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 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), Bihlemeier (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 <u>Lathyrus</u>, <u>Phaseolus</u>, <u>Melilotus</u> and <u>Lupinus</u>. This, as well as the anatomic studies of 19 other spp. revealed 6 types of 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 'cuticle', 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),

ts c/seed-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 *Melilotus* michrochemically and found that the impermeable region was due to a layer of tightly appressed suberin caps.

Hamly (1932) reported softseededness in *Melilotus alba* 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 *Medicago*. 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 /..

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 *Xanthium* 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-

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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 <u>Avena fatua</u>, 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 ~~are~~ 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 ~~is~~ 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 ~~is~~ 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 ~~are~~ 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 ~~is~~ was increased by the stretching of the cuticle consequent upon swelling. The earliest absorption ~~takes~~ took place 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 Gibberella saubinetti 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 Hordeum, Triticum, Bromus and Poa, 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

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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 <u>Chloris ciliata</u>, 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 / ..

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 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

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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

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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 <u>Aspergillus</u> amd <u>Rhizopus</u>, found no perceptible favourable influence on the germination of <u>Triticum</u>, <u>Trifolium</u> etc. Barton (1940) treating numerous dormant seeds with growth substances, found these of very little value.

<u>Genuine germination-promoting and germination-retarding (or inhibiting) substances.</u>

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 <u>Trifolium</u>, <u>Lepidium</u> and <u>Linum</u> on the mucilage of <u>Viscum</u> 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 difference 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

capable / t...

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 representing 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 conditions / ..

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.

T A B L E 7 / ..

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

Discussion : - Reference to table 7 shows that the trend of delayed germination of the seeds of individual ecotypes seldom gave a regular curve. This irregularity was only partly due to the variability of the material because some differences 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 were to be found in a number of the kinds. Equally marked increases were also experienced. With only one or two exceptions, these falls did not occur until the advent of summer. Panicum coloratum ecotypes C. 98, C. 100, A. 175, Panicum laevifolium, Panicum phragmitoides C. 21, Digitaria ecotypes A. 30, A. 34, A. 85, A. 108, A. 119, D. 13, C. 69, A. 50 and Paspalum notatum 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. Panicum spp. G. 1 and C. 21; and Digitaria 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 Digitaria 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 Digitaria ecotypes A. 23, A. 40, A. 50, D. 25 D. 29, C. 69 and P. coloratum 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.

T A B L E 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: over 90 %	71-90 %	51-70 %	31-50 %	11-30 %	under 10%	Total Number of Ecotypes tested
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	4	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	Second Room	Test Outdoor	Third Room	Test Outdoor	Fourth Room	Test Outdoor	Fifth Room	Test Outdoor	Sixth Test 6 months afterwards Room	Outdoor
			BIMONTHLY TESTS									
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	77.7
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 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: 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. 4/2.	0	2.8	0.3	6.3	-	4.3	7.3
do 2-2. 4/2.	0.5	0.8	2.0	16.0	-	16.0	16.0
do 3-2. 4/2.	0.3	0.8	1.8	5.5	-	3.8	11.5
do 3-4. 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. Locality.	Plot number. 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	1.1	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 %
Brachiaria brizantha :								
(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
ECHINOCHLOA sp.:								
(Sharangani)	N112 24/1.	1.5	8.3	12.8	29.8	+23.5 ø	35.0	-
PASPALUM :								
P. notatum, (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
P.scrobiculatum (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
SETARIA :								
(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
UROCHLOA :								
	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 showed 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.

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:		Second Test:		Third Test:		Fourth Test:		Test repeated directly after previous test.	
	coats broken: %	coats intact: %	coats broken: %	coats intact: %	coats broken: %	coats intact: %	coats broken: %	coats intact: %	coats broken: %	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:										
)11/2.	-	-	-	-	82.0	-	74.0	1.0	40.0	26.0
n'Gamiland,(in sun) / do (in lab.)) "	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

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 %
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 were ~~are~~ still restricting.

However, the seed~~s~~ 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 were ~~are~~ 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 if ~~when~~ the caryopses of Urochloa were ~~are~~ removed from the coverings, and then scratched, the germination immediately rose ~~rises~~ 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

the / ..

') 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 / ..

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 evaluation of the condition of the embryo. other factors!

The effect of seed-coats on the course of delayed germination. - 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 *Paspalum notatum* A.240, of 3/2/41, and of *Brachiaria brizantha* 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 *Paspalum* and 24, 27, 44 and 14 for the *Brachiaria*, the controls throughout being 0%. At the commencement of this study the *Paspalum* and *Brachiaria* 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 *Paspalum*, whereas in the case of the *Brachiaria* 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,

when / ..

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.

S u m m a r y .

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 <u>Panicum</u> 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 <u>Urochloa</u> and the two <u>Setaria</u> 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 <u>Setaria</u> ecotypes, breaking of the seed-coats resulted in a marked lowering of germination.

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

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.
