of seeds.

The Extent and Distribution of the Associated Phenomena.

(1) The course of delayed germination.

Materials and methods in the survey of 1936-7 season seed. - During the 1936-37 season a commencement was made with the collection of seeds of native grasses (assembled at the afore-mentioned stations) for this survey. The seeds of a large number of ecotypes belonging to a number of species of the following genera were used : *Digitaria*, *Panicum*, *Urochloa* *Echinochloa*, *Paspalum*, *Setaria*, *Eragrostis*, *Brachiaria*, *Sporobolus*, *Themeda* and *Dactyloctenium* . Practically all of the collected grasses were examined for seed-setting for this purpose, as it is of course impracticable to incorporate those with too low seed content. Samples with less than about 30% seed content were afterwards discarded. Many could thus not be included on account of ergot or poor seed-setting.

Harvesting was done by hand, heads being cut when dry or lightly rubbed together and shaken on the plots. In this way seeds were obtained that were as physiologically dry as possible, as green seeds are only dislodged with more severe handling. All seeds were kept in brown paper bags, in a laboratory room, until immediately after the first test on the 14th of April, 1937, when the different paper bags, each re-

presenting / ..

presenting the harvest of a demonstration plot, were placed outdoors in galvanized iron trays. Every night, during the rainy season, the trays were put under a verandah. Six bi-monthly tests were conducted during the first year, the last one being followed by an 8th test some 6 months afterwards.

Germination tests were made in petridishes in a Hearson incubator run continuously at about 28°C. Particulars of the method are detailed elsewhere. As cleaning of seed samples was impossible, except in the panicums, uncleaned portions of the samples (to obtain at least 400-500 caryopses) were used for each test.

It should be mentioned here, that germination periods (i.e. duration of tests) of the different kinds of seeds were not always the same for all lines under test, as this was impossible owing to the inherent differences of the seeds of different grasses. On the whole, for example, the digitarias showed a tendency to germinate over a more extended period, whereas the panicums appeared to have a greater germination speed under the condition of our experiments. The duration-of-test periods were, therefore, so chosen that as good an indication as possible of the conditions of the seed in respect of delayed germination could be obtained and at the same time a relatively accurate basis of comparison for different grasses secured. That a time limit should be instituted for such studies is only appropriate, for many seeds, particularly during their after-maturation period, are inclined to continue their germination over a fairly extended period,

As a rule, the more favourable the conditions for the germination of the particular seed or the more advanced the stage of after-maturation, the less the germination curve is flattened out. In the material and results under review, this has been realized to a marked degree, indicating that the con-

ditions / ..

ditions chosen as regards temperature, seedbed etc., were perhaps as favourable as could be hoped for. This leads to the consideration as to what conditions (and especially that of temperature) constitute the ideal germination environment to obtain a true evaluation of the condition of delayed germination. The provision of an artificial environment for the germination of seed to ensure as close an evaluation as possible of the condition of delayed germination of any seed sample, at any time or under any given condition and for all kinds of seed, is not an easy matter. Alternating temperatures are naturally out of the question as such are liable to cause marked stimulation in many cases as was observed above. Furtheron additional results are presented, so that at this stage we will content ourselves with the observation that there seems to be little disadvantage, if any, attached to the temperature chosen in studying this particular phase of the problem, as it appears that the natural progress of after-maturation of the majority of grasses (seeds) are fairly clearly defined by the germination tests. The results referred to, therefore, more than any theoretical consideration, strengthen the assumption that this temperature appears to have been favourable for the purpose. Additional evidence for this viewpoint, it is considered, will become available furtheron.

In passing it might be mentioned that in the germination tests under review 400-800 seeds per test (and often more) were used and daily counts were made. The results are tabulated in table 7, a summary thereof appearing in table 8.

Table 7. Showing the progress of delayed germination with outdoor storage, of seed harvested in the 1936-37 season.

Kind of grass (ecotype). Plot number. Date of harvest.	Period of test days	Percentage Germination on: 13th May 1937	14th June 1937	9th. Aug. 1937	12th Oct. 1937	9th. Dec. 1937	5th. Feb. 1937	22nd Mar. 1938	29th Sep. 1938
DACTYLOCTENIUM :									
D.aegypticum. 17.2.37. (Rust der winter).	9	0.2	2.1	0.7	2.5	3.5	2.6	4.0	7.8
DIGITARIA :									
A.17. 12-2-37. (Inkruip no.1).	14	0.3	0.4	0	5.3	6.4	6.2	11.0	18.3
A.23. 12-2-37. (Port Elizabeth).	14	64.3	70.0	70.0	64.2	65.6	50.2	49.7	27.7
A.30. 2-37. (Candover no.1).	14	-	-	70.2	-	80.1	46.8	60.5	62.4
A.34. 2.37. (Pretoria small no.1).	15	79.5	95.5	95.0	95.3	95.5	75.2	79.7	72.3
A.37. 12-2-37. (Padden).	12	1.4	3.3	2.9	-	8.7	14.3	22.5	-
A.38. 12-2-37. (Molopo no.1).	12	0.6	1.2	2.0	4.8	9.1	17.5	19.6	57.9
A.38. 22-2-37. (Molopo no.1).	12	1.4	1.1	5.8	-	34.1	35.0	46.3	61.5
A.39. 12-2-37. (Grootfontein).	11	22.8	31.8	20.0	23.4	42.8	46.3	68.9	-
A.40. 22-2-37. (Port Elizabeth no. 2).	15	61.8	76.4	82.0	77.7	81.8	77.8	62.7	50.1
A.50. 12-2-37. (Port Elizabeth).	15	59.8	83.0	81.3	78.1	81.2	57.9	37.8	-
A.54. 12-2-37. (Northam no.1).	14	44.1	47.4	45.4	-	-	-	-	-
A.59. 4-3-37. (Vukwe camp).	11	0.3	1.0	2.5	15.6	27.0	22.7	68.3	73.2
A.60. 4-3-37. (Makarikari).	13	-	1.0	0	4.6	16.4	12.4	19.8	29.9
A.64. 12-2-37. (Kuruman no.3).	15	0	0	2.8	4.4	5.2	29.7	32.8	50.0
A.65. 22-2-37. D. longiflora	10	1.2	-	1.4	9.6	39.8	-	80.2	70.6
A.65. 4-3-37. D. longiflora	10	28.9	-	-	-	39.7	-	-	-
A.69. 4-2-37. (Rietondale no. 10).	11	5.4	16.8	12.8	-	59.9	57.9	46.2	-
A.69. 12-2-37. (Rietondale no.10).	11	3.9	14.3	24.5	31.3	-	38.4	32.3	57.8
A.85. 12-2-37. (N. Rhodesia).	11	2.9	2.2	0	9.3	42.8	25.0	66.5	65.6
A.94. 22-2-37. (N.Rhodesia no.6).	11	0	0	5.2	-	18.8	21.4	47.8	58.2
A.101. 12-2-37. (N. Rhodesia).	11	0.2	0.6	2.1	13.0	32.7	-	35.5	77.3
A.102. 22-2-37. (N. Rhodesia no.4).	11	0	0.3	0	-	39.2	43.2	38.7	-
A.103. 12-2-37. (N. Rhodesia no.5).	11	0.3	0.4	4.4	-	39.4	44.8	35.5	60.9
A.107. 12-2-37.	9	-	-	3.3	-	-	36.4	-	-
A.108. 12-2-37 (Danspan).	13	60.5	-	56.7	81.2	82.7	71.3	54.5	32.5
A.114. 4-3-37. (Umfolozi Riv.).	9	14.7	-	18.3	45.7	78.7	74.7	82.2	95.3

Table 7. - continued.

Kind of grass (ecotype) / Plot number. / Date of harvesting.	Period of test days	Percentage germination on: 13th May 1937	14th June 1937	9th Aug. 1937	12th Oct. 1937	9th. Dec. 1937	5th. Feb. 1937	22nd Mar. 1938	29th Sep. 1938
DIGITARIA : (continued)									
A119. 12-2-37. (Kalkfontein no.2).	9	31.3	34.4	30.0	67.3	82.7	46.7	82.4	51.6
A.125. 4-3-37. (Matabele Location).	10	0.8	1.1	1.9	12.2	20.2	10.3	21.9	47.5
A.308. 4-3-37. (Wylliespoort no.2).	10	3.0	3.8	9.4	35.7	47.0	52.9	74.8	76.4
C.1. 2-2-37. (Kuruman).	9	3.8	0.3	-	4.5	3.0	11.8	-	-
C.9. 25-2-37. (N. Rhodesia).	13	2.8	1.0	0	8.1	26.8	14.6	49.9	35.3
C.56. 16-2-37. (Dunn's Finger grass).	17	7.3	16.0	42.2	46.7	73.0	55.9	76.7	72.0
C.60. 16-2-37. (Kuruman).	15	3.3	6.4	14.9	-	-	-	-	-
C.61. 16-2-37. (Molopo).	15	0.1	2.8	9.3	7.9	8.2	6.6	17.4	28.4
C.69. 11-2-37. (Rietondale).	15	22.1	21.2	-	40.7	70.8	17.0	54.0	48.4
C.69. 20-1-37. (Rietondale).	15	23.9	40.5	57.7	-	62.0	65.7	70.7	56.3
C.72. 11-2-37. (Rietondale).	15	23.6	34.1	41.3	52.0	57.2	53.4	57.8	44.0
D.7. 11-2-37. D.Pentzii (P.P.Rust).	10	2.8	3.7	3.9	5.2	15.6	10.0	17.9	43.2
D.13. 11-2-37. (Willowmore).	15	40.8	37.3	56.3	58.4	71.2	66.1	40.3	92.4
D.25. 11-2-37. (Grahamstown).	12	81.1	74.3	84.4	83.8	92.3	81.3	90.9	46.6
D.29. 26-2-37. D.littoralis (G'town).		-	-	-	-	-	82.4	-	-
D.56. 29-12-36. Seln. V.1.	14	24.8	21.3	51.2	37.2	33.5	41.3	76.3	56.8
Seln. 12-6. 20-1-37. (From "Kuruman").	11	1.9	2.4	2.5	5.4	6.2	3.6	9.9	36.9
Seln. 13-1. 21-1-37. (From "Molopo").	11	0.6	-	3.7	1.7	1.4	1.8	6.3	4.8
do 21-2-37. do	11	1.6	1.2	3.1	-	5.8	3.0	6.5	6.1
Seln. 15-7. 21-1-37. (From "Inkruip").	10	-	3.0	-	-	-	-	-	25.0
Seln. 27-6. 2-2-37. (From "Inkruip").	13	0	-	3.6	4.3	9.7	9.6	21.2	-
Seln. 24-3. 20-1-37. (From "Inkruip").	12	0.2	0.7	0.5	1.0	4.6	2.7	9.8	11.8
Seln. 24-5 20-1-37. (From "Inkruip").	12	0	0.8	3.3	2.0	2.6	-	7.3	33.6
ECHINOCHLOA : E.pyramidalis									
C.37. 16-3-37. (Rhodesia).	13	8.8	7.8	36.7	52.8	76.2	82.2	84.2	85.3
C.107. 4-2-37. E.pyramidalis.	13	-	-	-	-	-	69.7	80.7	81.0
ERAGROSTIS :									
F.18. 12-1-37. (Kuruman).	9	0	0	0	0.3	0.3	13.8	0.3	0.2
F. 20. 29-12-36	9	58.0	72.6	91.3	72.8	78.9	79.9	75.0	74.6

Table 7. -continued.

Kind of grass (ecotype). Plot number. Date of harvesting.	Period of test	Percentage germination on: 13th May 1937	14th June 1937	9th Aug. 1937	12th Oct. 1937	9th Dec. 1937	5th Feb. 1937	22nd Mar. 1938	29th Sep. 1938
PANICUM :									
A.175. 22-2-37. P.coloratum.	10.	3.7	31.0	64.8	85.1	85,7	65.0	92.6	89.6
A.177. 22-2-37. P.coloratum.	10	-	23.0	31.6	37.5	39.6	50.8	53.9	60.9
B.2. 22-2-37. P.deustum. 1	14	0.2	1.8	4.4	14.6	30.4	21.6	37.6	60.7
B.4. 18-2-37. P.proliferum.	14	4.2	6.4	4.6	9.9	11.1	29.5	-	-
B.7-10. 1-2-37. (Hammanskraal).	12	18.2	45.1	60.6	73.5	72.7	75.3	80.0	85.7
C.21. 29-.-37. P.phragmitoides (?)	10	23.2	34.6	-	68.4	94.3	68.1	64.9	38.8
C.75. 22-1-37. (N.Rhodesia).	10	16.0	22.8	19.0	29.1	49.4	61.3	58.3	-
C.79. 8-3-37. (Makarikari).	10	2.0	-	15.0	7.4	-	11.1	14.2	54.7
C.80. 29-1-37. (Makarikari).	10	-	0.6	3.4	4.7	1.7	6.5	6.6	-
C.91. 3-2-37. P.coloratum. (Bech'land)	10	1.7	-	0	0.1	2.4	-	2.9	10.2
C.92. 3-2-37. do (Springbuck fts.)	10	2.2	2.4	51.0	22.9	43.1	35.4	36.3	-
C.93. 30-12-36 P.coloratum. (Bech'land)	10	5.0	11.9	24.9	34.5	41.2	48.5	50.0	69.8
C.94. 3-2-37. P.coloratum. (Senekal).	10	10.5	28.3	55.9	72.8	77.4	73.4	76.6	88.1
C.97. 27-1-37. do. (S. Rhodesia).	10	0	2.5	8.0	22.2	33.2	82.0	30.6	55.6
C.98. 27-1-37. do (Hammanskraal).	10	0.7	7.0	27.2	58.2	69.5	13.4	64.2	91.2
C.99. 27-1-37. P.coloratum v.glaucum. Bechuanaland.	10	0.7	0.6	1.5	6.7	9.1	20.7	23.7	53.1
C.100. 6-1-37. do (N. Rhodesia).	10	0	0	3.7	5.9	15.6	41.7	20.5	61.4
C.101. (Hluti). 3-2-37. P.swazilandensis.	10	33.7	52.6	86.0	91.7	74.3	90.0	93.8	92.4
F.6. 20-1-37. P.maximum.	12	1.2	2.0	2.6	14.1	37.3	31.0	40.8	41.4
F.7. 20-1-37. P.maximum.	12	0.2	2.1	2.9	6.8	19.9	14.6	25.2	21.3
F.14. 27-1-37. P.minus. (Barkly West).	10	4.5	10.4	17.8	44.9	55.8	49.8	47.3	75.4
F.48. 3-2-37. P.maximum. (Komatipoort)	12	2.0	3.3	5.1	9.1	11.1	-	2.6	17.2
F.53. 18-1-37. P.coloratum (Louis Tric.)	10	0.2	0.5	1.7	3.8	14.0	5.8	5.6	45.6
G.1. 3-2-37. P. sp. (Nile River).	10	3.0	22.3	28.2	35.4	59.2	59.6	62.2	41.6
G.7. 27-1-37. (Komatipoort).	10	0.5	1.4	6.9	45.4	34.3	26.4	42.2	67.1
G.29. 29-2-37. P.maximum (Louis Tric.)	12	6.9	10.8	27.6	56.7	72.4	75.3	73.0	76.6
G.30. 29-12-36. P.coloratum. (Danspan).	10	8.5	9.2	9.3	39.8	51.3	63.8	63.4	-
G.34. 3-2-37. P.maximum. (M'latele loc)	16	0.2	7.5	16.3	34.7	37.2	42.8	27.6	28.9
G.38. 27-1-37. P.maximum. Rancher's Ltd.	12	0.7	0	0	1.4	1.9	0.5	1.5	5.1

Table 7. -continued.

Kind of grass (ecotype). Plot number. Date of harvesting.	Period of test	13th May 1937	14th June 1937	9th Aug. 1937	12th Oct. 1937	9th Dec. 1937	5th Feb. 1937	22nd Mar. 1938	29th Sep. 1938
		Percentage germination on :							
PANICUM : (continued).									
G.39. 26-2-37. P.maximum.(L.Brak Riv.)	16	16.5	22.8	38.9	54.5	70.7	-	49.6	49.8
P.laevifolium. 17-2-37. (Rust der winter).	10	0.2	6.9	12.5	37.6	40.2	35.6	14.6	51.1
P.proliferum.	10	-	4.1	9.2	-	-	-	39.1	23.7
PASPALUM :									
A.4-11. 1-4-37.	14	0.4	-	2.4	4.1	22.1	44.8	23.9	49.6
A.8. 1-4-37. P.notatum.	14	-	0.7	1.7	2.6	36.2	35.6	-	49.8
SETARIA :									
H.7. 21-1-37. (N.Rhodesia).	11	1.0	11.9	3.6	31.1	22.8	34.6	68.7	67.5
F.9. 12-3-37. S.aurea. (Groenkloof).	12	1.6	6.5	18.0	30.7	53.0	58.4	63.5	75.6
F59. 4-1-37.	12	-	-	-	-	-	77.6	-	-
F59. 27-1-37.	12	4.2	21.9	37.9	55.8	69.3	-	63.3	77.0
SPOROBOLUS :									
F.12. 11-3-37. S.fimbriatus. (Hammanskraal).	9	-	-	-	-	5.1	6.6	5.2	8.2
G.25. 23-1-37. do. (Zebediela).	9	0	0	0.3	0.7	0.8	0.4	1.4	8.8
THEMEDA TRIANDRA :									
B.2/C.33. 31-12-36.	14	23.4	60.6	54.3	54.3	64.8	49.7	42.4	54.3
B.2/D.91. 31-12-36. (Pretoria).	14	20.3	34.9	25.4	44.5	40.3	27.1	23.9	-
UROCHLOA :									
A.263. 4-3-37. (Elands Riv.)	12	0	0	0	0.3	0.7	0.3	0.2	0.2
C.28. 5-3-37. (Magut).	12	0	0	0	0.3	1.0	1.0	2.9	3.6
C.76. 28-1-37. (Dongola Riv.).	10	0.6	0.5	2.4	2.5	1.7	5.5	7.6	14.6
C.78. 28-1-37. (Olifants Riv.).	10	0.2	0	0.3	1.0	-	2.7	6.3	11.3
F.43. 8-3-37. (Nile Riv.).	12	0	0	0	0.3	2.5	2.8	11.8	5.5
F.54. 4-2-37. (Northam).	12	0	0	0.2	0.2	4.6	9.3	3.1	4.5
F. 57. 4-2-37. (Nongoma).	12	0	0	0	0	0.9	0.9	0.3	0.9

<u>Discussion :</u> - Reference to table 7 shows that the trend of delayed germination of the seeds of individual ecotypes seldom ~~gives~~ gave a regular curve. This irregularity ~~is~~ was only partly due to the variability of the material because some differences ~~are~~ were too large to be attributed to this factor alone. Apart from this irregular progress of after-maturation, very sudden and marked declines in germination capacity ~~are~~ were to be found in a number of the kinds. Equally marked increases ~~are~~ were also experienced. With only one or two exceptions, these falls ~~do~~ did not occur until the advent of summer. <u>Panicum coloratum</u> ecotypes C. 98, C. 100, A. 175, <u>Panicum laevifolium</u>, <u>Panicum phragmitoides</u> C. 21, <u>Digitaria</u> ecotypes A. 30, A. 34, A. 85, A. 108, A. 119, D. 13, C. 69, A. 50 and <u>Paspalum notatum</u> A. 4/11 are cases in point and this is most probably to be attributed to the high summer temperature outdoors. Very often they exhibited a partial or complete recovery. It is not unlikely that this phenomenon is, in some grasses at least, only an induced or temporary delay ("secondary dormancy"). There seems to be good evidence, however, that some have suffered a gradual and permanent loss of viability, within the 18 months of the test, e.g. <u>Panicum</u> spp. G. 1 and C. 21; and <u>Digitaria</u> ecotypes A. 23, A. 50, A. 40 and A. 108. A few kinds exhibited a decline after 18 months, after their previous recovery (for example <u>Digitaria</u> ecotypes A. 119 and C. 69). That the seed with the quicker after-maturation have a tendency to loose their viability fairly soon, appears to be borne out by the behaviour of kinds such as <u>Digitaria</u> ecotypes A. 23, A. 40, A. 50, D. 25 D. 29, C. 69 and <u>P. coloratum</u> C. 21. This may also be noted in the first column of table 8.

Seed showing any particular type of progress of delayed germination does not appear to be restricted to any definite geographical or ecological region. Toble and Coffman (1940)

studying / ..

studying individual plant samples of Avena fatua, reported a marked difference in the proportion of dormant seeds from different localities and a wide variation in dormancy among plants from any given locality. Toole (1941), in studying the resistance to germination of various Sporobolus spp., also found that such resistance was not restricted to samples from any particular geographical region. Contrary to expectation, genera like Sporobolus and Urochloa, which are non-stoloniferous and usually well distributed, showed a marked delayed germination in these tests.

TABLE 8 : A SUMMARY OF THE PROGRESS OF DELAYED GERMINATION AS SHOWN BY THE NUMBERS OF THE DIFFERENT GRASSES (SEEDS) WHICH GERMINATE WITHIN CERTAIN FIXED % RANGES AT THE VARIOUS TESTS .

Months of Outdoor Storage in Paper Bags	Number of Ecotypes showing Germination:						Total Number of Ecotypes tested
	over 90 %	71-90 %	51-70 %	31-50 %	11-30 %	under 10%	
At 2nd bimonthly test, 9.8.37, after approximately 4 months	2	4	11	7	17	55	96
At 4th bimonthly test, 9.12.37, after approx. 8 months	6	16	12	22	19	28	101
At 6th bimonthly test, 22.3.38, after approx. 12 months	20	21	21	18	12	4	96
At 7th test on 29.9.38, after appr. 18 months	12	15	20	20	16	[illegible]	87

In the previous season's studies it was found that Digitaria sp. D. 56, "Peddie", gave 97% germination within 2 months after harvesting. Also Digitaria sp. D. 5, "Port Elizabeth", D. milanjiana sp. D. 36 and P. coloratum sp. C.102,

"Hammanskraal" / ..

"Hammanskraal" showed fairly rapid progress of delayed germination.

Some 18 of the above kinds, mainly panicums (viz. panicums C.21, C.75, C.79, C.80, C.91, C.92, C.94, C.97, C.98, C.99, C.100, C.101, F.14, F.6 and F.7; and Digitaria ecotypes C.56, C.1 and A.114) were also under observation the previous season (indoor storage) and it is interesting to note that if their performance 6 months after harvest is compared in the two seasons, it is found that in only 3 of them (C.92, C.56 and A.114) the germination was a good deal different in the first season; all three registered under 10%. The remaining 15 kinds exhibited almost identical germination in the two seasons.

Outdoor and Indoor storage. - To what extent the after-maturation may be affected by room storage as against outdoor storage, is shown in the following comparison between outdoor (in open) and indoor storage in brown paper bags, the chief difference between the two methods of storing being probably mainly the daily range in temperature fluctuations. In the above survey, outdoor storage was resorted to as it was considered that these would most nearly approximate natural conditions.

TABLE 9/..

TABLE 9 : A COMPARISON OF OUTDOOR AND INDOOR STORAGE OF SEED (IN PAPER BAGS). THE VALUES REPRESENT GERMINATION PERCENTAGES.

Particulars of seed used.	First Room	Test Outdoor	BIMONTHLY TESTS: Second Room	Test Outdoor	Third Room	Test Outdoor	Fourth Room	Test Outdoor	Fifth Room	Test Outdoor	Sixth Test 6 months afterwards: Room	Outdoor
Digitaria A17.	0.3	-	-	0.4	4.2	0.0	2.6	5.3	2.9	6.4	10.6	18.3
do A34.	79.5	-	90.8	95.5	78.1	95.0	92.2	96.3	90.2	94.6	87.4	72.3
do A308.	3.0	-	4.4	5.0	9.4	27.5	23.6	36.2	30.2	47.0	57.7	76.4
do C61.	0.1	-	1.1	2.0	8.2	9.8	10.5	11.3	3.5	6.9	6.3	28.4
Sporobolus sp. F12.	0.0	-	1.1	-	3.7	-	4.0	-	8.4	5.1	11.6	8.2
do F20.	58.0	-	74.0	79.7	69.7	92.1	84.7	78.5	-	-	-	74.6
Panicum deustum B2.	0.2	-	3.0	1.8	6.3	4.4	17.4	14.5	26.8	30.4	47.2	54.3
Panicum laevifolium	0.2	-	-	6.9	18.6	12.5	37.3	37.6	36.2	40.2	42.1	51.1
MONTHLY TESTS.												
Digitaria sp. (Molopo)	0.0	0.5	0.0	3.7	5.5	10.7	4.9	16.9	6.5	18.7	7.0	16.5
Brachiaria isachne	0.6	5.3	5.9	6.4	18.9	21.7	9.3	27.8	-	-	-	-
Setaria sphacelata H10.	1.3	4.4	-	13.4	8.6	33.6	16.2	50.2	31.2	42.8	33.2	56.3
Digitaria line 12-8.	2.7	7.0	5.0	18.6	8.4	17.9	12.1	58.7	7.5	35.5	-	-
do D23.	14.3	31.8	38,0	69.2	26.5	47.2	22.4	73.6	19.5	69.6	25.9	77.6
Panicum minus B7-11.	4.0	6.9	9.7	29.4	11.5	40.2	16.9	50.9	23.6	61.1	26.3	64.3
Digitaria sp. A23.	18.4	23.0	38.9	75.0	45.3	87.4	56.7	86.7	-	-	-	-

In the case of the seeds subjected to "monthly" tests, the favourable influence of outdoor storage ~~is~~ was, on the whole, very marked, whereas the same cannot be said of the "bimonthly" lot, and the only explanation that can be offered, is that in the "bimonthly" studies carried out a year before the former, the brown paper bags were packed close together in galvanised iron trays so that, possibly, the seeds were not subject to the same temperature as in the seeds submitted to the monthly tests where the paper bags were kept apart, outdoors.

The behaviour of N'Gamiland ecotypes and of *Setaria* and *Chloris gayana* selections. - In April 1936, 24 selections of *Setaria* were made (? two or three species) and after a period of six months, germination tests were conducted, when it was found that the approximate percentage of germination varied from 8 - 81 %. In contrast to this 16 selections of *Chloris gayana* made about the same time and germinated after about the same period, varied approximately from 60-100% in germination capacity.

In 1938 the survey was extended to grasses (*Digitaria* ecotypes) then recently brought from N'Gamiland. The seed were stored indoors in paper bags. The results are recorded in table 10.

TABLE 10 : PROGRESS OF AFTER-MATURATION OF N'GAMILAND *Digitaria* ECOTYPES, 1937-38 SEASON, AS SHOWN BY GERMINATION TESTS CONDUCTED PERIODICALLY. DURATION OF TESTS 12 DAYS.

Particulars of Grass.	Date harvested 1938	First test Oct. 1938 %	Second test June 1940 %	Third test June 1941 %
SEHITWA.				
No.3, Row 22, plant 6	10/3	0.7	25.1	31.3
" 4, " " " 4	10/3	0.5	7.3	23.3
" 4, " " " 2	24/2	1.1	38.4	39.1

MAUNS / ..

Particulars of Grass	Date harvested 1938	First test Oct. 1938 %	Second test June 1940 %	Third test June 1941 %
MAUNS.				
No. 1 Row 30 plants 1-2	24/3	0.1	2.4	13.1
" 1 " "	6/5	1.0	3.1	13.0
TSOTSOROGA PAN.				
No. 2 Row 12 plants 9 & 10	?	0.1	2.2	5.4
" 2 " 12 " "	19/4	-	16.8	21.8
" 5 " 19 " 17 & 18) " 5 " 9 " 9 & 10)	24/3	0.1	5.6	11.0
" 5 " 19 " 17 & 18	24/2	0	12.6	24.2
" 5 " 9 " 9 & 10	19/4	2.7	57.1	58.5
KWAAI.				
No. 4 Row 27 plants 4 & 6	24/3	4.8	3.4	14.1
" 7 " 23 " 7 & 8	24/3	3.9	57.4	66.1
" 8 " 23 " 9	11/2	-	74.2	56.2
" 9 " 22 " 10	11/2	-	47.3	40.7
" 9 " 22 " 9 & 10	24/2	9.9	71.0	58.7
" 9 " 22 " 9 & 10	24/3	8.2	42.7	51.3
" 14 " 21 " 6	24/3	2.2	54.6	61.6
" 17 " 11 " 8	24/3	0.9		
" 17 " 12 " 1 & 2	24/3	-	43.2	35,7
" 20 " 10 " 6,7,8 & 10	24/3	5.5	9.3	9.6
" 26 " 48 " 1,6 & 17	22/3	-	50.3	42.8
" 27 " 48 " 15	22/2	-	47.0	66.6
NKOANA PITS.				
No. 1 Row 30 plants 5 & 6	10/3	0.7	11.2	39.4
" 1 " 30 " 5 & 6	24/3	1.5	12.4	49.5
" 1 " 30 " 5 & 6	24/2	1.2	9.3	60.9
" 6 " 31 " 9	24/3	1.4	10.0	27.5
GOMOTI RIV.				
No. 3 Row 17 plants 4 - 10) No. 3 " 18 " 1 - 10)	24/3	4.8	25.3	33.3
GOHA HILLS.				
No. 1 Row 1 plant 5	22/3	1.4	4.9	27.3
" 5 " 20 " 6	24/3	0	8.0	34.6
" 9 " 19 " 9 & 10	24/3	1.2	7.0	21.5
" 9 " 19 " 9 & 10	11/3	1.3	5.5	15.3

GOHA HILLS / ..

Particulars of Grass	Date harvested 1938	First test Oct. 1938 %	Second test June 1940 %	Third test June 1941 %
GOHA HILLS (continued):				
No. 9 Row 19 plants 9 & 10	24/2	-	5.5	51.7
" 10 " 5 " 4 & 6	22/3	-	-	79.7
" 20 " 1 " 4	22/3	0.12	5.3	40.3
" 21 " 1 " 1	22/3	-	9.9	40.3
" 22 " 9 " 7	24/2	-	-	54.8
" 24 " 48 " 26	22/3	-	64.0	87.9
" 24 " 48 " 22 & 3	22/3	-	22.9	73.2
" 25 " 48 " 27	22/3	-	11.5	20.0
" 25 " 48 " 25	22/3	-	36.9	47.8
" 26 " 46 " 44 - 9	22/3	-	52.4	60.3
RAKOPS.				
No. 1 Row 30 plants 3 - 4	11/2	-	-	18.8
" 1 " 30 " 3 - 4	24/2	0.5	-	18.2
" 2 " 20 " 5	24/3	0.85	-	6.2
" 2 " 30 " 3 - 4	8/3	-	-	25.8
" 2 " 30 " 5	24/2	0	-	68.8
" 2 " 30 "	10/3	-	-	70.7
" 3 " 22 " 8	24/2	-	-	62.7
" 4 " 45 " 20 - 22	22/3	-	-	21.8
ZANGHUN PAN.				
No. 2 Row 7 plants 4 - 7	22/3	-	26.2	56.7
" 2 " 48 " 19	22/3	0.9	-	39.2
" 2 " 24 " 7	24/2	3.7	30.3	40.4
" 2 " 24 " 7	10/3	2.4	21.5	36.7
" 3 " 48 " 20 - 1	22/3	-	10.0	15.8
RAKUKU.				
No. 2 Row 4 plants 1 - 5	22/3	-	-	7.2
" 2 " 12 " 9	24/2	-	2.0	2.6
" 2 " 11 " 6,7 & 9	24/3	-	1.7	7.2
" 1 " 24 " 8	24/3	-	0.1	1.2
" 1 " 24 " 8,9 & 10	24/2	-	22.7	21.5
" 3 " 10 " 3	24/3	-	-	38.3

Discussion. - After over two years of storage

the / ..

the seeds of the majority of these ecotypes germinated under 30% and few (6) gave more than 50%, only two of which had approached a 75% germination. A year afterwards the two best already appeared to be on the decline; a few had attained the 80 - 90% mark but a number still showed poor germination, whilst several had increased by about 50% in their germination capacity. Seeds from the same plots, but harvested at different dates, were included in these studies and it will be observed that in a few cases differences as much as 30 and 40% were realized after two or three years (e.g., Goha Hills 9 & 24). Very interesting is also the phenomenon of marked variability in germination capacity of ecotypes from the same locality.

Seed of the 1940 - 41 season. - During the last season (1940-41) attention could again be given to this work, when seeds of a number of the previous grasses were once more included. In addition, ecotypes of *Chloris gayana*, other panicums, etc., were included. Seeds were stored in laboratory in tins with perforated lids. In these tests 15 day periods were used for all kinds of seed as this is more convenient. In a few instances seeds from the same plot but of different dates were incorporated. Those seeds which could be cleaned before-hand, e.g. of *Panicum*, were germinated 4 x 100. The temperature employed was ca. 28°C. The results to date appear in table 11.')

') The discussion following table 11 does not take into account the data presented in the last column (6th test), as these figures became available subsequently. It therefore remains to be indicated that, according to the values of the 6th test - after about 12 months -, only 12 of the ecotypes under observation (excluding rhodesgrasses), germinated 50% and over, whilst 23 germinated 30% and over. Attention should also be drawn to the very marked rises in germination registered between the 5th and 6th tests by *P.maximum* A361 (from 16 to 83%), as well as by several rhodesgrasses (e.g., A169, from 10 to 70%).

TABLE 11 / ..

TABLE 11 : THE COURSE OF DELAYED GERMINATION OF 1940-41 SEASON SEED, AS SHOWN BY THE PERCENTAGE GERMINATION ') WITH BI-MONTHLY TESTS. THE THIRD LAST COLUMN SHOWS THE PERCENTAGE DIFFERENCE ") BETWEEN SOIL AND INCUBATOR TESTS.

Name of grass. Plot number. Locality. Date harvested 1941.	1st Test %	2nd Test %	3rd Test %	4th Test %	Diff. Soil & Incub. Tests. %	5th Test %	6th Test %
	march	may	July	Sept		Nov	Feb
PANICUMS :							
P. laevifolium, N36. (Wakkerstroom) 27/1.	6.3	0.8	1.0	4.0	+49.5	3.5	11.5
P. maximum, N86. 24/1.	0.3	11.3	3.3	6.3	+69.3	5.0	10.8
P. phragmitoides, N121 (N'Gamiland) 27/1.	0.5	9.3	9.5	10.3	+30.3	13.0	21.8
do. 8/2.	2.5	3.3	9.5	8.0	+50.5	19.8	26.8
P. maximum (?), N122. 18/1.	1.8	20.5	27.3	21.3	-	32.8	37.0
do. 24/1.	1.8	16.3	22.0	22.3	-	26.5	27.5
P. maximum (?), N123. (Nanyuki) 24/1.	1.8	16.8	20.3	24.8	-	23.8	30.5
P. minus, A146. 24/1.	0.3	1.0	0.8	6.0	+31.0	2.8	11.5
P. maximum, A154. (Coast) 24/1.	0.5	8.8	34.0	52.5	+63.5	34.8	55.3
do 3/2.	0.8	5.5	19.5	29.0	-	25.3	29.8
P. maximum, A262. (Rustenburg) 24/1.	0	0	0.5	0	-	0	0
P. maximum, A277. (Dongola) 25/1.	0	3.0	2.0	2.0	+9.0	5.5	4.0
P. maximum, A361. (Nelspruit) 28/1.	1.0	35.3	77.3	79.5	-	15.8	82.5
P. maximum, A384. (Nelspruit) 28/1.	3.5	41.3	46.5	39.0	-	59.0	49.8
P. maximum, A434. (Nelspruit) 28/1.	8.8	46.8	61.3	69.3	-	84.8	85.0
P. maximum, A390. (Wylliespoort) 28/1.	0.3	10.8	17.0	21.0	+12.5	17.0	21.5
P. maximum, A436. (Eersteling) 28/1.	0.8	14.5	18.5	26.0	+56.5	37.3	60.0
P. maximum, A439. (Pretoriuskop) 28/1.	2.3	11.5	6.0	18.3	+ 6.3	10.5	16.5
A443. (Hammanskraal) 25/1.	5.3	22.5	44.5	49.8	+25.8	46.5	61.8

') In all seeds except those of Chloris and Digitaria ecotypes, precleaning was done, and in such cases, therefore, 4X100 seeds were used per test. The replications of individual tests were scrutinized in accordance with the Canadian Germination Tolerane Tables (Oct.1939). Adjustments were made where necessary.

") After the 4th test, germination tests were conducted in soil(in trays) outdoors, for comparison with incubator values. The percentage difference in the table is expressed as + or - values in relation to the incubator values.

Name of grass. Plot number. Locality. Date harvested 1941.	1st Test %	2nd Test %	3rd Test %	4th Test %	Diff. Soil & Incub. Tests %	5th Test %	6th Test %
PANICUMS : (continued)							
(Krokodilpoort) A490. 28/1.	0.8	31.3	37.0	41.8	-	39.5	51.3
(N'Kandlha F.) A494. 28/1.	5.8	16.8	27.8	17.0	-	25.6	44.0
Selection (Makarikari) 1-6. 10/2.	0.0	0.5	0.5	1.5	-	0.8	2.5
do 2-1. do 4/2.	0	2.8	0.3	6.3	-	4.3	7.3
do 2-2. do 4/2.	0.5	0.8	2.0	16.0	-	16.0	16.0
do 3-2. do 4/2.	0.3	0.8	1.8	5.5	-	3.8	11.5
do 3-4. do 4/2.	1.5	2.8	1.6	4.0	-	2.3	6.0
DIGITARIA :							
(Kaprivi) N25. 27/1.	0	0.2	0.8	6.8	+ 7.5	1.1	28.9
do N31. 15/2.	1.1	0.8	1.5	5.2	∅ + 4.0	10.1	-
(Chobi River) A701. 11/2.	1.2	1.1	2.8	7.1	∅ + 8.0	5.0	9.2
(Dongola) A309. 25/1.	5.9	9.6	46.0	22.2	-16.5	3.9	41.3
(Rhodesia) A85. 14/2	0	-	0.5	4.3	+ 6.0	4.9	-
D. foliosa, A74. 14/2.	0.5	1.5	2.2	26.3	∅ + 4.0	17.0	35.9
(Gomoti Riv.4) A604. 30/1.	0.5	0.5	0	1.3	+ 9.0	0.7	1.9
(Gomoti Riv.3) A613. 30/1.	0.3	1.1	0.1	2.2	+16.5	2.3	6.6
(Gomoti Riv.) A685. 5/2.	0	0	0	0	+ 2.5	1.1	1.1
(do no. 4.) A689. 11/2	0	0	0	0.1	+ 7.0	0.3	0.8
(Gomoti Riv.) A699. 5/2.	0	0	0	0	+ 7.5	0.5	5.4
(Kwaai no.23) A601. 30/1.	0.9	0.9	1.2	1.5	+ 4.5	0	3.5
(N'Gami lake) 11/2.	0	0.2	0	0	+ 5.5	0	0
(Mobabi flats) A708. 11/2.	0	0	0.3	0.2	+10.5	1.5	1.9
do A717. 5/2.	0.2	0.5	0	0.6	+ 8.5	0.6	2.4
(Nkoana P. 5) A394 30/1.	0	0	0	1.5	+ 5.0	0	1.6

∅ These values were obtained with soil and incubator tests, using 2x50 seeds per test.

Name of grass. Plot number. Locality. Date harvested 1941.		1st Test %	2nd Test %	3rd Test %	4th Test %	Diff. Soil & Incub. Tests %	5th Test %	6th Test %
DIGITARIA : (continued)								
(Rakops no.5)	A596. 30/1.	0.1	0.5	0.2	1.3	+10.0	0.3	2.1
(do. no.6)	A597. 30/1.	0	0.3	0.2	0.2	+ 3.0	0.5	0.7
(TsotsorogaP.5)	A494. 6/2.	0	0	0	0.2	+ 9.0	0	1.0
do	1/2.	0	0.4	0	0.2	+12.5	0	1.9
(Zanghun Pan 2)	A614. 30/1.	0.4	1.4	0.7	3.6	+ 4.5	0.6	7.0
do	A616. 31/1.	0.7	101	1.1	5.1	+ 3.5	1.0	7.3
do	A720. 11/2.	0	1.5	0.3	0.5	+10.0	1.1	1.2
do	15/2.	0.1	0	0.2	0	+ 3.5	0.2	0.7
(Inkruip)	A423. 28/1.	0	0.8	0.3	0.5	+ 9.0	0.6	1.6
(Rietondale)	A96. 3/2.	11.2	11.3	18.4	57.6	+ 5.5	65.3	59.7
(Lake Shirwa)	A710. 5/2.	0	0.1	0	0	+ 4.5	0	0
	A817. 10/2	0	5.8	56.4	59.8	-32.0	70.4	90.1
CHLORIS GAYANA :								
(Olifants Riv.)	A202. 7/2.	1.9	2.5	24.3	15.1	-	34.8	68.2
(Salt Pan)	A170. 7/2.	1.3	-	9.4	18.6	-	41.5	44.7
(Zebediela)	A167. 7/2.	1.3	16.1	18.0	29.5	+26.0	78.0	58.4
(Commercial)	A168. 7/2	1.1	40.3	17.0	37.2	-	33.6	66.8
(Tugela)	A502. 7/2.	0.2	2.1	6.5	16.2	-	16.3	63.7
(do no. 2)	A174. 7/2.	4.8	33.8	33.5	60.9	+35.6	70.3	73.8
(Lourenco M.)	A169. 7/2.	1.9	3.2	3.9	14.0	-	9.9	70.3
(St.Elm Hosp.)	A367. 7/2.	2.8	3.2	6.7	21.2	-	12.7	35.2
(do. no. 1)	A172. 3/2.	12.1	65.3	40.2	83.8	-	76.2	94.3
(do do)	A172. 7/2.	3.4	59.7	22.8	64.7	-	53.3	72.6
(do do)	A172. 30/1.	3.8	0.2	28.5	51.6	-	49.8	79.2
Selection from "Commercial"	3/2.	5.3	10.1	26.0	38.8	-	62.6	-
(Umfolozi Riv.)	A245. 3/2.	5.6	30.8	19.1	61.7	-	73.9	80.2

Name of grass. Plot number. Locality. Date harvested 1941.		1st Test %	2nd Test %	3rd Test %	4th Test %	Diff. Soil & Incub. Tests %	5th Test %	6th Test %
<u>Brachiaria brizantha</u> :								
(Rustenburg)	A259. 24/1.	0	0	0	0.5	-	0.8	-
do	A259. 3/2.	0	0	0	0	-	0	-
(Weenen)	A495. 28/1.	0	0.5	0.5	9.8	-	38.3	45.3
<u>ECHINOCHLOA sp.</u>:								
(Sharangani)	N112 24/1.	1.5	8.3	12.8	29.8	+23.5 Ø	35.0	-
<u>PASPALUM</u> :								
<u>P. notatum</u>, (Rietondale)	A240. 27/1.	0	0	0	0.3	+ 1.0	0	0
(do)	A240. 3/2.	0	0	0	0	+ 2.5	0	0
(do)	A240 30/1.	0	0	0.3	0	0	0	0
<u>P.scrobiculatum</u> (Wylliespoort)	A275. 25/1.	0	0	0.3	0.5	+ 6.5	0.0	3.3
do (Kabulabula)	A630. 1/2.	0	0	0	0	+ 0.5	0	1.0
do (do)	A630. 25/1.	0	0	0	0	+11.5	4.8	17.0
do (Pungwe)	A386. 28/1.	0	0	0	0.5	+47.5	11.0	45.0
<u>SETARIA</u> :								
(St.Lucia Lake)	A298. 3/2.	0.8	4.3	17.3	29.8	+16.5 Ø	38.0	54.5
(do)	A298. 25/1.	1.5	11.0	12.8	27.0	+35.5 Ø	35.0	-
(White Riv.)	A296. 25/1.	2.3	27.8	42.5	52.0	-15.0 Ø	77.7	57.5
(do)	A287. 25/1.	9.8	27.3	39.7	44.3	+15.5 Ø	59.3	49.0
(do)	A287. 3/2.	1.0	16.0	17.0	26.0	+ 7.0	29.8	29.8
(do)	A286. 3/2.	0.3	17.5	23.5	41.8	+ 4.5 Ø	44.3	54.7
<u>UROCHLOA</u> :								
	N85. 24/1.	0	0.5	0.5	4.3	-	1.8	0
(Rietondale)	A183. 27/1.	0	0	0	0.5	-	0.3	-
(Hammanskraal	A182. 4/2.	0	0	0	0	-	0.5	-
(Matubatuba)	A468. 11/2.	0	0	0	0	-	0.3	0.8
(Rietondale)	A183. 4/2.	0	0	0	0.5	-	0	0.3

Discussion. - The N'Gamiland digitarias (all except the last four and the first six in the above table) behaved the same as in the previous survey (table 11), so that a prolonged delayed germination may be anticipated for them. Seeds of these grasses will most probably not be ready for sowing until the second or third season after harvesting. In comparison with the results of the earlier survey, the other digitarias in the present list ~~are~~ were up to expectation. After about 10 months the majority were germinating under 20%, only 2 registering over 65%. Also *Urochloa* ecotypes ~~are~~ were up to expectation, as compared with the values recorded in the earlier survey and the evidence on hand would tend to strengthen the belief that this genus is one of the worst groups in this respect. The paspalums also exhibited long periods of delayed germination as they only germinate between 0 and 10% after about 10 months, and would therefore not be ready for planting at the time of the first planting season. Apparently the experience is the same in the U.S.A. The values recorded for *Setaria* ecotypes agreed with the results obtained in earlier studies and, compared with the results of other genera, they ~~are~~ were of average performance. The variation show~~s~~ed a gradual rise from about 30% to 77% after about 10 months. The rhodes grasses (*Chloris gayana*) showed a wide range of variation in the progress of their delayed germination, though as a group the periods ~~are~~ were shorter than any other group under observation. The performance of the panicums ~~is~~ was, if anything, poorer than that obtained in earlier tests, when the majority tested over about 40-50% after 10-12 months. It may be concluded that they exhibit, as a group, shorter periods of delayed germination than the digitarias but are surpassed by the rhodes grasses.

The three *Brachiaria brizantha* ecotypes showed low germination after 10 months and it may be assumed to be a species with a long period of delay, the seeds of which will not be ready

for / ..

for planting by the first growing season. The value of 35% (after about 10 months) for Echinocloa is well below the values previously obtained, so that good germination in the field may perhaps be anticipated for the majority by the time of the first growing season.

With the exception of the 13 rhodesgrass ecotypes, only 6 of the ecotypes listed in the above table exhibited 50% and more germination, whereas 16 showed 30% and over.

Also in these studies irregular progress in the delayed germination of certain ecotypes was evident. Except in the case of one Panicum, this group of grasses has shown little improvement between the third and fourth tests. In a few cases declines in germination were also registered here, as for instance in Chloris gayana. As, however, these seeds were kept in the laboratory, it is not likely that the irregularities would be as marked as experienced in the earlier studies. Differences, due to date of harvest, have in some instances proved to be quite appreciable. Thus, in the second test a difference of over 60% was recorded for Chloris gayana A. 172, whilst afterwards differences of 20 - 30% were still obtained.

The foregoing results, obtained on the seeds of a large number of native grasses over several seasons and embracing a number of the more important genera from an agricultural point of view, reveal that, with few exceptions, the seeds of these grasses have fairly prolonged delayed germination as established by the conditions of the incubator tests. This condition of affairs makes it desirable to consider and study suitable means of meeting the situation.

Soil tests. - In order to ascertain what the differences would be between germination in an incubator at 28°C and that in soil outdoors of the seed listed in table 11, soil

tests / ..

tests were undertaken in trays outdoors as soon as spring had set in. The data are tabulated in column 5 of table 11, the results being expressed as plus or minus differences in relation to the incubator figures. In the case of the panicums, the soil tests (2 x 100 seeds per test) were compared with the incubator values of the previous (fourth) test. In the other grasses the comparisons were made with new incubator control tests of 2 x 100 seeds per test and the soil tests were also conducted with 2 x 100 seeds per test, except for the few kinds of seeds indicated in the table, which were used 2 x 50 per test.

The results are interesting. In all but three grasses the soil conditions proved to be more favourable for germination than the incubator conditions. Though large numbers of seeds per test could not be employed, the values (representing duplicate tests) should nevertheless give a good indication. The only 3 - (negative) soil values exhibited large differences and should, therefore, be significant. Incidentally two of these ~~are~~ were the only digitarias which have shown an appreciable germination in the incubator. Better germination in the soil than incubator was anticipated from past experience and the main cause is considered to be the more favourable temperature conditions prevailing outdoors. It ~~will be~~ was shown ~~elsewhere~~ above that light may be responsible for a certain amount of discrepancy between incubator and soil tests. However, it is felt that some other important factor (s) might also come into play.

Very interesting is the phenomenon that the observed delayed germination of the panicums, as a group, ~~is~~ was overcome to a very large extent by soil conditions. In a number of further <u>Panicum</u> selections ("makarikari") not included in the table, the plus values for soil tests varied from 2.5 to 50.5% , though none of the incubator values exceeded 2.5%.

In / ..

In the digitarias, the plus differences were ~~are~~ small and agreed with expectation, but a difference such as plus 45.5% realized with Paspalum scrobiculatum is very obscure, where the other two ecotypes of this species were ~~are~~ far below, and where all were ~~are~~ showing no germination progress in the incubator. Our experience with the seed of this particular ecotype is that the embryo and not the "testa" was, at the time that this test was undertaken, almost entirely responsible for the observed delayed germination. Yet for this one ecotype the "soil effect" could eliminate this "embryo"-inability, to the extent of almost 50% whereas in the other two very little or hardly any effect was obtained. The discrepancy between incubator tests (28°C) and soil tests has in fact been previously observed for Paspalum scrobiculatum.

It would almost appear that about 50% of the factor (s) responsible for "embryo" disability is perhaps to be partly or wholly ascribed to another cause (s); or otherwise, that "embryo" inability comprises more than one factor or a "system" which can only be eliminated in a series of changes or steps.

This high value for "soil effect" has actually been equalled and surpassed by certain panicums, the highest difference in the latter being 69%. Perhaps we should seed to discover the means by which this is accomplished.

Whilst, on the one hand, there is evidence that for certain seeds delayed germination is not disadvantageous from the agricultural viewpoint (because a good germination may be obtained under field conditions by the time of the next growing season), there are, on the other hand, strong indications that for the majority, such conditions will not be realized, particularly in the digitarias.

(2) An Analysis of the Apparent Causes of delayed Germination.

In the literature the two usual or main causes of

delayed / ..

delayed germination that are recorded are :-

1. those due to seed-coats and

2. those due to conditions associated with embryo preparedness. In the case of the Gramineae, however, the first-mentioned is generally regarded as the one most commonly responsible, but as far as the writer is aware, there appears to be no very definite agreement on the whole matter and also that no systematic attempt has been made to analyse the causes of delayed germination over its full period. As this appeared to be an important consideration in the study of methods for the elimination of delayed germination, particularly where our experience in this respect has often been of a somewhat contradictory or obscure nature, attention was directed to this phase of the problem in order to try and gain a better understanding of the extent of the fundamental controlling factors. The study has, however, been only recently undertaken and then only after much time had been devoted to methods for the overcoming of delayed germination.

Methods and materials. - For these studies a number of different kinds of newly harvested seeds, belonging to several genera, were employed. The seed-coats (testa and pericarp) of the caryopses of these were broken and thereafter germinated in the usual way. The method adopted was to file the fruits of the larger kinds until a small portion of the seed-coats had been removed and in the smaller kinds to carefully set free the caryopses from their coverings and then to scratch them. In Sporobolus and Chloris gayana the removal is comparatively easy but in the panicums, digitarias and others this required more skill, careful handling being necessary for all, so that the work entailed was quite appreciable. Under the circumstances, therefore, it was decided to use only 2 x 50 or 2x25 seeds per test. The results, to date, of this investigation are tabulated in table 12.

T A B L E 12 / ..

Table 12. The effect of breaking of the seed-coats on the percentage germination of various kinds of seed - being an analysis of the respective contribution of the main factors of seed-coat restrictions and 'embryo' inability to the progress of delayed germination.

Kind of seed; date harvested in 1941; plot number and ecotype.	First Test: coats broken %	First Test: coats intact %	Second Test: coats broken %	Second Test: coats intact %	Third Test: coats broken %	Third Test: coats intact %	Fourth Test: coats broken %	Fourth Test: coats intact %	Test repeated directly after previous test: coats broken %	Test repeated directly after previous test: coats intact %
Brachiaria brizantha:										
Rustenburg, A259; 24/1.	3.0	0.0	9.0	0.0	6.0	0.0	21.0	1.0	-	-
Weenen, A495; 28/1.	0.0	0.0	18.0	0.0	3.0	0.0	36.0	23.0	12.0	41.0
Chloris gayana:										
Umfolozi, A235; 3/2.	84.0	4.0	100.0	8.0	96.0	-	-	25.2	-	73.7
Rietondale No.1, A172; 7/2.	72.0	16.0	96.0	14.0	-	-	-	24.1	-	46.7
Echinochloa:										
N.112; 18/1.	74.0	1.0	82.0	6.0	93.0	21.0	-	-	-	32.8
Digitaria:										
n'Gamiland, (in sun))11/2.	-	-	-	-	82.0	-	74.0	1.0	40.0	26.0
do (in lab.) 11/2.	32.0	2.5	72.0	0.2	84.0	-	76.0	0.0	78.0	0.0
Kwaai No.11, A398; 30/1.	-	-	78.0	± 1.0	98.0	-	-	0.0	-	-
do No. 4, 3/1938.	-	-	-	-	70.0	14.0	-	-	-	-
Tsotsoroga Pan No.2, 2/1938.	-	-	-	-	82.0	5.4	83.0	0.0	-	-
Gomoti R., A685; 5/2.	-	-	-	-	43.0	2.0	82.0	4.0	-	1.0
do A689; 11/2.	-	-	-	-	89.0	1.0	61.0	0.0	30.0	0.0
NkoanaPits A394; 30/1.	-	-	-	-	78.0	4.0	92.0	1.0	-	0.0
Sehitwa, A710; 11/2.	-	-	-	-	81.0	0.0	62.0	0.0	14.0	0.0
TsotsorogaPan No.5., 1/2.	-	-	-	-	73.0	11.0	90.0	0.0	-	0.0

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		First	Test	Second	Test	Third	Test	Fourth	Test	Test repeated directly after previous test.	
Kind of seed; date harvested in 1941; plot number and ecotype.		coats broken %	coats intact %	coats broken %	coats intact %	coats broken %	coats intact %	coats broken %	coats intact %	coats broken %	coats intact %
Panicum:											
P.maximum, N122;	18/1.	18.6	6.0	57.0	21.0	46.0	25.0	19.0	27.0	60.0	52.0
Nelspruit, A434;	28/1.	39.0	41.0	93.0	66.0	78.0	78.0	88.0	80.0	-	-
Makarikari 2-23;	12/2.	48.5	0.0	94.0	2.5	-	-	-	23.4	-	-
P.proliferum, A436;	28/1.	50.0	6.0	74.0	23.0	-	-	-	-	80.0	61.0
Wylliespoort, A390;	28/1.	14.0	1.0	66.0	11.0	58.0	15.0	20.0	18.0	38.0	10.0
Paspalum:											
P.notatum, A240;	27/1.	16.0	0.0	13.0	0.0	45.0	0.0	56.0	0.0	-	0.0
P.scrobiculatum, A275	25/1.	1.0	0.0	7.0	0.0	24.0	0.0	41.0	1.0	-	0.0
do A386;	28/1.	-	-	-	-	100.0	0.0	100.0	18.0	-	11.0
do A630;	1/2.	-	-	-	-	43.0	0.0	20.0	0.0	18.0	0.0
do do	25/1.	-	-	-	-	21.0	2.0	17.0	0.0	26.0	0.0
P.dilatatum,	21/2/41.	-	-	-	-	34.0	1.0	-	-	-	13.1
Setaria:											
St.Lucia Lake, A298;	25/1.	1.0	6.0	6.0	8.0	10.0	20.0	22.0	22.0	22.0	49.0
White River, A296;	25/1.	-	-	-	-	-	-	15.0	55.0	18.0	50.0
Sporobolus:											
N.K. 297;	27/1.	0.0	0.0	0.0	1.0	16.0	-	42.0	0.0	-	-
N. 352;	2/1.	-	-	2.0	0.0	4.0	-	7.0	0.9	-	-
Urochloa:											
A183;	24/1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Discussion. - At the outset it should be explained that reference to "embryo" and "seed-coat" restrictions does not necessarily imply an interpretation in the strict sense of these terms but should rather be regarded as terms of convenience, although it seems that the "seed-coat" factor is really applicable in the strict sense.

The results to date have brought to light very interesting facts. It is evident that in the Brachiaria, Sporobolus and Paspalum ecotypes under study, the embryo as well as the seed-coat played important roles in delayed germination for several months after harvest. The embryos gradually became more capable of germination, whereas the seed-coats ~~are~~ were still restricting.

However, the seed of P. scrobiculatum A. 630 of 1/2/41 showed a distinct retrogression of the embryos at the time of the last and second last tests, the phenomenon also being very noticeable in the case of the Brachiaria. This is most probably only a temporary decline of germinability.

The position in regard to the Urochloa is not clear and presumably none of the embryos ~~are~~ were as yet ready for germination. This is perhaps a generic characteristic. Only time will help to answer the question; it is hard to believe that embryo immaturity could be entirely or partly responsible for the delay.

It has, however, been found at the time of the final test that ~~when~~ if the caryopses of Urochloa ~~are~~ were removed from the coverings, and then scratched, the germination immediately ~~rises~~ rose to 88%, in comparison with a germination of 0% for seeds scratched inside their coverings.

The Echinochloa, the Chloris gayana and the Digitaria ecotypes, as well as certain panicums, belong to a group in which the embryo is far ahead of the seed-coats, the latter

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seizing to inhibit only gradually. It is quite certain then that at least in these kinds the seed-coat does not retard the after-ripening of the embryo permanently, if at all. Further direct evidence on this point is submitted below. This is important because one might have thought that embryo inability is directly associated with seed-coat restriction as a result of the possible restricted or inhibited gas exchange.

In connection with the digitarias it can be mentioned that the seeds of two N'Gamiland ecotypes, "Kwaai No.4" and "Tsotsoroga Pan No.2", giving at 3½ years respectively 14% and 5% germination, yielded 70% and 82% germination respectively, with breaking (scratching) of the seed-coats. The Eidmann (Na selenite) test ') showed that a certain percentage of the seeds of these two ecotypes had already lost viability, but that the embryos were not responsible for the observed delayed germination, and that the seed-coats were, therefore, entirely responsible for the observed delayed germination at the age of 3½ years. It is evident that viability may be lost before all or even a high percentage of the seed-coats have lost their powers of restraint.

It is further apparent that in none of the kinds of seed under study was only one of the two factors responsible for the delayed germination and that on the whole, the seed-coat factor plays the greater role. In Panicum A.434 the progress of embryo and seed-coat delay was apparently proceeding simultaneously.

The phenomenon of embryo retrogression is also very clearly exhibited by certain Digitaria and Panicum ecotypes. It should also be mentioned here that it has been found that it often makes a great difference whether seed-coats are broken after the caryopses are set free or without removing them. At

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') Eidmann test values were 69.5% and 68% viable resp.

the time of the last test above, 13 ecotypes were thus compared. Two of the panicums and one of the setarias were apparently somewhat unfavourably affected by the setting-free of the caryopses. Of the other 10 ecotypes, three were about equal with the two methods, but 7 clearly benefited by the removal of the caryopses, showing considerable differences in some cases - the differences being as much as 88% (Urochloa). One and the same method of breaking seed-coats was used throughout for every kind of seed listed in the table.

The behaviour of the 2 setarias, in which the breaking of the coats caused a drop in germination, is puzzling.

The high soil test value of Paspalum A.386 (table 11), in relation to the other values for the ecotypes of this species, is now far more clear, if the respective values in table 12 are considered alongside thereof. why? soil effect on seed coat?

In passing it might be mentioned that for a Chloris gayana ecotype, it was established that after 48 hours imbibition, scratching had no longer any effect on germination. It further appears that in those cases where the seed-coat offers resistance to germination, water penetrates but whether readily enough or whether this occurs in preferred regions of the grain, is not known. It is conceivable that rate of penetration or preferred paths of penetration are important in pregermination events.

The value of this type of study for the problem of finding suitable methods for overcoming delayed germination will be apparent. In the first place, it would perhaps be desirable to consider methods for the two individual factors separately or at least attempt an analysis of the effect of a treatment on the individual factors. If it is decided to direct attention to the restrictions caused by the seed-coats, it would perhaps be best to wait until the embryo factor has been naturally eliminated as in this way the interpretations will not be unduly complicated. Unfortunately it is not possible with this analysis to obtain an exact evaluation of the seed-coat factor when its percentage contribution is equal to or greater than the percentage contribution of the embryo factor, but only when the reverse is the case. On the other hand, of course, the value obtained for "coats broken" is always a true evaluation of the condition of the embryo.

<u>The effect of seed-coats on the course of delayed germination.</u> - Where the results showed that both seed-coat and embryo play important parts in the observed delayed germination, the question arose as to how far the seed-coat restrictions are themselves responsible for the delay occasioned by the embryo. That is, whether gas exchange is restricted, and if so, its effect on the after-maturation associated with the embryo. In order to study such a possible influence, a large number of seed of <u>Paspalum notatum</u> A.240, of 3/2/41, and of <u>Brachiaria brizantha</u> A.259, of 3/2/41, were scratched on 16/10/41 and thereafter germinated on 3/11/41, 17/11/41, 4/12/41 and 6/1/42. The germination percentages recorded were 11, 12, 8 and 40 for the <u>Paspalum</u> and 24, 27, 44 and 14 for the <u>Brachiaria</u>, the controls throughout being 0%. At the commencement of this study the <u>Paspalum</u> and <u>Brachiaria</u> germinated 56% and 21% respectively, with breaking of the seed-coats and at the last date of test the values under the same conditions were resp. 23% and 44%. It would thus appear that for the period studied, scratching has, if anything, been unfavourable to the course of after-maturation of the embryos of the <u>Paspalum</u>, whereas in the case of the <u>Brachiaria</u> no improvement is evident. It, therefore, seems doubtful whether the restrictions imposed by the seed-coats are unfavourable to the course of the delayed germination attributed to the embryo as would appear to be sub-

stantiated / ..

stantiated by the indirect evidence indicated above.

The influence of coverings (bracts) on the course of delayed germination. - When caryopses of ecotype A.172 (of 7/2/1941) of Chloris gayana were removed on 19/4/41 and germinated on 26/9/41, the percentage germination was 61.5. Germination fell rapidly, being 12.5% 11 days afterwards and 9.0% on 7/12/41. At the last-mentioned date the control registered 46.7% and one is forced to conclude that with this particular ecotype and at this season, removal of the bracts has depressed the germinability far more than was experienced with the uncleaned fruits.

Here we may perhaps once more revert to the enquiry as to the suitability of the temperature employed (and to some extent also of the other conditions) in the tests, to provide a criterion of the state of delayed germination. In table 11 it will be observed that in those kinds of seeds in which a progress could be clearly discerned, there is a very clear rise, step by step, which would not have been obtained under less favourable conditions. In addition, the soil tests with the Digitaria ecotypes very strongly support this view. Also, the values tabulated in table 12 appear to bear this out, since all the test with "broken" seed-coats show a similar, consistent, increase in germination in the consecutive tests, in those cases where the "embryos" were clearly after-ripening. At first sight the urochloas might appear not to support such a view but elsewhere they have shown to be able to germinate at 28°C to some extent, after long periods or with treatments. Moreover, they, as well as other resistant kinds, have failed to respond to lower even temperatures. It seems not incorrect, therefore, to regard the conditions employed as favourable enough to serve as an interpretation of the state of after-maturation of seeds. It is, therefore, tacitly assumed that the seed of any of these ecotypes should germinate completely or nearly so, at ca.28°C,

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when fully after-ripened and, moreover, that where the soil is able to produce a higher germination, within reasonable limits, than that obtained at 28°C, the increase so registered amounts to stimulation.

Summary.

The above investigations may be summarized as follows:-

1. Several surveys have been undertaken at different times to study the course of delayed germination.
2. Delayed germination is exhibited by the seed of all of the many ecotypes, belonging to a number of genera and species, under observation.
3. The duration of delayed germination varied from about 2 months in the Peddie ecotype of *Digitaria* to well over 3½ years in a number of N'Gamiland ecotypes of the same genus and the maximum period may apparently be much longer.
4. The extent of the variation in resistance to germination does not appear to be a characteristic of the seed of any group (species or genus) of grasses, or to be restricted to seed from any geographical or ecological region.
5. Although environmental conditions during the development, field maturation and storage of seeds, may have an important effect on the course of delayed germination, the basic factors responsible for delayed germination appear to be inherited.
6. The course of delayed germination is frequently not a smooth one, as sudden rises and falls, which usually coincide with the advent of summer, are exhibited in seed stored both outdoors and indoors.

7. In certain cases a discrepancy, occasionally of some magnitude, exists between laboratory and soil tests, indicating that the observed delayed germination may be partly or largely overcome by soil conditions. This is particularly noticeable in the *Panicum* ecotypes studied.

8. An analysis of the apparent causes of delayed germination was made by breaking of the seed-coats of a number of lines of seed, belonging to several genera. This was repeated at consecutive intervals over a period of about 9 - 10 months.

9. It was revealed that in all cases both seed-coat restrictions and "embryo" unpreparedness play a role in the observed delayed germination.

10. The relative importance of these factors, in the course of the observed delayed germination, varied with the ecotype. In certain instances the inhibition of germination, due to the "embryo", was of short duration, as compared with seed-coat restrictions, whilst in other cases the "embryos" only gradually became capable of germination.

11. In the case of the ecotype of *Urochloa* and the two *Setaria* ecotypes employed, the position was not clear, as in the former no germination was secured by the breaking of seed-coats, even after about 10 months, unless the caryopses were freed, when the germination rose to 88%. In the *Setaria* ecotypes, breaking of the seed-coats resulted in a marked lowering of germination.

12. On the whole, however, the restriction ~~s~~ ~~of~~ the seed-coats ~~were~~ was a factor of far longer duration than that of "embryo" inhibition; so much so, that in certain cases (*Digitaria* lines) loss of viability to the extent of approximately 20% was found to have already occurred after 3½ years, when

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the seed-coats were still responsible for all the delayed germination registered.

13. The phenomenon of "embryo" retrogression, which is most probably only a temporary decline of germinability, corresponding to the falls of germination referred to under 5. above, was clearly exhibited by certain ecotypes, belonging to several genera.

14. The value of this type of analysis in the study of methods for overcoming delayed germination ~~was~~ is indicated.

15. An attempt was made to determine the role of the seed-coats on the course of delayed germination, it being established that for the ecotypes studied, no retardation of delayed germination was discernible as a result of possible seed-coat restrictions which fact was also borne out by indirect evidence, as pointed out. Neither was there any positive proof, in a preliminary study, of a possible retarding effect of the presence of bracts on the course of delayed germination.

III.

STUDIES ON CHEMICAL METHODS FOR OVERCOMING DELAYED GERMINATION.

With ordinary agricultural seeds the problem of delayed germination seldom, if ever, forms a disadvantage in practice and attention has mostly been directed thereto with an object other than that of finding means of hastening the process for purposes of practical application. In contrast to this, however, are the numerous investigations on the chemical stimulation of germination which were generally undertaken for the stimulation of germination for agricultural use though not particularly for the improvement of delayed germination.

It might be mentioned here that practically all the studies reported in this and the following chapter were undertaken long before those on the apparent causes of delayed germination, reported in the previous chapter.

Preliminary studies on vapours and gases.

The following vapours and gases were tested out in order to learn something about the response of dry seeds to such treatment:- Hydrochloric acid, nitric acid, acetic acid,

sulphur / ..

sulphur dioxide, nitrogen peroxide, ammonia, carbon bisulphide, carbon dioxide, oxygen, ether, chloroform and acetylene. An excess of everyone of these substances was used and in all except hydrochloric acid the atmospheres in the various flasks were made humid at the commencement of each test by placing moist filter paper inside.

For every treatment except chloroform and ether, nine kinds of seed (all harvested March 1936) were used and these were placed in small cotton muslin bags in large well-stoppered 3 litre flasks in which they were subjected to the influence of the above-mentioned gases and vapours. The flasks were kept sealed for two months when they were opened and the seeds tested in the usual way at 30°C. The seeds of individual treatments were all kept together in one flask.

Discussion of results.

In the case of chloroform and ether, only two *Digitaria* ecotypes were employed and for these two treatments as well as for hydrochloric acid, acetic acid, ammonia, nitrogen peroxide and sulphur dioxide the results were negative, these chemicals apparently proving harmful with a two months' treatment.

In these studies were employed :- *Digitaria* ecotype C.1 (Kuruman) and a selection 24-3 of the ecotype "Inkruip"; *Panicum coloratum* ecotype C.98; *Panicum* sp. ecotype "Makarikari"; *Panicum minus* ecotype F.14; *P. maximum* ecotype F.6; *Chloris gayana* ecotype F.15 and *Setaria sphacelata* ecotype H.10. The latter two were harvested in May 1936, the others all in March, the test being conducted end of July 1936.

In the case of carbon dioxide, the germination over the first eight days' duration of the test showed over 40% stimulation for *Panicum coloratum* ("Hammanskraal") C.98, 62.5%

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for Panicum minus v. planifolium F.14, and 16% for Panicum sp. ("Makarikari") C.79, as compared with their respective controls, whereas no or slight stimulation was obtained with the other kinds. F.15 was discarded after a few days owing to fungi but the treatment appeared to have been harmful. Carbon bisulphide gave no or slight stimulation while nitric acid vapours gave for Panicum C.79 a 33% increase and for Digitaria 24-3 a 53% increase (over their controls) within the first eight days of the test, whilst for the others the effect was either harmful or valueless.

With oxygen, Panicum minus F.14, gave a 28% increase, for Panicum C.79 a 41% increase and for Digitaria ("Kuruman") C.1 a 20% increase for the first eight days in comparison with their respective controls. With the rest of the seed (lines) only slight or no increases were registered.

Afterwards carbon dioxide and oxygen were used at room temperature and at 45°C for keeping (storing) seeds in, the gases being renewed after every monthly test. Seven lines, the results for two of these appearing in table 13 , were tested for six months. It will be observed that at 45°C both oxygen and carbon dioxide used alone, were harmful, particularly the former, as the germinative power appeared to be soon lost, although in two of the five grasses a slight increase over the control was registered at the first monthly test. O_2 at room temperature seemed to be about equal to the controls. CO_2 at room temperature did not equal the controls and only in one case showed a gradual increase up to the 6th monthly test. In table 13 the monthly values of two of these grasses are tabulated.

TABLE 13 / .,

TABLE 13: THE MONTHLY GERMINATION OF TWO ECOTYPES TREATED WITH CO_2 AND O_2 AT ROOM TEMPERATURE AND 45°C, FOR SIX MONTHS.

Name of Grass	No. of monthly test	Percentage Germination:				
		Control	CO_2 at room T	CO_2 at 45°C	O_2 at room T	O_2 at 45°C
Panicum minus var. planifolium B. 7/11	1st	4.0	0.6	5.0	2	0
	2nd	9.7	5.2	8.1	12.7	0
	3rd	11.5	6.1	6.2	10.0	0
	4th	16.2	8.8	3.5	16.3	0
	5th	23.6	8.2	2.1	16.6	0
	6th	26.3	11.8	0	22.2	0
Digitaria sp. "Inkruip" 27-9	1st	0	0	2.2	0	9.8
	2nd	0	0.3	6.3	0.2	0
	3rd	0.4	0.8	0.9	0.7	0
	4th	1.1	0.2	0	0.9	0
	5th	1.1	1.0	0	1.0	0
	6th	1.2	0.5	0	1.6	0

With acetylene, *Panicum* C.79 and *Panicum minus* F.14, gave respectively 27% and 14% increases over their controls. In the case of the other seeds, the effects were either indifferent or harmful.

The above percentages were secured at even temperatures over an eight-day period. Thereafter all tests were subjected to various combinations of alternating temperatures and it is interesting to record the effects. Amongst those kinds of seeds that received the CO_2 treatment, *Panicum* C.79 and *Setaria* H.10, showed very distinct stimulation when room temperature (six hours) plus 30°C (eighteen hours) followed the even temperature treatment at 30°C. Under the same conditions, *Panicum* C.79 and *Panicum minus* F.14, with the CS_2 treatment, exhibited marked increases over the even temperature periods, indicating that the lack of germination capacity experienced

after / ..

after two months of this treatment is not all to be interpreted as being due to harmful effects. Perhaps a great deal, if not entirely, is to be ascribed to induced or secondary delay or "dormancy".

With HNO_3 treatment, only Digitaria 24-3 appeared to have exhibited some stimulation on substitution of alternating temperatures. The total germination of 80% is perhaps largely the result of the original treatment. In the case of the O_2 treatment, no marked effect as a result of alternating temperatures is observed. On the other hand, a favourable influence from such treatment was detected in certain of the kinds subjected to acetylene gas. Again Panicum C.79 was distinctly stimulated, but the germinability of Setaria H.10 could also be improved in this way. It is, therefore, not clear whether the lack of germination was due to loss of viability or not. In a few of the cases bacteria and fungi developed abundantly in the seed-beds.

Though other workers have used ammonium salts, the use of ammonia vapour has apparently been rarely used. McCallum (1909), using this gas, obtained favourable results with potato tubers. Barton (1940), employing concentrations of 1000 and 250 p.p.m. for 1, 4, 15, 60 and 960 minutes of continuous flow over moist and dry seeds of radish and rye obtained a toxic effect in the case of moist seeds of both kinds whilst in the case of dry seeds no reduction in percentage was experienced.

CS_2 has often been studied. According to Lehmann and Aichele (1931), Prillieux (1878) obtained harmful effects after three days treatment of wheat. In connection with disinfection studies these authors recorded the harmful effects reported by several authors. Addition to the soil gave stimulation, according to Koch (1912) - as cited by Lehmann and Aichele etc.. Bokorny (1913) obtained favourable results with it, dissolved

in / ..

in water, and when alcohol was added (1 c.c. per litre of water).

Chloroform and ether have often been employed not only for seeds but also for woody plants, etc., and as ether has been employed by many workers, a complete review would be out of place here. Both dry and moist (frozen or soaked) seeds were employed in past studies. Coupin (1899) and Burgerstein (1906) - cited by Lehmann and Aichele (1931) - demonstrated the importance of moisture content of seeds in this respect. Ether was not only employed as a vapour but also in aequeous solution. That the state of delayed germination is also an important consideration seems clear and the results of Kiessling (1911) - cited by Lehmann and Aichele (1931) - confirm this. He appears to have been the only worker who gave attention to this aspect. Not only the condition of the seed, but also that under which the test is carried out (temperature, etc.) must be important. Howard (1915) - Bulletins 17 and 21 - reviewed most of the earlier work on anaesthetics (plants and seeds) and also reported his own work on the effect of ether on CO_2 production in cuttings under various conditions and on dry, soaked and frozen seeds. Lehmann and Aichele (1931) reviewed much of the work on Gramineae. Both favourable and unfavourable effects were realized .

Chloroform was studied under very similar conditions by a number of investigators and more or less the same remarks apply here as immediately above. Acetylene has been reported as a rootforming substance from the Boyce Thompson Institute.

Giglioli (1895), after 16 years storage of lucerne seed in an alcoholic solution of SO_2, still found 0.15% germination. It was also found most harmful by Barton (1940) who studied its effects on dry seeds and moist seeds at 250 and 1000 p.p.m. for periods varying from 1 min. to 16 hours. Apparently only these workers have employed this gas in such

studies / ..

studies. Work on NO_2 has not come to the writer's notice.

For the marked disagreement between the two sets of experiments with CO_2 and O_2 the only explanation that suggests itself is the question of moisture or humidity of the atmospheres in the two series.

The above results with CO_2 and O_2 treatments do not appear to be very consistent and it is perhaps surprising that stimulation was obtained with both gases, though not with the same ecotypes. That these gases play an important role in delayed germination seems certain, if only under certain conditions, and it appears not unlikely that with further investigation it should be possible to employ them for the overcoming of delayed germination. That these gases, alone and in mixtures, play and can play a very decisive role in the events associated with the disappearance of delayed germination, has been established by various workers though pre-treatment of dry seeds has hardly ever been reported on.

Giglioli (1895), using O_2 and CO_2 (dry) realized respectively 0.68% with lucerne seed after 16 years and 0% with lucerne, wheat and vetch after 17 years storage. Kiessling (1911) found that with oats and barley, increased O_2 is deleterious to fully after-ripened, but favourable to non-after-ripened seeds. Crocker (1906) amd Shull (1914), working with _Xanthium_ seeds, found that by increasing O_2 supply an immediate increase in absorption and germination resulted as was later (1935) found by Thornton. Atwood (1914) obtained similar results with _Avena fatua_. Becker (1912) - cited by Shull (1914)- studying _Dimorphotheca pluvialis_ found better germination in O_2 than in air (especially the ray seeds). Exposure for 30 hours to O_2 (though not 15 hours) favoured further germination in atmosphere. Increased O_2 pressure favoured the germination of _Calendula eriocarpa_ seeds, whilst two _Atriplex_ spp. were

injuriously / ..

injuriously affected. Kidd (1916) considered that "the widely occuring phenomenon of delayed germination in the case of the moist resting seeds are related to an inhibitory partial pressure of CO_2 in the tissues of the embryo". Working with potato tubers he, 1919, found an O_2 and CO_2 concentration, above 5.1% and 20% respectively, harmful, the deleterious action of the former increasing in the presence of CO_2. Harrington (1917) showed that CO_2 (in a wide range of concentrations) induced germination of non-afterripened Johnson grass seeds. Gardner (1921) promoted the germination (in darkness) of Rumex Crispus and carrot seeds by increased O_2 pressure. Harrington (1923), working with cereals, obtained similar results but non-afterripened seeds of Johnson's grass failed to respond to an increase of O_2 (Harrington and Crocker 1923). With Typhia latifolia seeds, Morinaga (1926) found poor germination in air but reduction of this concentration of O_2 by addition of H or N to the extent of 40-80%, gave approximately 90% germination. A 94% germination was secured with a 99% H mixture. When seedcoats were broken, the germination took place at O_2 pressure of 1-90% of that of the atmosphere. Cynodon dactylon seeds also germinate better with reduced O_2 partial pressures (dilution with H or N) but the effects were not as marked. Kondo and Okamura (1930) found hulled rice stored in CO_2 retained germination capacity perfectly for 4 years. Braun (1931) found that 5-8% CO_2 was most favourable for the hastening of the sprouting of dormant potato tubers.

Thornton (1933) reported on the influence of CO_2 on the O_2 uptake and acidity of tubers, bulbs etc. He, 1933, further recorded the effects of CO_2 and O_2 and mixtures of these on the sprouting of potato tubers. In 1935, after studying the O_2 and CO_2 requirements and development of dormancy in the upper and lower seeds of Xanthium, he also found that the

needs / ..

seeds for germination were very different for the two types of seed (intact) and their naked embryos at different temperatures. Like Shull (1914), he drew attention to the normal procedure in germination with O_2: "Germination of the intact seeds in O_2 takes place with the growth of the cotyledons before the growth of the radicle rather than by growth of the radicle followed by an enlargement of the cotyledons as is the normal procedure." He, 1936, showed that lettuce seeds ordinarily requiring 20°-26°C to germinate (in darkness) would give good germination in the presence of CO_2 even at 35°C. Higher CO_2 concentration (in conjunction with O_2) was needed for germination at higher than at lower temperatures. In 1939 the same author reported on the relationship of O_2 to CO_2 in breaking the dormancy of potato tubers, CO_2 in presence of 20% O_2 being found very effective. After further investigations (1939), he claimed that too much O_2 prevented sprouting and that freshly harvested potatoes would sprout in 7 days if held in 5 to 10% of O_2 under moist conditions; in 9 days with 2% O_2 under dry conditions. Under natural conditions this takes place because of the reduced permeability of the periderm to O_2, subsequent to the suberization of its tissues.

Potzoff (1936) found that CO_2 or O_2 atmospheres did not influence after-ripening of tobacco seeds, Zimmerman and Hitchcock (194) obtained favourable results by treating Althea cuttings with high concentrations of CO_2.

Though several authors have employed HCl, HNO_3 and acetic acid solutions for promotion of germination with varying success, exposure to vapours has not been recorded and few have done work on their effect on delayed germination. Harrington (1917) found no forcing action with HCl and acetic acid solutions on Johnson's grass seeds. Gardner (1921) promoted the germination of tobacco seeds and Rumex crispus in darkness by

means / ..

means of HCl solutions. Ray and Stewart (1937) subjected non-after-ripened Paspalum seed to 37% HCl, obtaining slight improvement in germination. Barton (1939) employed it in high concentration as a scarifying agent for the seed-coats of certain grasses.

Short-period gas and vapour treatments.

As the abovementioned results appeared to indicate the possibilities of this type of treatment, a number of gases and vapours were tested out over short periods. The following were employed : Thioacetic acid, thioglycollic acid, ethyl thiocyanate, ethyl iodide, ethylene dichloride, carbon tetrachloride, chloroform, carbon bisulphide, ether, formalin, ammonia, glacial acetic acid, toluol, nitric acid, nitrogen peroxide, carbon monoxide. The seeds of seln.24-3 from the "Inkruip" Digitaria ecotype, with an extended delayed germination, was used in all these tests unless otherwise stated, because it was considered that if good stimulation could not be secured with this, it was hardly worth while testing out seed of other ecotypes, although it was realized that the response might vary with the ecotype. Germination tests were conducted in the usual way at ca. 30°C. The seed was harvested in March 1936 and practically all the tests were conducted during that year. In all these tests a standard type dropping bottle was used to measure the quantity of the chemical and no water was used unless stated.

Thioacetic acid at the rate of six drops per two litre flask (air) gave 6.7%, 5.3%, 47.8% and 0% germination after one hour, two hours, 10 hours and 24 hours respectively. Employing only one period (eight hours) but varying concentrations, viz. 1, 2 and 4 drops p. 2 L., the germinations were 4.6%, 7.4% and 3.4% respectively. With the control at approximately / ..

proximately 6%, the maximum stimulation was over 40%.

Thioglycollic acid with the same ecotype gave 29% germination, using 2 drops per 2 L. flask for 1 hour; with 1 drop the germination was 27.9% and 17.5% respectively for six and 19 hours; with 4 drops, 34%, 25.6% and 8.8%, for 2, 11 and 24 hours respectively; and with 5 drops, 30.6%, 15.1% and 10.6% for 2, 3 and 4 hours respectively. The control tested about 1%.

Ethyl thiocyanate at a concentration of 0.75 c.c. per 2 L. flask, yielded after 6 hours with <u>Digitaria</u> seln. 24-3, <u>Panicum coloratum</u> C.91 and <u>Panicum maximum</u> F.7, 37.2%, 5.5% and 0% germination respectively; after 24 hours, 29.1%, 14.6% and 0% respectively; after 3 and 5 days no germination and after 11 days, 7.8%, 6% and 0% respectively, the controls being all approximately 2%. The response is somewhat unusual.

Ethyl iodide at a concentration of 4-5 drops per 2 L. flask exhibited 19.5%, 26.6%, 32.1%, 17.9% and 0% germination over 1 hour, 3 hours, 6 hours, 22½ hours, 11 days, 14 days and 21 days respectively; for a 17 hour period, 4.8%, 13.5% and 17.6% germination were realized with 12 and 5 drops respectively. Using 5 drops over periods of 3, 6, 12, 24 and 48 hours, the percentage germination was respectively 12.4%, 14.0%, 27.8 13.7% and 16.2%. Over a period of 3 hours, 10 drops gave 13.0% germination and with 1 drop over periods of 7½ hours, 24 hours, 2 days and 5 days the percentages were 4.1, 4.7, 8.3 and 1.0 respectively. The control was approximately 14% germination.

With ethylene dichloride, used at the rate of 1, 2 and 5 drops per 2 L.flask, <u>Digitaria</u> 24-3 germinated 2.4%, 1% and 2.6% respectively and with 10 drops over periods of 1 hour, 3 hours, 10 hours, 24 hours, 9 days and 15 days, resulted in 5.4%, 2.3%, 2.4%, 4.1%, 4.6%, and 23% germination respectively, the control being approximately 6%.

Employing carbon tetrachloride, at 10-11 drops per

2 L. / ..

2 L. flasks gave 19.5% and 13.9% respectively, the control being about 14%. Formalin, 40%, used at a concentration of 10 drops for 1 hour and 4 hours, resulted in 11.8% and 25.3% respectively, while 5 drops for 4 hours yielded 23.5% and 2 drops for periods of 4 hours, 25½ hours and 2 days resulted in 10.7%, 21.0% and 18.5% respectively, the control being about 14%.

Ammonia, tested out in the concentrations of 1, 2 and 4 drops per one L. flask for 1 hour periods showed 32.4, 35.0 and 19.6% germination respectively, whereas 1 drop (per 2 L.flask) at periods of ½, 1 and 1½ hours showed respectively 9.4%, 25.3% and 9.0%, with the control at about 14%. Carbon tetrachloride used together with ammonia gave lower values than for the sepapate compounds. On the other hand, glacial acetic acid tried out with concentrations of 1, 2 and 4 drops for 1 hour periods, yielded only 10.3%, 9.0% and 3.5% germination respectively, the control being about 14%. Toluol gave even lower values.

Nitric acid which had previously, with two months' treatment, given very promising results with seed of <u>Digitaria</u> seln. 24-3, was again used at shorter intervals and controlled concentrations. In subdued light 10 drops per 2 L. flask gave after 1¾ hours slightly better germination in a dry atmosphere than in a humid atmosphere; after 3 days the moist atmosphere still gave a germination but not the dry atmosphere; after 10 days, however, the seeds in the moist atmosphere had also lost their germinating power. Using (in dark) 2, 5 and 10 drops (the acid spread out in the flask) as well as 5 c.c.acid, per 2 L. flasks for three days, best germination was obtained with 2 drops, 1 drop yielding no improvement in germination and the other concentrations no germination. In the dark set, the 2 drops for 2, 5 and 26½ hours yielded 36.6%, 13.5% and 27.4% respectively with contral at 11%. Using 2 drops per 2 L. flask for 1½ hours, 4 days, 10 days, 25 days and 70 days in darkness,

/..

the percentage germination obtained was respectively 4.6, 33.0, 35.0, 0.0 and 0.0, with control at 9.8%. Panicum minus var. planifolium, F.14, with concentrations of 3 drops per 3000 c.c. jars, with and without $CaCl_2$ germinated as follows :-

	with $CaCl_2$	without $CaCl_2$	with $CaCl_2$	without $CaCl_2$	with $CaCl_2$	without $CaCl_2$	Control
for:	2 hrs	2 hrs	5 hrs	5 hrs	10 hrs	10 hrs	
	%	%	%	%	%	%	%
	76.4	63.1	82.4	58.2	2.6	40.6	28.7

The importance of the humidity factor is clearly indicated, the effect of humidity being reversed for the 10 hour period as compared with the 2 and 5 hour periods. Employing the same strain and the same concentrations for 2 hours, (a) acid alone, (b) acid with $CaCl_2$; (c) acid with pyrogallic acid; (d) acid with pyrogallic acid plus $CaCl_2$, gave 42.7%, 64.6%, 33.6% and 36.7% germination respectively, indicating the importance of the presence of oxygen for a favourable reaction. The action of nitric acid fumes is no doubt a complex one and the substances formed are naturally influenced by temperature, illumination, acid concentration, humidity, amount of seed, the period of treatment and volume of air.

Nitrogen peroxide being set free by nitric acid when it fumes, was also tested out as it was thought that the stimulative properties of nitric acid fumes might be due to this gas. Using P. minus F.14 and employing the reaction excess copper plus nitric acid, the following concentrations were studied for 2 hours in 3000 c.c. jars:- (a) No $CaCl_2$ plus 3 drops acid; (b) $CaCl_2$ plus do.; (c) No $CaCl_2$ plus 10 drops acid; (d) $CaCl_2$ plus do. The percentage germination was respectively 71.8, 44.3, 85.4 and 75.8 proving the value of a humid atmosphere for low concentrations of the treatment which seems contrary to the nitric acid treatment alone. That the presence or absence of $CaCl_2$ has little or no value with 10 drops acid for 2 hours,

was / ..

was also established for 5 other strains with 10 drops acid and no $CaCl_2$ for 2 hours. Other strains varied in their response from fair to nothing. For a period of 1 hour this treatment appeared less effective. Lead nitrate, as a source of the gas, was also tried. No doubt the 2 months' treatment mentioned above was too long to be effective.

Carbon monoxide used alone in 1, 2, 5, 20 and 50% mixtures with air to germinate Digitaria seln. 24-3 in, resulted in only the 2% mixture giving stimulation. With 200 uncleaned seeds the germination was 8.5% and of 20 cleaned seeds 15 germinated. The rest of the mixtures yielded no germination.

Discussion of results.

On the whole the results are somewhat disappointing, though it is perhaps remarkable to find that of the 18 compounds used for the treatment of dry seeds, only four, toluol, acetaldehyde, ethylene and HCN showed no improvement in germination over the control. Experience has, however, shown that the kind of seed used is one of the most difficult to stimulate and seed of other ecotypes would perhaps have given much higher values. Thioacetic acid, carbon tetrachloride and HNO_3 (NO_2) gave the best results.

Thioacetic and thioglycollic acids were reported as effective in breaking the dormancy of potato tubers (Miller 1930). Ethyl thiocyanate has not (?) been employed by other workers. Ethyl iodide was found effective for forcing of plants by Stuart (1909) and Denny and Stanton (1926). Ethylene dichloride vapours gave favourable results in the forcing of early sprouting of potato tubers and the shortening of the rest period of woody plants at the Boyce Thompson Institute (Denny 1926a, 1926b ; Denny and Stanton 1926). Carbon tetrachloride (vapours) has apparently been rarely used. Stuart (1909) and McCallum (1909)

used / ..

used it for plant forcing, it being reported effective by the latter. Müller (1928) usedfit with barley and considered that a more intensive germination was indicated. The influence of formalin solutions on germination has been studied by many workers, both favourable and unfavourable results being recorded. Hurd (1921) demonstrated the effect of injury to seed-coats and of subsequent drying. Atwood (1922) showed the importance of after-treatment, whereas Molz and Müller (1925/6) - cited by Lehmann and Aichele (1931) - found that temperature of germination was important. Zeuschner (1926) claimed that coat thickness variarions in various wheats were not responsible for the different responses. The use of carbon monoxide has apparently only been reported by Giglioli (1895) who recorded 84% germination for lucerne after 16 years' dry treatment and from the Boyce Thompson Institute (Zimmerman et al, 1933) where it was found to induce root initiation.

Solutions of organic and in-organic compounds.

Solutions of the following compounds were used for seed treatment as a means of overcoming delayed germination, the tests being conducted in 1936 and 1937: Thioglycollic acid, thiourea, potassium thiocyanate, semi-carbazide hydrochloride, sodium thiosulphate, alpha naphthalene acetic acid and beta indolyl acetic acid. Also, nitric acid, phosphoric acid, boracic acid, ammonium dithiocarbonate, hydrogen peroxide, succinic acid, sodium hydroxide, sulphuretted hydrogen, acetaldehyde, and potassium permanganate were tested out, but so far have shown little or no promise. The same methods of testing as above, were employed.

When seed of Digitaria seln. 24-3 was steeped in a 2% thioglycollic acid solution for 1, 3, 10, 24 and 49 hours,

the / ..

the germination obtained was respectively 9.3%, 17.6%, 33.7%, 10.6% and 2.1%; with a 0.5% solution and 1, 3 and 6 hours, the germinations obtained were 5.6%, 8.0% and 5.6% respectively, whereas with a 0.1% solution and 1, 3, 9½ and 50 hours, the percentages were 6.9, 4.9, 9 and 8,8 respectively. When the latter concentration was used as a medium, the germination was 15.8%. The control was approximately 6%.

Thiourea, when used as in the last-mentioned, at a concentration of 1%, then after 1¼ hours Digitaria seln.24-3 , Panicum coloratum C.91 and P. maximum F.7 gave respectively 6.4%, 0% and 31.4%; after 4 hours, 7, 0 and 30.8% respectively; at 6 hours, 4.3%, 0% and 25.8% respectively; whilst after 12 hours the values were respectively 8%, 0% and 14.0%. All three controls were about 2%.

Potassium thiocyanate as a 1% solution and with one hour soaking gave with lines seln.24-3, C.91 and F.7 respectively, 11.3%, 1.2% and 27.9% ; with 2 hours, respectively 9.8%, 0% and 27.2%; with 4 hours, 4.6%, 0% and 31.3% respectively ; with 6 hours, 6.7%, 0% and 14% respectively and with 12 hours, respectively 6.1%, 0% and 3.45%. A 2% solution showed after 12 hours respectively the following : 21.7%, 0% and 30%; after 18 hours, 21.7%, 0% and 26.4%; after 24 hours, 24.5%, 0% and 15.4% ; and after 41 hours, 18.3%, 2.1% and 29.2%. As a medium of ca. 0.09% concentration seln.24-3 gave 36.6% germination and as a medium of 0.009% the germination was 12.8% for the same time and kind. All three the controls exhibited about 2% germination.

Semi-carbazide hydrochloride with Digitaria seln. 24-3, giving as control about 6%, yielded respectively 8.1%, 6.1% and 3.5% germination in a 0.1% solution for 1, 3 and 9½ hours; in a 0.2% solution for 1, 3¼. 10, 24 and 50 hours the percentages were respectively 12.0, 7.4, 12.5, 14.2 and 10.5,

whereas / ..

whereas with a 0.5% solution for 1, 3, 6 and 50 hours, 7.9%, 10.4%. 5.3% and 4.6% respectively were realized. A 5% solution gave 9.1%, 7.0%, 4.8% and 2.5% with ½ hour, 1 hour, 2 hours and 19 hours treatment respectively, whilst a 0.1% solution used as a medium, gave 8.3% germination.

Sodium thiosulphate was tried out on line seln.24-3 in several concentrations, each for 2 periods, but with no success.

Alpha naphthalene acetic acid and beta indolyl acetic acid were studied in more detail, as indicated in the table below. With the Panicum F.14 it proved fairly beneficial giving increases of over 35%, whilst the Digitaria 15-7 was deleteriously affected.

TABLE 14 / ..

T A B L E 14 : THE PERCENTAGE GERMINATION OF *DIGITARIA* SELN. 15-7 AND *PANICUM* ECOTYPE F14, WHEN TREATED WITH ALPHA NAPHTHALENE ACETIC ACID AND BETA INDOLYL ACETIC ACID

T r e a t m e n t	1hr. Soaking F14 %	1hr. Soaking 15-7 %	2hrs. Soaking F14 %	2hrs. Soaking 15-7 %	6hrs. Soaking F14 %	6hrs. Soaking 15-7 %	As a Medium F14 %	Control F14 %	As a Medium 15-7 %	Control 15-7 %
Alpha naphth.acetic acid. 0.01 gm : 100 cc. water	57.7	2.4	57.2	2.6	68.4	2.7	29.0	ca.30	8.3	ca.17
Beta indol. acetic acid. 0.01 gm : 100 cc. water	57.6	6.0	34.5	5.4	62.8	5.1	46.6	do	14.4	do
Alpha naphth. acetic acid 0.05 gm : 100 cc. water.	37.6	2.8	-	-	47.2	3.0	-	do	-	do
Beta indol. acetic acid. 0.05 gm : 100 cc. water.	37.1	3.3	-	-	41.6	4.3	-	do	-	do
	18hrs. Soaking	18hrs. Soaking	12hrs. Soaking	12hrs. Soaking						
Alpha naphth.acetic acid. 0.005gm : 100cc. water.	-	-	37.2	11.7	62.6	6.3	22.8	do	8.0	do
Alpha naphth.acetic acid. 0.0005gm : 100cc.water.	63.4	22.3	55.4	7.8	-	-	46.4	do	16.4	do

63.4
37.7
37.6

22.3
2.4
2.8

Solutions of alpha naphthalene acetic acid of 1 pt. per 20,000; 1;100,000; 1;1,000,000; 1:10 million and 1:100 million, used as media with lines selns 24-3 and 15-7 showed no trend of response in either direction and when Panicum ecotype F.14, was soaked in all of the latter solutions for 12 hours, no definite trends were obtained either. In the case of F. 14 the control gave the same percentage germination as the different media but, if anything, a slightly better value in the soaking trial. Digitaria line 24-3 also showed no definite response to this chemical, used as media (with quartz sand) in the above concentrations. There seemed to be no improvement in germination when, after soaking, the seeds were first dried in the sun or room and thereafter stored for 16 days or as long as 5 months.

Discussion of results.

Thioglycollic acid proved to be no more stimulative in the solution form than in the vapour state. The optimum concentration appeared to be about 2%. Thiourea, though it stimulated one of the panicums, was apparently harmful to the Digitaria. This chemical has proved most useful for hastening the sprouting of potatoe tubers (Denny, 1926) and for breaking their dormancy (Miller, 1933). Also, Deuber (1931) found it to have a beneficial èffect on maple seeds. Potassium thiocyanate has proved to be somewhat similar to the last-mentioned. Though Digitaria selection 24-3 could not be stimulated by means of soaking, a solution thereof, used as a medium for germinating seeds in, gave an increase of over 30% in germination. For the sprouting of potato tubers, Denny (1926) found it excellent. Semi-carbazide hydrochloride has not (?) been used by other workers; it proved to be of no value under the conditions of the above test as was the case with sodium thio-

sulphate / ..

sulphate . The latter was, however, found excellent for the sprouting of potato tubers (Denny 1926, 1935).

The two growth substances alpha naphthalene acetic acid and beta indolyl acetic acid have been fairly extensively used for rootformation on cuttings, for which they have been found very effective. In this connection the investigations of the workers at the Boyce Thompson Institute perhaps deserve special mention. Few have studied the effects on seeds. Amlong and Naundorf (1937) found that strong heteroauxin solutions gave better germination of old seeds. Lustig and Wachtel (1938) reported that heteroauxin had no effect on the germination of cress seeds. Barton (1940a), treating non-dormant seeds with vapours, liquids or dusts, found these of little or no value. With dormant seeds of apple, etc., no beneficial and even some harmful effects were shown. The present tests have throughout given harmful or indifferent results with the Digitaria, whilst the Panicum, under certain conditions, was found to be well stimulated.

S u m m a r y .

1. Preliminary studies on the effects of vapours and gases on dry seeds were undertaken to ascertain whether this method would offer any possibilities of overcoming delayed germination.

2. Chloroform, ether, hydrochloric acid, acetic acid, ammonia, nitrogen peroxide, sulphur dioxide, carbon bisulphide, acetylene, nitric acid, oxygen and carbon dioxide were tested out, an excess of each substance being employed. Nine lines of seed were subjected to treatment for 2 months. The first 7 substances enumerated produced negative results, which, in some instances, may have been due to the period of treatment having been too long.

3. / ..

3. CO_2 produced as much as 62.5% stimulation with P. minus F.14, whilst 2 other lines were also distinctly benefited, little or no increase being registered with the other seed. O_2 gave distinct increases in 3 of the lines, the maximum being 41% for Panicum C.79.

4. CS_2 proved of little or no value under these conditions, whilst with acetylene an increase of 27% over the control wer realized with Panicum C.79 , the other lines being harmfully or indifferently affected. With HNO_3 , 2 kinds showed appreciable benefit, amounting to 53% increase for Digitaria seln.24-3, within the first 8 days of test, which was also the period used in the above comparisons.

5. O_2 and CO_2, used at room temperature and at 45°C, for storing seeds in, were found to be of no value over a period of 6 months, and proved to be harmful at 45°C, after about the first month. At room temperature these gases equalled or were below the controls.

6. Short-period treatments, using mainly Digitaria seln.24-3, were tested out with gases or vapours of thioacetic acid, thioglycollic acid, ethul thiocyanate, ethul iodide, ethylene dichloride, carbon tetrachloride, chloroform, carbon bisulphide, ether, formaline, ammonia, acetic acid, toluol, nitric acid, nitrogen peroxide, carbon monoxide, acetaldegyde, ethylene and hydrocyanic acid gas.

7. Though improvement in germination was realized with all except 4 of these chemicals, the results appear to be of little practical value. Thioacetic acid, CCl_4 and HNO_3 were the best, registering maximum increases of 43%, 43% and 54% respectively over the controls.

8. Solutions of thioglycollic acid, thiourea, potassium thiocyanate, semi-carbazide hydrochloride, sodium thiosulphate,

alphanaphthalene / ..

alphanaphthalene acetic acid, beta indolyl acetic acid, acetaldehyde and others, were used for overcoming delayed germination.

9. Seeds were either soaked in solutions of these chemicals or, in some instances, the solutions were used as media. The results were less favourable than with the gases and vapours, the best increases being realized with the two growth substances, though one of the two lines of seed employed was unfavourably affected.

IV.

STUDIES ON PHYSICAL METHODS FOR OVERCOMING DELAYED GERMINATION.

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.

(1) Outdoor treatments, with and without humidity control.

Methods and materials.
Discussion of results.

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

Methods; even temperatures.
Discussion of results.
Alternating temperatures.
Heat.

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

Materials and methods.
Discussion of results.

(4) Summary.

B. The effect of various combinations of heat, cold and sunlight.

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

The effect on room storage.
The effect on outdoor treatment.

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

(3) The effect of the alternation of various periods of heat and sunlight.

(4) The alternation of various periods of low temperature and sunlight.

(5) The alternation of various periods of low temperature and heat.

(6) Summary.

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

D. / ..

D. Miscellaneous treatments.

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

(2) Soaking; soaking and drying.

(3) Hotwater treatment and soaking and freezing.

(4) Breaking of seed-coats.

(5) Ultra-violet and radium oxide treatment.

(6) Oxygen pressures.

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 ECOTYPES (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 %
Panicum minus F.14	50.9	56.1	10.5
Panicum sp.C.79	47.5	54.3	16.8
Panicum coloratum (?) C.98	14.7	42.3	3.0
Digitaria seln. 24-3	4.3	57.5	3.5

(1) Outdoor treatments, with and without humidity control.

Methods and Materials.

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. *goed minder sal af*
2. Seeds kept in white muslin bags placed in a glass dish with glass cover, in sun, permitting air circulation, not rain water. *minder goed. sal af later*
3. Seeds kept in muslin bags in sealed glass container in sun with 0% humidity. *sleg.*
4. Seeds kept in muslin bags in sealed glass container in sun with 50% humidity. *swak.*
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. *goed.*
7. Seeds kept in shade, outdoors, in muslin bags in sealed glass container with humidity 0. *sleg*

8. / ..

8. Seeds kept in shade, outdoors, in muslin bags in sealed glass container, with humidity 50%.

9. Seeds kept in shade, outdoors, in muslin bags in sealed glass container, with humidity 90%.

10. Seeds kept like No. 2, in shade.

13. Seeds kept in sun, outdoors, in sealed tin (only opened for testing).

14. Seeds kept in sun, outdoors, in unsealed tin permitting air circulation.

15. Seeds placed in muslin bags kept in brown paper bag outside.

Materials.

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) :-

Digitaria ("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 Digitaria 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 Panicum B.7-11. The Digitaria 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 Digitaria ecotypes A.23 and D.23 and seln.12-8, and the Panicum B.7-11, aeration is distinctly more favourable than non-aeration, though in the two kinds Setaria H.10 and Panicum 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 Digitaria 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,

when / ..

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.

The / ..

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 <u>Poa pratensis</u> 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 <u>Alopecurus pratensis</u> and <u>Holcus lanatus</u> 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.

(2) <u>Incubator tests at different temperatures, with and without controlled humidity</u>.

(2) / ..

(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 appearing / ..

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°C and 45°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°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°C plus 18 hours at ca.28°C; (b) 2 hours at 65°C plus 22 hours at ca.28°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°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 :-

<u>Setaria</u> sp. B.3-1 (of 28/2/38)
do. B.3-3 (of 28/2/38)
<u>Panicum</u> sp."Makarikari" (of Jan.1937)
<u>Digitaria</u> 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" <u>Panicum</u> 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 <u>Digitaria</u> 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) <u>The effect of pre-treatment of fresh seeds at certain temperatures on the course of delayed germination with subsequent room storage.</u>

<u>Materials and methods.</u>

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 / ..

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[*] (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[*] (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[*] (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)	83.9 (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[⊖](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[⊖](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[⊖](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[ɵ] -	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[ɵ] -	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
ɵ - " " " " 24/3/41 and 25/3/41
r - " " " " " 7/4/41
n - " " " " 21/4/41 and 24/4/41
ӿ - " " " " 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 derived 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

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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 ecotypes 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.

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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).

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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.

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

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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

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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 *Digitaria* which registered over 60% increase in germination in the room-storage series. On the other hand, the *Panicum* showed no stimulation with room storage, whereas the *Setaria* seed fell in between them. There was in both room and outdoor series little to choose between the various periods of pre-cooling. The *Digitaria* seed showed stimulation only after the third month, the germination being below the control before this. In the case of the *Setaria* seed at room temperature, the response was a good deal less favourable though very regular.

In the outdoor series, the *Digitaria* 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 *Setaria* and *Panicum* seed both showed slight stimulation, the outdoor control of the latter exhibiting slightly superior germination to the treatments after 3½ months.

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

The alternations tested out were :-

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

The same *Panicum* seed was used but the *Setaria* was the line B.3-1 of 28/2/38 and the *Digitaria* 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

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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 2½ and 3 months. The severity was apparently largely determined by the length of the heat treatment. The maximum stimulation exhibited by the *Digitaria* (within 2½ months) and *Setaria* (in 1½ 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 <u>Digitaria</u> (70% stimulation). With the <u>Setaria</u> and <u>Panicum</u> 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 <u>Digitaria</u> (approx.70%) and the <u>Setaria</u> (approx.55%), when compared with room controls, but marked declines were exhibited with certain treatments. With the <u>Panicum</u>, 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.

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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 Panicum, Urochloa and Digitaria 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 $CaCl_2$ (xxxxx) is also unfavourable for the progress of delayed germination of this line of seed, as the limited results with

$CaCl_2$ / ..

$CaCl_2$ (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 Setaria 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 Setaria seln.B.3-1 of 28/2/38 and Digitaria 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*,

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

Nc 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)

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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

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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 Sporobolus ecotype A.228 and of 1 year old seed of Digitaria 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.

TABLE 20 : THE EFFECT OF DIFFERENT OXYGEN PRESSURES ON THE % GERMINATION OF FRESH SEED OF A Sporobolus ECOTYPE AND OF 1 YEAR OLD SEED OF A Digitaria 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 %	%
Sporobolus :							
(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
Digitaria :							
(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 Sporobolus, 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 Digitaria would appear to indicate that also

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

GENERAL SUMMARY AND CONCLUSIONS

This paper records the results of studies conducted over a period of several years on certain seed problems, which have presented themselves in the course of endeavours towards the more profitable utilization of indigenous grasses. These studies deal largely with the question of suitable methods for the overcoming of delayed germination (III and IV), but also, in a preliminary way, with the seed-setting propensities of a number of these grasses and of selections (I). Moreover, the extent and the apparent causes of delayed germination were studied. In addition, certain results obtained from studies conducted on the actual germination of seed during the condition of delayed germination, are given (I). For the sake of a better appreciation of the problem, an effort has been made to present the scope thereof as revealed by the literature.

The seed-setting studies were, as far as possible, made under conditions of natural pollination, but owing to early shedding in the panicums in general, the individual heads had to be covered shortly after anthesis of the earlier flowers, thus necessitating daily shakings of enclosed heads. The results, based on heads enclosed on small demonstration plots, show, on the whole, great variability in the seed-setting ability of individual ecotypes and selections. The N'Gamiland

Digitaria ecotypes included, were selected for good seed-setting and the values recorded, therefore, do not reflect the true position within this genus, the ecotypes of which are, on the whole, poor seeders, the majority setting seed sparingly, while a few apparently set no seed. General experience would indicate that seed-setting ability is not restricted to species boundaries. On the other hand, the best seeders in this genus would appear to originate from the drier regions, which fact is, to some extent, brought out in the data presented, although ecotypes from the same geographical region may vary very considerably in this respect. Some excellent seeders have been revealed, though in the majority of cases extreme variability is displayed within the ecotype, which is not readily accounted for. The "makarikari" selections (Panicum coloratum ?) exhibit great differences in seed-setting between individual selections, varying from 1 - 71%, indicating that much scope for improvement exists. On the whole, variability within this series is reasonably low, which is also somewhat the case with the 10 Chloris gayana ecotypes, of which one shows a very low value for seed-setting. The variability in the Cenchrus ecotypes is extreme, both as regards individual ecotypes and within the group as a whole. Judging from the data on Digitaria Smutsii, it would appear that season may have a very big influence on seed-setting, which agrees with experience in the field. In contrast to the Panicum selections, those within the D. Smutsii group show little variation in seed-setting ability. Disease is a very important factor in the seed-setting of native grasses.

Germination studies were so far only possible with seeds which were in a condition of delayed germination. Under these conditions it has been found that alternating temperatures may produce considerable increase in germination, as compared with even temperatures, which in no case have been

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able to effect complete germination of any kind of seed, still in the condition of delayed germination. The requirements of various kinds of seed, in regard to alternating temperatures, varied with the kind and age (i.e. condition of after-maturation) of the seed. Under the conditions of the present tests, it was found that certain kinds of seed could not be stimulated by any of the temperature combinations employed. Lack of response in this connection was not restricted to genus or species, so far as the results go. Even after certain treatments had given fairly successful stimulation, alternating temperatures could still induce further stimulation in certain kinds of seed, though not in others.

Low temperatures of 15°C or 20°C so far appear not to be of any value, for the improvement of germination capacity, even when the moisture content of the sand was varied with the 15° temperature and, as far as experience goes, this also applies to even temperatures of 35° and 40°C. Pre-cooling at ca. 5°C for various periods induced favourable response in one of the two kinds employed, the most favourable period appearing to be about 2 weeks. Within reasonable limits, the moisture-content of the quartz sand used during pre-cooling, had no distinct effect on the course of germination.

Light (diffused) may have an influence on the germination of certain kinds of seed and this may be quite appreciable. Of the several lines of seed examined for light requirements, the larger number appears not to be sensitive to it. As regards the light-sensitive types, the majority so far germinate better in the dark than in the light, but on the other hand, light was favourable to a <u>Setaria</u> (A.296) ecotype. KNO_3 may have a favourable influence on certain kinds; for others it was found harmful. In the last-mentioned species the favourable effect is, however, only obtained in light, not in the dark,

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with which the effect is harmful, whereas in certain others the reverse seems to be the case. With the same concentration of $MgCl_2$, $MgSO_4$ and $NaNO_3$, the last appeared to be harmful in light, the others giving responses about equal to water, both in light and in dark.

A very large percentage of seed-setting ecotypes were under observation for the progress of their delayed germination and everyone so far has exhibited this characteristic, which was found to vary from less than 2 months in the "Peddie" ecotype (Digitaria), to over 3½ years for other ecotypes of this genus. After the latter period it was still found that certain ecotypes were showing a germinability of only 1 - 10%. Resistance to germination does not seem to be restricted to certain genera or to ecotypes from a particular geographical or ecological region, and ecotypes of the same species, as for example Chloris gayana , may exhibit extreme differences. Under the conditions of storage employed (both outdoor and indoor), the course of delayed germination is seldom a smooth curve, Sudden rises and falls may be experienced, the former occuring mainly with the advent of summer. Recovery, partial or complete, is often obtained. On the whole, delayed germination is protracted.

An analysis of the apparent causes of delayed germination has revealed that both seed-coats and "embryos" play a part in all the genera so far studied, the repsective roles, however, varying markedly in different kinds. In Echinochloa, Chloris gayana and Digitaria, as well as certain Panicum ecotypes studied, the "embryos" soon take the lead in the discontinuation of inhibition, the seed-coats retaining their resistance for much longer periods. In the seed of the ecotypes of the Brachiaria, Sporobolus and the majority of those of the Paspalum under observation, the inhibition of the "embryos"

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is only gradually discontinued. Rarely, apparently, do the two factors cease to inhibit germination simultaneously. In the Urochloa, the embryos apparently continue to remain a hindrance to germination, even after about 9 months or more, when the removal of the caryopses (with breaking of seed-coats) gave 88% germination. Embryo retrogression, as indicated by declines in percentage germinability, occur with the advent of spring and summer and seems to be a fairly general phenomenon with a number of the ecotypes studied.

The seed-coat factor would, therefore, seem to be a much more important one than the "embryo" factor in the resistance of these seeds to germination. In fact, it was found that 3½ years old Digitaria seed, germinating under 15%, had already lost about 30% viability; that is, when apparently 85% of the seed-coats were still unready. Such an analysis is considered to be of great value in the study of methods for the promotion of delayed germination.

A large number of organic and inorganic chemicals, including two growth substances and certain of those compounds which has been found effective by other investigators for the breaking of "dormancy" and for root formation, were tested out. The gas and vapour treatments included both short and long periods (up to 2 months). The majority of these chemicals produced stimulation at certain concentrations and periods. Usually only one or two ecotypes were under observation. Several of these chemicals showed excellent stimulation. For example, CO_2 gave 59% increase over its control after 2 months, with Panicum minus F.14. HNO_3 vapours similarly secured a 53% increase with Digitaria seln.24-3. In the same way a 41% increase was registered by Digitaria C.1 with O_2 treatment. At 45°C these gases were very harmful after the second month.

Vapours of thioacetic acid, carbon tetrachloride and

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ethyl thiocyanate gave 40, 43 and 35% stimulation respectively, with the resistant seeds of Digitaria 24-3. NO_2 yielded over 40% increase with Panicum F.14. Soaking in alpha naphtalene acetic acid and beta indolyl acetic acid, though giving good stimulation with the one kind, was, if anything, harmful with the other. On the whole, gas and vapour treatments seem to offer better chances of success than solutions.

Extensive studies were made of physical methods for the hastening of delayed germination, particular attention being given to temperature effects. It was found that continuous exposure of seed (dry) outdoors (sunlight), gave marked stimulation with certain lines after several months, the amount and the period for maximum stimulation depending upon the kind and, so far as can be ascertained, on the age of the seed, but, no doubt, on other conditions as well, such as the time of the year. Germinability may, however, deteriorate very rapidly, even before full stimulation could be attained. The favourable effect does not appear to be one of wavelength only, if at all, since with the use of various "filters", yellow and "darkness" treatments gave far better stimulation than red, for the Setaria seed used, and since, moreover, another treatment outdoors, without direct exposure, realized equally good stimulation. In shade, 0 and 50% humidity proved of little value, the 90% appearing very deleterious. Exposed to sunlight, the 0 humidity was apparently also of no value, whilst 50% humidity, though initially beneficial for certain kinds of seed, brought decline of germinability to all seeds after 4 months. On the whole, restriction of both, aeration and humidity, at the degrees used, were apparently far less beneficial, or even harmful, as compared with free aeration and unregulated humidity, both in shade and in sun, outdoors. The more resistant seeds were, on the whole, stimulated less than

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the less resistant seeds. Aeration would seem to be an important factor.

Storing seed at 0%, 50% and 90% humidity, as well as under conditions of complete aeration and in a sealed atmosphere, inside a refrigerator, indicated rather variable responses for different kinds of seed, so that the relative merits of these treatments remain somewhat obscure, although distinctly harmful effects were discernible in the case of the less resistant kinds of seed after four or more months.

When, however, these conditions are repeated at higher temperatures of 25°, 35° and 45°C respectively, the harmful effect of 0%- and 90%-humidities are clearly demonstrated, particularly the latter, under which seeds loose germinability in a few months' time. The 50%-humidity, though still having some stimulation value at 35°C, has a deleterious effect at 45°C, the seeds loosing their germinability after 2 to 3 months. A sealed atmosphere appears to be more favourable than any of the controlled humidities, but the best stimulation was realized with seeds receiving aeration, there being, apparently, little to choose between 35°C and 45°C. A few of the lines employed - the Urochloa and ecotypes of Panicum and Digitaria - were very resistant and were, moreover, not at all or only very slightly influenced by these treatments. The use of extreme alternating temperatures (25° and 45°C; and 28° and 65°C) appeared to be no more favourable for the hastening of delayed germination than the higher temperatures, employed continuously.

The value of various warm temperatures (28°, 40° and 50°C) for the improvement of delayed germination of fresh seed of various kinds, when subjected to these temperatures for 1 - 2 months and thereafter kept at room temperature, was also studied. It was revealed that for the ecotypes of Digitaria, Panicum and the one species of Paspalum utilized, the

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method proved to be of little benefit with the periods tested out, even after about 9 months. The Paspalum notatum seed was, however, benefited by a 60 days' treatment at 40 and 50°C, so that a period of 30 days is perhaps too short for these resistant kinds. A 76 days' period at 50°C with one rhodesgrass ecotype gave about 70% stimulation 2 months after the heat treatment, the germinability dropping subsequently. Pre-treatment at 20°C would appear to be of no value and 28° after harvesting is, if anything, favourable for this ecotype.

Heat at 65°C gave fairly good and quick stimulation with the several ecotypes employed, the period needed for maximum stimulation varying with the ecotype. After about 70 days the germinability exhibited complete deterioration, which may, however, not necessarily signify loss of viability.

The value of heat (65°C), cold (3°C) and sunlight, in single combinations with each other, alternated for varying periods and also heat and cold, used as pre-treatment, for varying periods, with both outdoor (sunlight) and room storage were also investigated for the improvement of delayed germination. The responses obtained with the 3 kinds of seed used were very variable; stimulations of as much as 80 to 90% were, however, realized. The heat and cold alternations induced the best stimulation with the Digitaria and Setaria, but this was followed by sudden and complete deterioration of germinability. In all combinations with sunlight, the Panicum outdoor control eventually equalled the stimulation obtained with the treatments. Pre-cooling with both room and outdoor storage was of great benefit only to the Digitaria and particularly with room storage.

With soaking and drying as well as with soaking, fairly good stimulation was realized with certain kinds, but hot-water, soaking and freezing, ultra-violet light and radium

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oxide treatments were, so far as these studies go, of little or no value. Breaking the seed-coats mechanically, by means of rubbing, gave marked stimulation, but the small size of the caryopses of most of the native seeds and the close envelopment of seed coverings (bracts) would seem to be very unfavourable factors from a practical standpoint.

Though it has not been possible to standardize methods for overcoming delayed germination, as an outcome of these studies, valuable information has been accumulated, which should be very helpful not only in further studies, but also in our future needs, so far as the more practical aspects of our investigations are concerned. When seed supplies of useful ecotypes and selections become available, not only will it then be possible to undertake certain large-scale studies along the lines already indicated, but it will then become necessary to adopt suitable storage measures to bring about the desired ageing within reasonable time. If germination capacity is not high enough at the time of the first planting season, it will be desirable to keep the seeds over until the following season. Two or three months of outdoor exposure should contribute materially to the improvement of the germinability, without incurring much risk of loss of viability.

Although the problem is perhaps more complex than one would wish to think, particularly where seed in a condition of delayed germination may be looked upon as being composed of various physiological groups (the size of these depending upon the stage of after-maturation), it is nevertheless possible that it will eventually, in practice, solve itself.

Finally, the main results may be briefly summarized as follows :-

1. Seed production is very variable, the majority of the assembled ecotypes being low or poor seed-setters, but good scope for improvement would appear to exist.

2. The germination of seed in a condition of delayed germination was largely or partly affected by such methods as alternating temperatures, pre-cooling at 5°C, regulation of light conditions, KNO_3, and breaking of the seed-coats, though so far not by temperatures of about 15°C or 20°C. Seed coverings (bracts) may form a hindrance to germination in certain ecotypes.

3. No species (ecotype) showed immediate germination, the duration of delayed germination varying from about 2 months to well over 3 years, and may be a good deal longer.

4. In all genera studied, both seed-coat restrictions and "embryo" inhibition were found to be responsible for the observed delayed germination, the former having shown itself to be the factor of longest duration.

5. For the purpose of overcoming delayed germination, CO_2, O_2, HNO_3-fumes, NO_2, CCl_4, thioacetic acid vapours and solutions of the growth substances alpha naphthalene acetic acid and beta indolyl acetic acid, were found to be the most effective chemical treatments.

6. Of the many physical treatments employed for overcoming delayed germination, outdoor exposure - insolation, as well as indirect exposure to sunlight -, heat, alternations of heat and sunlight and of heat and cold, and also soaking, produced marked stimulation.

In conclusion the view may be expressed that though the results appear to be contradictory, this is perhaps to be expected, not only in the light of the results of other workers, but also from the findings here reported in regard to the causes of delayed germination. It would thus seem that direct and indirect evidence lend support to the viewpoint that, within a single sample, seed - in a state of delayed germination - is composed of physiological classes, each, so to say, requiring different conditions for overcoming delayed germination.

Acknowledgments.

The writer desires to express his appreciation to Dr. J.C. Ross, Chief of the Division of Soil and Veld Conservation, Department of Agriculture, for his kind permission to make use of the results presented in this paper and for facilities granted.

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For the generous help received from his wife, the writer expresses his indebtedness and gratitude.

VI.

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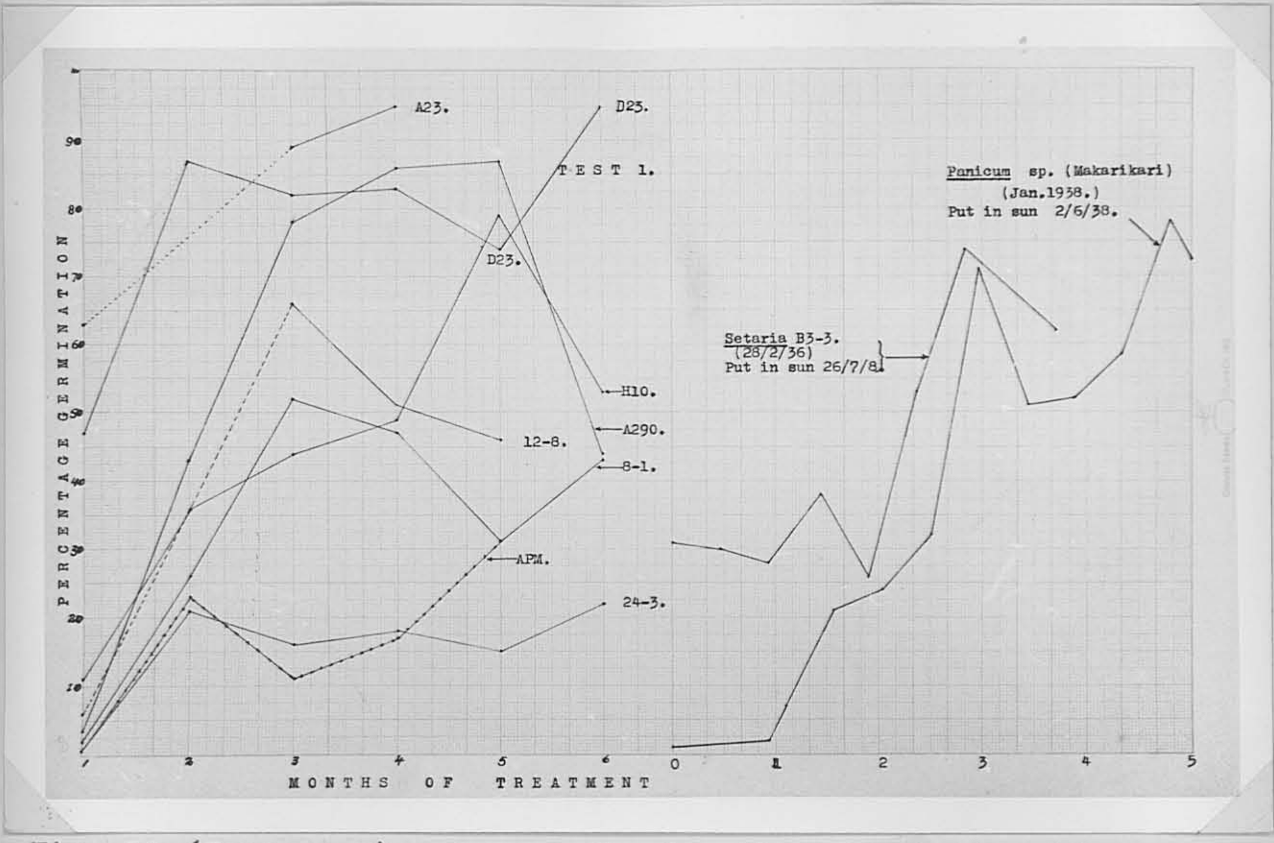

Fig. 1A.(Test no.1). Curves showing the effect of outdoor exposure (in sun and rain) on the course of delayed germination of Digitaria lines 12-8, 8-1, and 24-3; of ecotypes A23 and D23; of Panicum maximum APM; of Paspalum scrobiculatum A290; of Setaria sphacelata H10. Seed was spread out on wire gauze trays, placed on the bare ground.

1B. Curves showing the effect of sunlight on the delayed germination of Setaria B3-3 and Panicum sp. (Makarikari). The controls did not exceed 40% and 10% resp.

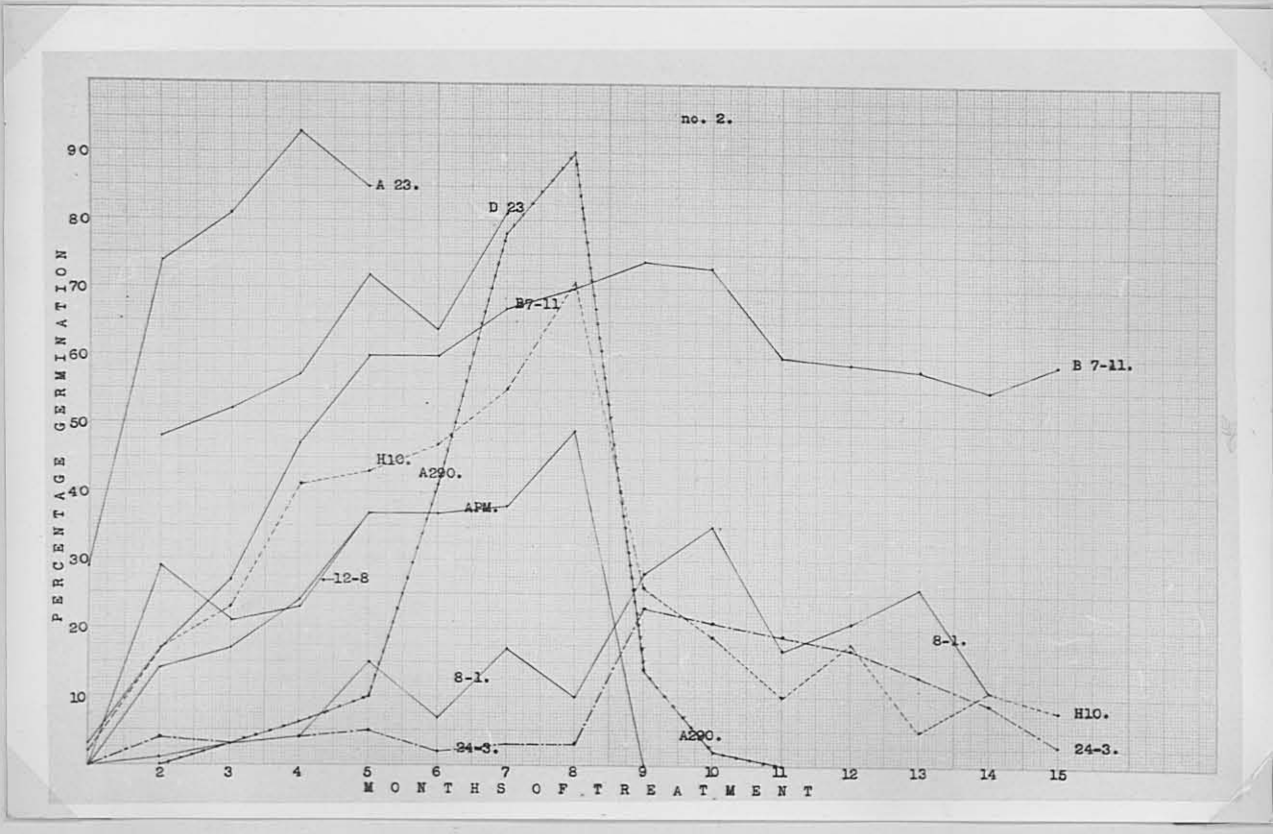

Fig. 2.(Test no.2). Curves showing the effect of exposure of Digitaria lines 12-8, 8-1 and 24-3, ecotypes A23 and D23, of P.maximum APM, of P. minus B7-11, of Setaria sphacelata H10 and of P.scrobiculatum A290, in muslin bags, placed in a glass dish with loose-fitting glass cover, outdoors, on the course of delayed germination.

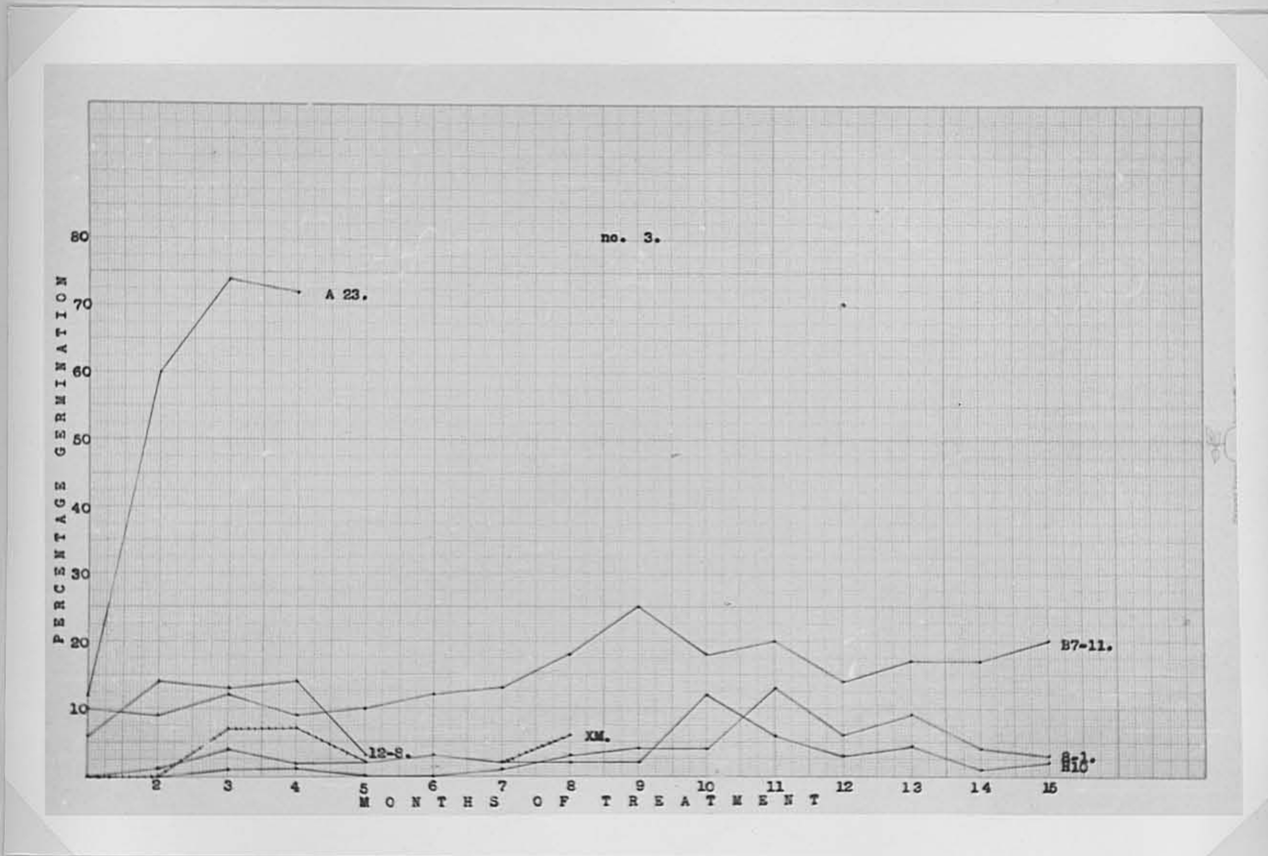

Fig. 3. (Test no.3). The course of delayed germination of seed of <u>Digitaria</u> 12-8, 8-1, A23 and "Molopo", of <u>P. minus</u> B7-11 and of <u>S.sphacelata</u> H10, when kept in muslin bags placed in a sealed container with O humidity, exposed outdoors.

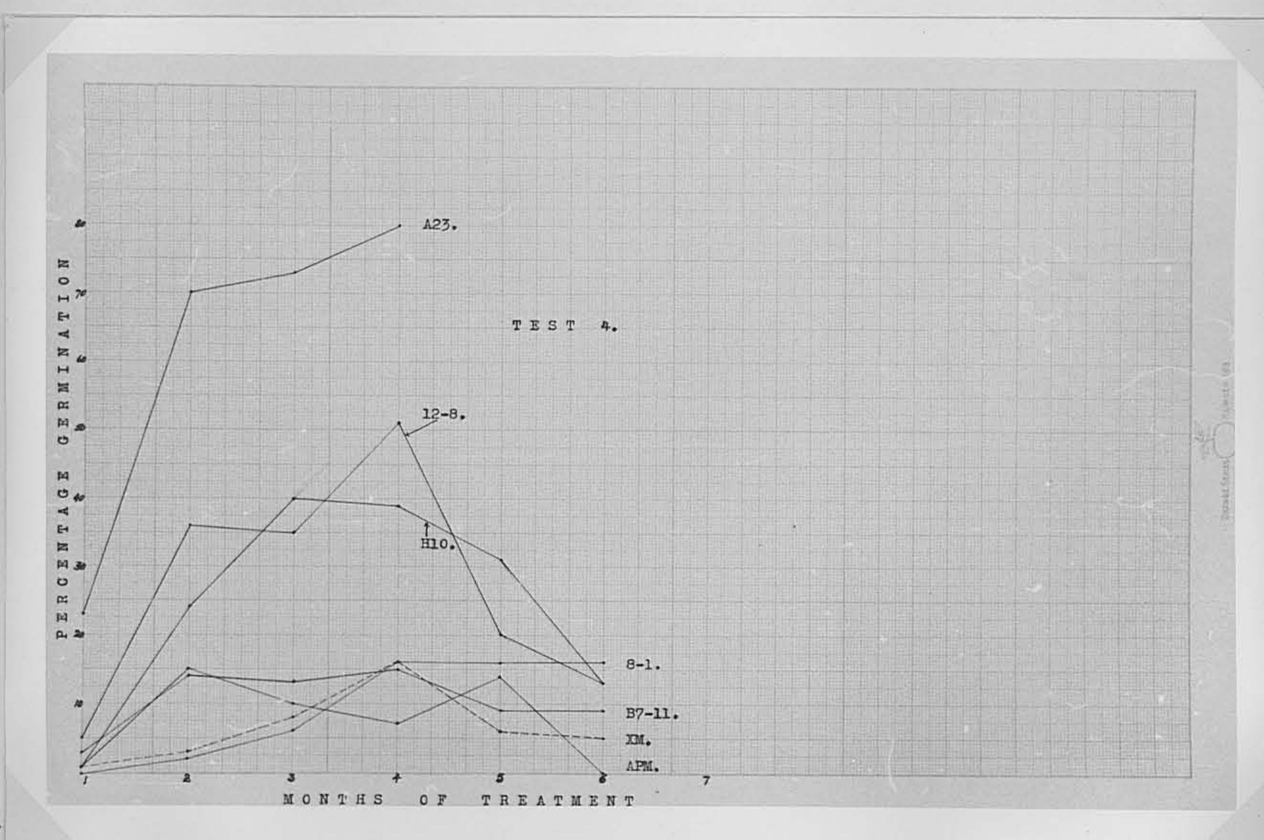

Fig. 4. (Test no.4). The course of delayed germination of seed of <u>Digitaria</u> 12-8, 8-1, A23 and "Molopo", of <u>Panicum minus</u> B7-11, of <u>Panicum maximum</u> APM and of <u>Setaria sphacelata</u> H10, when kept in muslin bags placed in a sealed glass container with 50% humidity, exposed outdoors.

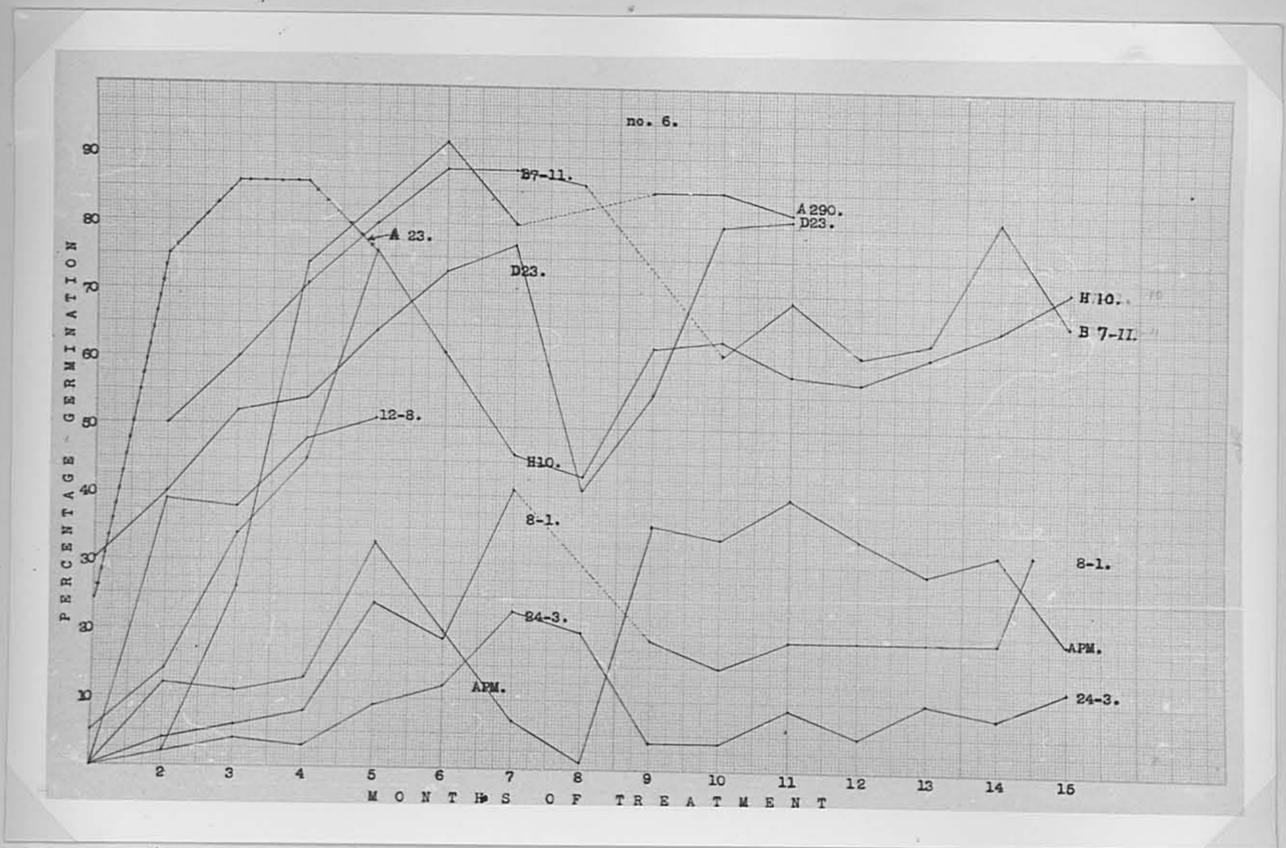

Fig.5.(Test no.6). The course of delayed germination of seed of Digitaria 24-3, 12-8 and 8-1, of Digitaria ecotypes A23 and D23, of Panicum maximum APM, of Panicum minus B7-11, of Paspalum scrobiculatum A290 and of Setaria sphacelata H10, when ~~the~~ kept in muslin bags, placed in a jute bag (not exposed to rain), outdoors.

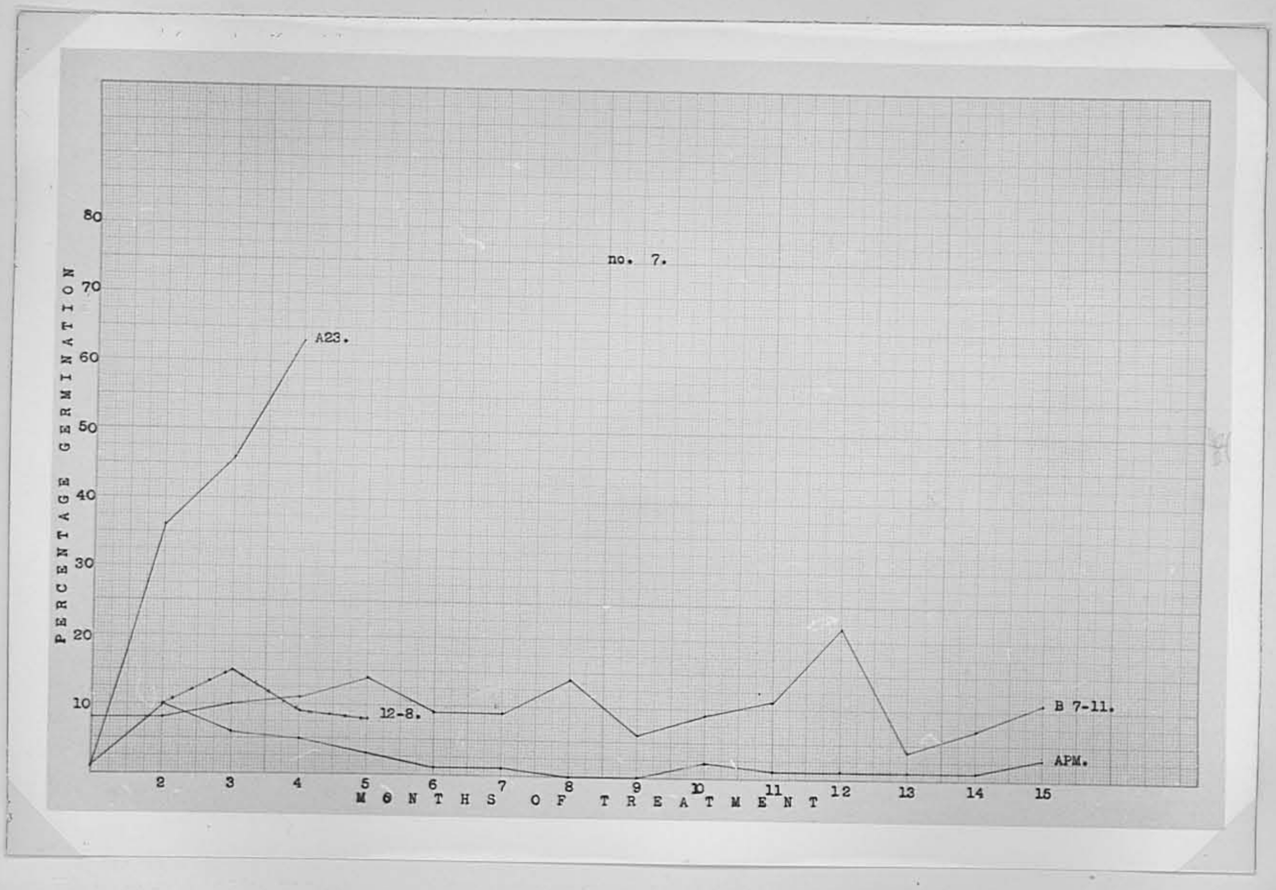

Fig. 6.(Test no.7). The course of delayed germination of seed of Digitaria 12-8, and A23, of Panicum minus B7-11, of P. maximum APM, when kept in shade in a sealed glass container with 0 humidity, outdoors.

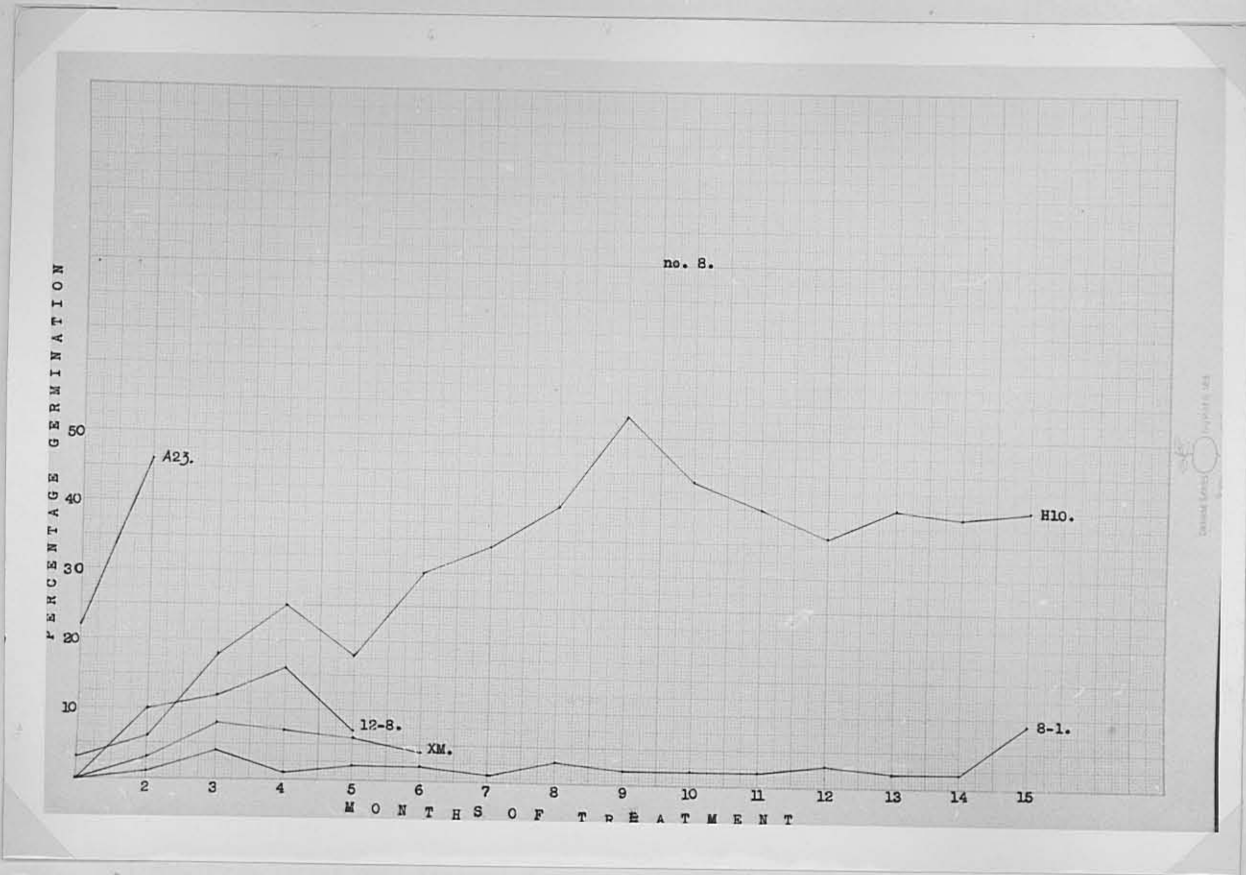

Fig. 7. (Test no.8). The course of delayed germination of seed of Digitaria 12-8, 8-1, A23 and "Molopo" and of Setaria sphacelata H10, when kept in a sealed glass container with 50% humidity, in shade outdoors.

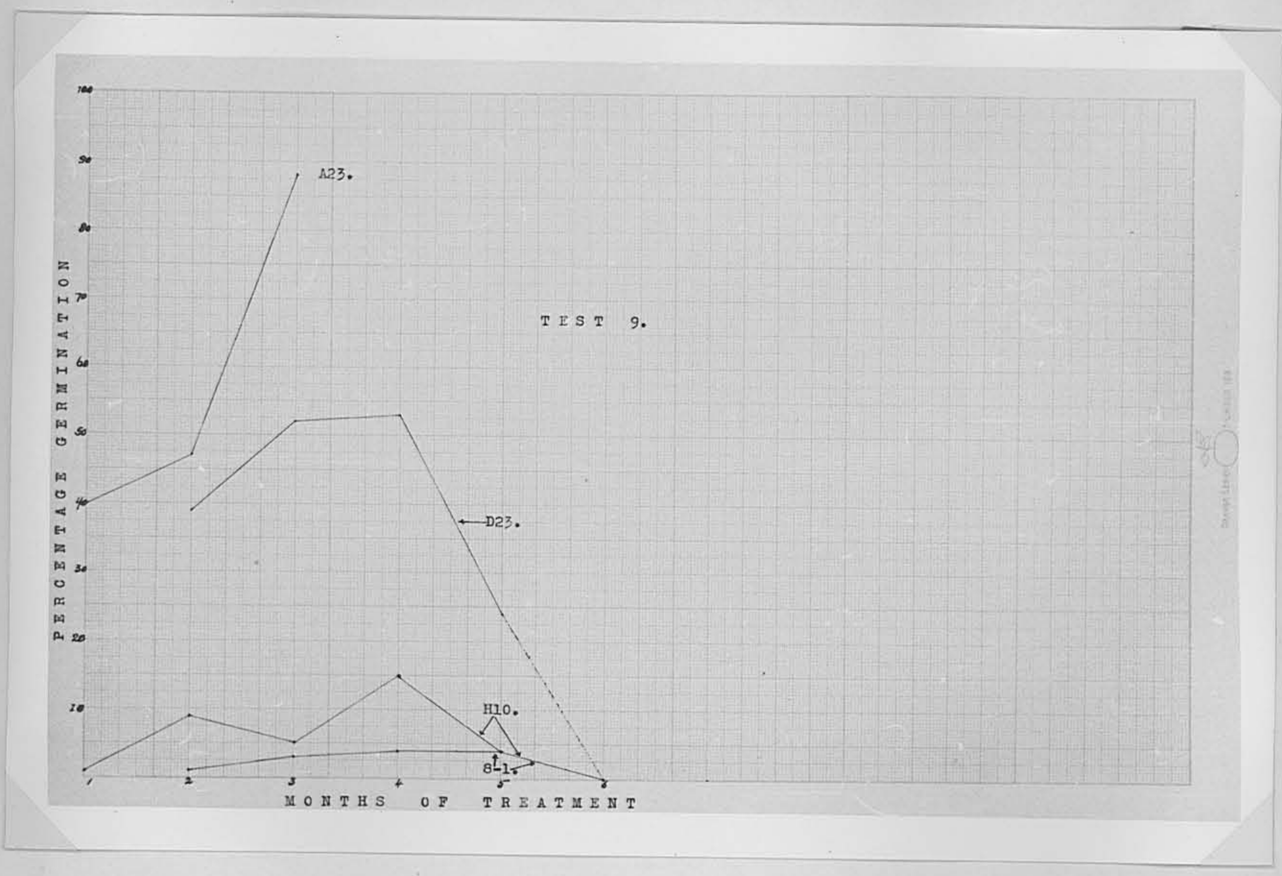

Fig. 8.(Test no.9). The course of delayed germination of seed of Digitaria 8-1, A23, and D23, and of Setaria sphacelata H10, when kept in a sealed glass container with 90% humidity, in shade, outdoors.

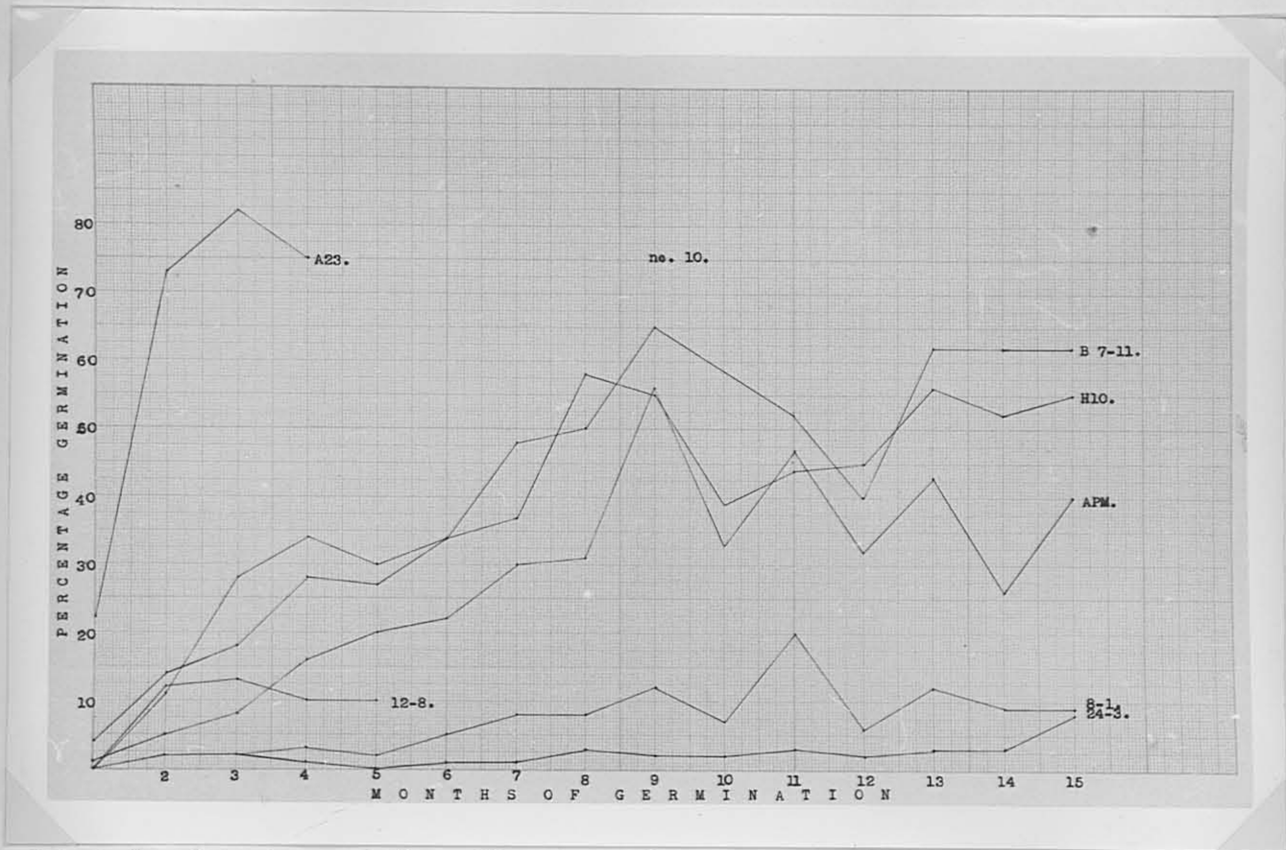

Fig. 9. (Test no.10). Showing the course of delayed germination of <u>Digitaria</u>, lines 12-8, 8-1 and 24-3 and ecotype A.23; of <u>Setaria sphacelata</u> H.10; of <u>Panicum maximum</u> APM and of <u>Panicum minus</u> B.7-11, when the seeds were kept in muslin bags, placed in a glass dish with glass cover (permitting air circulatio), in shade, outdoors.

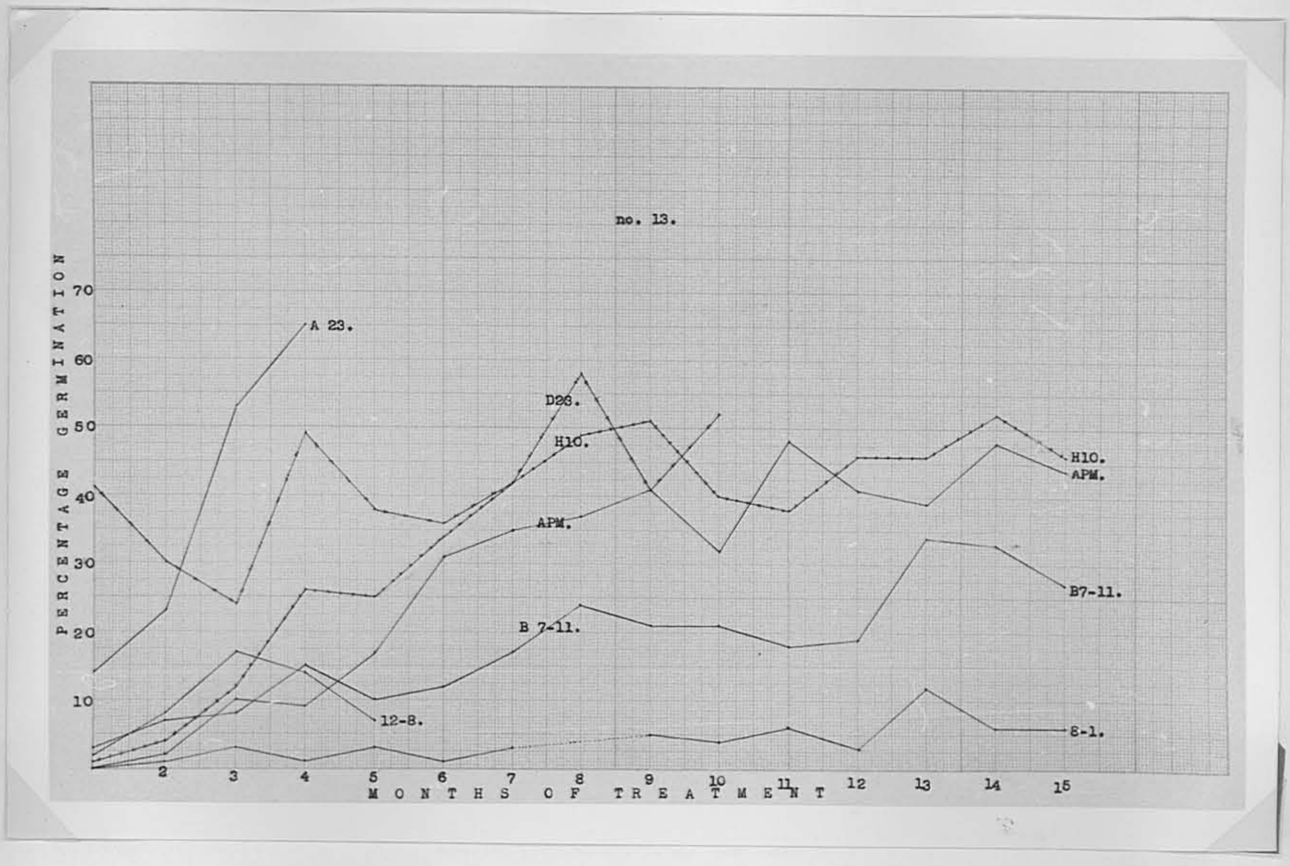

Fig. 10. (Test no.13). Showing the effect of sealed outdoor storage, in a tin, on the course of delayed germination of seeds of <u>Digitaria</u> lines 12-8 and 8-1 and of ecotypes A.23 and D.23; of <u>Panicum maximum</u> APM; of <u>P. minus</u> B.7-11 and of <u>Setaria sphacelata</u> H.10.

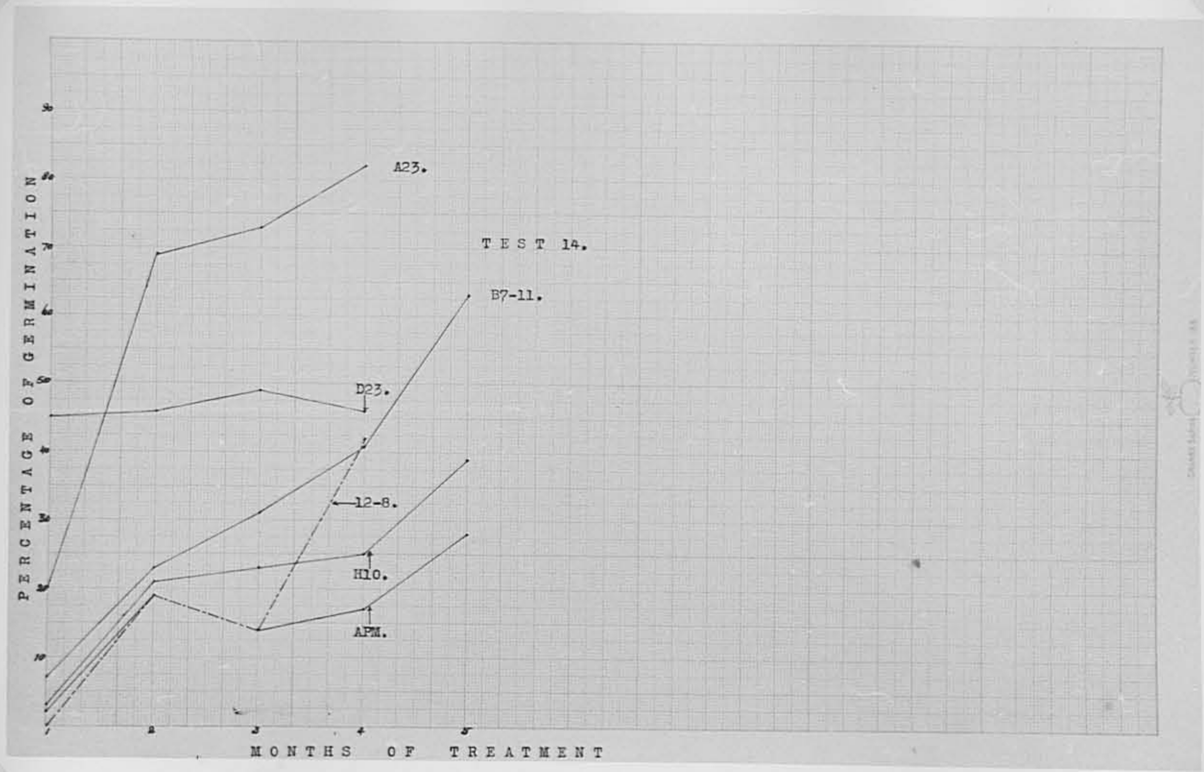

Fig. 11. (Test no.14). Showing the effect of outdoor storage in tin, permitting air circulation, on the course of delayed germination of seed of Digitaria ecotypes A23 and D23 and of line 12-8; of Panicum maximum APM; of P. minus B7-11, and of Setaria sphacelata H10.

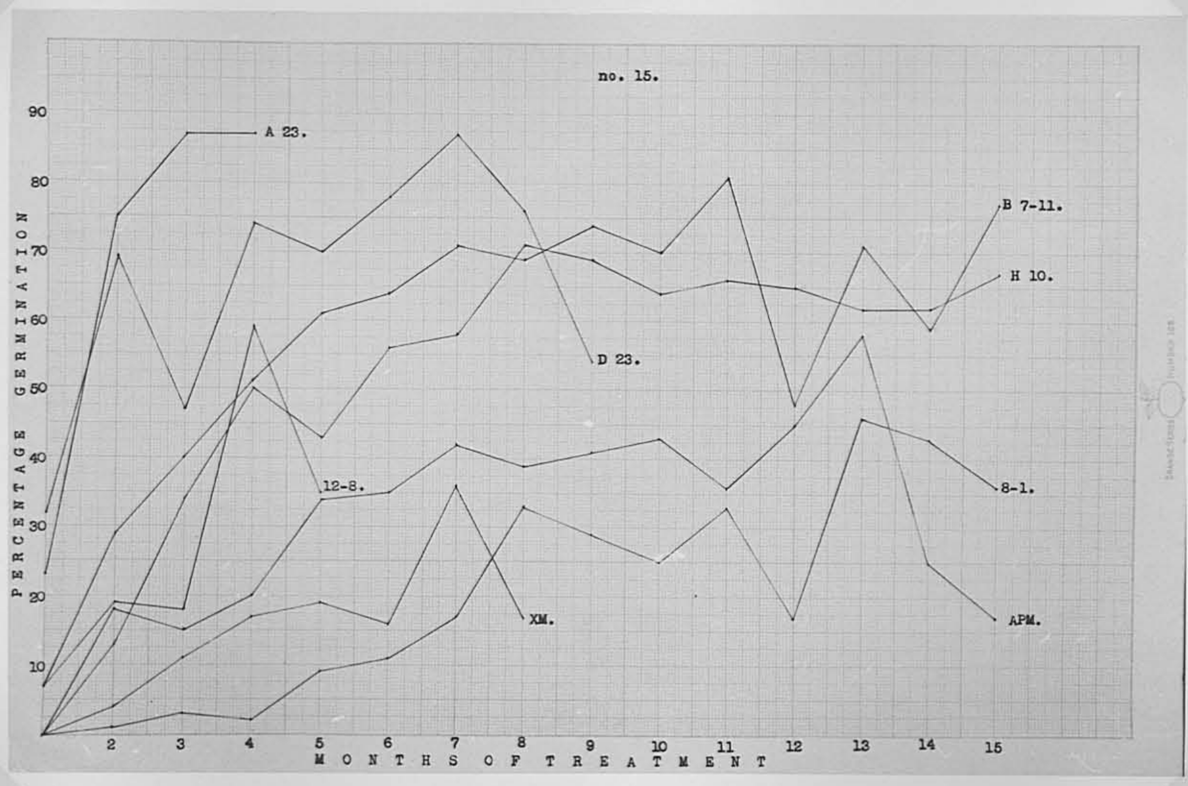

Fig. 12. (Test no.15). Showing the effect of placing seed in muslin bags kept in a brown paper bag outside, on the progress of delayed germination of Digitaria ecotypes A23, D23 and "Molopo" and of lines 12-8 and 8-1; of Panicum maximum APM; of P. minus B7-11 and of Setaria sphacelata H10.

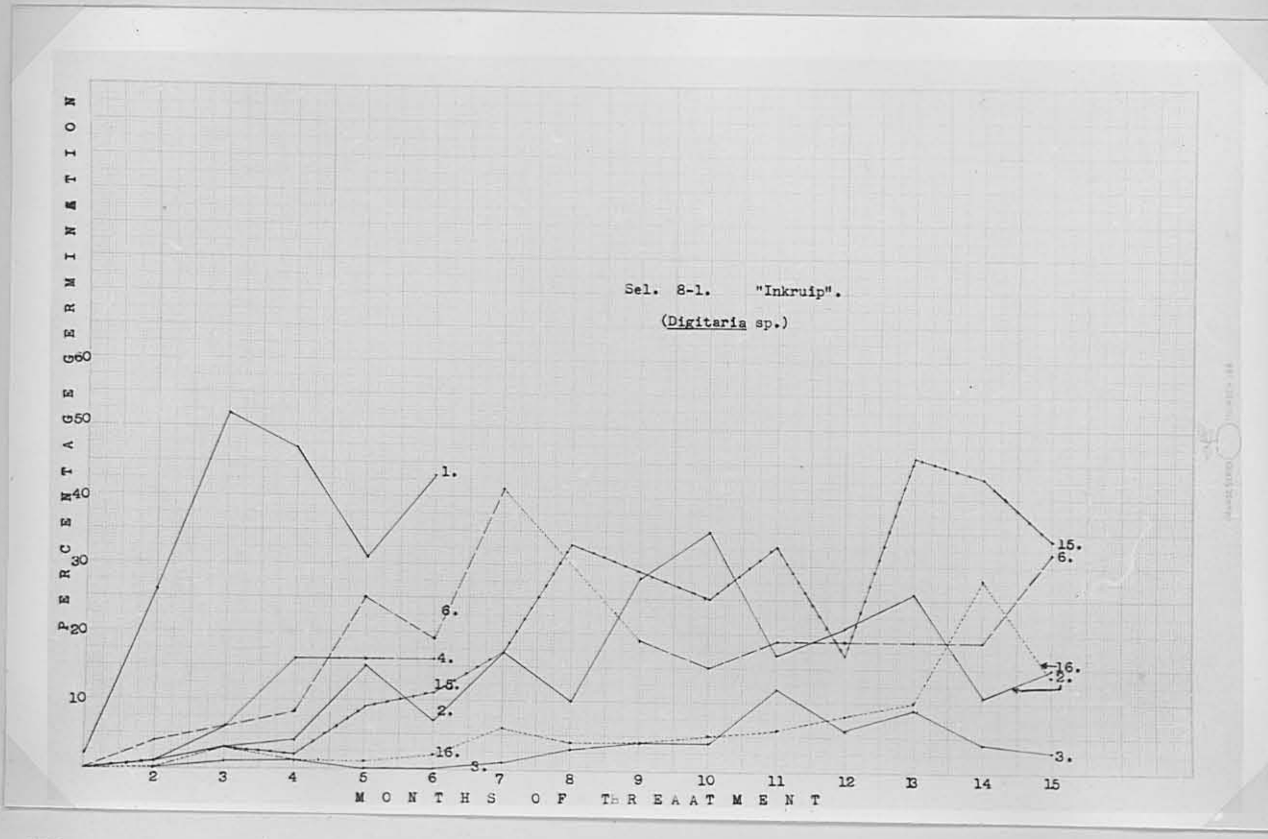

Fig. 13. Showing the effect of 7 outdoor treatments on the course of delayed germination of seed of Digitaria line 8-1. The numbers of the graphs refer to the even-numbered treatments described in the text.

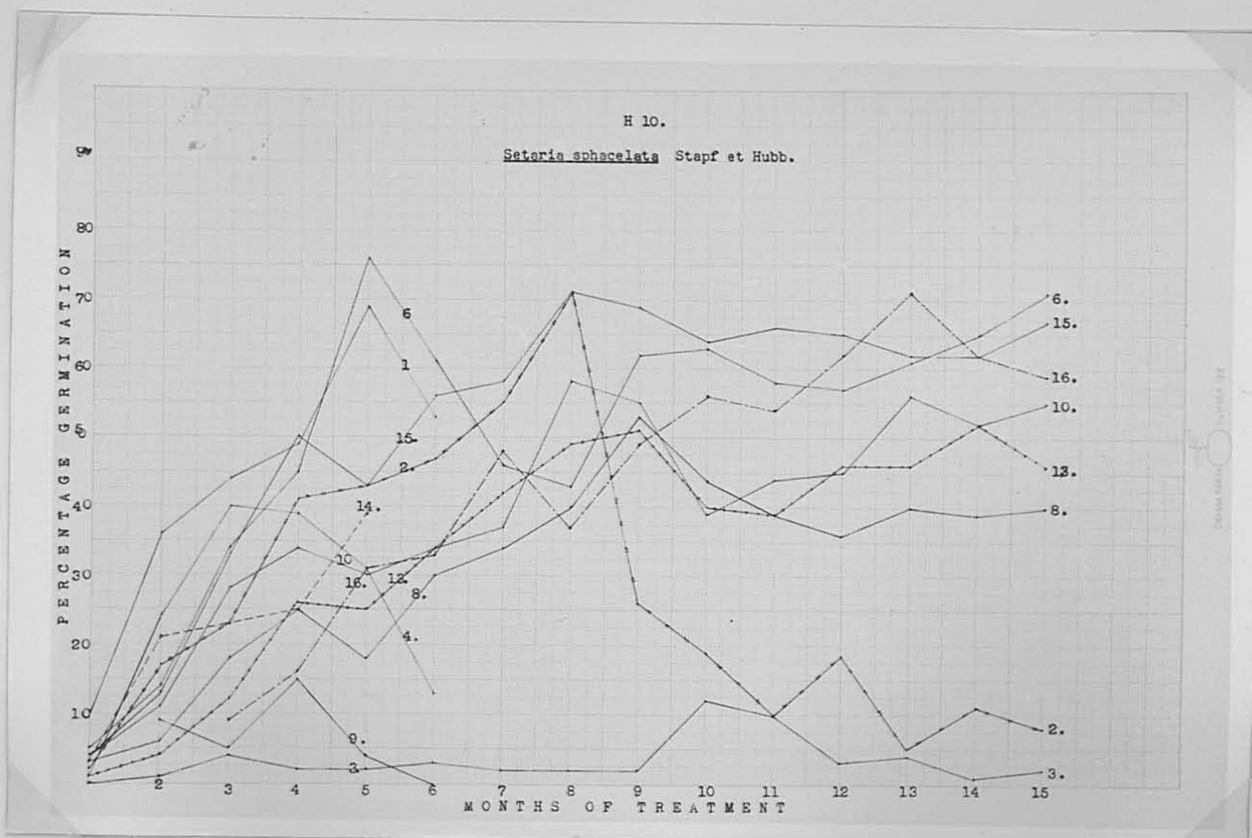

Fig. 14. Showing the effect of 12 outdoor treatments on the course of delayed germination of seed of Setaria sphacelata H10. The numbers of the graphs refer to the even-numbered treatments described in the text.

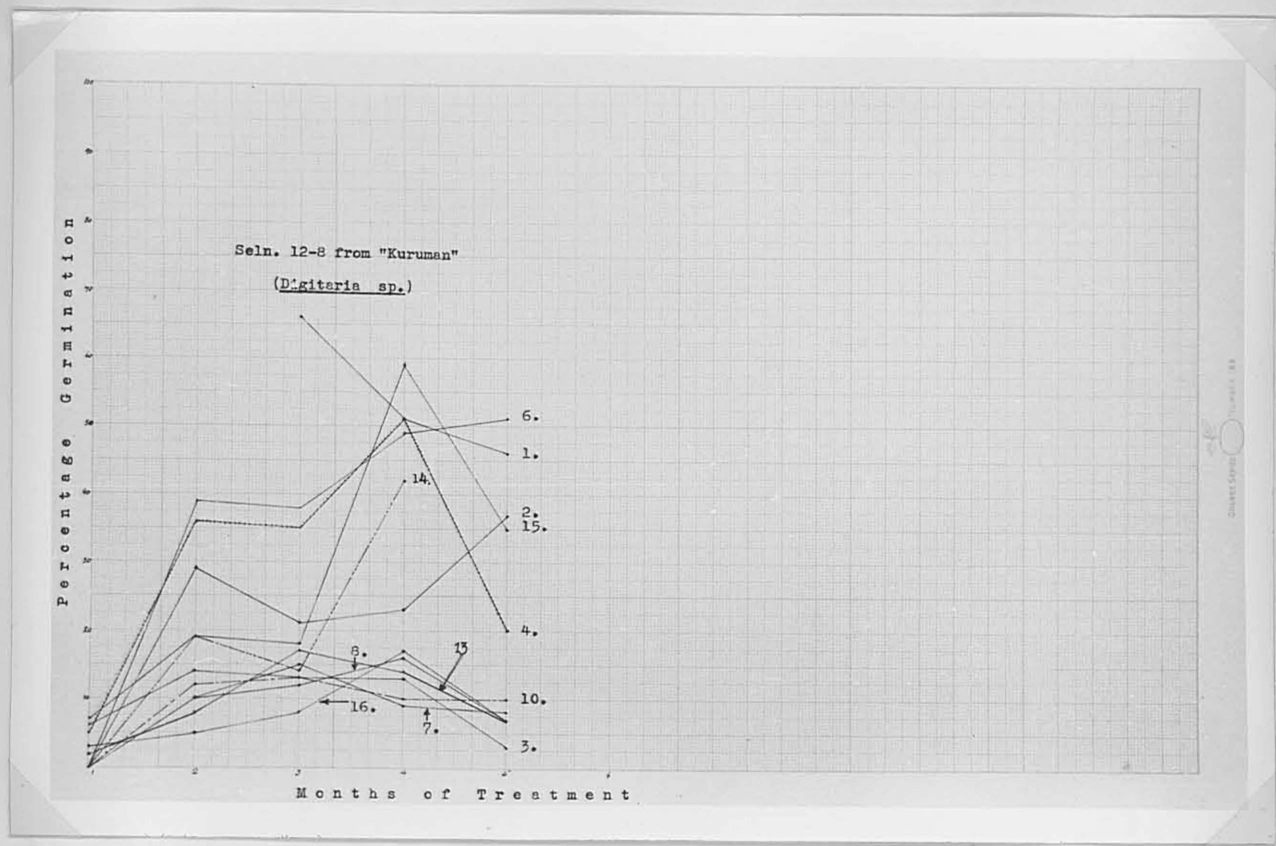

Fig.15. Showing the effect of 12 out-door treatments on the course of delayed germination of seeds of Digitaria line 12-8. (The numbers of the graphs refer to the even-numbered treatments described in the text.)

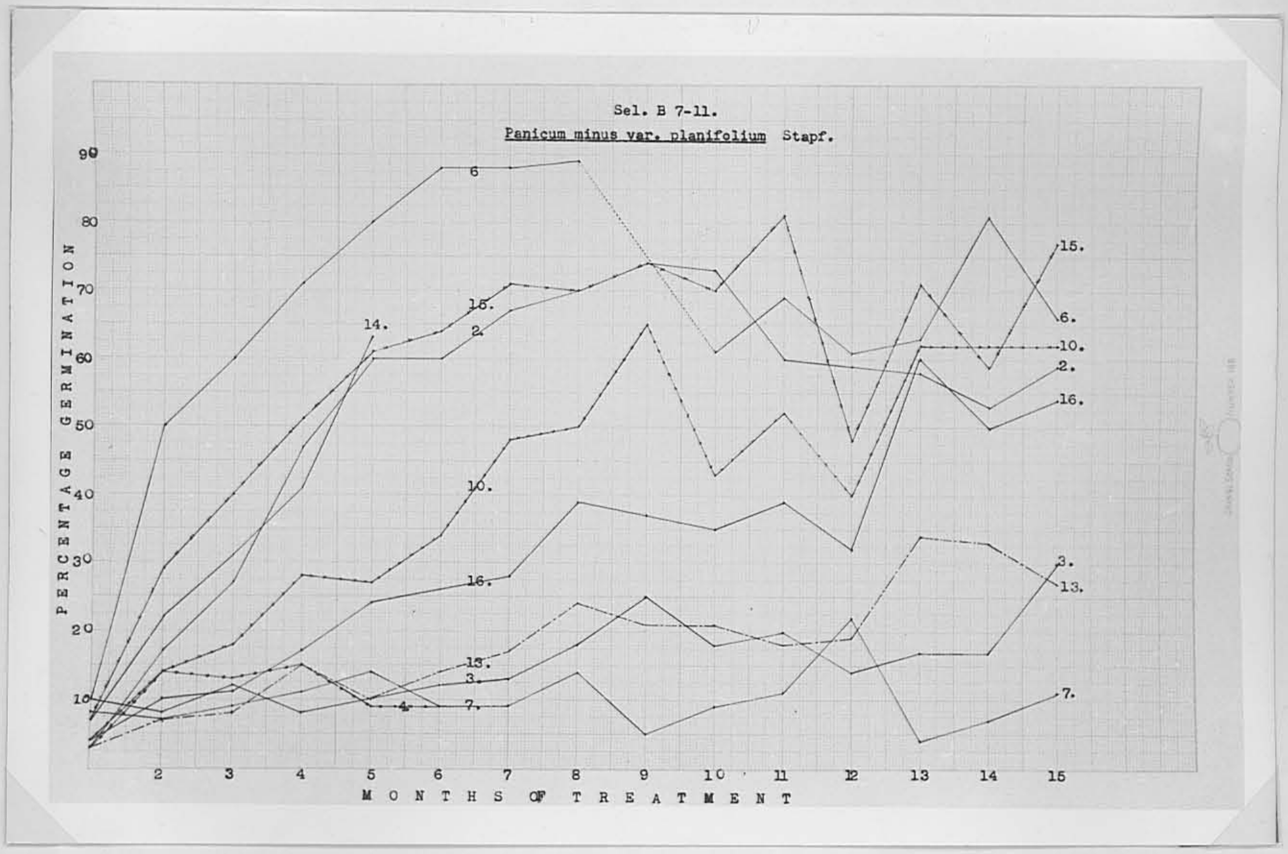

Fig.16. Showing the effect of 10 out-door treatments on the course of delayed germination of seeds of Panicum minus line B.7-11. (The numbers of the graphs refer to the even-numbered treatments described in the text.

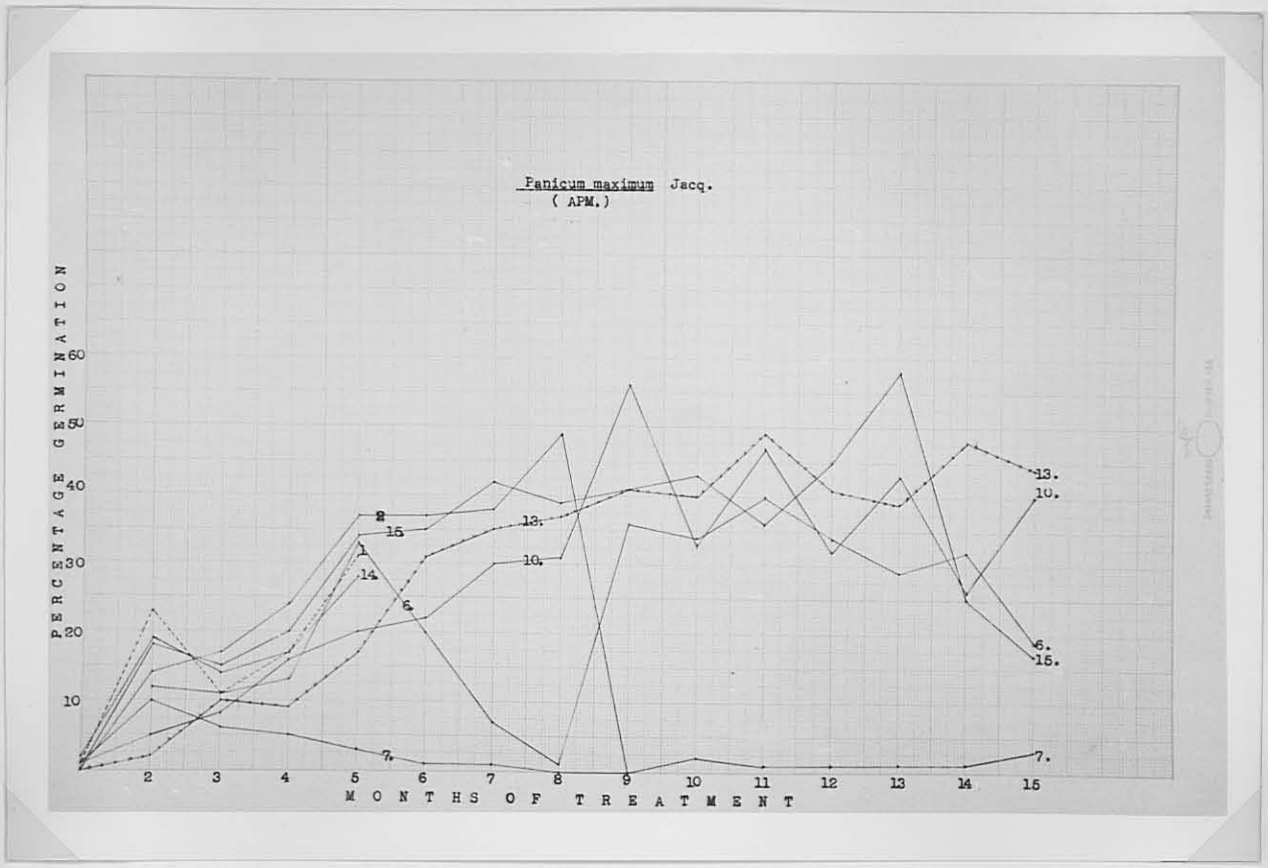

Fig. 17. Showing the effect of 8 out-door treatments on the course of delayed germination of seeds of Panicum maximum APM . (The numbers of the graphs refer to the even-numbered treatments described in the text).

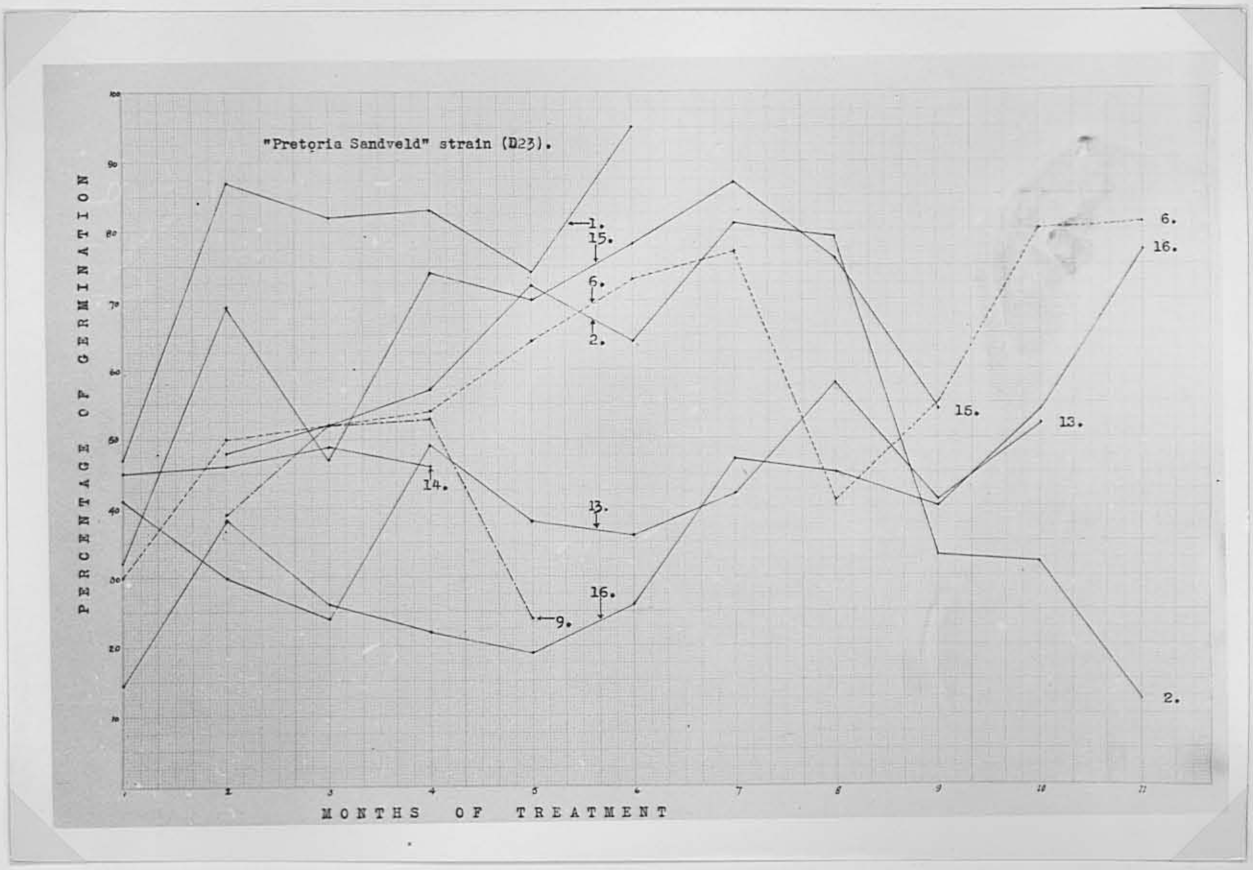

Fig.18. Showing the effect of 8 out-door treatments on the course of delayed germination of seeds of Digitaria ecotype D.23. (The numbers of the graphs refer to the even-numbered treatments described in the text.)

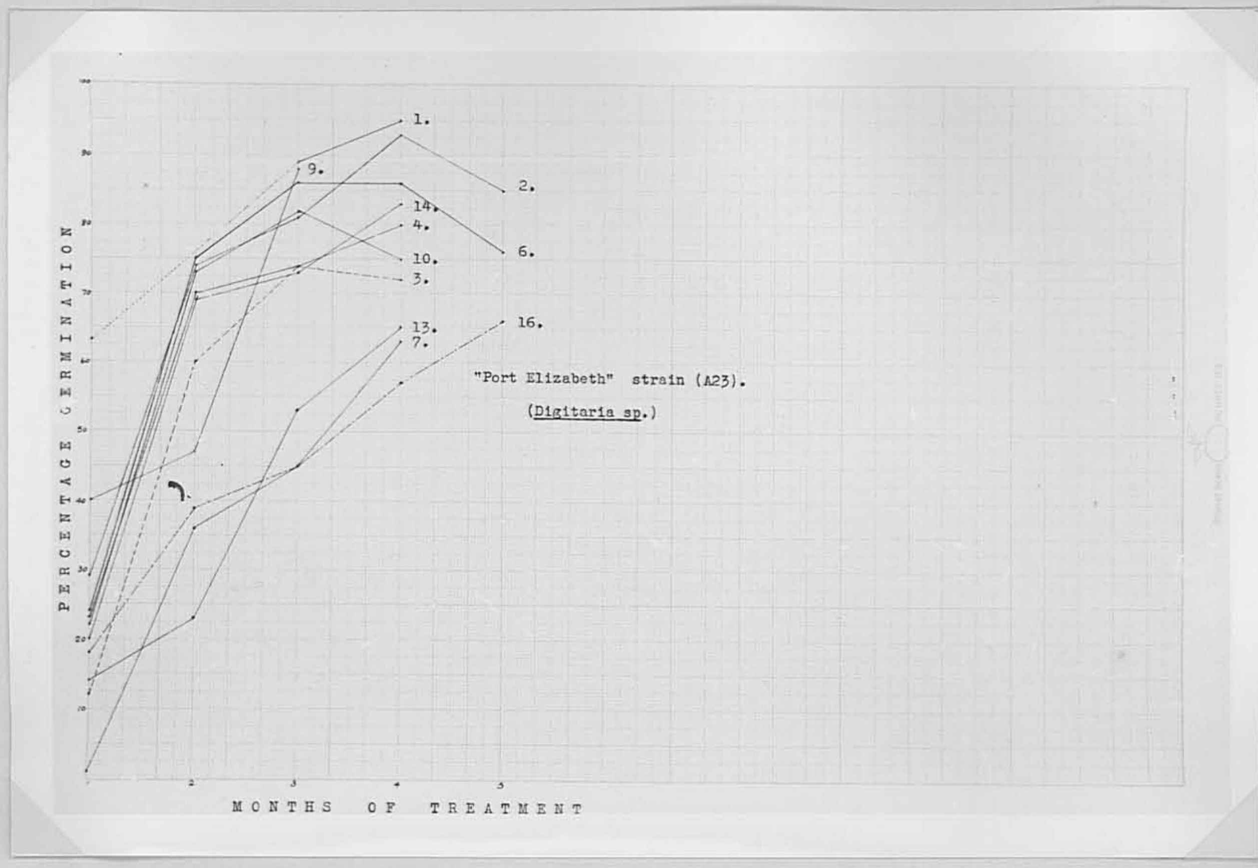

Fig. 19. The effect of 11 outdoor treatments on the course of delayed germination of seed of Digitaria A23. (The numbers of the graphs refer to the even-numbered treatments described in the text.

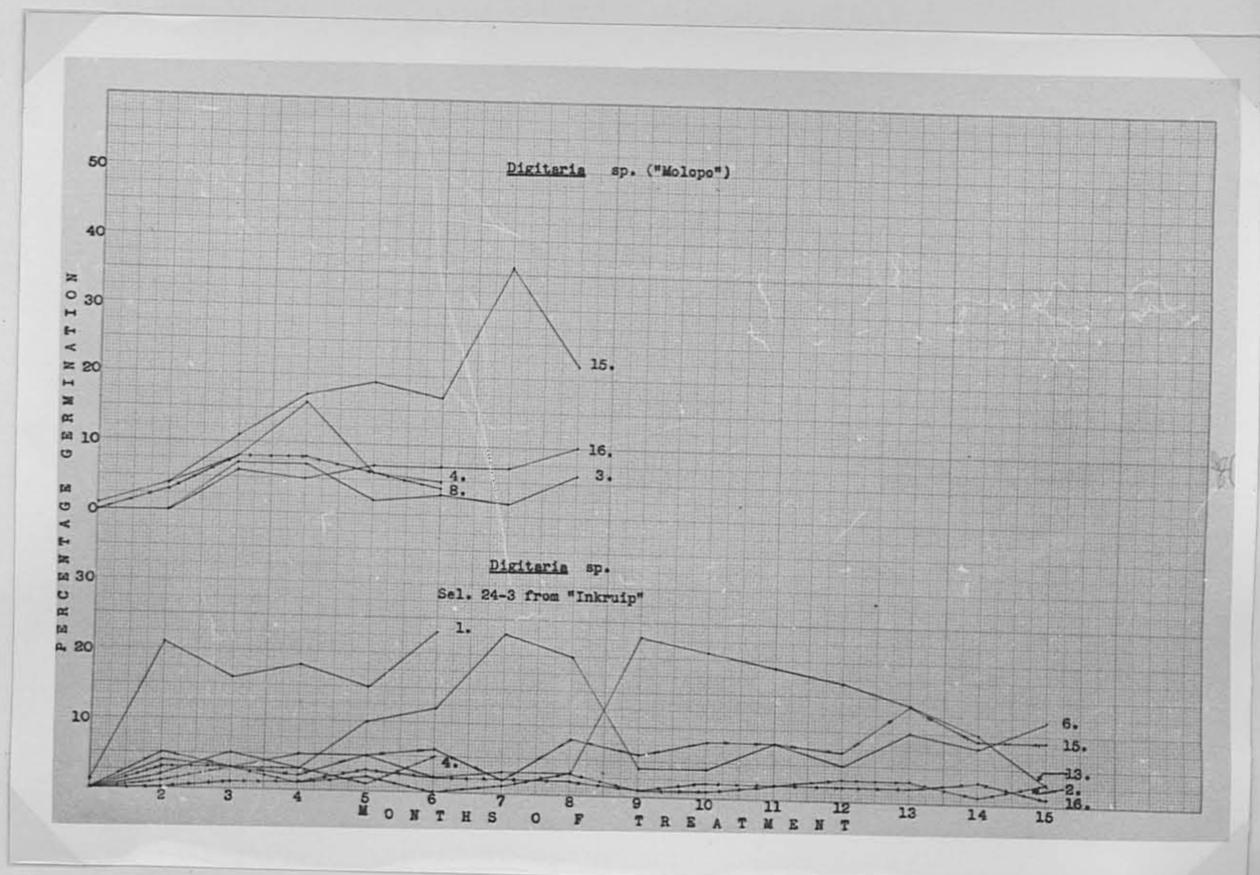

Fig. 20. The effect of several outdoor treatments on the course of delayed germination of Digitaria 24-3 and Molopo. (The numbers of the graphs refer to the even-numbered treatments described in the text.

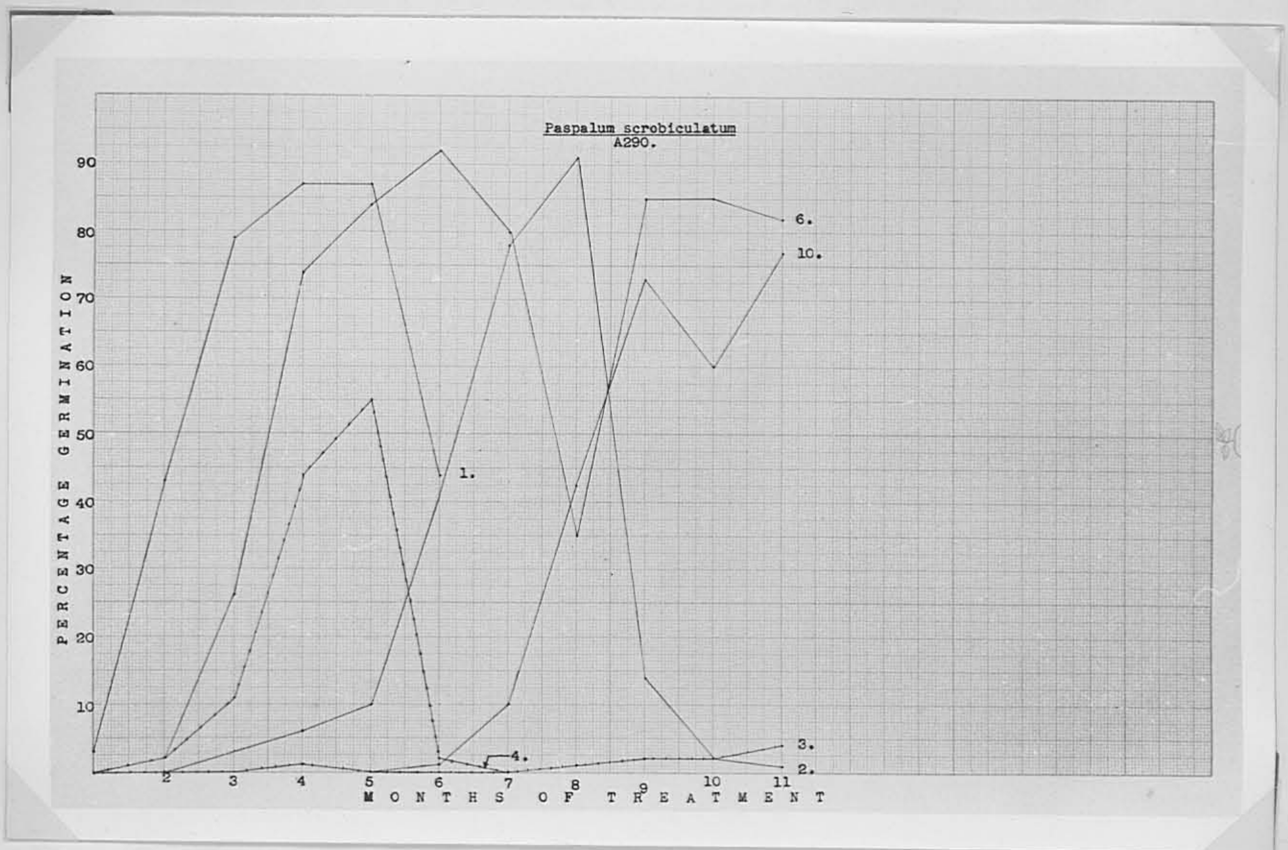

Fig. 21. Showing the effect of 6 out-door treatments on the course of delayed germination of seeds of Paspalum scrobiculatum A.290. (The numbers of the graphs refer to the even-numbered treatments described in the text.)

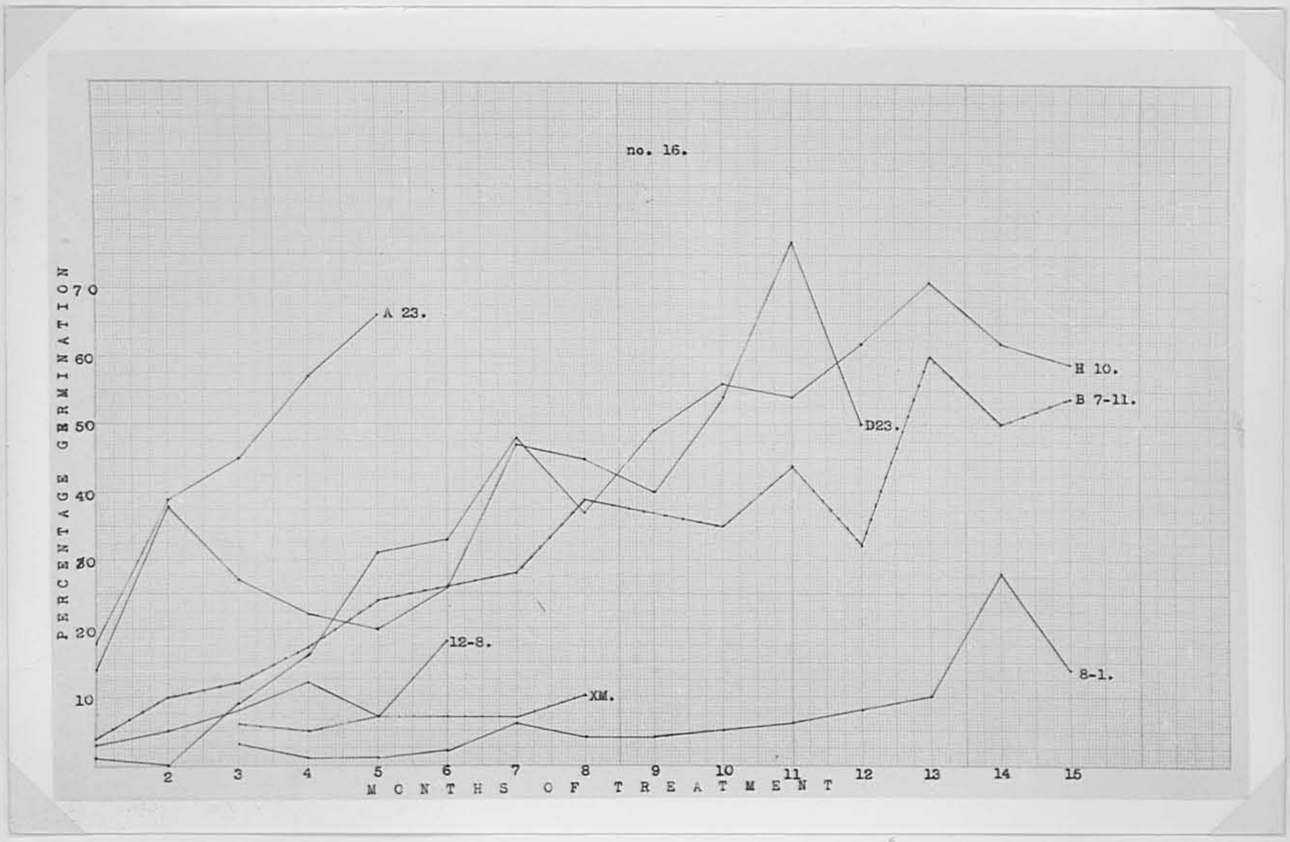

Fig.22. (Test no.16). Showing the effect of placing seeds in muslin bags kept in a brown paper bag, indoors, on the progress of delayed germination of seeds of Digitaria ecotypes A.23, D.23 and "Molopo" and lines 12-8 and 8-1; of Panicum minus B.7-11 and of Setaria sphacelata H.10.

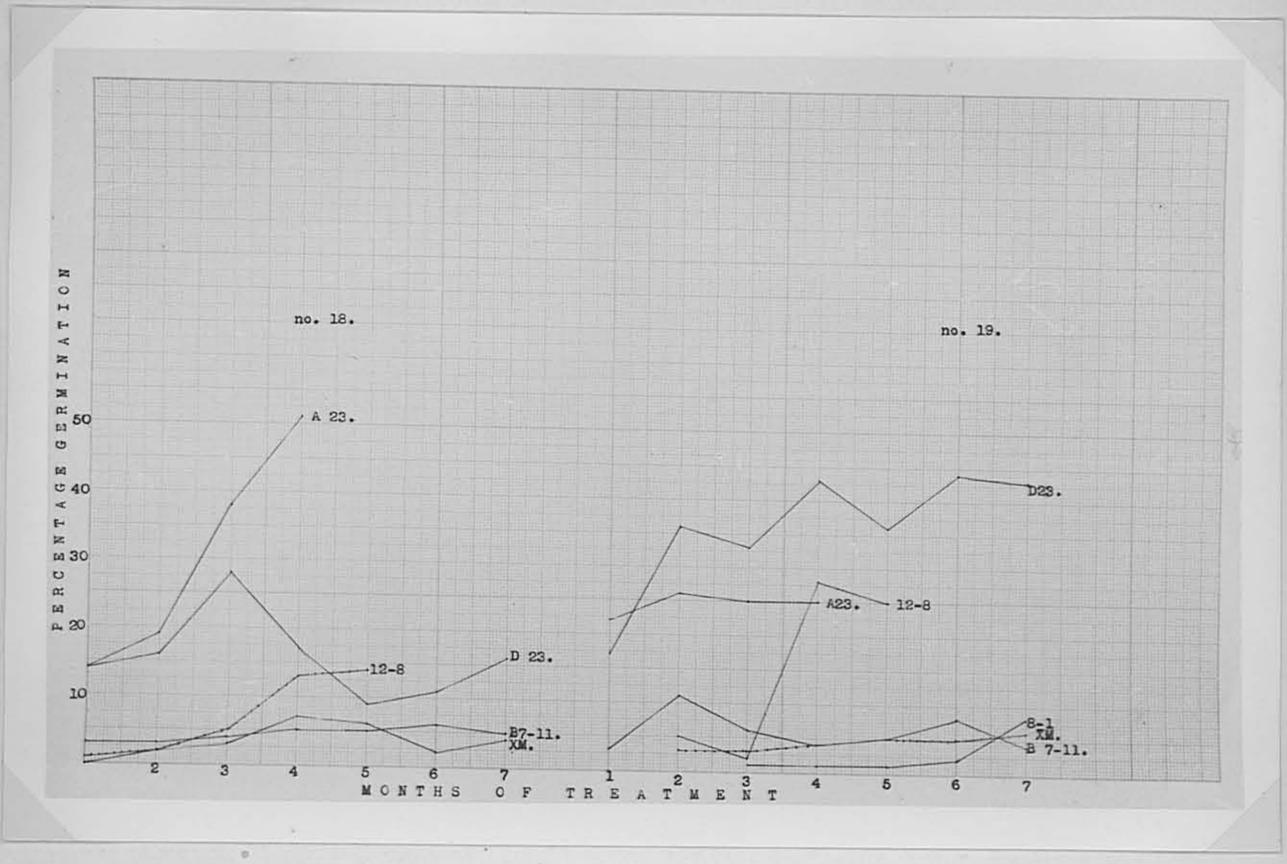

Fig. 23. (Test no. 18). Showing the effect of keeping seed in a sealed glass container at 50% humidity (in a domestic refrigerator) on the course of delayed germination of Digitaria A23, D23, 12-8 and "Molopo"; and of Panicum minus B7-11.

(Test no.19). The course of delayed germination of seed of Digitaria A23, D23, 12-8, 8-1 and "Molopo" and of Panicum minus B7-11, when ~~the seed~~ kept in a sealed glass container at 90% humidity, in a domestic refrigerator.

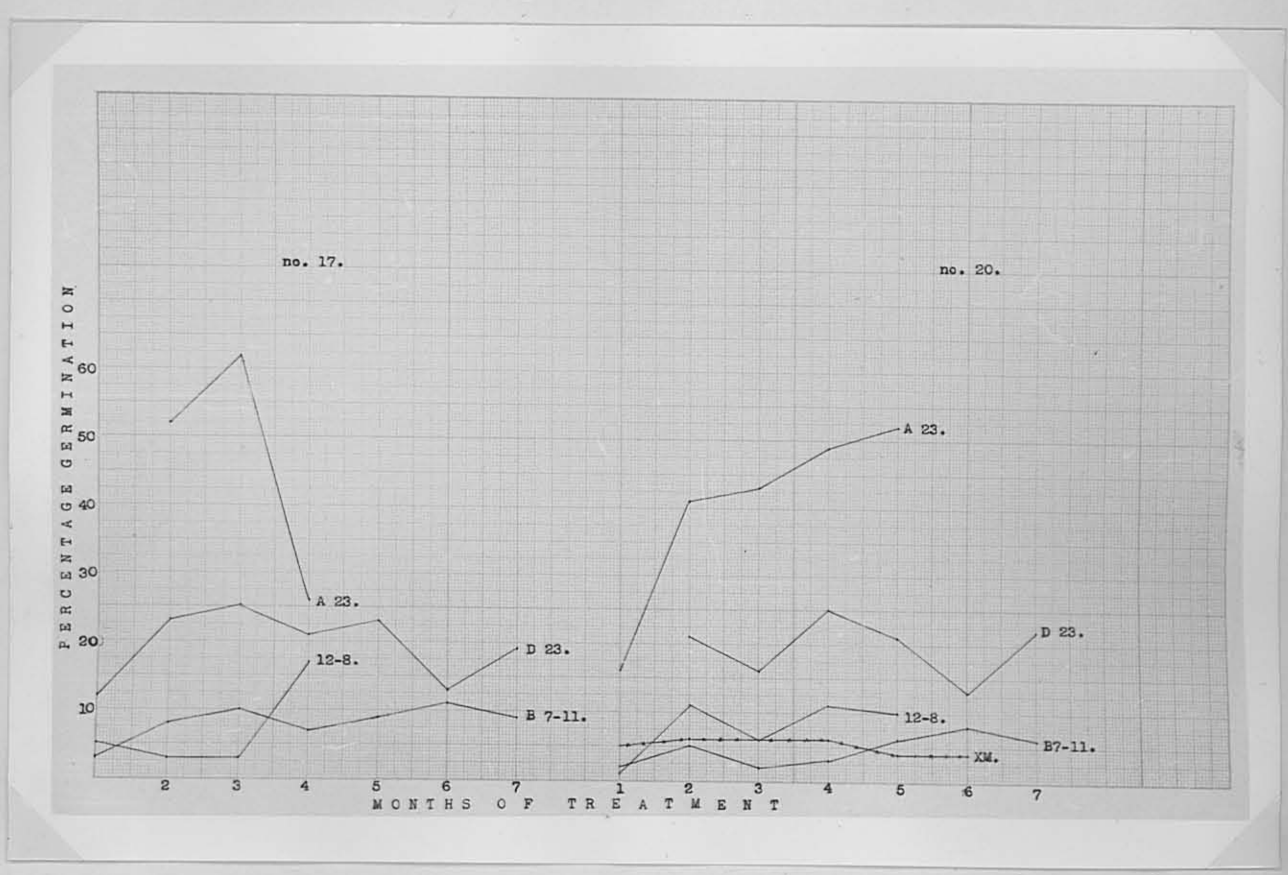

Fig. 24. (Test no.17). The course of delayed germination of Digitaria A23, D23 and 12-8 and of Panicum minus B7-11, when the seed were kept in a sealed glass container at 0 humidity in a domestic refrigerator.

(Test no.20). The course of delayed germination of Digitaria A23, D23, 12-8 and "Molopo"and of Panicum minus B7-11, when seed were kept as in the previous but uncontrolled humidity.

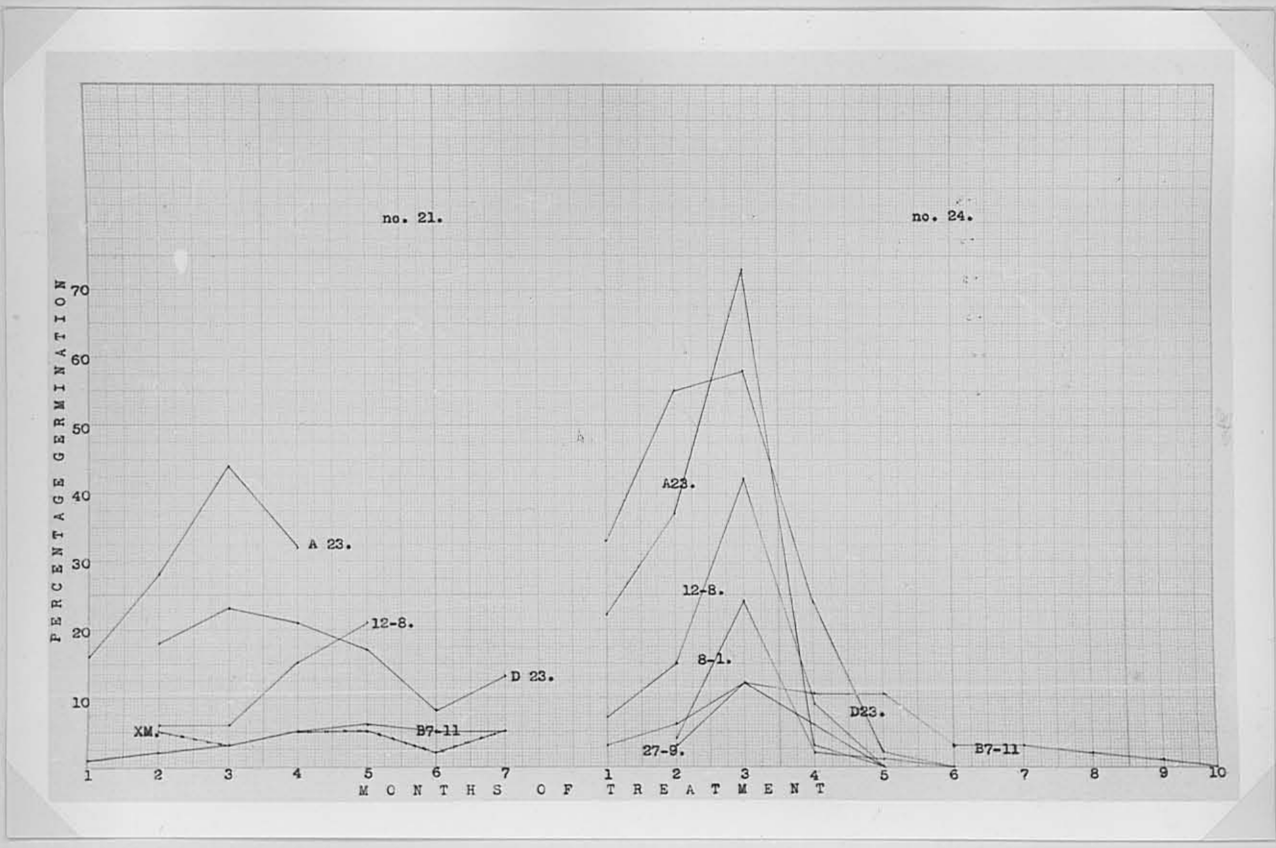

Fig. 25.(Test no.21). The course of delayed germination of seed of Digitaria A23,D23, 12-8 and "Molopo", and of Panicum minus B7-11, when kept in an open container inside a domestic refrigerator.

(Test no.24). The course of delayed germination of seed of Digitaria A23, D23, 12-8, 8-1 and 27-9, and of Panicum minus B7-11, when kept in a sealed glass container at 90% humidity inside an incubator running at ca. 25°C.

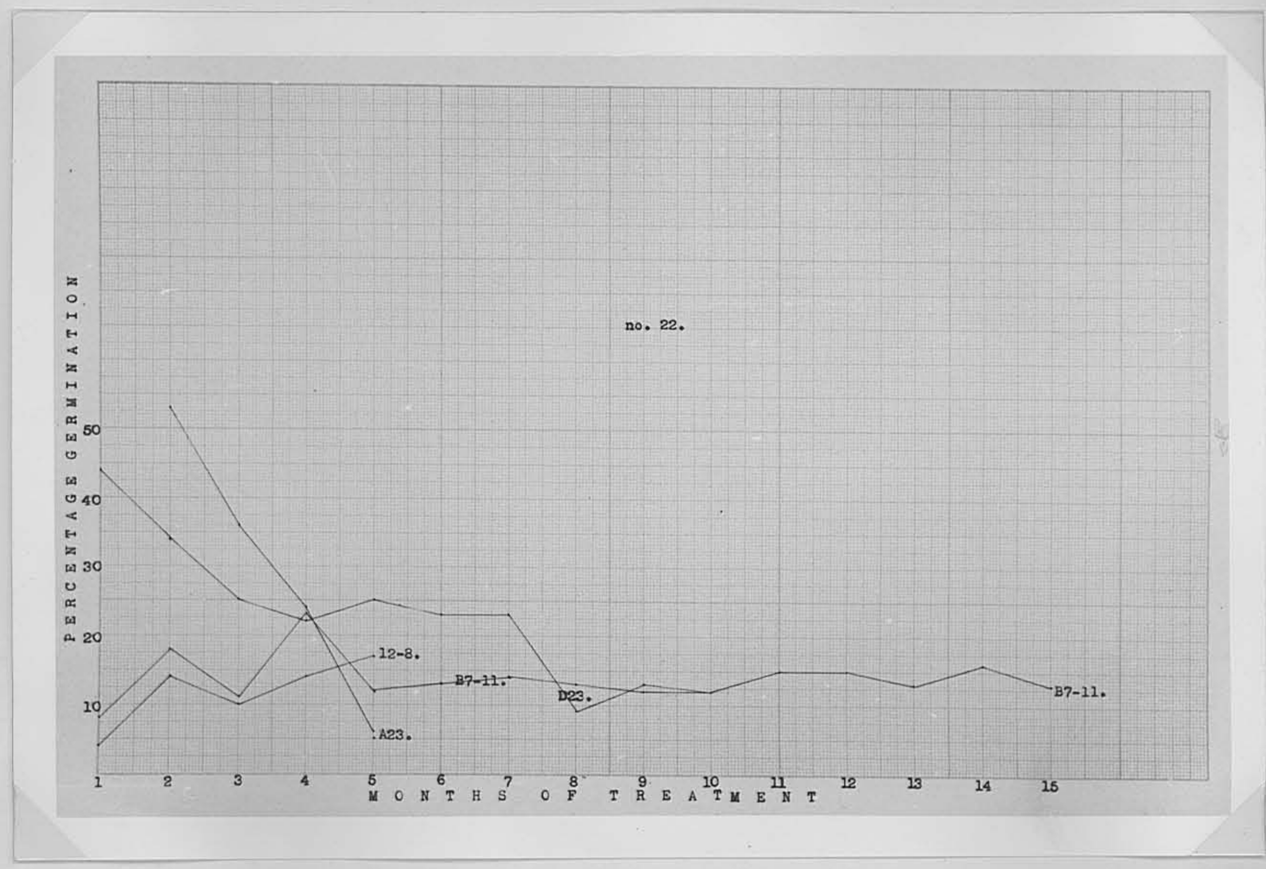

Fig. 26.(Test no. 22). The course of delayed germination of seed of Digitaria A23, D23 and 12-8, and of Panicum minus B7-11, when kept in a sealed glass continer at 0 humidity inside a 25°C incubator.

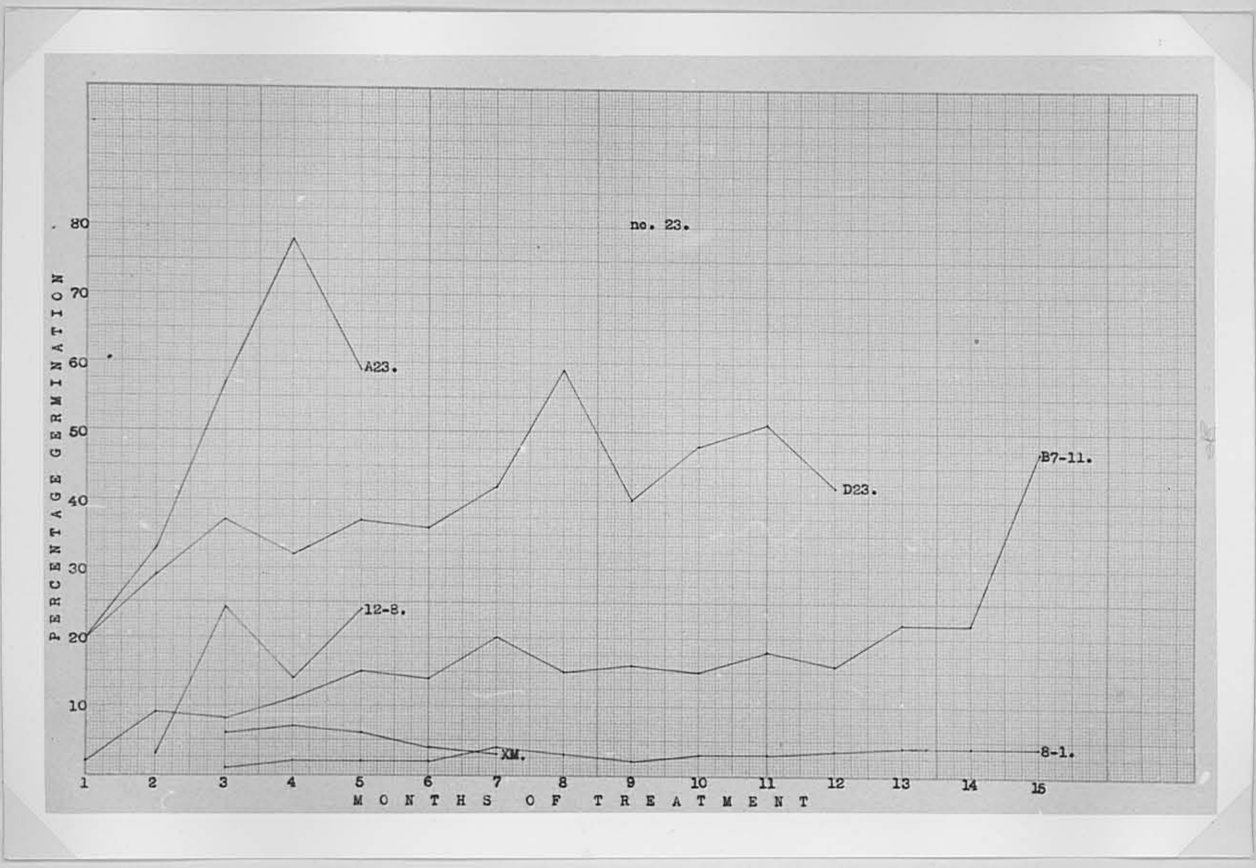

Fig.27.(Test no.23). The course of delayed germination of seed of <u>Digitaria</u> A23, D23, "Molopo", 12-8 and 8-1, and of <u>Panicum minus</u> B7-11, when kept in a sealed glass container at 50% humidity inside a ca. 25°C. incubator.

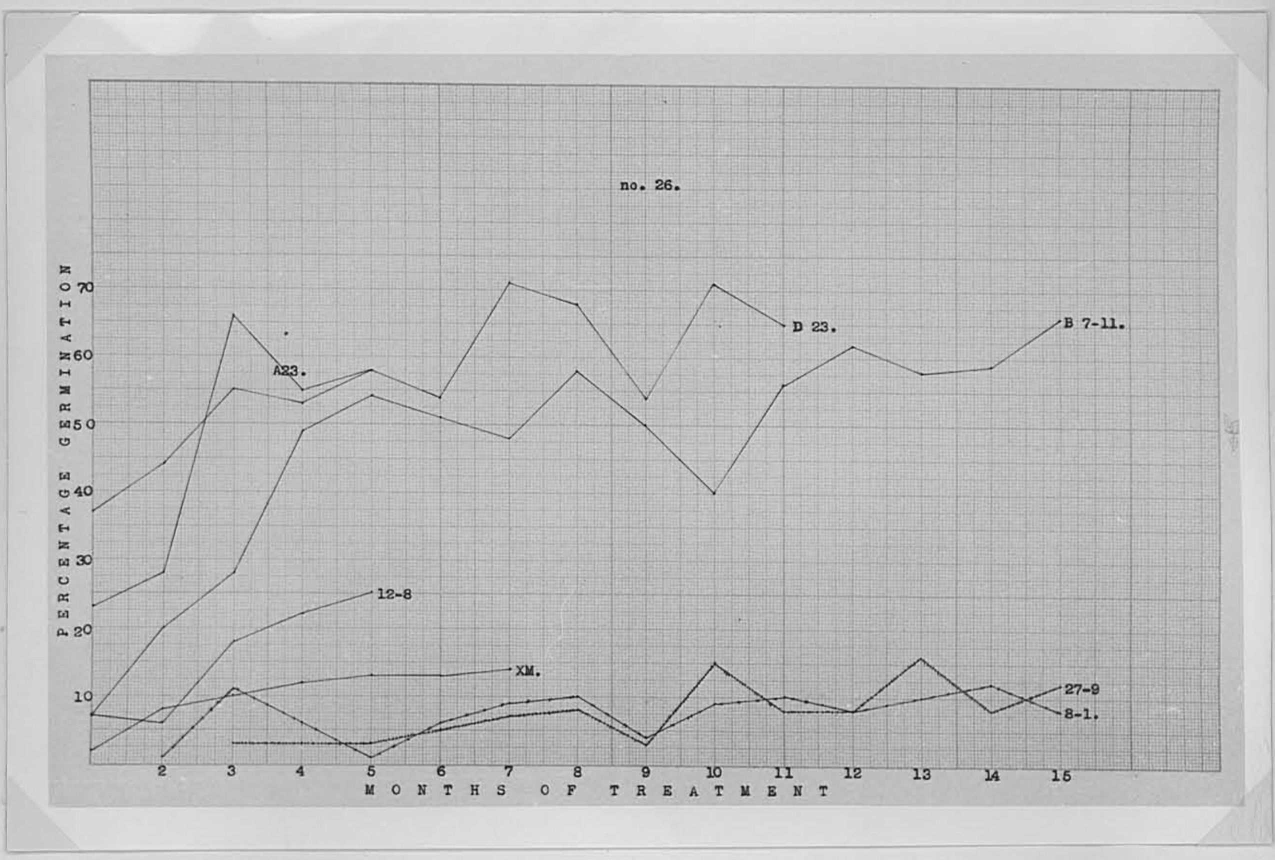

Fig.28.(Test no. 26). The course of delayed germination of seed of <u>Digitaria</u> A23, D23, "Molopo", 12-8, 8-1 and 27-9, and of <u>Panicum minus</u> B7-11, when kept in an open container inside ~~in~~ an incubator run at ca. 25°C.

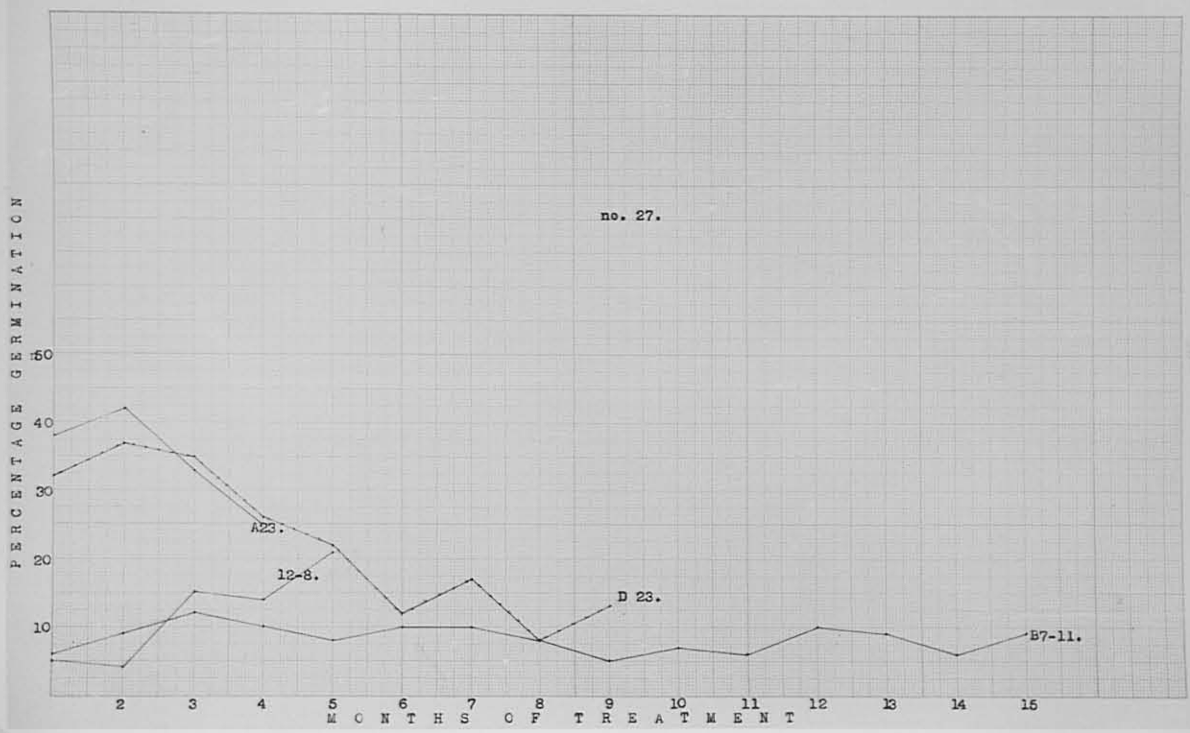

Fig.29.(Test no.27). The course of delayed germination of seed of Digitaria A23, D23, and 12-8, and of Panicum minus B7-11, when kept in a sealed glass container at 0 humidity in side an incubator run at ca. 35°C.

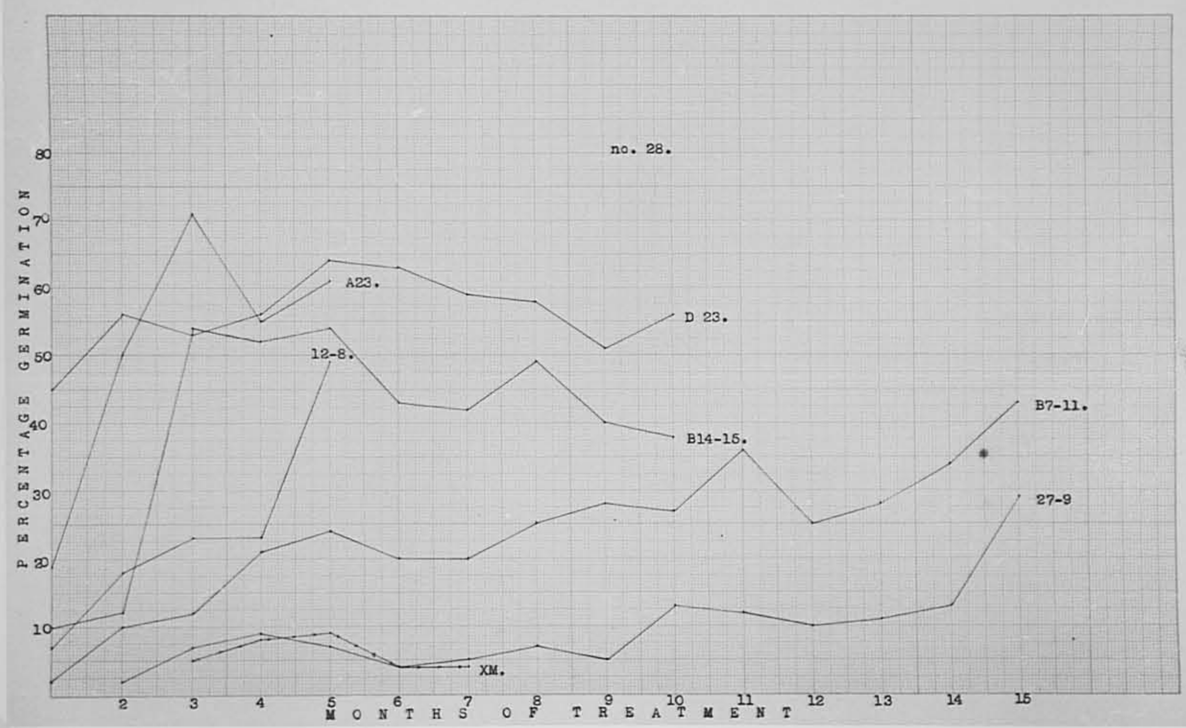

Fig. 30.(Test no.28). The course of delayed germination of seed of Digitaria A23, D23, "Molopo", 12-8, and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15, when kept in a sealed glass container at 50% humidity inside an incubator run at ca.35°C.

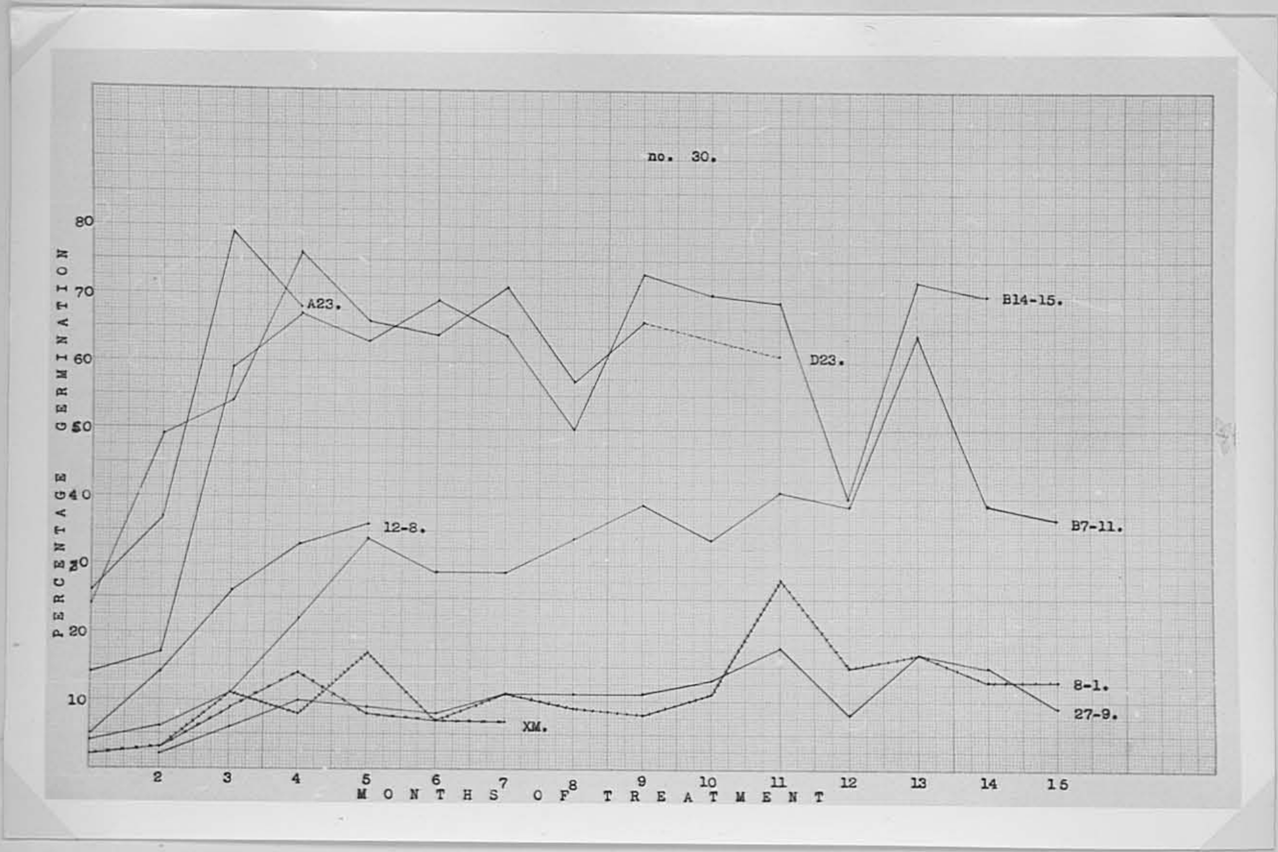

Fig. 31. (Test no.30). The course of delayed germination of the seed of Digitaria A23, D23, "Molopo", 8-1, 12-8 and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15, when kept in a sealed container with uncontrolled humidity (sealed after every monthly test) inside an incubator run at ca.35°C.

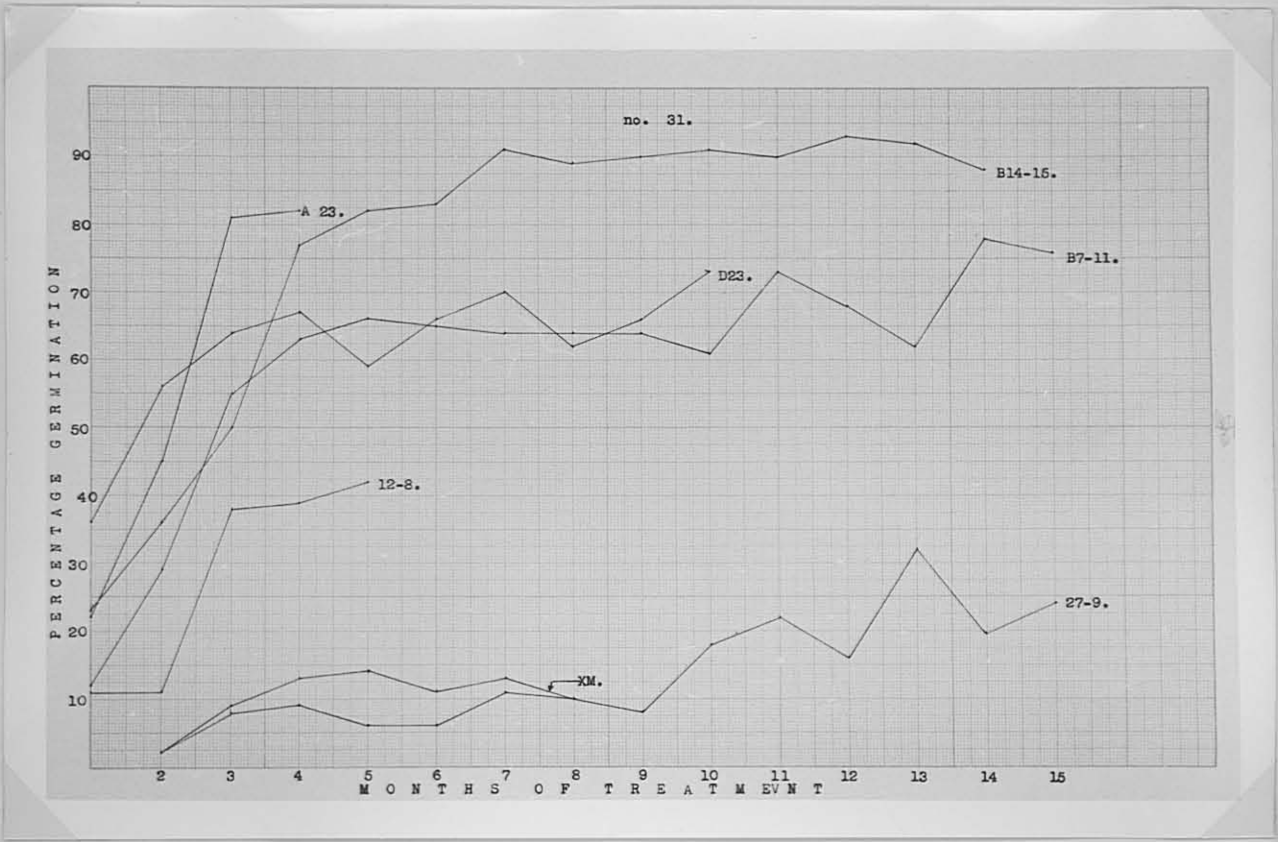

Fig. 32.(Test no.31). The course of delayed germination of seed of Digitaria A23, D23, "Molopo", 12-8 and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15, when kept in an open container inside an incubator run at ca.35°C.

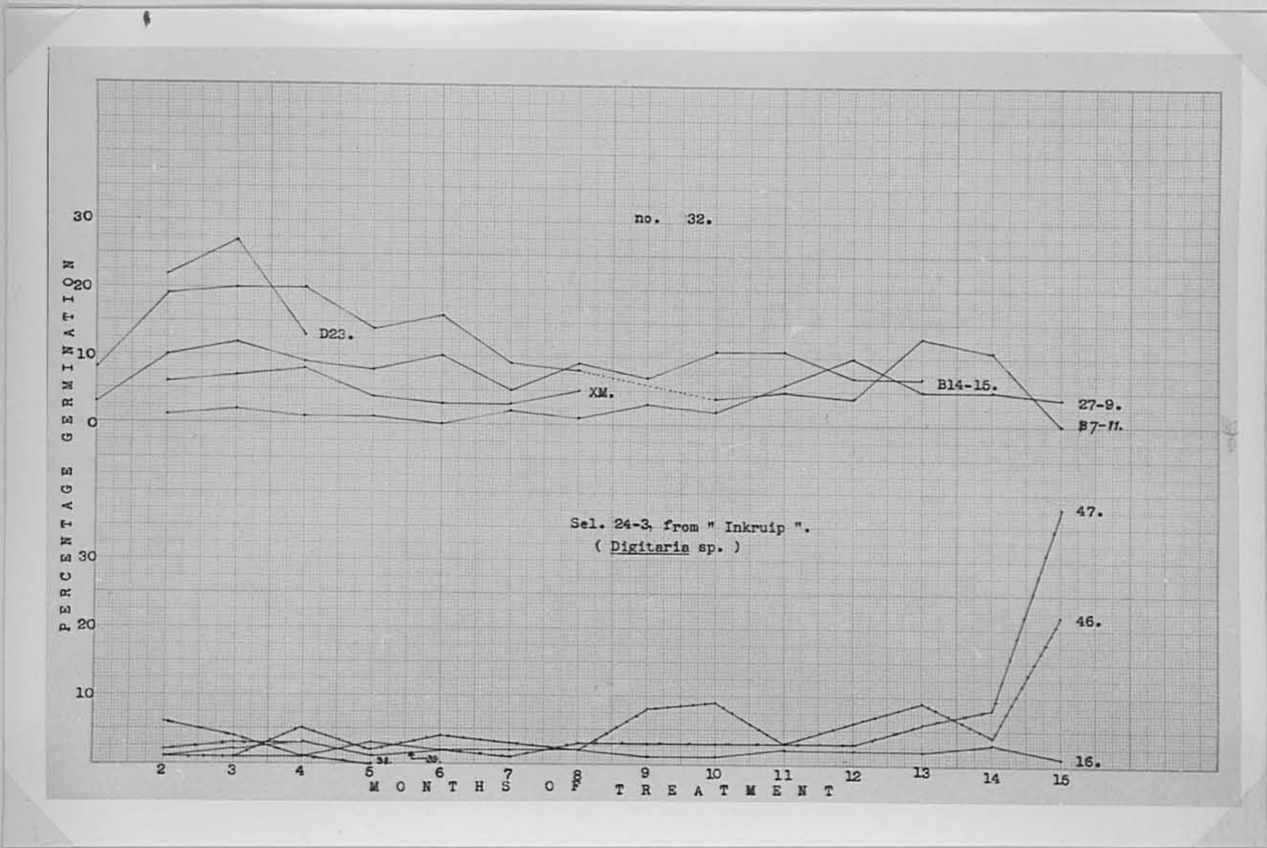

Fig. 33.(Test no.32). The course of delayed germination of seed of Digitaria D23, "Molopo", and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15, when kept in a sealed glass container at 0 Humidity inside an incubator run at 45°C.

(Digitaria seln. 24-3). The effect of 5 incubator treatments on the course of delayed germination on the seed of Digitaria 24-3. (The numbers of the graphs refer to the even-numbered treatments described in the text).

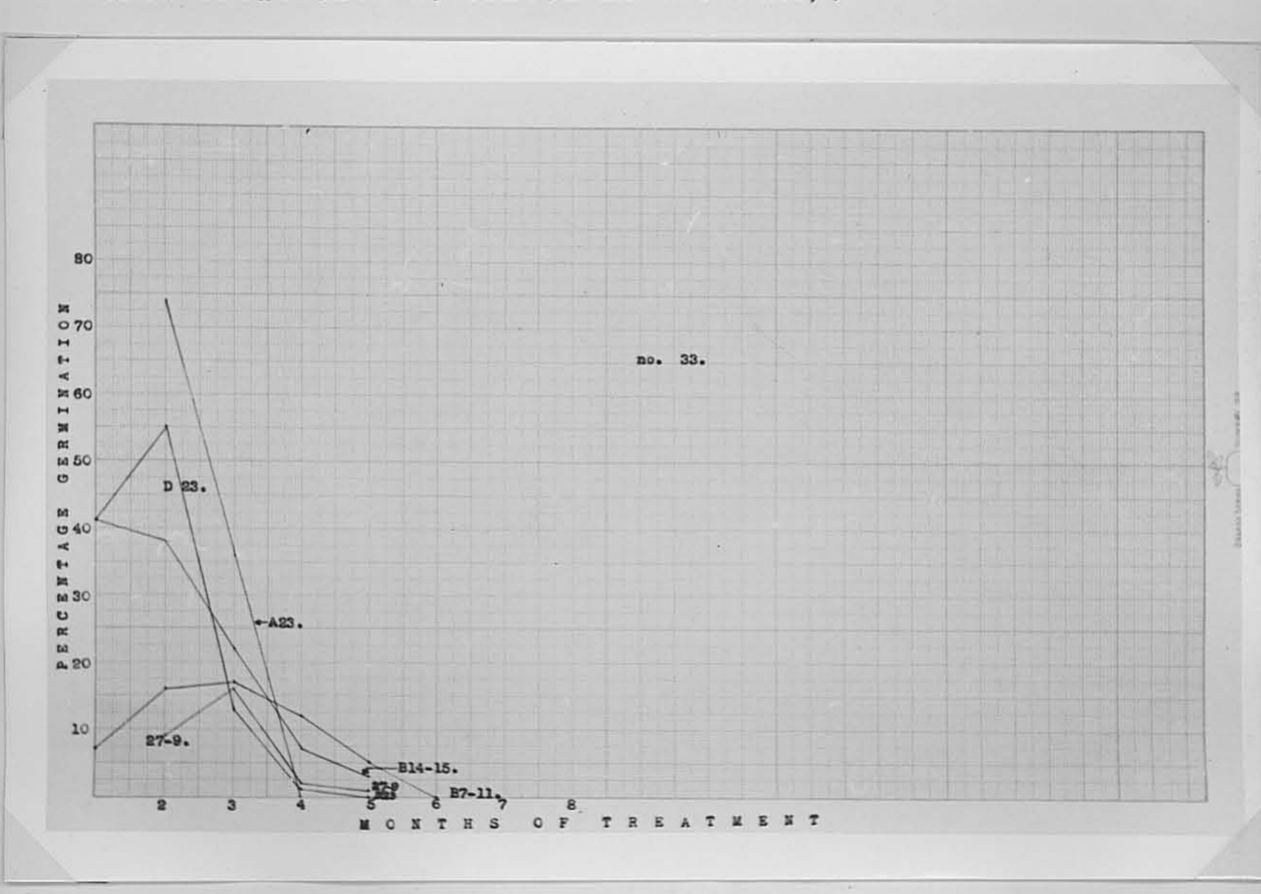

Fig. 34.(Test no33.). The course of delayed germination of seed of Digitaria D23, A23 and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15.

80% by 45°C

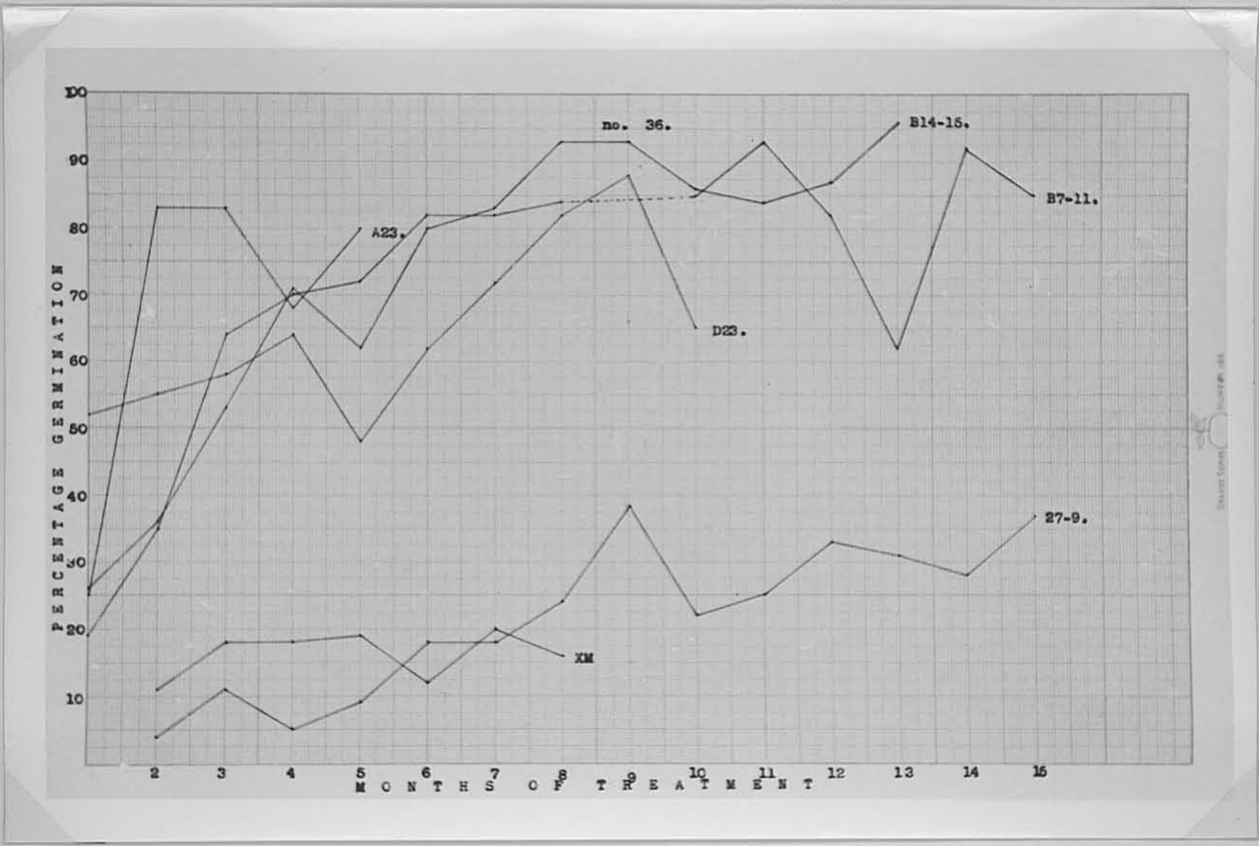

Fig.35. (Test no.36). The course of delayed germination of seed of Digitaria A23, D23 and "Molopo", and 27-9, of Panicum minus B7-11 and of Echinochloa pyramidalis B14-15, when kept in an open container inside an incubator run at ca.45°C.

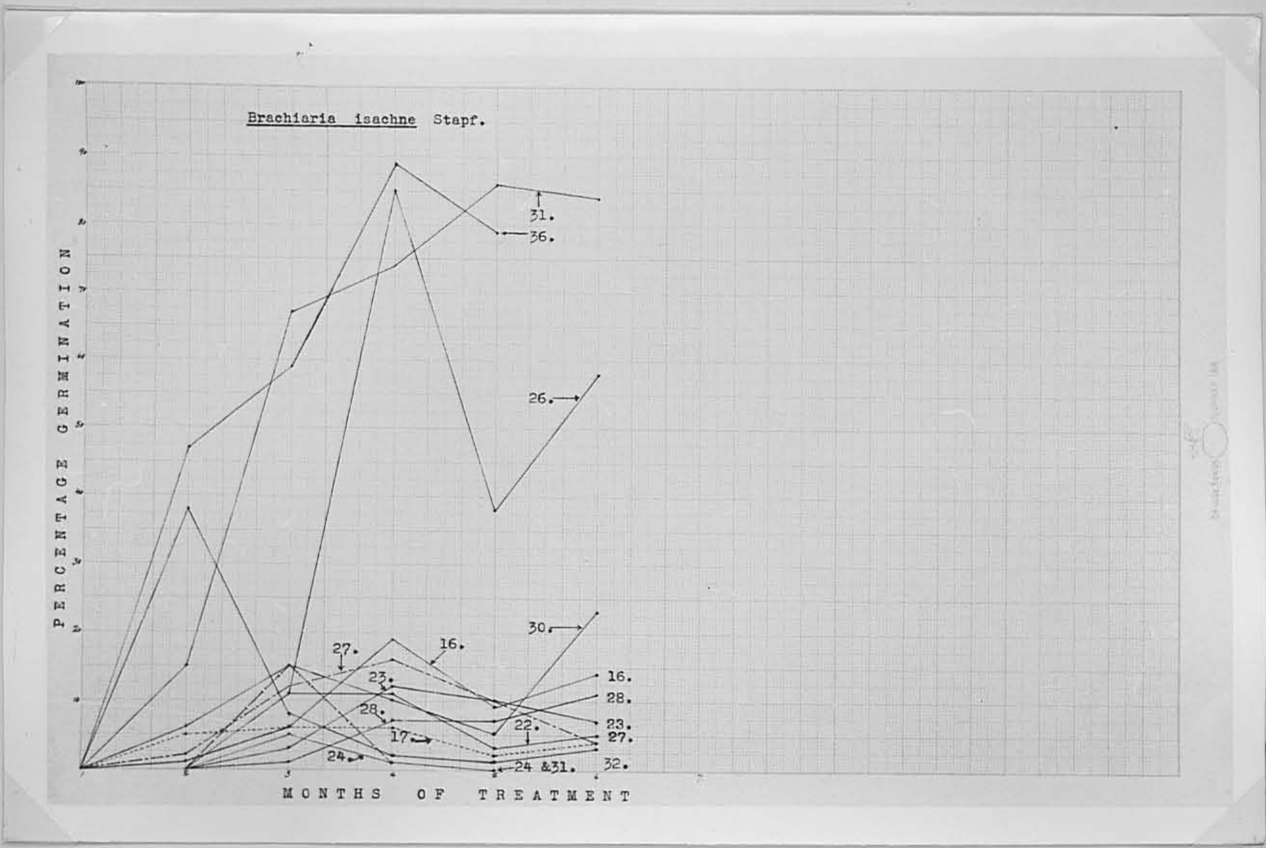

Fig.36. The effect of 13 incubator treatments on the course of delayed germination of Brachiaria isachne. (The numbers of the graphs refer to the even-numbered treatments described in the text.

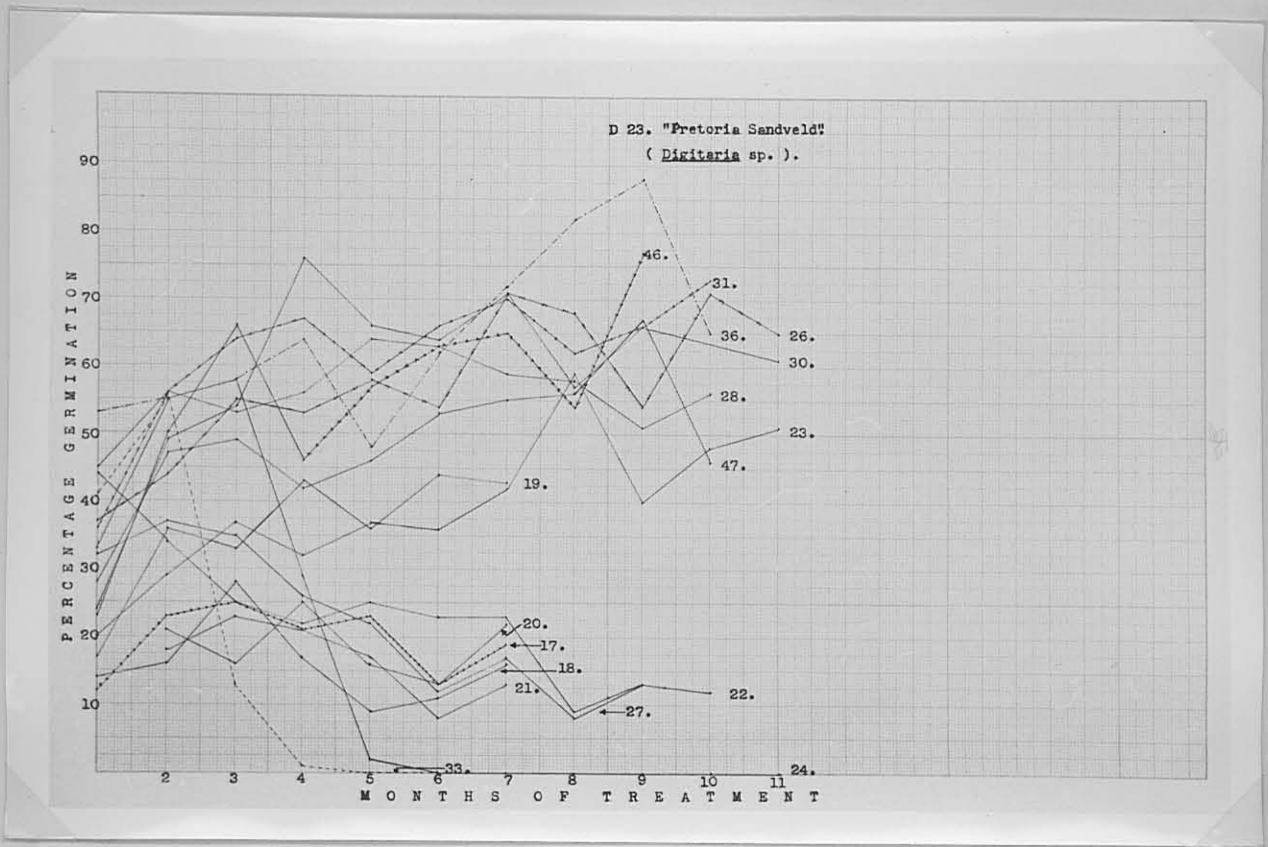

Fig. 37. The effect of 19 incubator treatments on the course of delayed germination of seed of Digitaria D23. (The numbers of the graphs refer to the even-numbered treatments described in the text.

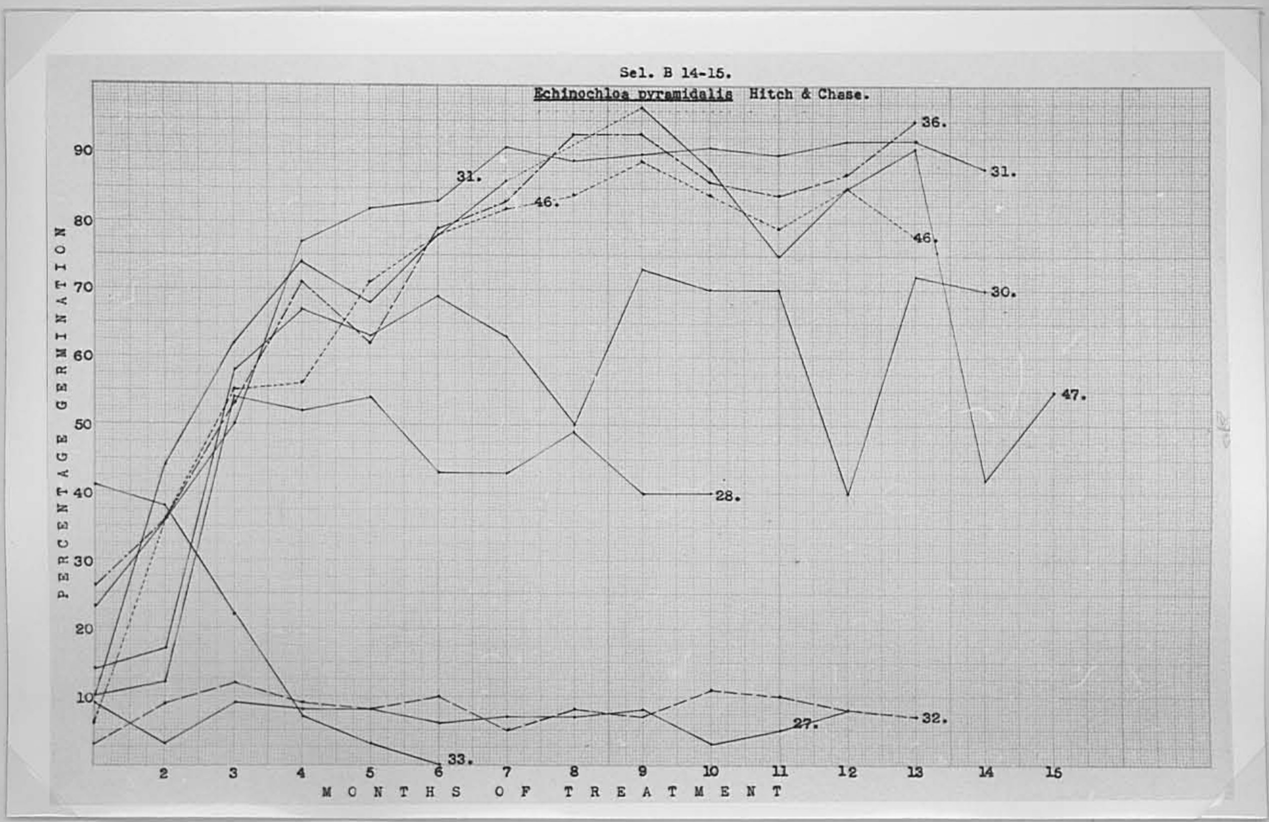

Fig. 38. The effect of 9 incubator treatments on the course of de/layed germination of seed of Echinochloa pyramidalis B14-15. (The numbers of the graphs refer to the even-numbered treatments described in the text).

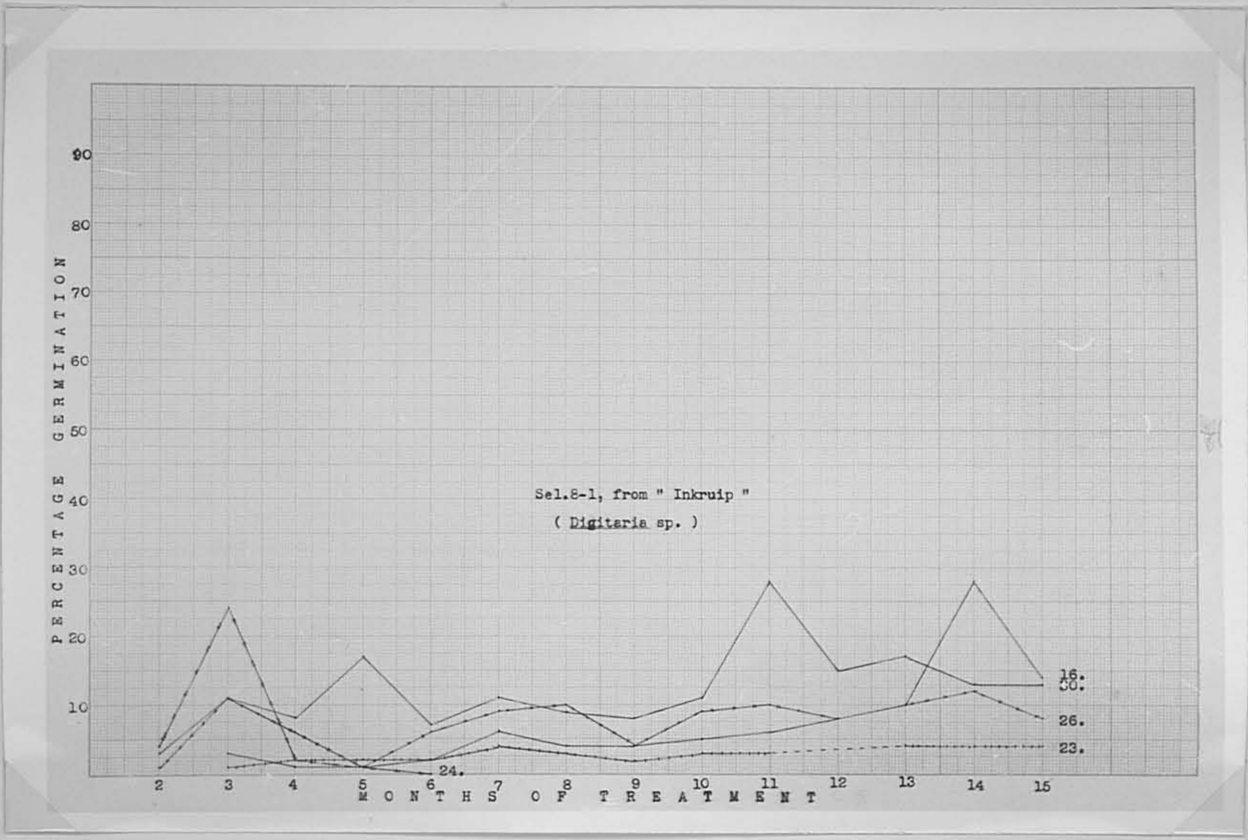

Fig. 39. The effect of 5 incubator treatments on the course of delayed germination of seed of Digitaria 8-1. (The numbers of the graphs refer to the even-numbered treatments described in the text.

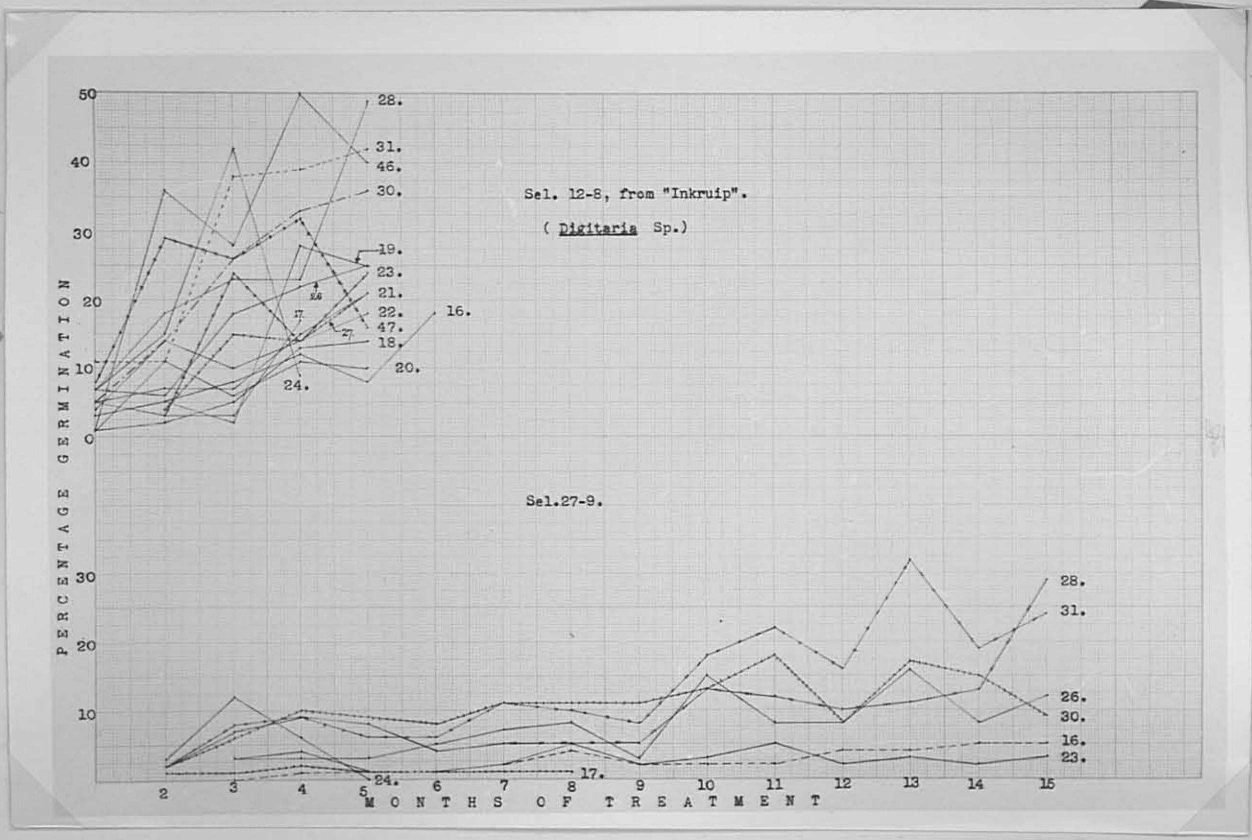

Fig. 40. (Digitaria line 12-8). The effect of 16 incubator treatments on the course of delayed germination of seed of Digitaria 12-8. (The numbers of the graphs refer to the even-numbered treatments described in the text.

(Digitaria line 27-9). The effect of 8 incubator treatments on the course of delayed germination of seed of Digitaria 27-9. (The numbers of the graphs refer to the even-numbered treatments described in the text.

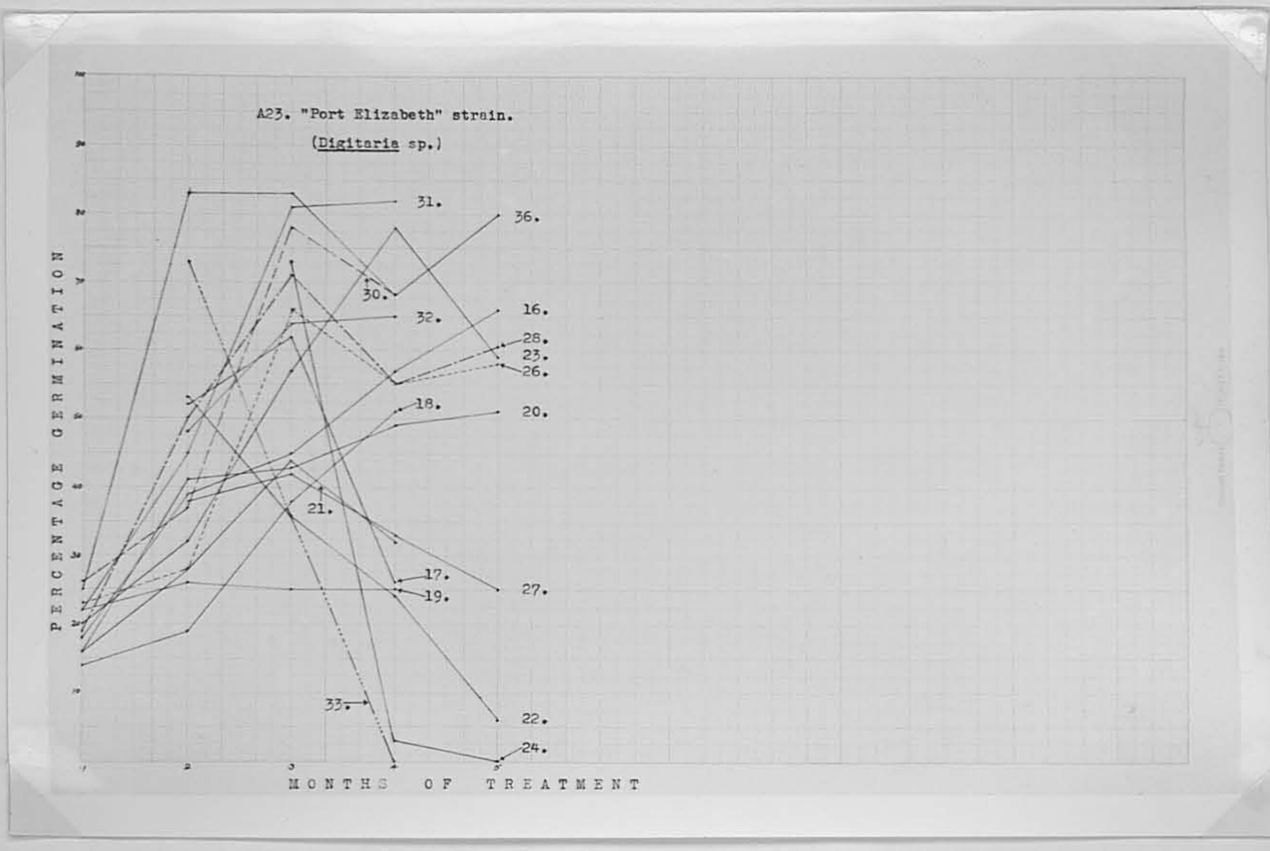

Fig.41. Showing the effect of 17 incubator treatments on the course of delayed germination of seeds of *Digitaria* ecotype A.23. The numbers of the graphs refer to the even-numbered treatments described in the text.

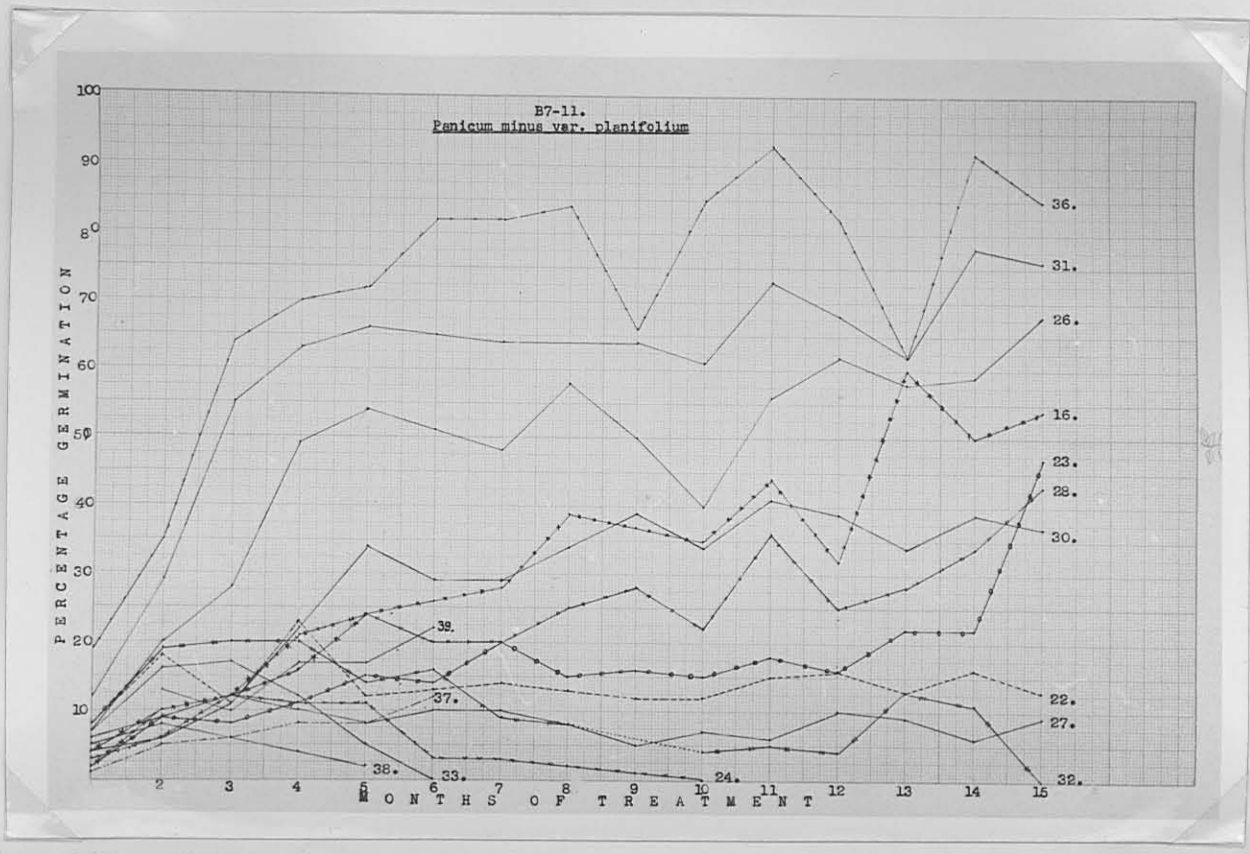

Fig. 42. Showing the effect of 15 incubator treatments on the course of delayed germination of seed of Panicum minus B.7-11. The numbers of the graphs refer to the even-numbered treatments described in the text.

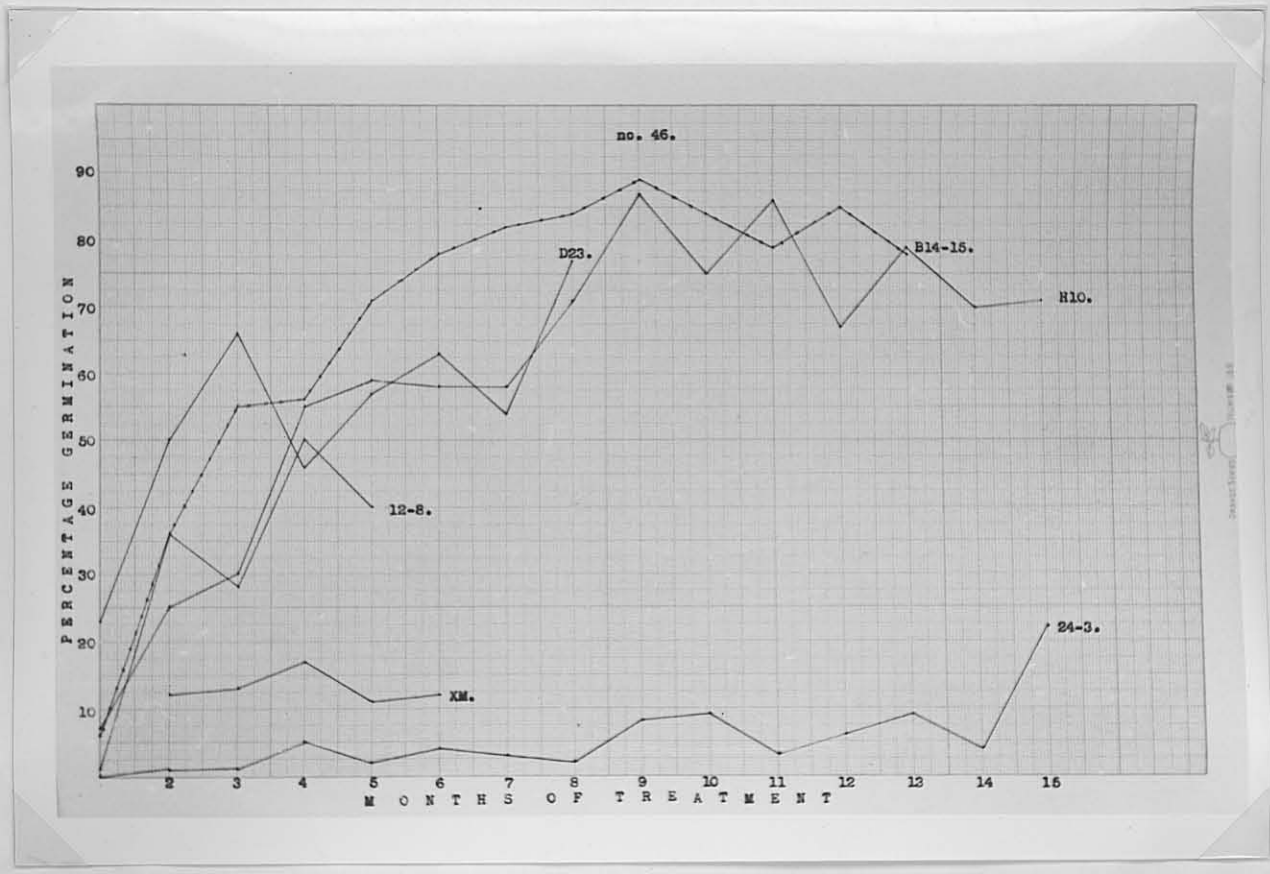

Fig. 43. (Test no.46). Showing the effect on the delayed germination of seeds of Digitaria lines 24-3 and 12-8 and ecotypes D.23. and "molopo"; of Echinochloa pyramidalis B.14-15; and of Setaria sphacelata H.10, when their dry seeds were subjected to alternating temperatures of 6 hrs. at 25°C. and 18 hrs. at 45°C. (at atmospheric humidity).

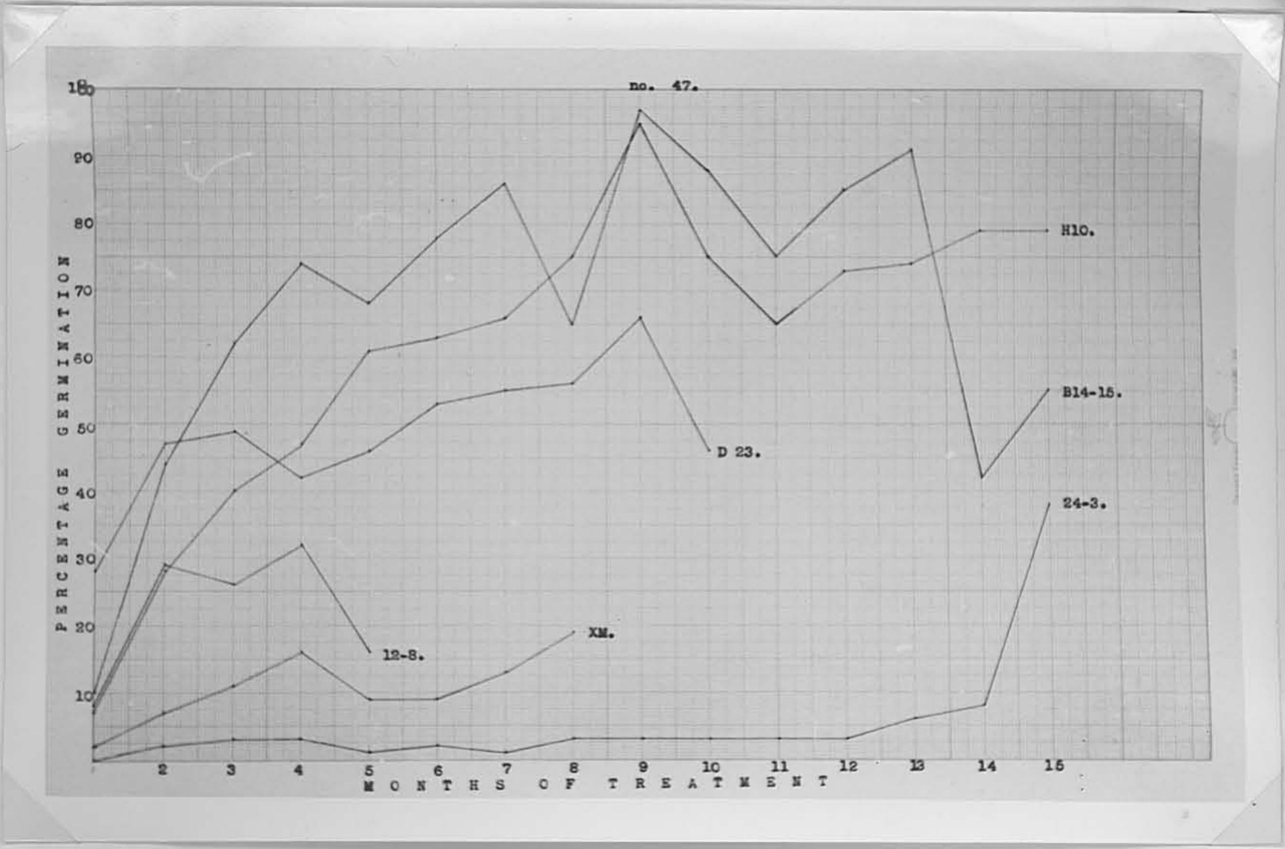

Fig. 44. (Test no.47). Showing the effect on the delayed germination of seeds of Digitaria lines 24-3 and 12-8 and ecotypes D.23 and "molopo"; of Echinochloa pyramidalis B.14-15; and of Setaria sphacelata H.10, when their dry seeds were subjected to alternating temperatures of 18 hrs. at 25° and 6 hrs. at 45°C (at atmospheric humidity).

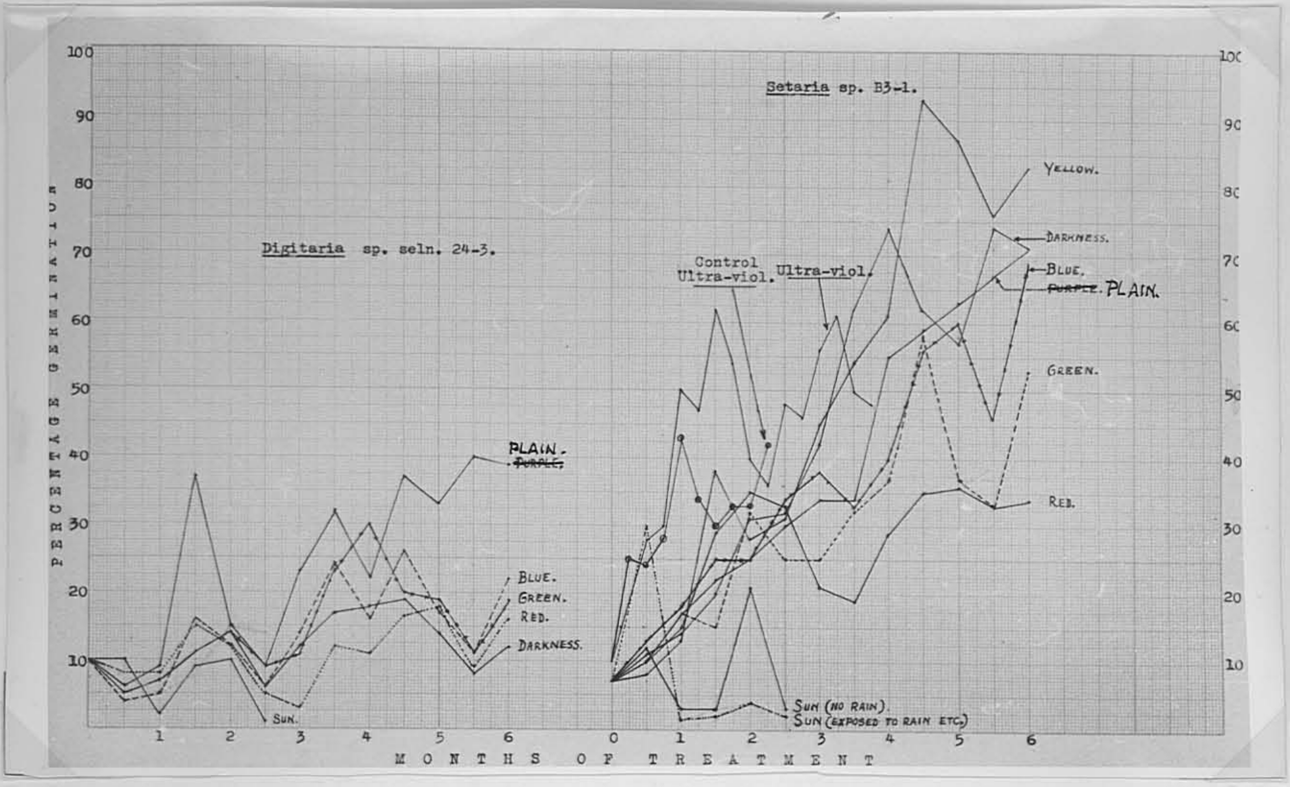

Fig. 45. Showing the effect of ultraviolet light on the delayed germination of Setaria line B.3-1 (treating dry seeds); and of the effect of plain glass, red, yellow, green and blue 'filters', used in conjunction with sunlight, as well as full exposure and darkness treatments outdoors, on the delayed germination of Setaria B.3-1 and Digitaria seln. 24-3.

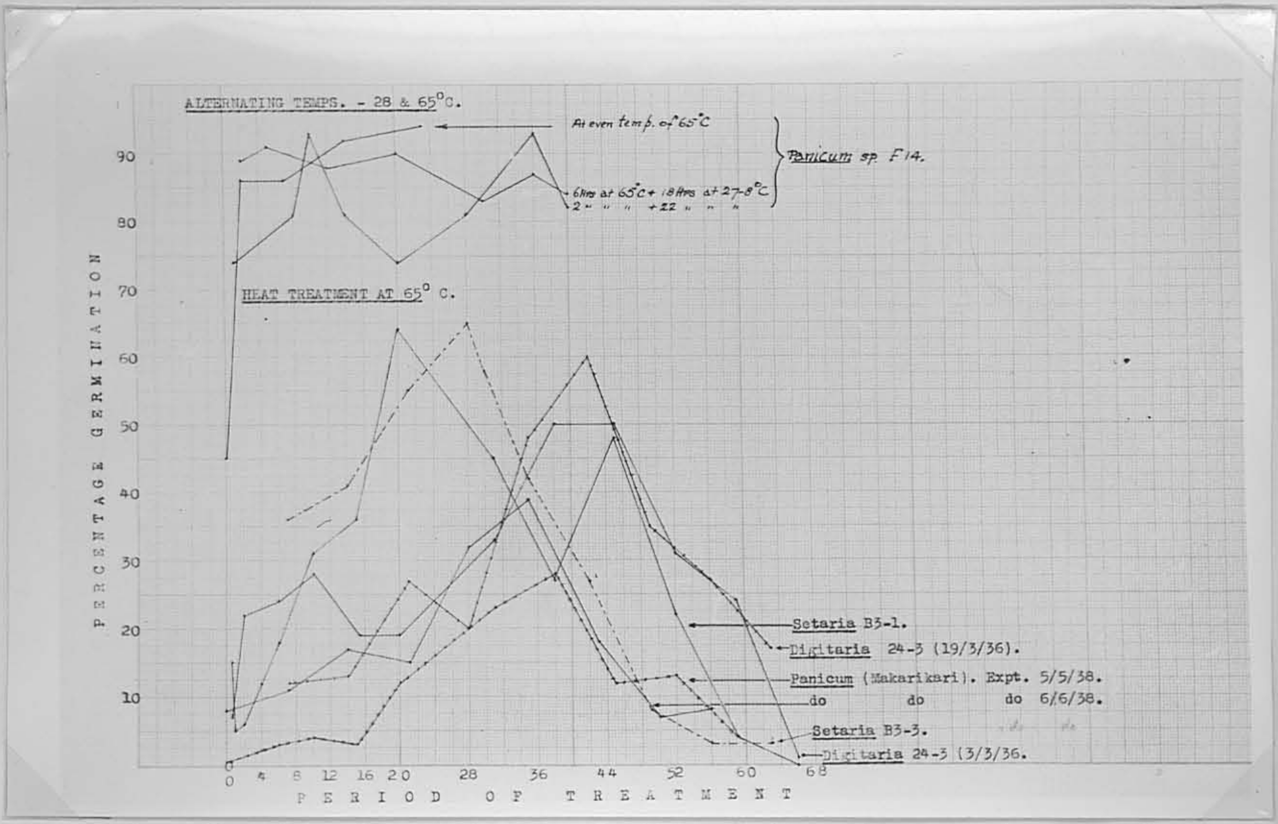

Fig. 46. Showing the effect of alternating temperatures of 28° and 65°C. on the delayed germination of Panicum minus F.14 (treating dry seeds); and of heat (65°), on that of Setaria lines B.3-1 and B.3-3; on Panicum ecotype "makarikari"; and on Digitaria line 24-3.

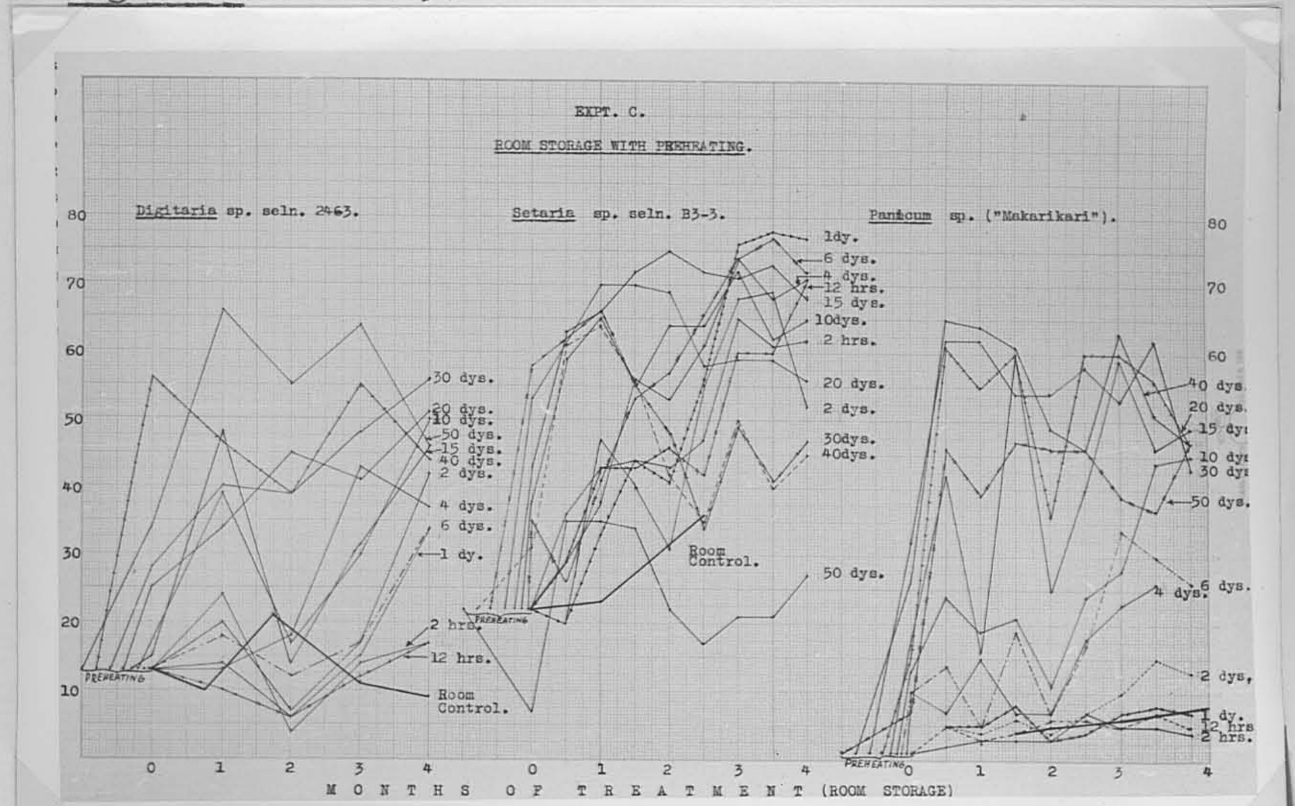

Fig. 47. (Expt.C.). Showing the effect of room storage with preheating at 65° for various periods from 2 hrs. to 50 dys. on the delayed germination of Digitaria line 24-3, Setaria seln. B.3-3 and Panicum sp. "makarikari ecotype.

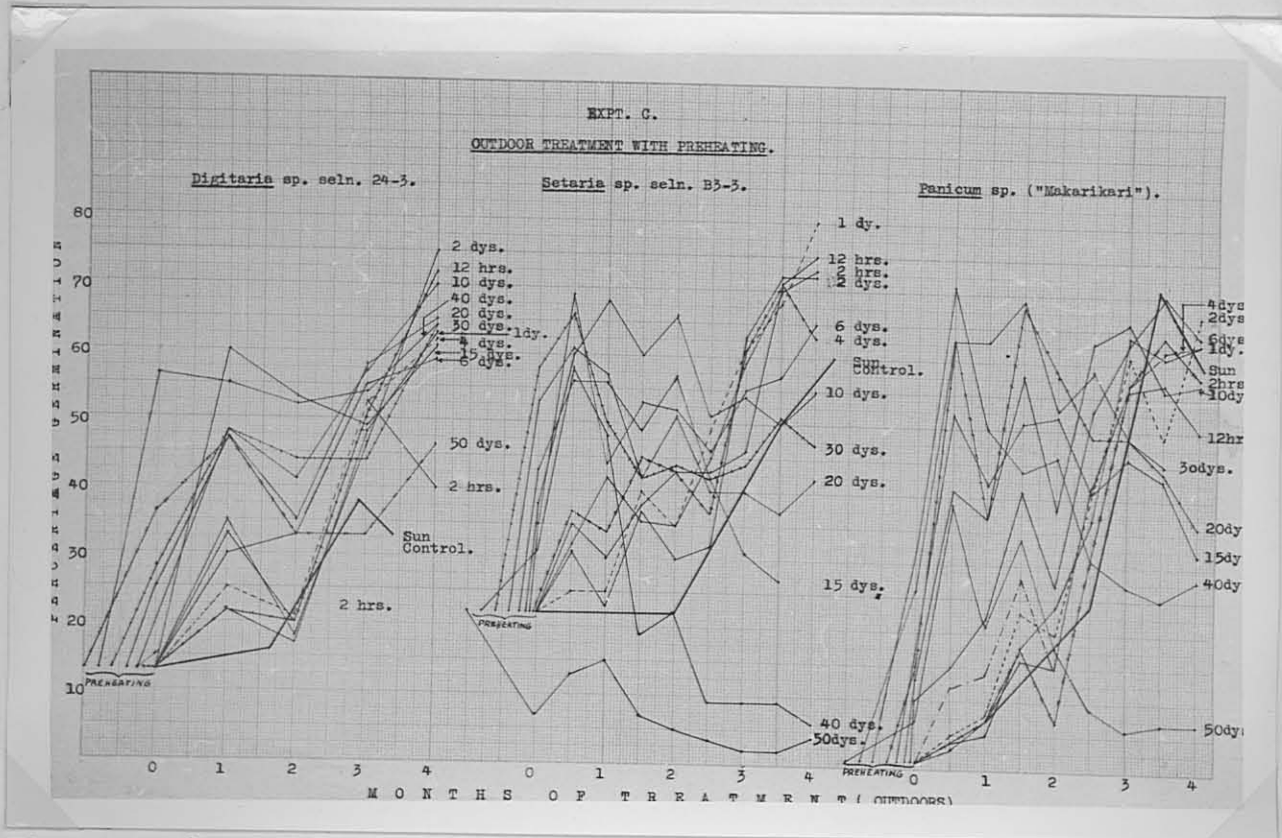

Fig. 48. (Expt.C). Showing the effect of outdoor storage with preheating at 65°C., for various periods from 2 hrs. to 50 days on the delayed germination of Digitaria line 24-3, Setaria sel. B.3-3 and Panicum sp. ("makarikari" ecotype).

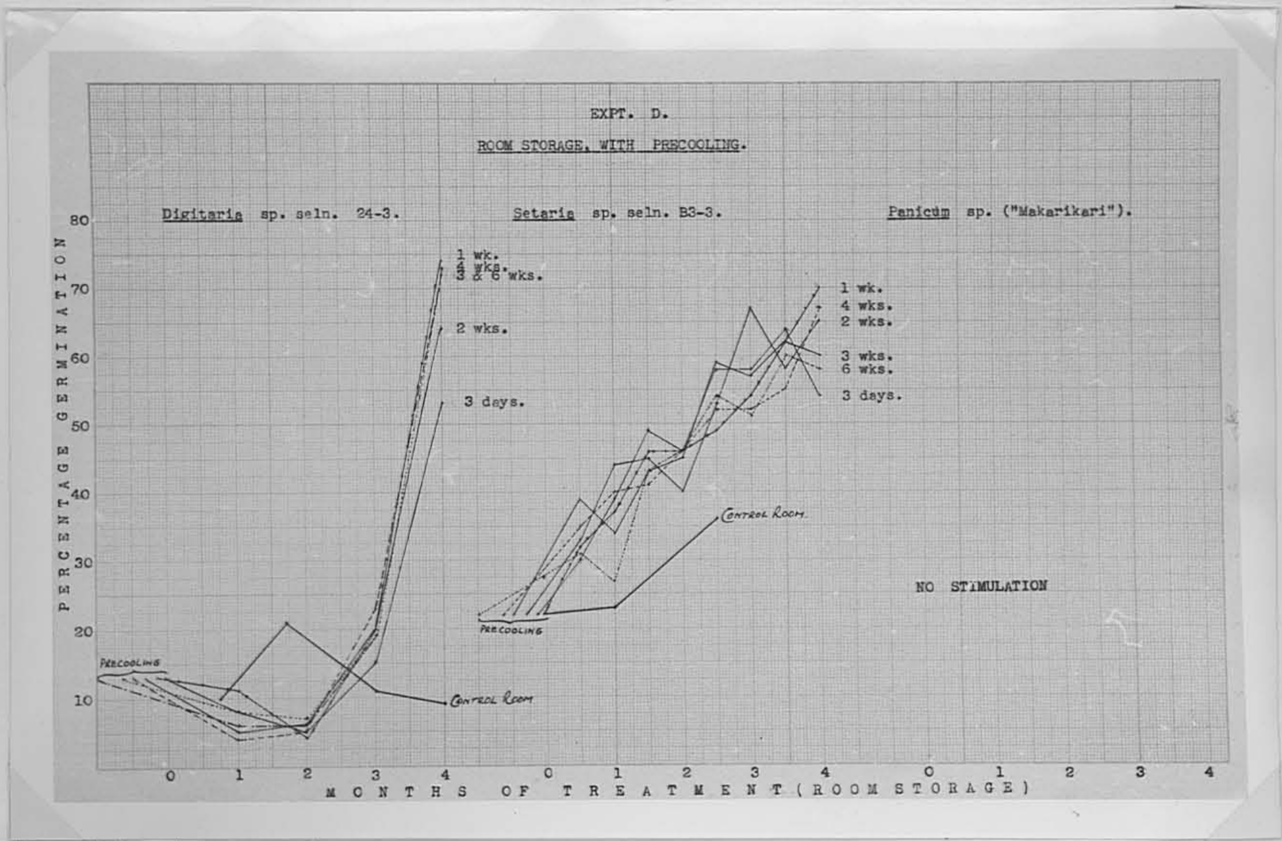

Fig. 49. (Expt.D). Showing the effect of room storage with precooling at 3°C for various periods from 3 days to 6 weeks on the delayed germination of Digitaria line 24-3, Setaria seln. B.3-3 and Panicum sp. ("makarikari" ecotype.)

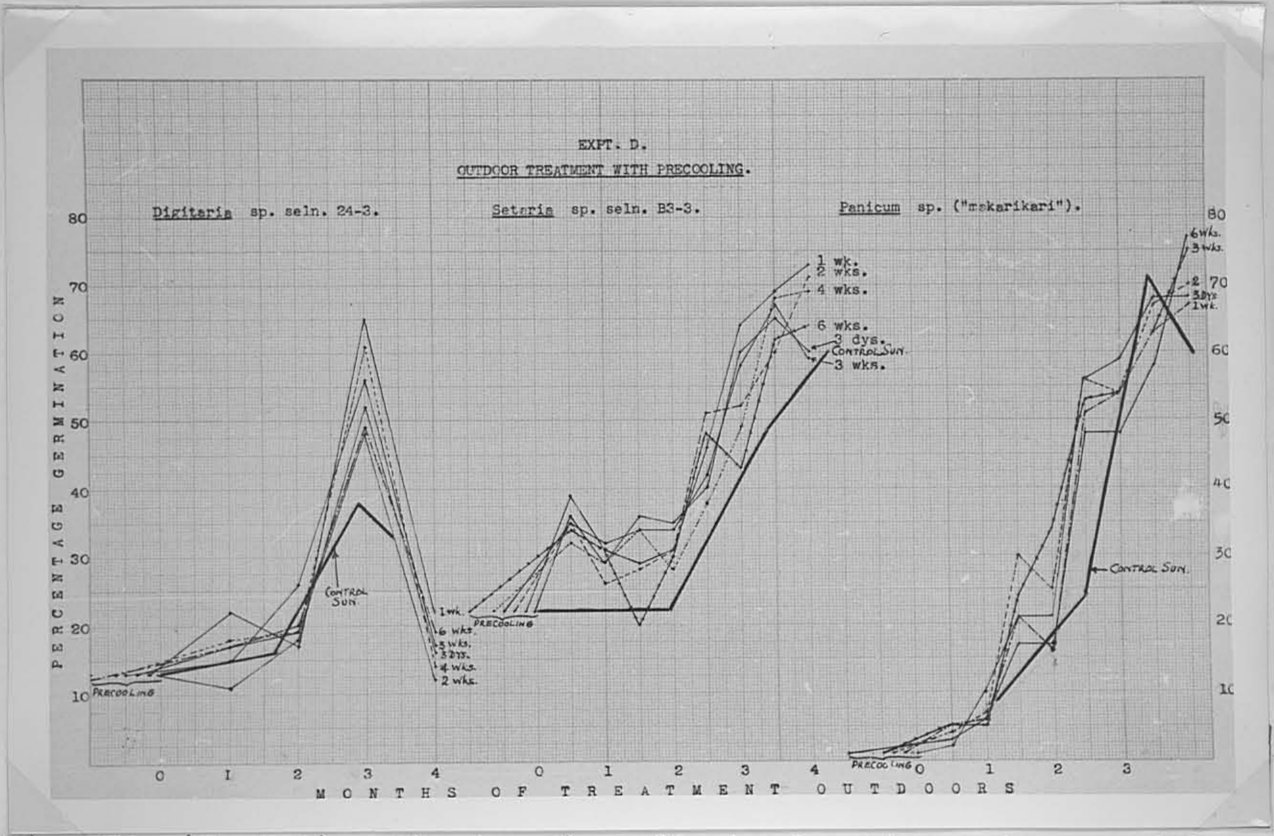

Fig. 50. (Expt.D). Showing the effect of outdoor storage with precooling at 3°C, for various periods from 3 days to 6 weeks on the delayed germination of Digitaria line 24-3, Setaria seln. B.3-3 and Panicum sp. ("makarikari" ecotype).

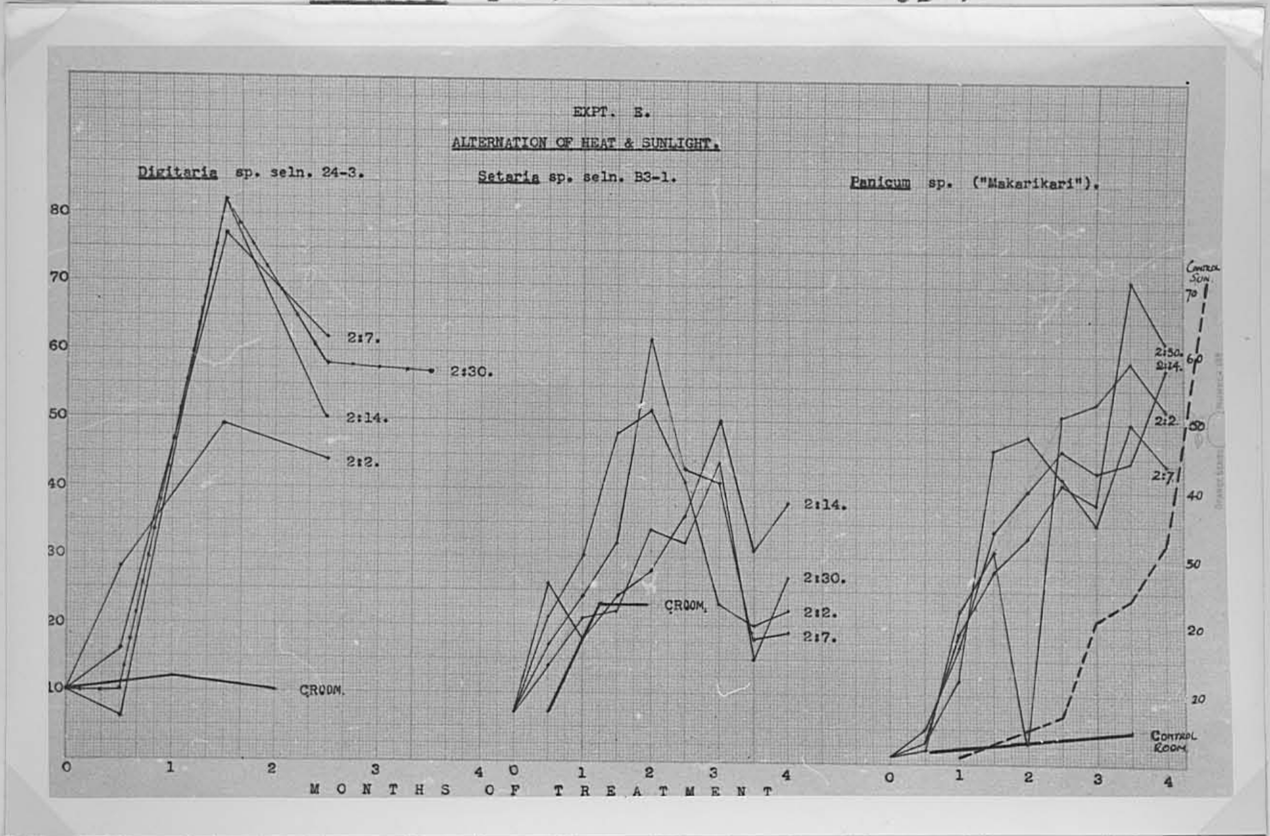

Fig. 51. (Expt.E). Showing the effect of alternations of heat (65°C) and sunlight of respectively, (a) 2 hrs. : 2 days; (b) 2 days : 7 days; (c) 2 days : 14 days and (d) 2 days : 30 days, on the delayed germination of Digitaria line 24-3, Setaria seln. B.3-1 and Panicum sp. ("makarikari" ecotype) when seeds were treated dry.

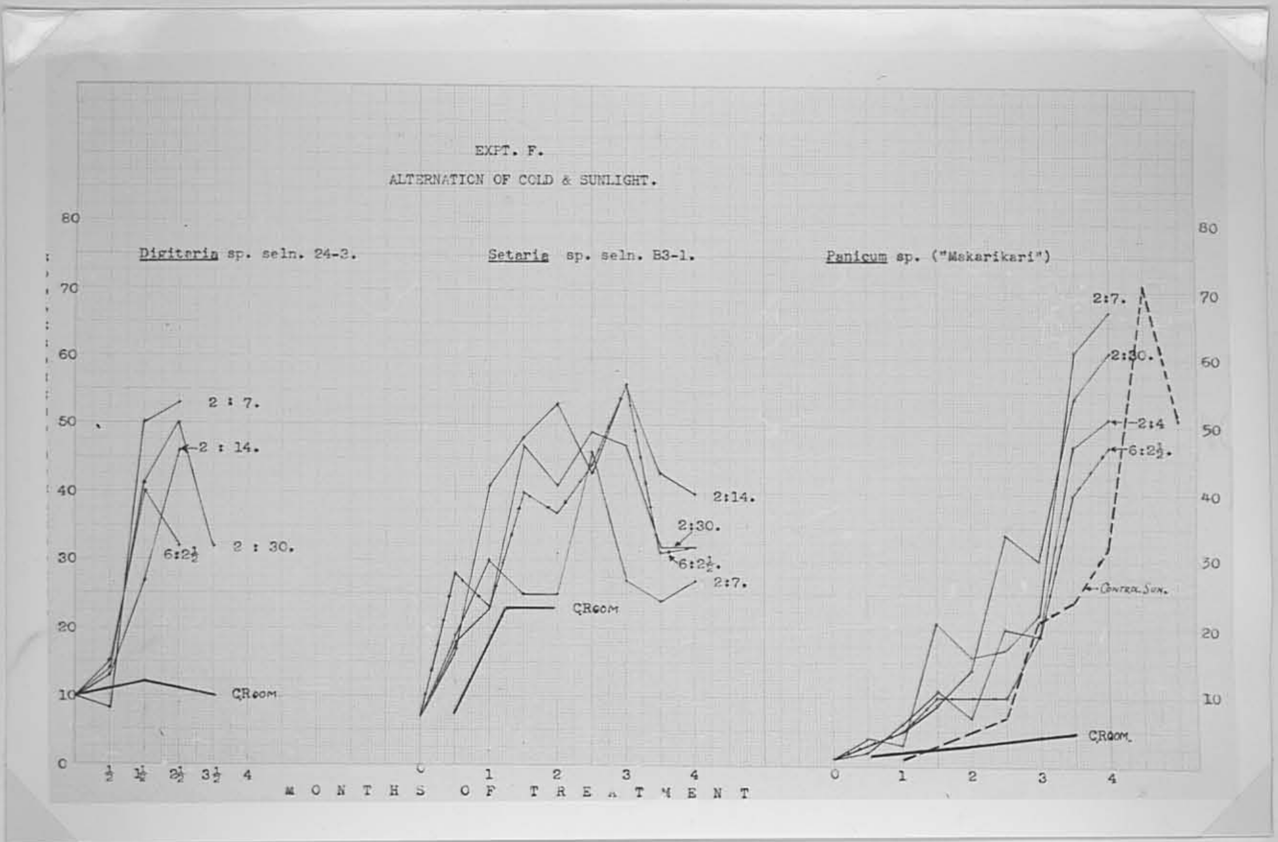

Fig. 52. (Expt.F). Showing the effect of alternations of cold (3°C) and sunlight of respectively, (a) 6hours: 2½ days; (b) 2 days: 7 days; (c) 2 days : 14 days; (d) 2 days : 30 days, on the delayed germination of <u>Digitaria</u> line 24-3, <u>Setaria</u> seln. B.3-1 and <u>Panicum</u> sp. ("makarikari" ecotype).

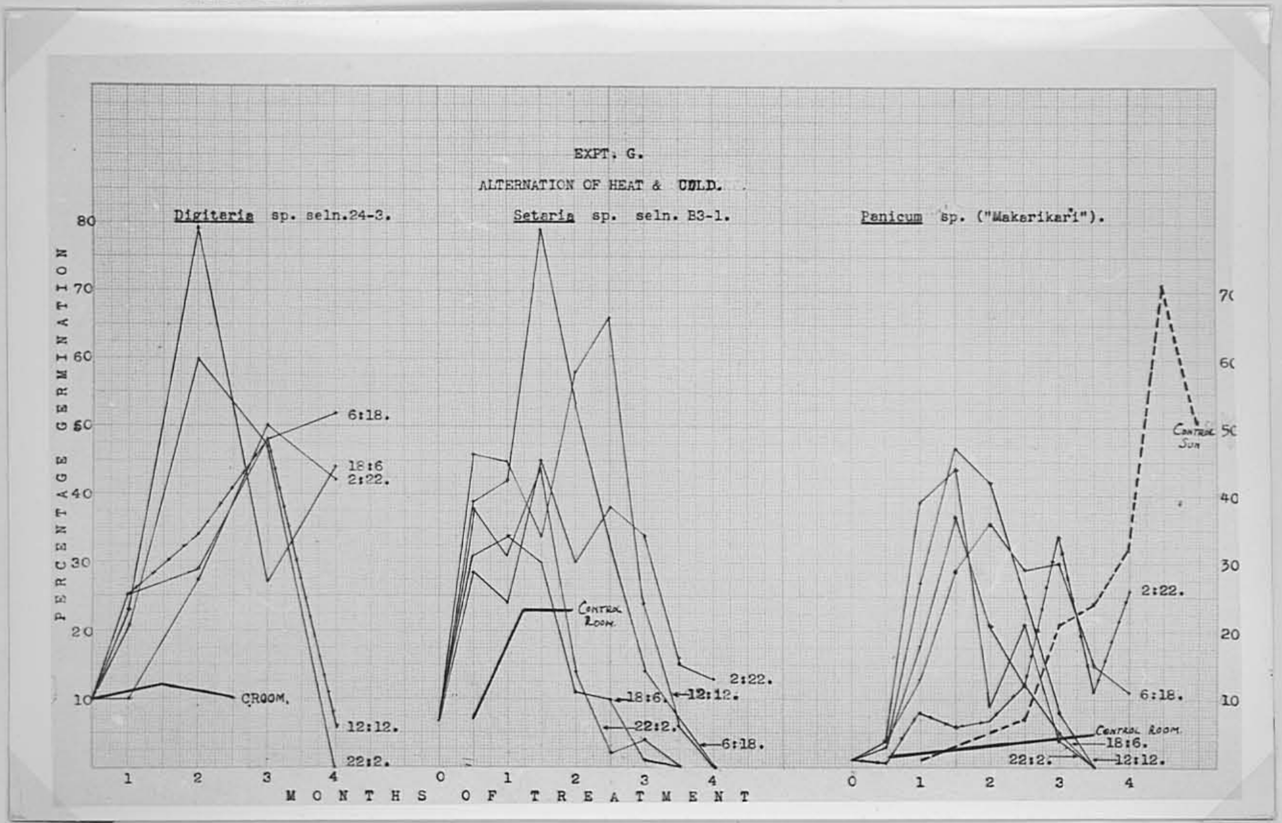

Fig. 53. (Expt.G). Showing the effect of alternations of heat (65°) and cold (3°C) of. respectively, (a) 2 hours : 22 hours; (b) 6 hours : 18 hours; (c) 12 hours : 12 hours; (d) 18 hours : 6 hours; (e) 22 hours : 2 hours, on the delayed germination of <u>Digitaria</u> line 24-3, <u>Setaria</u> seln. B.3-1 and <u>Panicum</u> sp. ("makarikari" ecotype) when seeds were treated dry.

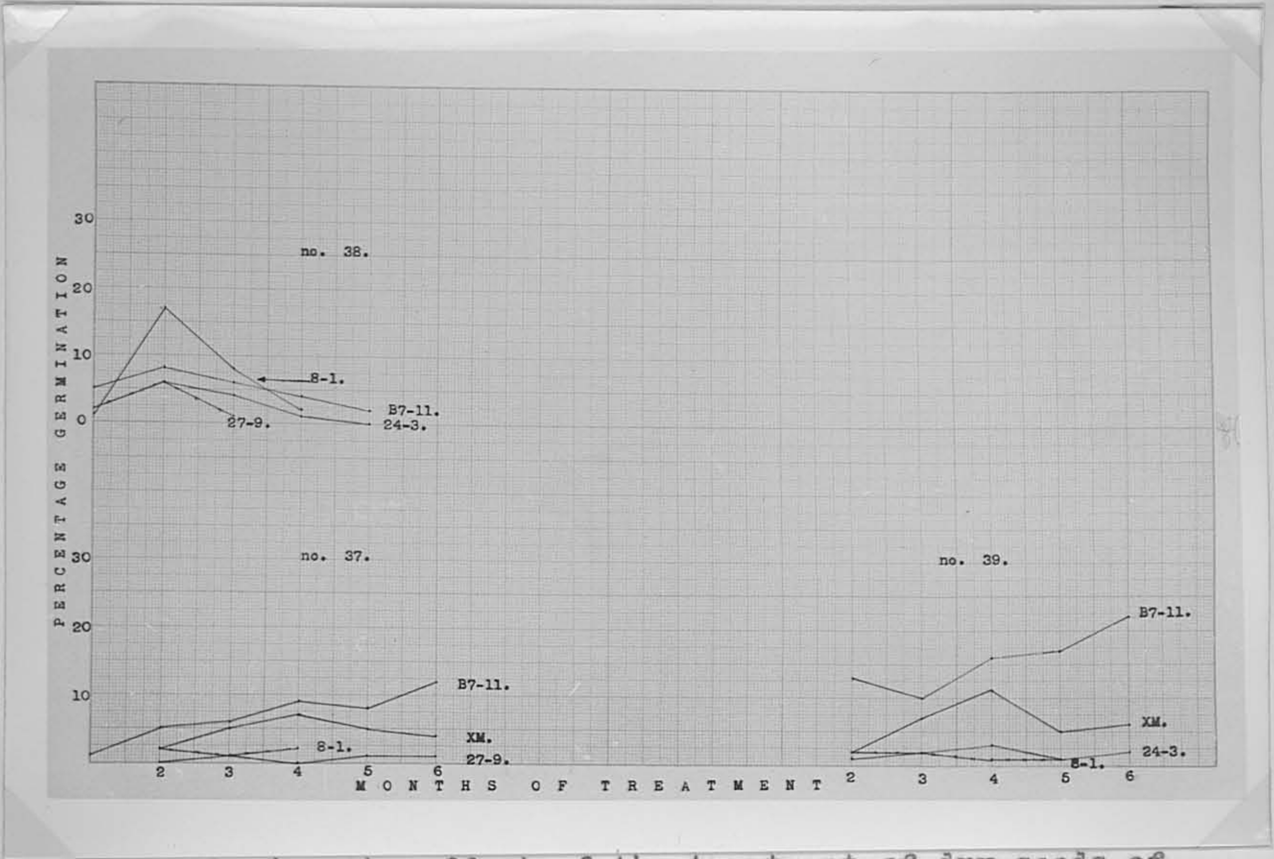

Fig. 54. Showing the effect of the treatment of dry seeds of Panicum minus B.7-11 and of Digitaria line 27-9 with CO_2 at room temperature (test 37), with CO_2 at 45°C (test 38) and with O_2 at room temperature (test 39), on the course of their delayed germination.

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VIII.

A P P E N D I X.

Table A. The effect of various outdoor and indoor treatments on the course of delayed germination of Digitaria ecotype "molopo" (XM.), as shown by the monthly germination percentages. The number of treatments refer to the even-numbered treatments described in the text.

Months of Treatment.

no. of treat-ment.	1	2	3	4	5	6	7	8
3			7.2	6.9	2.2	2.8	1.6	6.1
4	0.6	3.5	8.0	15.7	6.1	4.7	-	-
7		8.9						
8	3.4	8.0	7.1	6.2	3.7	-		
15	0.5	3.7	10.7	16.9	18.7	16.5	36.1	21.6
16	0	0	5.5	4.9	6.5	7.0	7.1	9.5
17	0	4.4	5.0	6.5	6.9	2.6	3.7	-
18	0	2.3	3.3	6.6	6.4	2.1	4.0	-
19	0	2.6	2.9	3.5	5.4	5.3	6.1	-
20	0	4.5	5.8	6.3	6.4	4.0	3.8	-
21	0	4.8	2.7	5.5	5.0	2.0	4.7	-
22	0	0	6.0	6.3	6.1	4.1	3.3	-
23	0	0	6.1	6.6	6.3	4.3	3.2	-
24	0	5.7	7.5	3.3	0	0	0	-
26	0	1.7	8.2	9.8	12.3	12.5	12.6	13.6
27	0	0.7	5.6	5.8	5.3	2.0	1.3	3.3
28	0	0	5.4	8.0	9.4	3.9	3.5	-
29	0	0	0	0	0	0	0	
30	1.6	3.0	8.9	13.9	7.7	7.4	6.9	-
31	0	1.7	9.2	12.8	13.8	10.9	13.3	9.9
32	0	5.8	6.6	6.9	4.1	3.0	3.2	4.9
33	1.7	3.4	6.2	0.8	0	0	-	
34	0	0	0	0	0	0		
36	0	11.0	17.9	17.9	19.4	12.4	19.9	16.4
37	0	2.4	5.0	7.0	4.7	4.1	-	
38	1.6	0.3	0	0	0	0	-	
39	0	3.0	6.5	10.7	5.1	5.7	-	
40	0	0	0	0	0	0	-	
46	0	11.6	12.5	17.2	11.2	12.0	-	
47	1.8	7.4	11.1	16.2	8.9	9.2	13.3	18.5

Table B. The effect of various outdoor and indoor treatments on the course of delayed germination of Digitaria ecotype "Port Elizabeth" (A.23.) as shown by the monthly germination percentages. The numbers in the first column refer to the even-numbered treatments described in the text.

Months of Treatment.

no. of treatment.	1	2	3	4	5	6
1	63.2	-	89.0	94.9	-	-
2	29.4	74.0	81.0	93.5	85.1	-
3	11.7	60.3	74.0	72.3	-	-
4	22.9	70.2	73.7	80.2	-	-
6	23.9	75.5	86.2	85.9	76.5	-
7	0.8	35.8	45.5	63.2	-	
8	22.0	45.8	-	-	-	
9	40.4	47.5	87.7	-	-	
10	21.7	72.8	81.7	75.4	-	
13	13.8	22.8	52.8	64.9	-	
14	20.0	68.7	73.2	82.8	-	
15	23.0	75.0	87.4	86.7	-	
16	18.4	38.9	45.3	56.7	66.1	-
17		52.4	62.2	26.3	-	
18	13.6	19.4	38.0	50.7	-	
19	21.9	26.3	25.0	25.4	-	
20	15.9	40.7	42.7	48.8	51.5	-
21.	16.4	27.6	44.3	32.2	-	
22	0	53.0	35.8	23.8	6.2	-
23	20.3	32.5	56.6	77.7	59.4	-
24	21.6	37.2	73.3	3.3	0.3	-
26	23.1	28.0	66.0	55.0	58.4	-
27		37.6	42.0	32.7	24.8	-
28	18.6	49.8	70.7	55.0	60.6	-
29	0	0	0	0		
30	25.8	37.0	78.5	68.3	-	-
31	22.3	44.7	81.2	82.0	-	
32		47.8	64.0	64.8	-	
33		73.5	36.3	0.4	-	
34		0	0	0		
36	25.1	83.0	82.6	68.0	80.3	-

Table C. The effect of various outdoor and indoor treatments on the course of delayed germination of *Digitaria* seln. 12-8 from the "Kuruman" ecotype. The numbers in the first column refer to the even-numbered treatments described in the text.

Months of Treatment

no. of treat-ment.	1	2	3	4	5	6
1	6.5	-	66.1	51.0	46.4	-
2	0.5	28.6	21.5	22.7	36.6	-
3	5.9	14.4	12.8	13.5	3.1	-
4	5.2	35.6	34.8	51.2	20.2	-
6	0	38.6	37.8	48.2	57.3	-
7		9.7	15.4	8.6	7.9	-
8	0	9.6	11.7	16.5	7.3	-
10	0	12.0	12.8	10.2	10.3	-
13	1.7	8.4	17.1	13.8	7.1	-
14	0	18.8	13.7	42.2	-	-
15.	7.4	18.6	17.9	58.7	35.5	-
16	2.7	5.0	8.4	12.1	7.5	-
17	5.3	2.8	2.6	16.8	-	-
18	0.5	1.6	4.9	12.9	14.3	-
19	0	4.7	2.2	27.7	24.9	-
20	1.5	10.9	5.9	10.7	9.5	-
21	0	6.4	6.4	15.0	21.2	-
22	3.7	14.1	10.1	13.9	16.5	-
23	0	3.4	23.6	13.8	23.9	-
24	6.5	14.6	42.4	8.6	0	-
26	6.8	5.8	18.0	22.4	24.9	-
27	5.4	3.7	14.5	14.4	20.7	-
28	7.0	17.6	22.9	22.8	49.1	-
29	0	0	0	0		
30	4.8	14.0	25.6	32.8	35.7	-
46	1.1	36.0	27.9	50.2	40.1	-
47	8.2	28.9	25.9	32.1	16.2	-
31	10.6	10.5	38.1	39.2	42.4	-

Table D. The effect of certain outdoor and indoor treatments on the course of delayed germination of Digitaria sp., seln. 24-3, from the "inkruip" eco-type. The numbers in the first column refer to the even-numbered treatments described in the text.

No. of treat-ment.	Months of treatment.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.1	21.4	16.3	17.7	14.7	22.5	-								
2	0	4.1	2.8	4.5	5.0	2.3	2.8	2.9	22.8	20.7	18.8	17.4	13.5	9.8	3.1
3	0	0.9	0.7	0.4	0.6	0.3	0.1	0.8	0.7	0.4	3.9	0.5	1.7	1.4	3.2
4	0	0.8	2.6	2.9	1.4	5.3	-								
6	0	1.6	4.5	3.2	9.5	11.7	23.2	20.3	4.3	3.7	8.0	4.9	10.2	7.8	11.9
7.	0.9	2.9	0.2	2.1	0	1.2	0	0	0.5	0.5	0.4	0.2	0	0	0.1
8	0.3	1.5	0.5	1.9	0	1.2	1.2	0.8	0.6	1.0	1.7	0.4	1.3	1.0	2.5
9	0	0.3	3.3	1.3	0.1	0	0	0	0	0	0	0.2	0	0	-
10	0	2.4	2.0	0.7	0.5	1.5	0.6	3.0	1.9	1.8	2.9	2.3	2.6	3.4	8.1
13	0.4	2.8	2.8	0.7	1.7	0.2	0.9	2.7	1.0	2.3	2.2	3.3	2.7	0.9	2.7
14	0	1.0	1.6	1.0	3.9	-									
15	0	4.7	3.3	1.5	4.9	6.3	3.1	8.2	5.5	8.4	7.8	6.7	14.0	9.2	9.0
16	0	0	0.9	0.6	2.5	1.6	1.7	1.7	1.0	1.2	1.5	1.5	2.2	2.5	1.2
37	0	0	1.2	0.6	0.9	0	-								
38	0	5.7	3.8	0.7	0.3	0	-								
39	0	0.7	1.5	3.2	0.7	2.0	-								
40	0	0	0	0	0	0	-								
46	0	1.1	1.4	4.7	2.0	4.0	2.8	2.4	8.1	8.8	2.7	6.3	8.7	4.1	22.1
47	0	2.1	3.0	3.2	1.1	2.3	1.2	2.8	3.2	3.0	2.6	2.8	5.8	8.3	38.4

Table E. The effect of certain outdoor treatments on the course of delayed germination of <u>Paspalum scrobiculatum</u> ecotype A.290. The numbers in the first column refer to the even-numbered treatments described in the text.

No. of treat-ment.	MONTHS OF TREATMENT: 1	2	3	4	5	6	7	8	9	10	11
1	2.7	42.9	78.5	86.5	87.0	43.6					
2	0	0	2.7	5.9	10.1	40.7	77.8	90.7	14.5	1.6	0.5
3	0	0	0.2	1.1	0	0	0	1.2	1.9	2.2	4.1
4	0	1.9	10.7	44.3	55.2	1.9	0	0			
6	0.2	1.9	25.6	74.4	83.5	92.3	80.3	34.9	85.2	84.7	82.0
7	0	0	0.2	0	0	0	0	0	0	0.7	-
8	0	0	0	0	0	0	0	1.4	4.6	4.8	-
9		No	Germination.								
10	0	0	0	1.0	0	0.7	9.6	43.4	73.4	59.5	82.2

Table F. The effect of certain indoor treatments on the course of delayed germination of <u>Echinochloa pyramidalis</u> seln. B.14-15.

No. of treat-ment.	MONTHS OF TREATMENT: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	-	-	42.5	-	-	-	63.3								
27	9.0	2.8	9.1	7.9	7.7	6.5	7.4	6.6	8.3	3.1	4.9	8.2	-		
28	10.0	12.3	54.0	52.3	54.4	42.7	42.4	48.7	39.7	37.9	-	-			
29		No	germination.												
30	14.1	17.4	58.5	67.4	62.9	69.1	63.5	50.4	72.7	69.8	69.4	40.4	71.6	69.7	-
31	22.7	26.0	50.3	77.0	82.4	83.0	90.8	89.4	90.0	90.9	89.7	92.5	92.1	88.4	-
32	3.3	9.5	11.8	9.2	7.9	10.3	4.7	8.5	6.6	11.4	10.5	7.7	6.8	-	
33	40.7	38.0	22.2	7.0	2.8	0	0.1	0							
34		No	germination.												
36	26.4	35.6	53.0	71.0	61.8	79.5	83.1	92.7	93.0	85.7	83.9	87.3	95.5	-	
46	5.9	36.3	55.4	56.2	70.6	78.4	81.9	83.9	88.7	83.6	78.3	84.6	78.2	-	
47	10.0	44.1	62.0	73.7	68.0	78.1	85.8	64.6	96.8	88.1	74.9	85.0	91.2	41.9	54.8

Table G. The effect of certain outdoor and indoor treatments on the course of delayed germination of <u>Setaria sphacelata</u>, ecotype H.10. The numbers in the first column refer to the even-numbered treatments described in the text.

Months of Treatment.

No. of treatment.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	9.7	35.7	44.0	49.3	79.2	53.3	-								
2	2.4	16.8	22.9	40.8	42.8	46.7	55.2	71.1	25.7	19.0	10.1	17.8	4.9	11.5	7.9
3	0	0.7	3.7	2.4	2.2	3.2	2.0	1.6	1.7	11.9	10.0	3.3	4.1	1.1	2.1
4	1.2	24.0	40.0	39.4	31.2	13.1	-								
6	4.7	14.5	33.6	44.8	76.0	60.6	45.9	42.7	62.0	62.9	57.8	57.3	60.8	65.3	70.7
7	2.4	0.7	1.9	0.8	0.9	0.7	1.0	1.6	1.5	0.6	1.1	2.1	1.8	1.7	1.7
8	5.6	17.8	25.2	18.0	30.4	34.2	39.8	52.8	44.1	38.9	36.1	40.2	39.1	39.9	-
9	9.5	5.0	14.6	4.3	0	0	0	0	0						
10	3.6	11.2	27.6	34.1	30.4	33.6	37.0	58.4	55.2	38.7	43.8	44.9	56.2	51.8	54.9
13	0.7	4.1	12.5	26.4	25.1	33.6	42.3	48.8	50.6	40.3	37.8	45.7	46.2	51.7	45.7
14	3.1	21.2	23.4	25.4	39.4										
15	4.4	13.4	33.6	50.2	42.8	56.3	58.2	70.9	69.0	63.9	65.8	64.6	62.2	62.1	67.0
16	1.3		8.6	16.2	31.2	33.2	47.8	36.9	48.7	55.8	53.8	62.3	71.3	61.8	58.7
46	7.1	25.0	29.6	54.9	59.0	57.7	57.6	70.8	86.7	75.2	85.8	66.8	79.3	69.7	70.7
47	7.3	28.2	39.6	46.7	60.7	62.7	65.7	75.2	94.6	74.8	65.1	73.3	73.7	78.7	79.3

Table II. The effect of certain indoor treatments on the course of delayed germination of *Digitaria* sp., seln. 27-9 from the "inkruip" ecotype. The numbers in the first column refer to the even-numbered treatments described in the text.

No. of treatment.	Months of Treatment.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0.2	2.2	4.7	2.1	1.0	6.4	16.7	25.1	20.9	19.3	22.6	31.6	29.3	37.3	32.2
16	0	0	0.4	1.1	1.2	1.2	1.8	4.4	1.5	2.4	2.3	3.7	4.0	4.7	4.6
17	0	0.9	0.7	0.5	0.7	0.1	0.1	discontinued.							
18	0	0	0.7	0.7	0.5	0	0.9		"						
19	0	1.1	0.5	1.6	2.5	6.6	4.7		"						
20	0	0	0	0.5	1.0	0	0		"						
21	0	0	0.7	0.8	0.3	0	0		"						
22	0	1.3	0.7	1.6	0.4	0.5	0.5	0.7	0.4	0	0	1.0	0.1	1.0	0.2
23	0	0	2.8	4.2	0.8	0.7	1.9	4.5	-						
24	0	3.0	11.8	5.8	0	0	0	0	-						
26	0	0	2.6	3.3	2.8	5.4	7.3	7.5	3.0	14.7	7.5	7.5	15.5	7.8	11.9
27	0	0	1.1	1.4	0.4	0.4	0.3	0.5	0.6	0.9	0.7	0.8	0.6	0.6	0.6
28	0	1.7	6.9	8.6	6.7	4.1	5.4	-	5.4	13.3	11.7	9.9	11.0	12.7	28.6
29	No	germination.													
30	0	1.7	5.7	9.8	9.3	8.1	10.7	11.0	10.7	13.0	17.7	8.0	17.3	15.1	8.6
31	0	1.7	7.7	9.4	5.8	6.2	10.5	10.0	7.7	18.3	21.6	16.0	32.1	19.2	23.5
32	0	0.7	1.8	0.6	0.8	0.4	2.0	0.6	2.7	1.7	5.7	9.8	4.7	5.4	4.1
33	0	8.5	16.0	1.8	0.6	0	0								
34	No	germination.													
36	0	4.0	11.0	4.7	8.8	17.8	17.6	23.5	14.5	22.4	25.1	32.7	31.5	27.5	36.9
37	0	0.3	0.8	0.2	1.0	0.5	-	-							
38	2.2	6.3	0.9	0	0	0	-								
39	0	0.2	0.7	0.9	1.0	1.6	-								
40	9.8	0	0	0	0	0	-								

Table I. Showing the effect of certain outdoor and indoor treatments on the course of delayed germination of <u>Digitaria</u> sp. seln. 8-1 of the "inkruip" ecotype. The numbers in the first column refer to the even-numbered treatments described in the text.

No. of treat-ment.	Months of Treatment. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2.4	26.5	52.2	46.8	30.8	43.2	-								
2	0	0.6	2.9	4.1	15.1	6.7	17.5	10.0	27.9	35.4	16.8	20.8	26.2	11.0	15.0
3	0	-	1.4	0.8	0.3	0.2	1.0	2.7	4.0	4.0	12.5	6.0	9.3	4.2	2.8
4	0.3	2.4	5.7	15.8	16.3	16.1	-								
6	0	4.1	6.5	8.2	24.6	19.3	40.7	16.1	19.1	15.1	18.7	18.9	18.9	29.3	32.0
7	0	0.5	2.6	0.9	0.4	0.4	0	0.2	1.0	0	0.6	0	0.6	0	
8	1.5	3.8	1.1	1.6	1.8	0.8	3.4	1.8	1.1	1.7	2.7	1.8	2.0	8.6	
9	0.5	2.7	3.6	3.7	0.4	0	0.9	0	0	0	0	0	0	0	
10	0	1.8	2.0	2.7	1.9	5.4	7.6	8.0	12.4	7.1	19.7	5.9	11.8	9.5	8.5
13	0	0.6	2.5	1.4	3.0	1.1	3.4	-	5.2	4.4	5.6	3.2	12.5	5.9	6.5
14	0	0.2	1.5	2.3	-										
15	0	1.2	3.1	2.4	9.5	11.4	16.8	32.6	29.3	24.9	33.4	17.4	45.7	42.9	35.8
16	0	0	2.6	1.3	1.2	2.1	6.0	4.3	4.3	5.2	5.7	8.0	10.3	28.0	13.8
17	0	0	0.8	0.8	0.9	0.1	0		discontinued.						
18	0	0	0.4	0.5	0.5	0.2	0.2		"						
19	0	0	1.3	0.8	1.1	2.2	8.3		"						
20	0	0	0	0.9	0.7	0	0.2		"						
21	0	0	1.0	0.7	0.3				"						
23	0	0	1.2	2.2	2.2	2.2	4.2	3.3	1.5	2.6	2.7	-	3.8	3.5	4.0
24	0	4.0	23.6	1.6	0.5	0	0	0	0	0	0	-			
26	0	1.3	11.0	6.2	1.4	5.7	8.6	10.4	4.2	8.6	10.3	7.6	10.1	11.6	7.9
30	0	2.3	11.0	8.1	16.9	7.3	10.7	9.2	7.9	10.8	28.3	14.8	16.8	12.5	12.6
37	0	2.4	0.9	1.5	0.3	0.3	-								
38	1.2	17.3	7.5	1.5	0.4	0.3	-								
39	0	2.4	2.4	1.1	1.1	0.1	-								
40	3.3	0	0	0	0	0	-								

Table J. Showing the effect of certain outdoor and indoor treatments on the course of delayed germination of <u>Digitaria</u> sp. D. 23. The numbers in the first column refer to the even-numbered treatments described in the text.

Months of Treatment.

No. of treatment.	1	2	3	4	5	6	7	8	9	10	11	12
1	46.6	87.2	82.2	83.0	74.0	94.8	-	-				
2	[illegible]	48.2	52.0	57.4	72.5	63.6	81.3	78.6	32.8	32.2	12.0	-
6	29.8	49.7	52.2	54.5	63.3	73.5	77.2	40.9	54.7	79.8	81.4	-
9		39.2	51.7	52.9	24.5	0	0	0				
13	41.2	29.7	24.0	49.1	37.7	36.5	42.1	57.8	41.2	52.2	-	
14	44.6	46.3	49.4	45.8	-							
15	31.8	69.2	47.2	73.6	69.6	77.6	87.2	75.7	53.6	-		
16	14.3	38.0	26.5	22.4	19.5	25.9	46.6	45.2	40.2	53.6	77.0	49.8
17	12.1	23.4	24.6	20.5	22.6	12.8	18.5	-				
18	13.5	15.6	27.6	16.5	9.3	10.8	15.8	-				
19	17.3	36.2	32.9	42.7	36.4	44.0	42.9	-				
20		21.0	16.2	25.0	15.8	12.9	21.8	-				
21		17.6	23.1	20.9	16.8	7.5	12.8	-				
22	44.2	33.6	24.8	2.6	25.1	23.0	22.8	8.9	13.1	11.8	-	
23	19.5	29.0	37.1	31.7	36.9	36.3	42.2	59.3	40.1	47.8	57.2	41.5
24	33.4	55.0	58.2	28.5	2.4	0	0	0				
26	36.6	43.7	54.8	53.1	57.8	53.9	70.8	68.3	54.0	70.8	65.4	-
27	31.6	37.1	34.5	25.5	21.9	11.5	16.5	7.5	13.2	-		
28	44.7	56.4	52.6	56.2	63.9	63.4	59.4	58.0	50.8	55.7	-	
29	No. Germination.											
30	23.5	48.6	53.6	75.8	65.7	64.4	70.9	56.6	66.4	-	61.2	
31	36.3	55.6	63.6	66.6	59.1	65.8	70.4	62.4	65.8	72.8	-	
32	-	22.2	27.1	12.7	-	-	0					
33	40.5	54.6	13.3	0.5	0	0	-					
34	No Germination.											
36	52.7	54.6	57.8	64.2	61.7	71.5	82.2	87.6	64.7	-		
46	22.9	50.1	65.8	45.6	57.0	62.7	65.3	54.4	76.7	-		
47	28.2	47.4	49.3	41.8	52.9	52.9	54.7	56.2	66.6	45.8	-	

Table K. The effect of certain outdoor treatments on the course of delayed germination of the seed of <u>Panicum maximum</u> ecotype APM. The numbers in the first column refer to the even-numbered treatments described in the text.

MONTHS OF TREATMENT

No. of treatment.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.3	23.0	11.5	16.8	30.6	-									
2	0.2	14.1	16.9	24.0	37.4	37.5	37.8	49.3	0.2	0	0	0			
3	0	0.4	0.3	0	0	0	0								
4	1.1	14.6	10.4	7.3	13.6	0.5	-								
6	0	12.1	11.5	13.2	33.3	19.9	7.0	1.5	36.4	34.2	40.5	34.1	29.1	31.6	19.0
7	0.9	10.3	6.1	4.9	3.1	1.1	0.7	0	0	1.7	1.0	1.1	1.4	1.2	2.6
8	0.9				-										
10	0.6	4.9	8.0	15.9	20.0	22.1	30.1	31.2	56.0	33.5	46.7	32.4	43.2	26.0	39.8
13	0	2.4	10.0	9.4	17.1	30.8	35.2	37.1	41.4	31.9	48.1	40.6	39.5	47.7	43.7
14	1.6	18.6	13.8	16.6	28.5	-									
15	0.5	17.7	15.4	20.5	34.4	35.2	41.6	39.4	40.6	42.8	35.6	44.8	57.8	25.4	17.1

Table L. Showing the effect of certain outdoor and indoor treatments on the course of delayed germination of <u>Panicum minus</u> seln. B.7-11.

No. of treatment.	Months of Treatment.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	28.2	-	-												
2	3.5	16.8	26.9	46.9	60.3	60.2	67.3	70.3	74.3	73.3	60.3	58.8	58.1	53.4	58.6
3	9.7	8.5	11.9	8.5	10.0	12.1	12.8	18.4	25.0	18.1	20.4	14.2	17.4	17.4	20.4
4	2.6	14.0	12.8	15.4	9.2	9.2	-	-	-						
6	0	50.4	60.3	71.3	80.5	88.2	88.3	86.3	30.9	60.6	68.8	60.6	63.1	81.2	65.8
7	8.3	7.5	9.5	10.9	13.6	8.7	8.8	13.7	5.5	9.0	10.9	21.7	4.3	6.6	11.4
10	4.4	13.8	17.8	27.6	27.2	33.9	47.6	50.3	64.7	42.8	52.3	40.3	62.3	61.6	62.5
13	3.2	7.2	8.3	14.6	9.8	14.5	17.3	23.7	20.8	21.2	17.9	18.9	34.1	33.3	26.8
14	6.7	22.2	31.5	40.7	63.0	-									
15	6.9	29.4	40.2	50.9	61.1	64.3	71.5	68.6	74.0	70.3	80.7	47.8	71.2	59.3	77.3
16	4.0	9.7	11.5	16.9	23.6	26.3	28.2	39.2	37.3	35.4	44.1	32.3	60.3	49.6	54.1
17	3.0	7.8	10.1	7.1	9.2	16.7	9.2	discontinued.							
18	2.5	2.9	4.0	5.1	5.0	6.0	5.0		"						
19	2.7	10.6	6.4	3.7	5.3	7.7	4.0		"						
20	1.6	5.0	2.2	3.3	5.9	8.4	6.2		"						
21	1.3	1.8	3.0	5.1	5.7	4.8	5.0		"						
22	7.9	18.3	10.6	23.0	12.1	13.3	13.7	13.3	12.0	11.7	14.5	15.5	12.9	15.7	13.4
23	2.4	9.2	8.4	11.0	15.4	14.3	20.0	14.9	15.5	15.2	17.5	15.9	22.2	22.4	46.7
24	3.1	6.1	12.6	11.0	11.0	2.8	2.6	1.7	1.1	0.2	0				
26	6.8	20.3	27.7	48.5	54.0	50.7	47.7	57.8	48.6	40.2	56.1	62.1	57.6	59.1	67.5
27	5.5	8.7	11.8	9.8	8.4	10.0	10.0	7.8	5.4	7.0	5.8	10.3	8.7	6.2	8.5
28	1.9	9.8	11.9	20.6	23.8	19.7	19.8	25.2	28.0	22.2	36.1	24.9	27.8	34.0	42.7
29		No	Germination.												
30	4.1	6.4	10.7	21.6	33.8	29.3	28.5	33.6	38.6	34.4	41.2	38.8	64.3	38.7	36.9
31	12.1	28.8	54.8	63.2	66.3	65.0	63.7	63.7	63.7	60.6	72.7	67.9	61.8	78.2	75.9
32	7.6	19.3	19.5	20.0	13.7	16.0	8.7	7.7	52.2	4.3	4.7	4.2	12.8	11.2	0
33	6.4	15.6	17.0	11.6	4.6	0	0								
34	0	0	0.8	0	0	0									
36	19.4	34.8	64.1	70.4	72.4	82.2	81.7	83.5	37.5	85.4	93.4	82.3	62.2	91.7	84.7
37	0.6	5.2	6.1	8.8	8.2	11.8	-								
38	5.0	8.1	6.2	3.5	2.1	-									
39	0	12.7	10.0	16.3	16.6	22.2	-								
40		No	Germination.												

Table showing the effect of preheating at 65° C, with subsequent sunlight exposure, on the course of delayed germination of <u>Setaria</u> sp. seln. B.3-3 of 28/2/36, of <u>Panicum</u> sp. "makarikari" ecotype of Febr. 1938, and of <u>Digitaria</u> sp. seln. 24-3 of 19/3/36, as indicated by the percentage germination at consecutive intervals.

Period of heat pre-treatment.	% germination with sunlight exposure of: 2 wks.	4 wks.	6 wks.	8 wks.	10 wks.	12 wks.	14 wks.	16 wks.	control at: beginning.	2½ mth.	4½ mth.
					SETARIA:						
2 hrs.	32.3	41.6	35.8	35.4	45.4	58.8	68.2	72.9	22.0	29.8	60.4
12 hrs.	35.0	30.2	37.6	42.6	43.6	45.7	70.7	74.8			
1 day.	24.8	24.9	39.7	35.1	48.5	60.8	70.3	80.0			
2 dys.	30.5	22.6	37.0	30.4	32.3	62.7	72.3	72.0			
4 dys.	36.8	33.6	44.6	41.8	37.0	60.7	71.1	63.0			
6 dys.	69.2	44.4	53.1	52.2	45.9	54.8	57.2	65.3			
10 dys.	59.7	67.8	60.2	65.7	51.2	53.7	49.7	55.3			
15 dys.	56.2	55.7	48.6	57.2	41.8	30.5	26.9	-			
20 dys.	61.0	56.7	41.6	51.1	40.0	39.9	37.3	42.0			
30 dys.	65.7	49.6	42.2	44.2	41.9	44.3	51.1	46.7			
40 dys.	58.2	48.4	19.4	22.1	8.8	8.6	9.5	6.4			
50 dys.	13.0	14.8	6.7	4.9	2.7	1.6	1.9	3.6			
					PANICUM:						
2 hrs.	3.6	7.3	17.8	6.5	29.2	56.7	64.0	58.2	0.7	31.6	58.1
12 hrs.	3.1	6.5	15.7	15.1	40.7	56.3	56.8	49.7			
1 day.	4.1	5.4	17.5	23.8	36.8	64.4	61.3	63.0			
2 dys.	5.3	7.5	22.7	19.9	40.9	61.3	48.9	66.6			
4 dys.	12.0	14.3	27.5	14.6	42.2	55.7	61.6	62.9			
6 dys.	14.8	21.8	41.4	27.3	52.7	62.8	69.7	63.6			
10 dys.	40.7	36.8	57.8	37.6	63.3	65.5	56.3	56.6			
15 dys.	51.6	41.5	51.2	52.3	38.9	45.9	43.3	31.7			
20 dys.	63.0	36.7	67.5	58.4	49.3	49.1	44.4	36.4			
30 dys.	63.0	62.7	68.8	52.6	58.7	48.6	44.9	-			
40 dys.	70.6	49.7	44.1	45.7	30.8	25.6	24.8	27.8			
50 dys.	38.7	20.9	34.1	17.5	9.8	6.4	6.8	6.9			
					DIGITARIA:						(3½ mth.)
2 hrs.		33.2		19.5		52.2		39.7	13.3	24.4	32.9
12 hrs.		22.0		19.4		49.7		71.6			
1 day.		22.1		17.1		43.3		63.3			
2 dys.		35.3		18.1		44.5		75.3			
4 dys.		25.1		20.7		52.2		61.6			
6 dys.		29.7		32.5		54.7		58.8			
10 dys.		48.1		40.7		57.2		69.7			
15 dys.		± 60.0		53.1		48.8		60.8			
20 dys.		46.8		35.2		58.1		64.8			
30 dys.		47.8		44.3		44.1		64.2			
40 dys.		54.9		51.6		54.4		64.2			
50 dys.		46.9		33.0		32.6		45.7			

Table showing the effect of various periods of preheating at 65° C, with subsequent room stˈorage, on the course of delayed germination of Setaria sp. seln. B.3-3 of 28/2/36, of Panicum sp. "makarikari" ecotype of Febr. 1938, and of Digitaria sp. seln. 24-3 of 19/3/36, as indicated by the percentage germination at consecutive intervals.

Period of heat pre-treatment.	% germination with room storage of:								control at:		
	2 wks.	4 wks.	6 wks.	8 wks.	10 wks.	12 wks.	14 wks.	16 wks.	be-ginning.	2½ mths.	4 3/4 mths.
SETARIA:											
2 hrs.	36.2	43.3	43.5	42.8	46.8	65.2	60.8	62.0	22.0	36.1	-
12 hrs.	28.9	42.7	42.8	46.2	42.4	60.3	59.7	70.9			
1 day.	19.6	33.3	43.2	41.3	56.1	75.5	77.7	77.0			
2 dys.	19.6	46.8	40.1	31.0	55.4	68.0	69.4	51.6			
4 dys,	29.2	38.4	56.2	53.2	60.7	73.6	68.4	70.7			
6 dys.	25.8	40.9	53.2	57.4	63.4	73.7	77.3	71.7			
10 dys.	58.6	65.2	55.4	64.2	63.8	71.8	62.4	64.8			
15 dys.	63.3	65.7	72.2	75.1	71.5	70.7	72.9	67.5			
20 dys.	60.6	69.6	70.1	69.0	58.1	58.8	58.7	55.6			
30 dys.	?32.0	65.8	55.1	47.9	33.7	48.7	41.1	47.4			
40 dys.	60.7	64.3	55.8	42.2	35.4	50.1	40.3	45.3			
50 dys.	35.2	34.6	34.0	22.2	17.0	20.8	20.7	26.5			
PANICUM:											
2 hrs.	2.2	3.1	3.1	2.8	6.7	5.4	4.8	3.5	0.7	5.1	8.1
12 hrs.	4.5	2.9	3.7	6.4	6.1	4.9	7.1	4.8			
1 day.	4.6	4.8	7.9	3.0	4.4	6.9	8.0	7.3			
2 days	4.6	3.7	5.6	4.2	6.8	10.3	14.5	12.6			
4 dys.	7.2	14.5	7.0	7.1	17.6	22.6	26.1	-			
6 dys.	13.6	4.9	19.3	7.4	17.3	33.8	30.0	26.4			
10 dys.	23.5	18.5	21.2	11.4	24.3	28.1	43.8	44.6			
15 dys.	41.6	15.8	59.9	25.0	40.0	59.3	46.4	48.7			
20 dys.	61.4	54.6	59.9	36.1	60.0	60.4	55.7	46.5			
30 dys.	61.8	62.3	54.2	54.3	58.0	53.0	61.9	43.2			
40 dys.	65.0	63.9	60.6	48.7	45.7	63.1	51.4	46.7			
50 dys.	45.8	38.6	47.2	45.5	46.4	39.3	36.7	47.3			
DIGITARIA:											
2 hrs.		24.1		7.4		13.7		17.4	13.3	22.9	26.2
12 hrs.		9.5		6.1		12.1		16.9			
1 day.		14.3		6.2		14.7		33.6			
2 dys.		19.8		7.1		16.8		42.2			
4 dys.		12.6		17.5		42.8		36.8			
6 dys.		17.8		11.7		16.9		34.1			
10 dys.		39.2		16.9		29.6		49.8			
15 dys.		47.9		14.2		31.4		45.5			
20 dys.		34.0		45.1		40.6		51.1			
30 dys.		39.7		39.0		47.7		56.0			
40 dys.		47.1		39.0		55.0		43.8			
50 dys.		65.7		55.2		63.7		46.3			

Table showing the effect of various periods of precooling at ± 3°C, with subsequent room storage or outdoor storage, on the course of delayed germination of Setaria sp. seln. B3-3 of 28/2/36, of Panicum sp. "makarikari" ecotype of Febr. 1928, and of Digitaria sp. seln 24-3 of 19/3/36, as indicated by the percentage germination at consecutive intervals.

Period of cold pre-treatment.	% germination with storage of : 2 wks.	4 wks.	6 wks.	8 wks.	10 wks.	12 wks.	14 wks.	16 wks.	control at: beginning.	2½ mths.	4¾ mths.
				S E T A R I A - OUTDOOR STORAGE :							
3 dys.	35.8	28.6	35.5	34.7	39.7	59.8	64.7	59.5	22.0	29.8	60.4
1 wk.	39.4	31.1	29.0	31.2	46.3	64.2	67.7	72.7			
2 wks.	34.9	26.3	28.4	30.9	51.3	51.9	59.7	70.7			
3 wks.	34.9	32.3	33.7	34.0	41.9	57.8	67.0	58.9			
4 wks.	32 4	28.7	34.3	27.7	37.6	48.9	67.9	68.9			
6 wks.	33.7	30.8	19.7	29.8	47.7	42.8	62.2	63.6			
					ROOM STORAGE :						
3 dys.	32.2	37.4	46.0	45.7	57.9	57.5	63.6	53.7	22.0	36.1	-
1 wk.	30.0	38.7	48.7	46.4	48.8	54.3	61.6	70.2			
2 wks.	32.8	43.9	44.6	39.5	53.2	62.0	58.2	64.8			
3 wks.	38.8	34.1	43.2	44.7	59.3	57.3	62.3	59.9			
4 wks.	34.8	40.1	41.1	45.5	52.2	51.7	54.8	66.7			
6 wks.	31.2	27.4	43.2	45.7	53.6	50.7	60.3	57.6			
				P A N I C U M - OUTDOOR STORAGE :							
3 dys.	2.4	9.6	21.3	21.1	56.1	58.8	67.9	68.2	0.7	31.6	58.1
1 wk.	5.1	5.6	21.3	15.7	51.3	54.2	62.5	67.0			
2 wks.	4.4	7.3	29.7	25.1	56.3	54.4	67.2	69.5			
3 wks.	4.7	4.9	23.8	34.0	53.3	54.2	63.1	75.0			
4 wks.	4.2	7.9	19.9	23.8	52.3	46.7	64.2	65.1			
6 wks.	3.0	5.8	16.5	16.9	48.4	48.1	57.5	71.5			
					ROOM STORAGE :						
3 dys.	4.2	0.8	7.1	4.4	10.2	3.0	3.5	7.0	0.7	5.1	8.1
1 wk.	2.7	1.5	4.3	3.4	11.5	7.5	4.9	5.6			
2 wks.	1.5	2.3	3.3	7.2	11.3	2.3	2.9	6.7			
3 wks.	2.0	1.4	4.7	4.8	9.5	9.4	4.0	10.5			
4 wks.	2.0	1.5	4.6	2.9	8.7	2.5	4.0	5.8			
6 wks.	3.3	2.7	4.3	2.7	9.8	4.2	4.1	7.7			
		D I G I T A R I A - OUTDOOR STORAGE :									(3½ mth.)
3 dys.		11.0	[illegible]	17.9		51.9		16.0	13.3	24.4	32.9
1 wk.		21.8		16.5		64.6		22.1			
2 wks.		17.2		18.5		48.2		11.9			
3 wks.		15.0		25.8		55.9		17.2			
4 wks.		18.0		19.1		60.8		13.6			
6 wks.		16.9		20.1		48.9		19.3			
						ROOM STORAGE :					
3 dys.		8.3		4.7		15.4		52.9	13.3	22.9	26.2
1 wk.		11.4		3.5		19.8		74.4			
2 wks.		5.2		5.8		19.6		63.6			
3 wks.		4.1		5.0		23.1		72.3			
4 wks.		7.6		6.5		19.0		72.9			
6 wks.		5.6		5.7		19.2		72.3			

Table showing the effect of alternations of heat and sunlight (Expt. E.) of resp. (a) 2 hrs.:2 days, (b) 2 days : 7 days, (c) 2 days : 14 days, and (d) 2 days : 30 days, on the course of delayed germination of, (1) <u>Setaria</u> sp. seln. B.3-1 of 28/2/36, (2) <u>Digitaria</u> sp. seln. 24-3 of 3/3/36, and (3) <u>Panicum</u> sp. "makarikari" ecotype of Febr. 1938, as indicated by the percentage germination at consecutive intervals.

Treatment.	Kind of seed.	Control at beginning. %	% after 2 wks. 20/5/38	% after 4 wks. 3/6/38	% after 6 wks. 17/6/38	% after 8 wks. 1/7/38	% after 10 wks. 15/7/38	% after 12 wks. 29/7/38	% after 14 wks. 12/8/38	% after 16 wks. 26/8/38	Control at 27/6/38 %	Control at 12/8/38 %
(a)	Setaria	±7.	20.7	30.4	48.3	50.6	41.5	23.1	19.7	22.3	23.3	-
(b)	do	do	17.4	23.9	31.8	62.4	43.2	40.8	17.6	19.1	do	-
(c)	do	do	25.6	18.1	23.9	27.9	35.7	49.8	31.3	37.8	do	-
(d)	do	do	13.6	21.2	21.5	34.2	31.8	44.2	14.8	27.4	do	-
(a)	Panicum	0.7	2.3	22.2	31.4	3.3	51.0	52.7	59.3	52.3	2.7	5.1
(b)	do	do	3.1	12.1	45.7	48.3	42.3	35.3	49.7	44.2	do	do
(c)	do	do	5.1	17.0	33.5	40.3	46.3	42.8	43.6	58.3	do	do
(d)	do	do	3.3	19.1	27.5	33.4	40.7	37.9	71.3	62.1	do	do
(a)	Digitaria	±10	28.0		47.8		43.7		-		-	-
(b)	do	do	16.0		76.6		62.3		-		-	-
(c)	do	do	6.3		82.4		49.7		-		-	-
(d)	do	do	9.7		82.0		58.4		-		-	-

Table showing the effect of alternations of cold and sunlight (Expt.F.) of resp. (a) 6 hrs.:2½ days, (b) 2 days : 7 days, (c) 2 days: 14 days, (d) 2 days : 30 days, on the course of delayed germination of, (1) Setaria sp. seln. B.3-1 of 28/2/36, (2) Panicum sp. "makarikari" ecotype of Febr. 1938, (3) Digitaria sp. seln. 24-3 of 3/3/36, as indicated by the percentage germination at consecutive intervals.

Treat-ment.	Kind of seed.	Control at begin-ning. %	% after 2 wks. 20/5/38	% after 4 wks. 3/6/38	% after 6 wks. 17/6/38	% after 8 wks. 1/7/38	% after 10 wks. 15/7/38	% after 12 wks. 29/3/38	% after 14 wks. 12/8/38	% after 16 wks. 26/8/38	Control at 27/6/38 %	Control at 15/8/38 %
(a)	Setaria	7.0	28.3	22.9	40.1	36.8	43.7	56.0	31.4	31.9	23.3	-
(b)	do	do	18.6	30.1	24.6	24.8	46.2	26.8	24.4	27.4	do	-
(c)	do	do	16.7	41.3	47.9	52.6	43.2	55.9	42.7	40.2	do	-
(d)	do	do	17.6	22.5	47.3	41.1	49.2	46.8	31.5	31.6	do	-
(a)	Panicum	0.7	2.5	4.8	10.0	9.6	10.3	18.8	40.4	47.4	2.7	5.1
(b)	do	do	4.1	3.0	21.4	16.0	16.7	21.5	61.3	67.4	do	do
(c)	do	do	2.1	6.2	10.8	6.5	20.0	18.7	46.6	50.9	do	do
(d)	do	do	23.0	4.8	8.8	13.8	34.2	30.0	54.2	61.2	do	do
(a)	Digitaria	±10.0	14.9		39.8		32.1		-		-	-
(b)	do	do	7.7		50.0		52.7		-		-	-
(c)	do	do	12.5		26.9		45.7		-		-	-
(d)	do	do	14.4		41.0		50.2		31.6			

Table showing the effect of alternations of heat (±65°C) and cold (±3°C) of, respectively, (a) 2 hours : 22 hours, (b) 6 hours : 18 hours, (c) 12 hours : 12 hours, (d) 18 hours : 6 hours, and (e) 22 hours : 2 hours, on the course of delayed germination of seed of , (1) Setaria sp. seln. B.3-1 of 28/2/36, (2) Panicum sp. "makarikari" ecotype of Febr. 1938, and (3) Digitaria sp. seln. 24-3 of 3/3/36, as indicated by the percentage germination at consecutive intervals. (Expt. G.).

Treatment.	Kind of seed.	Control at beginning. %	after 2 wks. 20/5/38	after 4 wks. 3/6/38	after 6 wks. 17/6/38	after 8 wks. 1/7/38	after 10 wks. 15/7/38	after 12 wks. 29/7/38	after 14 wks. 12/8/38	after 16 wks. 26/3/38	Control at 27/6/38 (room) %	Control at 15/8/38 (room) %
(a)	Setaria	7.0	27.9	23.9	45.4	29.9	37.8	34.3	14.7	12.9	23.3	-
(b)	do	do	38.6	41.6	79.3	53.1	32.6	14.1	15.5	0	do	-
(c)	do	do	45.9	44.7	33.8	58.2	66.2	23.5	6.1	0	do	-
(d)	do	do	30.6	34.5	30.1	11.4	10.3	1.7	0	0	do	-
(e)	do	do	37.5	31.0	44.4	13.8	2.4	3.6	0	0	do	-
(a)	Panicum	0.7	0.4	8.1	5.6	7.0	11.9	33.8	11.4	26.2	2.7	5.1
(b)	do	do	3.5	12.5	29.0	36.1	28.5	30.3	15.1	10.9	do	do
(c)	do	do	2.8	27.4	46.8	41.6	24.6	8.4	0	0	do	do
(d)	do	do	3.1	18.0	37.3	20.7	12.2	4.5	0	0	do	do
(e)	do	do	3.5	38.8	44.2	9.0	20.9	3.9	0	0	do	do
(a)	Digitaria	±10.0	10.5		27.2		49.8		41.7		-	-
(b)	do	do	24.8		28.8		47.8		51.6		-	-
(c)	do	do	25.3		33.9		48.4		6.2		-	-
(d)	do	do	22.8		79.1		27.3		44.3		-	-
(e)	do	do	21.1		59.9		47.0		0		-	-

Table W. The influence of various temperature conditions (during the germination test), on the daily germination of different lines of seed. Date of test: 13/6/36.

Kind of seed; plot number Date harvested in 1936.	EVEN TEMPERATURE OF 30C						6hrs. @ 40 C. 18hrs. @ 30 C.				6hrs. @ room T 18hrs. @ 30 C				12 hrs.@ room T 12 hrs.@40-42 C				6hrs. @ roomT 18hrs.@ 40-42C				Tot. seed used
	2nd	3rd	4th	5th	6th	7th	8th	9th	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Panicum:																							
P.phragmitoides, C21. 6/3.	18	54	36	7	4	4	1	3	3	-	3	3	1	-	1	4	9	3	5	1			400
Rhodesian, C75.10/3.	-	-	3	-	31	3	1	-	1	-	1	-	-	1	-	-	-	1	-	-			400
P.coloratum, C91. 7/3.	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	4	1	1	-	-			400
do C92. 6/3.	-	2	-	1	-	-	-	1	-	1	-	-	-	1	1	3	6	1	3	2	6	5	300
do C94. do	2	26	8	6	1	2	-	-	5	-	-	-	-	-	-	2	2	-	1	-			300
do C97. do	-	5	3	-	-	-	-	-	-	-	-	-	-	1	4	13	5	-	1	-			300
do C98. do	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	14	17	5	4	1			300
do C99. do	-	-	3	-	1	-	-	-	-	-	-	-	1	-	2	9	10	1	-	-			400
do C100. do	-	1	4	1	-	1	1	-	-	-	-	-	-	2	1	2	4	6	2	-			300
do C102. do	-	20	12	2	1	3	-	-	-	-	1	1	2	2	1	8	1	5	1	-			300
P.swazilandensis, C101. do	3	35	17	5	7	1	-	-	-	-	-	1	-	-	-	-	1	-	3	-			400
P. maximum, F6. 10/3.	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-			300
do F7. do	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	4	6	2	4	3	1	5	400
P. minus, F14. do	2	4	7	7	2	1	2	17	14	12	2	5	10	18	9	55	51	16	7	2	0	3	400
Makarikari, C79. 9/3.	2	17	16	5	19	9	2	77	65	33	6	7	10	7	3	63	21	3	1	4	1	0	400
do C80. do	-	-	-	-	-	-	-	42	22	11	3	47	53	14	11	167	6	4	1	4	3	0	400
Digitaria:																							
Dunn's, C56. 4/5.	-	-	-	-	3	2	2	1	5	10	6	7	7	7	10	8	3	4	4	2			300
P.Elizabeth, D5. 12/3	-	1	43	-	73	31	12	3	-	11	7	5	5	7	-	1	-	-	2	2			250
Inkruip, C1. 26/3	-	-	1	-	6	2	1	1	2	-	-	-	-	-	1	1	-	1	1	-			621
D.milanjiana, D36 10/3	-	2	6	-	11	8	9	4	90	144	60	41	8	8	2	2	4	5	25	67	117	48	930
Umfolozi no. 2. A114.19/3.	-	-	-	-	1	-	-	-	-	-	-	1	-	1	1	0	4	2	2	3	1	5	842
N.Rhodesia, C9. 14/3.	-	-	-	-	3	7	12	14	18	9	19	32	7	9	10	0	7	4	10	2			245
Inkruip sel.24-3 3/3.	-	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	0		400
do 24-5 do	-	1	-	1	-	-	-	-	1	2	-	1	2	-	1	-	-	1	-	1	0		400
Chloris gayana F15.25/4	248	56	19	-	-	-	27	23	4	-	1	-	-	1	-	-	1	-	-	-			400
Spor.fimbriatus G37. 2/5.	-	1	20	8	1	-	2	145	81	82	6	7	-	1	-	7	3	2	5	-			400
Diplach. eleusine G18.25/4,	-	1	10	9	1	3	2	2	1	6	2	8	5	8	2	2	5	2	9	8	1		400
Setaria:																							
Rhodesian, H10. do	-	-	-	-	-	-	-	-	9	10	5	6	-	-	-	1	1	-	-	5	4	1	200

Table X. The influence of varying temperature conditions (during the germination test) on the daily germination of different kinds of seed. Date of test 1/8/36.

Kind of seed; plot No.	Date of harvesting in 1936.	EVEN TEMPERATURE OF ±30°C							6 hrs.@ +40°C 18 hrs.@ ±30°C				6 hrs.@room T 18 hrs.@ 30°C				6 hrs. @ room T 18 hrs. @ 40°C					Total no. germinating.	No. used
		2nd	3rd	4th	5th	6th	7th	8th	9th	10	11	12	13	14	15	16	17	18	19	20	21		
Panicum:																							
P. coloratum, C91.	7/3.	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-			2	400
do C92.	7/3.	4	3	1	1	2	-	1	-	-	3	-	-	2	6	-	1	1	3	1		29	300
do C94.	6/3.	45	82	11	5	10	4	2	1	1	3	-	-	2	-	-	-	-				170	400
do C97.	6/3	8	15	[illegible]	-	2	[illegible]	1	1	1	-	1	-	-	6	4	1	5	1			46	300
do C98.	6/3.	2	5	2	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-			12	400
do C99.	6/3.	4	8	1	2	-	1	1	-	-	-	-	-	1	-	-	-	-	-			18	400
do C100.	6/3.	4	8	3	2	-	2	--	-	1	-	-	-	-	22	4	-	11	2			59	400
P.swaziland. C101.	6/3.	73	95	22	8	4	4	3	2	1	-	-	-	-	-	1	-	-	-	-		213	400
P. coloratum, C102.	6/3.	47	84	14	15	8	2	1	3	5	-	-	2	-	-	1	-	-	-			182	400
P. maximum, F6.	10/3.	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	1	-			4	400
do F7.	10/3.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2			4	400
P. minus, F14.	10/3.	2	10	12	5	2	5	6	1	34	9	3	2	5	10	1	1	21	20	4		152	400
P.phragmitoides, C21.	6/3.	52	66	29	99	8	2	2	1	1	1	2	-	4	1	2	-	-	4			184	400
Digitaria:																							
Dunn's, C56.	4/5.	-	-	1	2	-	2	1	1	3	4	4	-	8	18	15	23	11	10	4		107	300
P.Elizabeth, D5.	12/3.	-	13	35	53	24	9	8	2	2	-	-	-	1	1	-	-	-	-			148	168
Inkruip, Cl.	26/3,	-	2	3	8	2	-	2	4	2	6	2	1	1	-	1	-	-				34	534
D.milanjiana, D.36.	10/3.	-	35	50	58	18	8	3	8	18	31	20	2	2	1	1	1	-	-	1		257	315
Umfolozi no2, A114.	19/3.	-	24	125	161	54	24	10	6	3	2	3	2	5	1	5	1	-	2			428	533
N.Rhodesia, C9.	14/3.	-	1	1	13	22	12	3	11	5	2	1	-	11	5	-	-	3	6	2		98	125
Seln.fr. Inkruip, No2	4/3.	-	3	1	2	4	1	1	1	-	-	-	-	-	-	-	-					13	375
do (3/3/36) No2	4/5.	-	1	7	5	7	1	1	-	-	1	1	1	1	1	1						28	400
Seln. 24/3, outdoors	2/3.	-	7	36	68	23	7	1	1	1	1	-	-	-	-	-						145	392
Chloris gayana, F15.	25/4.	276	2	2	1	-	-															281	300
Spor. fimbriatus G37.	2/5.	10	7	34	26	17	18	2	7	136	19	59	-	2	8	5	1	10	5	1		367	400
Dipl. eleusine, G18.	/4.	-	8	23	15	30	10	9	8	8	7	29	4	34	30	23	4	10	9	6		268	400
Setaria sp. H10,	25/4.	-	4	15	6	1	-	-	-	6	29	11	1	10	8	7	1	1	4	1	2	107	200

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Table Y. The influence of various temperature conditions (during the germination test), on the daily germination of different lines of seed. Date of test: 14/9/36.

Kind of seed; plot number. Date harvested in 1936.	EVEN TEMPERATURE OF c.30C.							6hrs. at 40 C. 18 " " 30 C				At room temperatur					18 hrs. at 40 C 6 hrs. at 30 C						Tot. seed used
	2nd	3rd	4th	5th	6th	7th	8th	9th	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Panicum:																							
P.phragmitoides, C21. 6/3.	133	104	18	9	1	3	-	-	5	1	-	-	2	1	-	-							395
Rhodesian, C75. 10/3.	-	3	18	4	4	3	1	1	6	1	4	2	-	-	-	1							400
P.coloratum, C91. 7/3.	1	2	2	-	-	2	-	-	2	-	1	-	-	-	1	-	-	-					400
do C92. 6/3.	15	10	6	3	1	-	1	-	-	1	-	-	2	1	1	-	1	2	1				400
do C94. do	162	52	16	5	4	5	2	2	1	1	3	1	2	-	1	1							395
do C97. do	25	33	8	3	-	1	-	-	-	-	-	-	-										400
do C98. do	26	10	5	3	-	-	-	-	-	1	-	-	1										400
do C99. do	26	12	5	8	-	-	-	-	-	-	-	-	-										400
do C100. do	13	9	1	2	-	1	-	-	-	-	-	-	1										400
do C102. do	168	89	22	7	6	1	2	3	1	-	1	-	3	-	-	-							391
P.swazilandensis C101. do	228	60	28	8	1	4	1	-	-	1	-	-	-	-	-	1							398
P.maximum, F6. 10/3.	-	-	-	-	-	1	-	1	2	2	-	1	1	-	-	4							400
do F7. do	-	1	-	-	-	1	2	-	1	1	2	-	-	1	-	1							400
P. minus F14. do	20	25	15	5	3	-	1	1	23	17	1	-	3	-	-	-							400
Makarikari, C79. 9/3.	3	9	4	6	8	3	-	-	184	59	18	6	9	1	1	5	3	6	10	11	-	2	400
do C80. do	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	9	1	-	15	81	20	10	400
Digitaria:																							
Dunn's, C56. 4/5.	-	-	4	2	1	3	3	1	1	2	-	-	-	1	8	-	18						400
P.Elizabeth, D5. 12/3.	2	20	65	69	24	26	8	2	4	4	3	-	-	1									288
Inkruip, C1. 26/3.	10	12	12	6	2	9	4	4	3	1	1												800
D.milanjiana, D36. 10/3.	77	264	269	66	23	18	5	3	12	9	6	3	10	1	-	4							864
Umfolozi no. 2, A114. 19/3.	-	2	24	57	37	16	3	2	11	16	5	3	2	3	4	-							1274
N. Rhodesia, C9. 14/3.	-	-	3	32	41	36	24	33	11	2	2	3	2	11	11	2							348
Inkruip seln. 24-3. 3/3.	-	1	-	-	1	-	3	1	1	-	-	-											738
do 24-5. do	-	-	13	14	16	5	4	3	-	3	-	-											878
Spor.fimbriatus, G37. 25/4.																							
Dipl. eleusine, G18. 25/4.	14	29	32	11	4	4	3	-	2	-	1	2	8	6	10	10	4	8	3	11	2	5	400
Setaria:																							
Rhodesian, H10. do	6	22	39	3	3	1	-	-	9	45	7	2	2	2b	1	-							194