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CONTENTS

A PHYSIOLOGICAL STUDY OF DELAYED GERMINATION IN COTTON

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Introduction: During the year 1930, a second generation of an interspecific cross, exhibited poor and delayed germination, while other crosses between different parents had uniform and quick sprouting. A large number of seedlings continued to come up even at the end of a month, often with their cotyledons enclosed in the seedcoat, in spite of the adequate moisture in the soil. These contributed very little to the yield, and their behaviour was very much similar to the second sown crop (*Plate II. Fig. 2*).

One of the criteria for a good and successful crop production lies in good and rapid germination followed by early growth. The disadvantages of a variety possessing delayed and protracted germination are many. It necessitates not only an initial high seed rate to ensure a good stand, but also forms a prospective nuisance in later years, as weed. Haphazard sprouting produces many weaklings which contribute very little to the yield besides delaying the general harvest of the crop.

The remarkable ability of certain seeds of cultivated and wild plants to remain viable for nearly half a century, even when lying buried in the soil, is a sufficient proof that dormancy is one of Nature's adaptations for securing longevity in seeds. The delay is in general more persistent in the wild types than in the cultivated races. The conscious selection pursued by man in his endeavour to domesticate and produce better varieties, has reduced to a minimum the rest period following a freshly harvested crop. Many of the present day cultivated varieties are marked by the complete absence of this quiescent period, and the continued presence of dormant seeds has been traced to both developmental and environmental causes.

Review of Literature: During recent years the enquiries have been centred round two main phases of the problem, viz., (1) the various methods by which dormancy is produced in Nature, (2) the exact conditions that are necessary for the maintainence of viability in seeds for a very long interval, and the conditions that force the germination of such seeds by modifying certain inhibiting factors.

The question of the influence of environment on the production of impermeability in seeds, has been debated for a very long time. A close relation between the moisture content, environment, and hardness has been noticed. Rose (1919) on Sambucus, and Toole and Drummond (1924) on cotton observed the onset of hardness when the moisture content of the seed fell below six per cent. Hiltner referred to by Croker (1919), and Bredeman (1931), found more hard seeds in dry periods and in dry climates. Jones (1928) concluded that the early vigour of the plant influenced the production of the hard seeds. It has also been found that the total water requirements of hard seeds are generally high. Guppy (1912), and Miazdticova (1932), showed that good permeable seeds required less water for germination than poor and delayed types. Youngman (1929), drew attention to the specific quantities of water needed for germination, and its relation to the climate under which each variety throve well.

The modes of securing this delay are varied and numerous, but they are generally found in the seed coat or the embryo. An interesting turn was given during recent years to this problem, as to the relative importance of these two plant parts in inducing the dormancy, but the volume of evidence adduced by numerous workers, point towards the seed-coat as playing a more important role. Ewart (1908) suggested a hypothesis that was incapable of experimental verification, that 'longevity depended upon how long the dry dormant protoplasm of the embryo was able to recombine and re-establish the molecular groupings of the proteid matter when remistened, and proceed with normal activity'. Crocker (1916) showed that 'loss of viability of seeds approaching air dry condition, is due to slow denaturing, or coagulation, of certain protoplasmic substances of the embryo'. The same author showed that delay in hard seeds might result from restricted absorption of water, low permeability to gases, or mechanical restraint by the seed-coat, or from rudimentary embryos.

Various substances in the seed-coat, and certain structural adaptations have been found responsible for the exclusion of water. Bergtheil and Day (1907), and Braun (1924), found the hardness was due to the presence of a thin cuticle. Jarzyomowski (1905), Coe and Martin (1920), Ohga (1925), Lute (1928), Reeves and Valle (1932), and Shaw (1932), each working with a different type of seed demonstrated that the light zone of the modified palisade, or the whole palisade layer of the seed-coat was of low permeability, on account of the reduced size of the lumina in these cells. The impermeability was to a large extent removed when the tips of the malpighian cells were broken by some mechanical means. Collins (1918) showed that there were restricted zones of absorption and transmission of water in barley, due to the structural peculiarities of the seed-coat. Shull and Shull (1932) attributed the irregularities in the water intake of hard seeds to the non-homogeneity of the coat and the contents. Denny (1917) demonstrated the reduced water absorption due to the presence of pectic compounds, lipoids, and tannins. Harrington and Crocker (1923), and Verschaffelt quoted by Crocker (1916), found the micropyle closed in certain types of impermeable seeds.

Again the seed-coat sometimes limited the exchange of gases, and thereby induced delay. Crocker (1906), and Shull (1911), found that the exclusion of oxygen needed for the embryo, raised the minimum temperature necessary for the germination, and that high temperatures generally increased the rate of oxygen and carbon-di-oxide diffusion. Shull (1911), and Atwood (1914), obtained increased germinations under high oxygen pressures, or when the coat was opened. Kidd and West (1917, 1920) showed that the gaseous exchange was lower in a thick or unripe testa, and that a higher concentration of carbon di-oxide found in certain soils inhibited germination.

In other cases where the water entered the coat readily, but yet resulted in delay, the causes have been traced to the mechanical restraint of the seed-coat. Muller quoted by Crocker (1916), and Crocker and Davis (1914) with Alisma, found that the breaking strength of the water saturated seed-coat was considerably in excess of the imbibitional and osmotic pressures of the embryo at the time of germination. Harrington and Crocker (1923), and Ives (1923), obtained a better germination when the pericarps were removed.

Many of the seed-coat characters respond to the treatments, and the nature of the treatment greatly depends upon the nature of the defect. Rose (1915) has reviewed the various treatments with sulphuric acid, puncturing, and scarification. The existence of such mechanical treatments on a commercial scale for the herbage seeds on the Continent, is a sufficient proof for the better crops obtained with such treated seeds. The treatments primarily reduce the seed-coat thickness, and rarely alter its composition. Nye (1929) obtained a high and quick germination when treated with sulphuric acid. Dilute acids and bases act on the colloids of the seed-coat and increase their water holding capacity by dispersing them, but Eckerson attributed the effect of these acids to the hypocotyl portion of the seedling. The increased absorption and germination noticed by Davis (1917), Shull (1920), Harrington (1921), and Evans (1922), under high temperatures during germination are due to both the breaking up of the colloids and rapid diffusion of gases.

A number of varieties have been noted to possess dormant or weak embryos. Dormant embryo improves after storage, but weak embryo which generally results from the wide crosses, germinates readily. Dry heating as a method to hasten after-ripening has been widely used with varying results. Dixon (1902), and Harrington and Crocker (1918), noticed that the time needed for germination increased with exposure to high temperatures, and the latter hence concluded that Ewart's hypothesis about the protoplasm of the embryo, could not be a correct view. Groves (1917), and Jones and Tincker (1926), observed a gradual decrease in the percentage of germination with increased time of heating. David and Rose (1912), and Eckerson (1913), have shown that the changes in the after-ripening consisted in increased water holding capacity, increased activity of the catalase and oxidase. Harlan and Pope (1925) on barley, and Lyons (1928) on wheat, observed lack of embryo development in a small percentage of seeds although the endosperm was normal.

A big embryo implies a big reserve for the growing seedling, and this is possessed generally by big and heavy seeds. Blackman (1919), and Ashby (1930), showed the advantages possessed by a larger seedling over a smaller one, since the growth might be viewed as an exponential function of increments. A correlation between the heavy seed and the subsequent growth has been established by Ewing (1910), Rudolphs (1923), and Williams (1927). Harris (1912), demonstrated the existence of selective mortality in beans, such that the light and very heavy seeds were weeded out leaving the mean of the viable seeds unchanged.

It may be seen from the review of liter ure given above that the modes of securing the dormancy in seeds, [illegible] confined to the dull monotony of one single method. An enquiry into the factors that caused the delay in germination in our material was therefore taken up.

Material. The following five varieties covering the parents and the crosses formed the material for the various experiments.

1.	Strain N 14 (*G. indicum*) hereafter referred to as variety			I.
2.	Strain 2113 (*G. herbaceum*)	,,	,,	II.
3.	Garo-hill cotton (*G. Cernuum*)	,,	,,	III.
4.	Isolated hybrid from *G. indicum* × *G. Cernuum* – (I × C 99)	,,	,,	IV.
5.	F_1 progeny (2113 × I × C 99)	,,	,,	V.

Methods. A large number of workers on this problem have used the rate of water imbibition as an index of impermeability in seeds, and in the experiments described below, the same measure is adopted. Random samples of one hundred good seeds from each treatment was placed between moist blotting sheets in germination trays. Progressive weights were recorded every four hours till there was no further absorption or germination. The emergence of the radicle to a length of five millimetres was taken as full germination, and such seedlings were removed as they were recorded so that the water absorbed was really the water necessary for the germination of the remaining seeds. The percentage increase in weights on the initial dry weight of seeds, was calculated and compared.

The influence of the coat properties on the rates of absorption in untreated seeds, when definite portions of the seed-coat were exposed, and when treated in different ways, were found. Other experiments were conducted to find the relation between the delay in germination, and the defects in the seed coat and embryo, when the water was normally absorbed.

Rates of Water intake: The five varieties exhibited inherent differences in the rate and total absorption of water. The curves of absorption (*Plate I. Fig. 1*) fall into two groups, viz., (1) for varieties I and II, and (2) for varieties III, IV, and V. The former group showed a substantial increase at the end of four hours followed by a rapid rise, and reached the upper saturation point before fifty-two hours. In contrast to this, the other group started absorption late, progressed slow, and touched the point of full saturation at the end of seventy-two hours. This group, continued to absorb even after the close of germination, and later studies on the embryo showed that such continuous absorption may be due to the empty spaces in the seed between the partially filled embryo and the seed-coat. Poor and delayed germinations resulted from slow rates of intake.

The differential permeabilities of the seed coats of different varieties, were found by blocking the micropyle with melted paraffin. Varieties IV and V (Plate I fig. I), showed the same rates of absorption as untreated seeds, while a perceptible fall was noticed in the other three varieties. The possible interference by the varying density of fuzz on seed was eliminated by treating the seeds with concentrated sulphuric acid. The behaviour of such treated seeds in the delayed lots, with or without closing the micropyle was in entire agreement with the other results. This experiment showed that in varieties IV and V, the micropyle did not function as a channel of water intake, and that the whole absorption was limited to the seed coat alone.

The rates of absorption through the micropyle, and the chalazal end, were determined. For this purpose the seeds were suspended on paraffin-coated paper floats, well cemented with a mixture of paraffin and wax, and the ends were just immersed in water, leaving the other portions of the seed free and dry on the float. Empty floats were used as controls, to find their absorption, and later correction. The results given (plate I fig. I), are very interesting and demonstrate the long initial delay in absorbing, low rise, and low total absorption particularly in varieties IV and V. The two varieties I and II, take in water readily both through micropyle and chalazal end.

This set of experiments prove that the varieties exhibit different absorption rates, and that the delay is partly due to the closed micropyle and low permeability of the seed coat.

Chemical properties of the seed coat. Hand sections of the seed coat were examined. and micro-chemical tests were tried with a view to find the chemical nature of the seed coats in these varieties. The presence of cutin was negatived by the action of Sudan III, and alcoholic solution of chlorophyll. There was no tannin or pectic compounds. Dilute acids and bases showed a tendency to break apart the seed coat at the junction of the palisade and the inner epidermis, more readily in the permeable group. This might be due to the looser arrangement of the cells or to the presence of less binding material. Cuprammonia dissolved very quickly the unthickened portion of the palisade in varieties I and II, and the quickness with which the walls went into solution, could be seen from the number of brown masses shooting out of the palisade. The 'light zone' of the palisade often referred to by other writers was very prominent in the hard seeds due mostly to the greater thickening and deposit of lignin. The lumen of the palisade in the permeable and impermeable groups was completely disorganised by concentrated sulphuric acid in about three and eight hours respectively. The brow pigment layer probably resisted the acid action in the latter.

Hard seeds were not different with regard to their moisture content from other seeds, but their ash contents (Table IV) were low, probably due to the greater amount of organic colloids.

Mechanical restraint imposed by the coat. It is commonly known that the seed coat is weakest at its full water holding capacity. The rates of absorption (Table I) for the seed coats only when the contents are removed, show that in addition to the low rate of water intake, there is higher saturation point for the impermeable varieties. The emergence of the radicle in such delayed varieties, does not synchronise with the rupture of the coat, showing that the pressure of the embryo is not sufficient to break through the seed coat. An attempt was made to follow the changes in the strength of the coat at different water contents, but the experimental error was very high that the differences were unreliable

The toughness or hardness of dry coats was also measured with the apparatus designed by Puri and Venkataraman. Weights were slowly added till a puncture in the seed coat was made by the pin resting on it. The average pressure required to puncture through the seed coat at the mid point on the dorsal side of one hundred seeds of each variety was found. Impermeable varieties have a higher scale of hardness.

It was found that the thickness of the seed coat measured on median cross sections (Table IV) followed closely the gradation of permeability and hardness.

Hardness is also conditioned by the presence of certain substances like cutin, lignin, etc., which lower the elasticity of the structure. The elasticity or the precentage stretching power of the coat was determined, by finding the percentage increase in the dimensions of the soaked seed, after fixed intervals of one and two days. The maximum distension (Table IV) is obtained with varieties I and II, at the end of a day, and moderately high increase with the other two during the same interval. The low elasticity of the coat will resist the swelling by imbibitional and osmotic forces of the normal embryo. The necessary pressure for breaking the coat fails to develop, and leads to delay in germination.

Methods of overcoming the seed coat defects. Partial removal of the seed coat, reduction of the seed coat thickness, and modifying its colloidal nature, were tried.

The embryo was made to absorb water directly by removal of the seed coat at the butt end of the seed. The rates of absorption are very high (Plate I. fig 1) in all the varieties, as the limiting agency of the seed coat has been removed. The embryo greedily absorbed water and swelled rapidly. The radicle in hard varieties emerged through the cut end taking a curved path; while they emerged through the micropyle in other varieties.

Strong commercial sulphuric acid was allowed to act upon the seed for intervals of 15, 30, 60, 90, 120, 150, minutes. The rates of water intake (Plate II. fig 1) show a steady and progressive increase in varieties IV, and V till 150′ treatment, whereas this increase in varieties I and II, is absent beyond 15′ treatment. Treatment up to 15′ only removed the fuzz adhering to the seed coat. The slow action of the sulphuric acid on hard seed coats seems to be due to a difference in its composition. The increased rate and total germination (Table I) obtained, for varieties III, IV, and V, in the two experiments indicate the bad effects of such hard seed coats in untreated seeds.

Constant temperatures of 28, 35. 40, and 45, degrees centigrade were maintained with an incubator. The rate of absorption increased with rise in temperature (Plate I. fig 2), in all the varieties, and the germination (Table III) also increased in varieties IV, and V, up to 40 degrees. Though there appears to be definite lethal temperatures for the different varieties, hard types possess a higher optimum for germination. The radicle was injured at 35 degrees in varieties I to III, and it was seen just as a white speck lacking growth.

Characters of the embryo. The size and weight of the embryo influence the germination. It was suspected that poor embryo development might be responsible for part of the poor and delayed germination in the varieties, and to test this possiblity, the proportional weights of the embryo and the seed coat for the different varieties (Table V), and for the different seed weight groups (Table VI), for variety V, were determined. It may be seen that the delayed varieties have a lower proportion of the embryo to the seed coat, than varieties I and II. The variability of the embryo in hard seeds is nearly double that of the permeable group, while the variability of the seed coat is practically unaffected. The proportion of the embryo to the seed coat in different seed weight groups shows that 3·2 % of the normal looking seeds lack embryo, and nearly 34 % possess embryos arrested at varying stages of development. The disparity in the proportional weights of the embryo and the seed coat, is gradually lessened from the lighter seeds to medium heavy seeds. Owing to the difference in their structure and composition, an equal rise in the weight of the seed coat and the embryo will not proportionately increase the breaking strength of the former and the swelling pressure of the latte-. Each small addition to the coat will increase its chances for delay in germination.

In order to test this hypothesis 2000 single healthy seeds from variety V were weighed and grouped according to seed weights. These were sown in small bed and kept watered through out the experiment. The record of germination was maintained up to twentieth day after sowing, and as soon as the seedling emerged, it was classified as normal or shrunken. The proportion of normal seedlings in relation to the total germination (Plate ... 2). from each of the seed weight groups, show a rise till 85 mgs., and a fall to zero later. An average difference to four days in the time taken to germinate was obtained between the normal and shrunken seedlings, and this difference would be very much increased under rapidly drying field conditions. The form and nature of the curve obtained for the germination add weight to the previous hypothesis that the delay and failures in light seeds are due to poor embryo, and that in heavy seeds, due to thick and unyielding seed coats. The maximum germination composed of good seedlings is obtained from average seed weights, due to the balanced development of the seed coat and the embryo. The embryo in light seeds was very variable, but in medium seeds and heavy seeds, the variability was very low.

Another cause for the delay may be the dormancy of the embryo, which sometimes requires after ripening. Dry heating the seeds brings about this change earlier. Short exposures of one and three hours at 50 degrees centigrade, and a long exposure of forty eight hours at 40 degrees were given. The results obtained were not consistent, and generally the rates of absorption were either decreased or remained unaffected. A slight forcing effect at long exposures (Table III) was noticed in varieties I and II, while varieties IV and V, exhibited a reduction in total germination.

Discussion. The factors causing delay in germination in the material under study, have been traced to both seed coat and embryo. The environmental and developmental causes leading to the presence of such hard seeds have been noted to be (1) an unusally dry period during the phase of crop maturation, and (2) the extra vigour of the plant in the early stages of its growth. As all the varieties were raised during the same season, the climate does not seem to be the casual factor. It was shown that the F-1 plants were vigorous, and it is very likely that these fast growing vigorous plants utilised the moisture available in the soil very rapidly and met with a scarcity at the fruiting period in the same manner as found by Jones in vetch. In addition, the early and quick development of thick seed coats in such types, may have adversely affected the development of the embryo.

The wide range of variability of the embryo weights in I × C 99, (although in its nineth generation), is probably due to the union of dissimilar gametes, because the two parents of this cross do not show such high variabilities. The percentage of empty seeds is very much higher than the figure obtained by Lyons for wheat. Failures in hybrid are maximum in light and very heavy seeds, and this result is similar to that found by Harris in phaseolus, but the causes of such failures appear to be different, viz; (1) due to the poor embryo in light seeds, and (2) due to thick impermeable seed coats in heavy seeds resisting the force of [illegible] expanding contents. The lower rate of absorption is partly due to the restricted transmission by the hard seed coat, and partly the result of slow absorption by the poor embryo through the two points of contact with the seed coat at the micropylar and chalazal ends. The embryo, however small or weak, readily absorbed and germinated when the seed coat was opened, showing that it was not dormant.

The differences in the rate and total quantity of water absorbed by the varieties, are due to the differences in the composition of the seed coat, and the environmental adaptations. A rapid absorption and a lower demand for water in *G. indicum* and *G. herbaceum*, are indispensable for their continuous survival, because they are generally found in dry places with rainfall not exceeding 30 inches, most of which are received in small quantities. The higher minimum water needed for germination by *G. Cernuum*, and its crosses are perhaps adaptations to the heavy downpours received during the year, in their native habitat (Assam). Part of the higher requirements in the hard seeds, may also be due to empty spaces between the weak embryo and the seed coat which gradually get filled up with water, or due to the colloidal composition of such coats.

The delay in the permeable seeds is due to the high breaking strength of the seed coat. The observations in the laboratory where the radicle emerged through the cut butt ends, and the germination of late seedlings in the field with the unbroken seed coats, are due to the failure of the embryo to develop the requisite pressure.

The various causes indicated, and the various methods tried in this paper to quicken and improve the total germination, show that the varieties possessing good embryo with hard seed coats, could be modified to produce a more vigourous and better crop. On the other hand, those containing weak embryos could only be induced to germinate without very much adding to the yield.

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Summary. (1) Delayed germination was observed in an inter-specific cross in cotton. (2) The rate of water absorption was associated with the rate and total germination. The parents were differently permeable to water and this was inherited by the hybrid. (3) The minimum quantity of water required for hard seeds was very high in comparison to others. Hard seeds limited or excluded water on account of closed micropyle, or the reduced size of the lumen in the palisade cells. (5) The breaking stre h of the coats was high

and the embryo was generally unable to develop this pressure by swelling. (6) Reduction of seed coat thickness by carbonisation, or removal of a portion of the seed coat, increased the germination. (7) Better germinations at higher temperatures were obtained with hard seeds. (8) The composition of the seedcoat is probably colloidal in nature, and this is shown by the low stretching power, high breaking strength and low ash contents. (9) The apparent vigour of the first generation hybrid resulted in the production of hard and thick seed coats. (10) The embryo development in the hybrid was very variable, and about 4% lacked embryos. (11) The proportion of healthy seedlings was most in medium heavy seeds, and the total germination was equally high here. (12) Weeding out of heavy and light seeds was likely under normal conditions due to the defects in the seed coat and the embryo. (13) The embryo in hard seeds was only partially developed and occupied only a portion of the seed cavity. The seed coat transmitted water in hard seeds with poor embryo, through the two points of contact only, resulting in slow germination. (14) The embryo was not dormant but was only weak. Dry heating protracted the germination or had no effect.

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Table I.

Percentage Germination.

No. of hours.	Untreated at 28 C.					Open at chalayal end.					Untreated and micropyle closed.					Delinted and micropyle closed.					Seed-Coat alone ** (Embryo removed).				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
24	...	...	...	...	...	...	...	...	...	...	12	10	...	...	...	12	10	...	...	...	79	49	50	48	41
28	...	...	...	...	...	28	31	7	5	4	32	34	...	...	...	32	34	...	...	...	88	54	60	53	47
32	50	...	...	...	...	57	51	16	16	14	58	62	9	10	20	58	62	9	10	20	90	56	71	63	49
36	55	...	...	...	...	84	95	23	23	23	72	86	28	20	32	72	86	23	20	32	...	64	79	70	55
40	83	...	...	...	...	91	97	57	42	51	80	88	41	25	39	80	88	41	25	39	...	66	84	75	60
44	88	3	2	...	6	...	...	65	69	63	85	90	51	34	46	85	90	51	34	46	...	68	92	79	66
48	94	48	5	6	12	...	...	82	75	75	87	94	62	44	48	87	94	62	44	48	...	...	97	81	73
52	...	89	17	16	16	...	...	84	83	81	87	94	72	52	59	...	...	72	52	59	...	...	106	86	76
56	...	90	31	24	26	...	...	86	85	88	87	94	76	52	59	...	...	76	52	59	...	...	108	90	83
60	...	95	39	26	38	...	...	86	85	89	87	94	78	52	62	...	...	78	52	62	...	...	...	94	87
64	...	...	57	34	40	...	...	87	85	91	87	...	78	56	64	...	...	...	56	64	...	...	...	99	91
68	...	...	75	36	40	...	...	87	85	91	...	...	78	58	64	...	...	...	58	64	...	...	...	104	99
72	...	...	75	36	40	...	...	87	85	93	...	...	78	58	64	...	...	...	58	...	...	...	...	108	103
76	...	...	80	38	44	...	...	88	85	93	...	...	78	60	64	...	...	...	60	...	...	...	...	112	109
80	...	...	...	38	48	...	...	...	...	...	...	...	...	60	64	...	...	...	...	...	...	...	...	114	115
84	...	...	...	40	58	...	...	...	...	...	...	...	...	60	64	...	...	...	...	...	...	...	...	...	...
88	...	...	...	40	...	...	...	...	...	...	...	...	...	60	...	...	...	...	...	...	...	...	...	...	...
92	...	...	...	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
96	...	...	...	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

* Percentage moisture absorbed.

Table II.

Percentage Germination.

No. of hours.	Delinted with $H_2 SO_4$ 15 mts.					Delinted with $H_2 SO_4$ 30 mts.					Delinted with $H_2 SO_4$ 60 mts.					Delinted with $H_2 SO_4$ 90 mts.					Delinted with $H_2 SO_4$ 120 mts.					Delinted with $H_2 SO_4$ 150 mts.				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
16	4	4	...	...	...	4	8	...	...	...	6	2	...	...	...	4	4	...	...	...	4	8	...	...	...	4	4	...	...	...
20	10	14	...	...	...	10	18	...	...	...	10	14	2	...	...	12	8	10	2	...	10	60	12	4	4	16	12	14	6	4
24	28	66	12	...	4	30	74	16	4	6	42	60	24	6	10	52	54	24	8	10	38	68	26	32	30	36	32	54	10	38
28	32	74	22	2	20	40	80	30	16	20	60	74	36	30	22	60	62	52	36	44	64	76	46	62	64	60	70	76	34	60
32	58	82	50	12	28	74	86	54	38	28	72	76	56	56	44	78	78	60	64	54	72	82	62	70	86	76	76	86	38	82
36	72	88	52	30	44	84	92	56	44	44	88	78	68	76	48	82	84	64	76	62	82	88	70	74	88	80	88	90	72	84
40	84	...	56	30	46	...	96	62	46	48	...	80	74	78	62	...	...	72	82	68	...	...	74	78	90	...	...	90	80	92
44	...	...	60	30	50	...	...	70	48	60	...	...	80	78	70	...	...	76	86	72	...	...	84	86	90	...	...	...	90	96
48	...	...	66	34	52	...	...	76	54	62	...	...	84	78	76	...	...	80	...	74	...	...	...	...	90	...	...	...	90	96
52	...	...	78	42	58	...	...	84	58	66	...	...	...	80	...	...	...	...	...	76	...	...	...	...	...	...	...	...	...	...
56	...	...	...	46	60	...	...	...	60	68	...	...	...	...	...	...	...	...	...	82	...	...	...	...	...	...	...	...	...	...
60	...	...	...	52	62	...	...	...	62	70																				
64	...	...	...	54	68	...	...	...	68	72																				
68	...	...	...	56	70	...	...	...	70	78																				
72	...	...	...	56	72	...	...	...	...	78																				
76	...	...	...	...	72	...	...	...	...	...																				
80																														
84																														
88																														
92																														
96																														

Table III.

Percentage Germination.

No. of hours.	Maintained at 35°C.					Maintained at 40°C					Maintained at 45°C.					Maintained at 50°C.				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
20	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	...	...	...	...	...	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	29	...	...	...	...	28	...	...	2	...	...	...	...	...	...	...	...	...	...	...
32	73	8	...	5	...	59	...	...	10	...	2	1	...	1	...	...	...	...	...	...
36	84	27	6	15	2	65	3	...	40	1	26	3	...	6	...	...	...	...	...	...
40	92	70	15	30	14	69	60	2	55	1	31	12	...	15	...	...	...	...	...	...
44	...	87	42	42	26	71	81	12	74	2	36	41	1	29	...	...	...	...	1	...
48	...	94	63	43	48	73	93	30	84	7	41	64	2	43	...	...	...	...	2	...
52	...	95	64	45	57	75	94	[illegible]	85	19	45	81	12	69	1	...	...	...	2	...
56	...	...	70	46	61	...	...	55	85	38	...	82	24	70	3	...	...	...	3	6
60	...	...	73	46	64	...	...	58	86	64	...	...	23	74	3	...	...	...	...	6
64	...	...	75	47	64	...	...	63	...	81	...	...	29	78	16	...	...	...	...	...
68	...	...	...	...	64	...	...	65	...	90	...	...	33	...	20	...	...	...	...	...
72	...	...	...	...	64	...	...	...	...	91	...	...	...	...	36	...	...	...	...	...
76	...	...	...	...	...	...	...	...	...	...	...	...	...	...	59	...	...	...	...	...
80	...	...	...	...	...	...	...	...	...	...	...	...	...	...	66	...	...	...	...	...
84	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
88	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

No. of hours.	Dry heated for 1 hour at 50°C.					Dry heated for 3 hours at 50°C.					Dry heated for 48 hours at 40°C.				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32	6	...	...	...	...	4	...	...	...	...	14	2	...	2	...
36	14	...	...	...	...	16	...	...	2	...	44	8	...	2	...
40	56	...	...	4	...	60	...	...	6	...	62	28	...	14	...
44	78	6	2	16	...	78	6	...	12	...	64	40	4	14	...
48	80	34	4	26	...	84	34	4	20	2	68	50	12	24	2
52	82	82	[illegible]	34	2	...	82	12	40	4	70	70	40	30	6
56	...	86	46	42	12	...	86	40	44	22	70	90	62	32	8
60	...	...	60	50	18	...	...	54	50	24	70	92	68	...	16
64	...	...	72	58	42	...	...	60	54	42	...	...	74	...	32
68	...	...	76	...	48	...	...	...	56	48	...	...	76	...	46
72	...	...	82	...	66	...	...	...	...	56	...	...	78	...	46
76	...	...	...	...	76	...	...	...	...	58	...	...	...	...	46
80	...	...	...	...	78	...	...	...	...	60	...	...	...	...	46
84	...	...	...	...	80	...	...	...	...	62	...	...	...	...	...
88	...	...	...	...	84	...	...	...	...	...	...	...	...	...	...

Table IV.

Selection No.	No. of determinations.	Average force required to puncture the seed cast in lbs.	Standard deviation.	Percentage increase in				Thickness of seed coat in μ	Percentage	
				Length		Breadth			Moisture	Ash
				1 day	2 days	1 day	2 days			
N. 14. I.	100	7·10	0·80	22·5	23·0	20·5	22·0	276	9·14	3·22
2113 II.	100	6·45	0·81	21·5	22·0	18·0	18·5	304	8·87	3·10
G. Cernuum III.	100	8·90	1·38	14·0	17·5	15·5	17·0	312	8·86	2·60
I × C99 IV.	100	8·75	1·08	9·5	15·5	8·5	14·0	328	8·90	2·49
(I × C99) × 2113 F_1 V.	100	10·80	1·25	5·5	7·0	5·0	8·5	358	8·11	2·57

Table V.

Selection No.		Percentage Weight.		Co-efficient of variability.	
		Seed-Coat	Embryo	Seed-Coat	Embryo
N. 14.	I.	48	52	12	11
2113	II.	50	50	11	11
G. Cernuum	III.	55	45	15	17
I × C 99	IV.	60	40	13	31
(I × C 99) × 2113 F	V.	57	43	19	32

Table VI.

Seed weight in m. gms. per seed. (Variety V)	Seed coat weight in m. gms. per seed.	Embryo weight in m. gms. per seed.	Percentage weight of embryo.
35	31	4	11
45	38	7	16
55	43	12	22
65	38	27	41
75	41	34	46
85	47	38	45
95	52	43	46
105	57	48	46
115	64	51	44
125	69	56	45
135	80		41

Rate of water intake.

Role of Seed-Coat and Micropyle.

Plate I. Fig. 1.

1.———untreated (Control).
2. - - - - - " Micropyle blocked.
3.—.—.—.—Delinted with Conc. H_2SO_4.
4.—.—.—. " " " Micropyle blocked.
5—×—×—Untreated Restricted absorption through Micropyle.
6..—..—.. " " Chalazal end.
7............... " " Chalaza exposed.

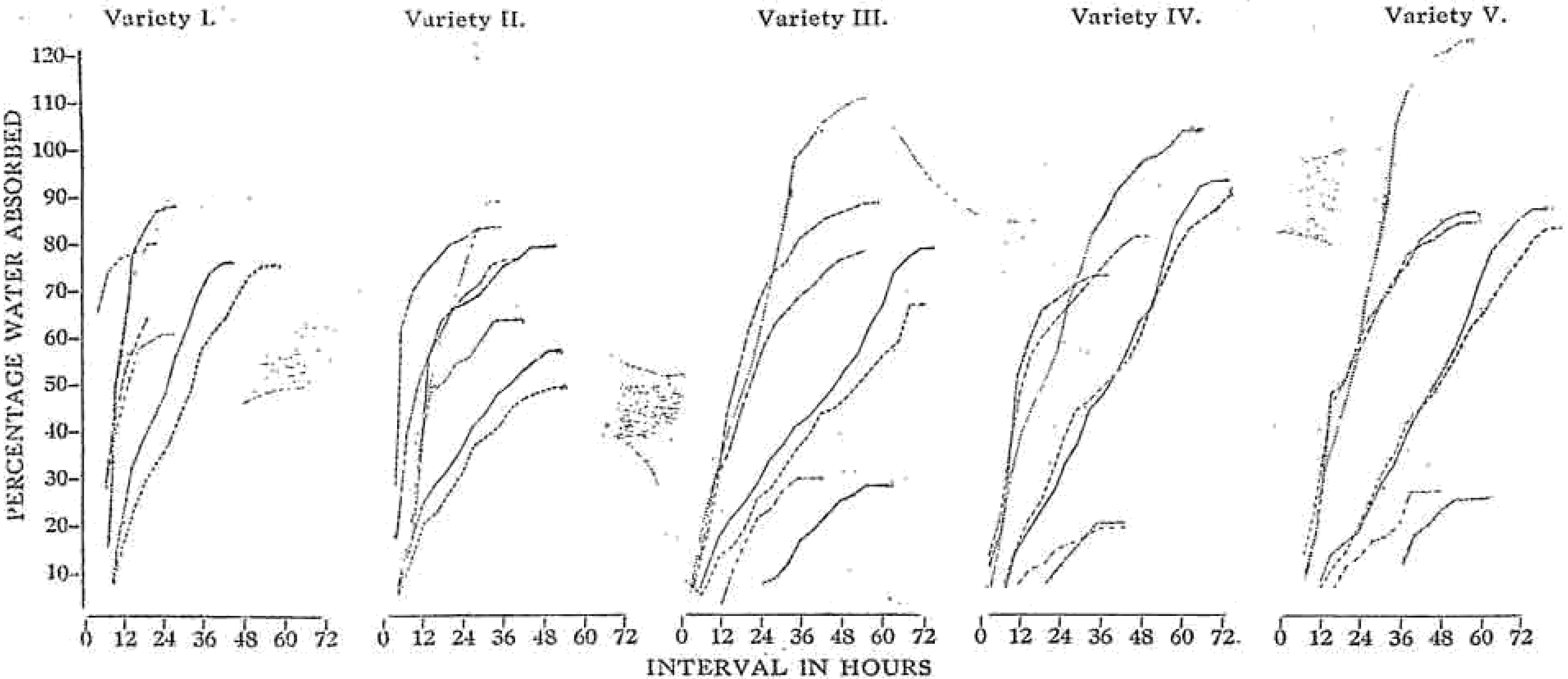
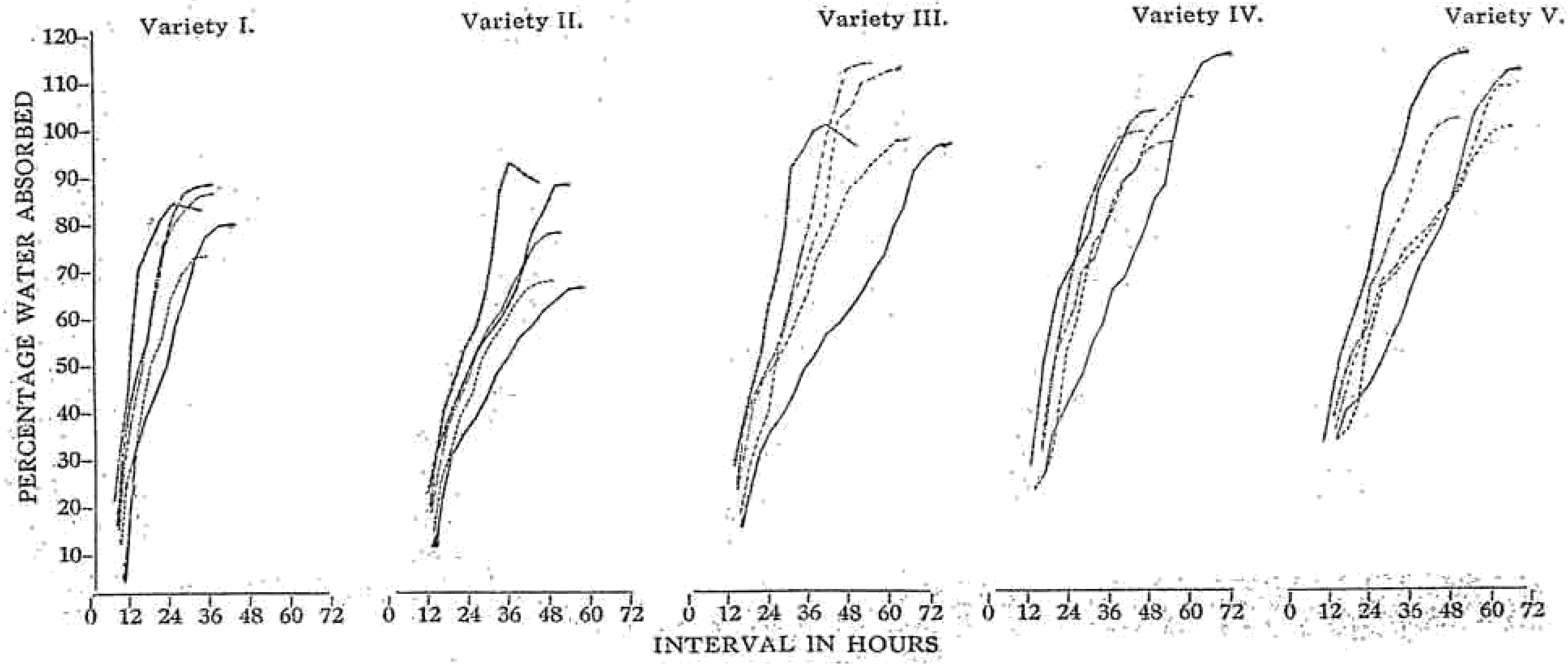


Plate I. Fig. 2.

Rate of water intake.

Effect of temperature.

1——— Germinated 28°C.
2— — — — „ 35°C.
3.—.—.—. „ 40°C.
4—.—.—. „ 45°C.
5—×—×—× „ 50°C.



Rate of water intake.

Effect of concentrated H_2 So_4 on Seed Coat. Plate II. Fig. 1.

1.———Untreated (control)
2.- - - -Treated with Conc. H_2 So_4 for 15 minutes.
3.—.—.—. " " " " 30 "
4.—.—.—. " " " " 60 "
5—×—×—Treated with Conc. H_2 So_4 for 90 minutes
6..—..—.. " " " " 120 "
7............. " " " " 150 "

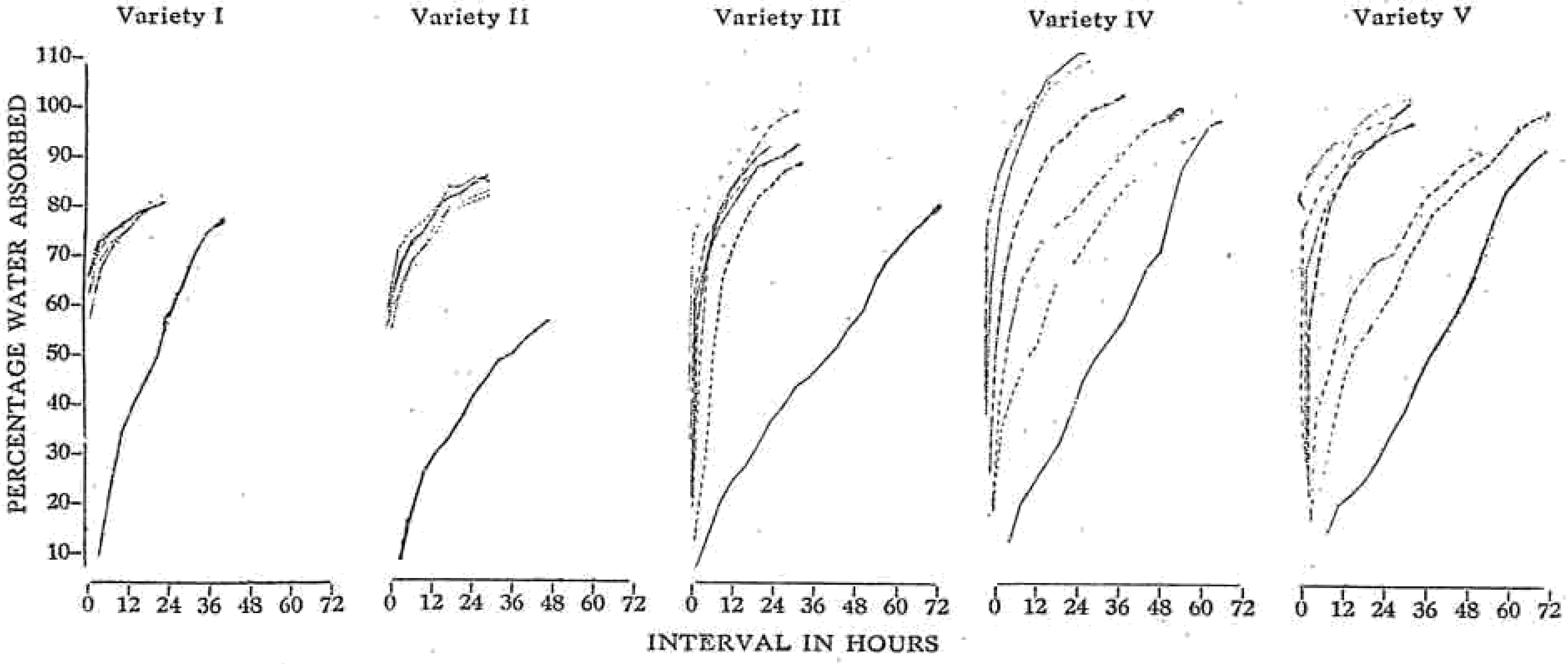


Plate II. Fig. 2.