STUDIES ON SEED DORMANCY IN RICE (*Oryza sativa*, L.) WITH SPECIAL REFERENCE TO SHORT DURATION VARIETIES

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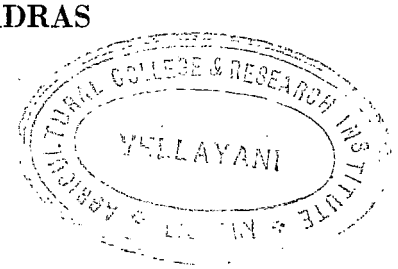

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P R E F A C E

The study of seed dormancy in rice on a scientific basis has received attention only recently. Delayed germination of seeds might prove extremely desirable in a wet harvest season as any variety which does not germinate, escapes considerable damage on the field due to sprouting. On the other hand, highly dormant seeds cause inconvenience as they fail to give a good germination if they have to be sown immediately after harvest. Also the high dormancy is a handicap to Geneticists and Plant breeders who are anxious to raise a number of generations in a short period. Thus in rice certain amount of dormancy is necessary for economic cultivation and it is also important that the dormancy should not reach beyond a level to be a hindrance in raising a quick succession of crops.

Literature on seed dormancy in cereals and other crops is abundant. From a practical breeding point of view, investigations such as the tissues concerned with dormancy, stage of maturity in relation to dormancy, variation in period of dormancy and genetics of dormancy are important. Work done on these aspects in cereals and other crop plants with special reference to rice have been reviewed and presented in the first part.

Although a good start has already been made to understand the basic problems of seed dormancy in rice, much remains to be investigated. Studies on the role of hull, the causes, nature and genetics of dormancy in six short duration varieties of rice and their hybrids have been undertaken and presented in the second part.

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L I S T O F T A B L E S.

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PART. I.

REVIEW OF LITERATURE

D E F I N I T I O N O F D O R M A N C Y.

In referring to literature on dormancy, the different terms used are often confusing. So a definition of the various terms in common use is attempted.

(1) Difference between dormancy and rest :

Usually these two terms are confused and synonymously used. A plant part may fail to germinate either due to some conditions within itself or due to unfavourable environment. Curtis and Clark (1950) reported that authors working with plant structures other than seeds have made a useful distinction between rest and dormancy. According to them failure to germinate is a condition of rest when it is due to some causes within the plant or its structures and a condition of dormancy when it is due to unfavourable environment. But those working with seeds have used the two terms synonymously. Failure of viable seeds to germinate, when placed under conditions ideal for germination is due to causes within the seed itself. Such seeds are said to be in a resting condition or in a condition of dormancy. The period of dormancy is referred to as the period of seed rest, period of delayed germination and the period of after ripening by various investigators.

In rice the term "Seed dormancy" refers to the failure of grains to germinate under proper conditions soon after harvest (Butany and Gangadharan, 1958). The period of dormancy is that from the time the grain is harvested till such time when full germination is obtained (Shanmugasundaram and

Venkatanarasinga Rao, 1951).

(ii) Types of dormancy :

The term "primary dormancy" refers to the initial dormancy of the embryo. Under unfavourable conditions for germination brought about by enclosing structures such as the seed coat or by environment an embryo may develop dormancy and this is the "induced or secondary dormancy" (Crocker 1906, Davis, 1930).

Dormancy may not be equally pronounced in all parts of the embryo. It may be characteristic of the hypocotyl. When naked embryos of this type are placed under germinating conditions, the hypocotyl fails to elongate and no roots are produced. But the cotyledons and plumule will continue to grow (Davis, 1930). By "complete double dormancy" is meant a combination of root and epicotyl dormancy (Crocker and Barton, 1957).

In the work presented here the term "complete dormancy" refers to the period between harvest at normal maturity and the time when the grains give germination upto and including 5%. "Partial dormancy" refers to the period taken by grains to increase their percentage of germination to 95, when part or whole of this period falls beyond the normal stage of maturity. When grains of a variety give 95% or more germination they no longer possess any dormancy. A combination of complete and partial dormancies makes up the total period of dormancy suggested by Shanmugasundaram and Narasinga Rao (1951).

REVIEW OF LITERATURE

(i) Factors affecting seed dormancy :

The different factors affecting seed dormancy discussed by Crocker and Barton (1957) and Namboodiri (1960) may be enumerated.

1. Hard fruit and seed coats.
2. Moisture content of the seed.
3. Maturity of the seed.
4. Oxygen and water availability to the embryo.
5. Light in relation to dormancy.
6. Method of storage of seed in relation to dormancy.
7. Duration of the crop and dormancy.

(ii) Methods of breaking seed dormancy :

(a) Mechanical treatments.

1. Scarification or wounding.
2. Hulling or dehusking.

(b) Physiological treatments.

1. Presoaking.
2. Artificial drying and heating.
3. Moist low temperature pretreatment.

(c) Chemical treatments.

(iii) Causes of seed dormancy :

Crocker (1916) quoted by Thornton (1945) in an early

review on the subject listed the following possible causes for dormancy in seeds.

1. Presence of rudimentary / embryos that must mature before germination can begin.
2. A state of dormancy in the embryo.
3. Impermeability of seed coat to water.
4. Encasing structures interfering with oxygen absorption and carbon-di-oxide elimination by embryo.
5. Mechanical resistance to expansion of embryo by encasing structures.
6. Secondary dormancy.
7. Combination of two or more of these causes.

Curtis and Clark (1950) added that the presence of germination inhibitors also causes seed dormancy. Butany and Gangadharan (1958) in their work on rice quoted Meyer and Anderson (1952) enumerating these possible causes of seed dormancy.

(iv) Tissues involved in seed dormancy :

The role of different tissues in relation to seed dormancy may be considered under two major headings.

A. Role of structures enclosing the embryo.

Ivanovskaja (1949) working on the dormancy period of agricultural plants confirmed the thesis of Lysenko that the embryos of dormant seeds germinate readily and that the period of dormancy is determined by the properties of the outer coat.

In species of Gramineae the structures enclosing the embryo or endosperm differ from those in other plants. So the two groups of plants may be considered separately in reviewing the role of outer structures in dormancy.

1) Plants belonging to family Graminaae : In cereals the structures encasing the embryo and endosperm can be divided into two distinctly different types - the hull and the seed coats.

a) Role of hull in seed dormancy : Hull consists of the flowering glumes viz, lemma and palea. They may inhibit germination when they enclose the kernal tightly as in rice.

Crocker and Barton (1957) suggest that the presence of seed or fruit coats or hulls of grasses sometimes impose the necessity of light for germination. Smith (1948) found that removal of hull from grains of wheat and barley resulted in considerable increase in the percentage of germination. Hulls were removed from ungerminated grains of wheat and oats after they had been in petridishes for 5 to 9 days. Most of these grains then germinated showing that the embryo already started germination but its growth was stopped by the hull. Harrington (1923) found that hulling breaks dormancy and gives satisfactory germination in oats and barley. Atwood (1914) showed that germination of dormant grains of Avena fatua L, can be brought about by removing the hull. Black (1959) also obtained similar results from grains of certain strains whereas some others were so dormant that the

treatment proved ineffective. Where removal of the hull was beneficial the magnitude of the effect depended on the degree of afterripening.

Smith (1948) observed that the presence of unshelled grains of wheat and barley in the same petridish with shelled grains seemed to inhibit the germination of the latter and also reduced the growth of mold on the shelled grains. Moreover germination of hulled barley grains was found to be inhibited by aqueous solution from chaff of two varieties of wheat thereby, indicating the presence of water soluble germination inhibitors in the wheat hull. Black (1959) demonstrated the presence of germination inhibitors in the hull and the caryopsis of oats in approximately equal amounts per unit weight of tissue. The hull plays a dual role in dormancy, due to the presence of inhibitors in it and by preventing leaching of inhibitors from the caryopsis. Removal of hull provides free leaching facilities and thus helps in removing the inhibitor from the caryopsis. When seeds pass over the period of after ripening, germination occurs not due to the loss of the inhibitors but may possibly be due to the formation of a specific germination promoter. Barton and Solt (1948) demonstrated the presence of inhibitors to the growth of wheat root tips in various dormant and nondormant seeds. But they could not show any relation between dormancy and the presence of inhibiting substances. Koller and Negbi (1959) found a water soluble germination inhibitor in the external layers of the caryopsis of Oryzopsis miliacea.

Ramiah (1937) reported that hulled grain of rice has no definite dormant period. Parija et al (1940), Chalam (1954) and Chalam and Behera (1956) are of opinion that the causes of dormancy in rice lie in the hull. They found that hulling promotes germination and suggest this as an effective method of breaking dormancy. Parija et al (1940) found that even very late varieties could be germinated immediately after harvest. Narayanan and Lakshmanan (1952) also noted that hulling improves germination. Sahadevan (1959) found that hulled grains gave more than 80% germination. He concluded that the embryo is active and dormancy is a function of the hull. Umali et al (1960) reported that hulling successfully broke dormancy. These authors suggested that the rice hull may serve as a barrier to germination or that it may contain inhibitory substances.

On the other hand Butany and Gangadharan (1958) found that while hulling improved germination considerably it does not break dormancy in all varieties. Even under hulled conditions dormant varieties require a certain period of rest for normal germination. These authors found that thickness of the hull did not influence dormancy as was observed by Chalam and Behera (1956). Thin hulled varieties such as GEB.24, T.412 and T.90 tested by them were dormant. They could not find any relationship between the amount of water absorbed by a variety and its germination percentage. These authors concluded that the hull on account of its hardness in the region of the lemma opposite the embryo probably prevents

germination of the embryo and penetration of the radicle. Removal of the hull or softening of its tissues by treatment with sulphuric acid appeared to remove this barrier and the radicle can push out easily.

b) Role of seed coat in dormancy : The external covering of the kernal known as the seed coat or the bran has been found to be responsible for seed dormancy in certain species of Gramineae. In cereals, the maternal tissue covering the embryo and endosperm consists of three different layers. The outer pericarp developing from the ovary wall, the true seed coat developing from or at the place of the integuments forming the middle layer and the inner perisperm developing from the unabsorbed part of the nucellus (Hector, 1934). In a mature seed the distinction between these three layers is generally lost and they are together known as the seed coat.

Coukos (1944) studied seed dormancy in five species of grasses where seed coat is the cause of dormancy. This seed coat restriction was not similar to dormancy in hard seeds because here the seed coats permitted absorption of water even in unscarified seeds. The author suggested that dormancy in these grasses may be due to gas exchange restrictions in the seed coat. Toole (1939) found in poverty grass that seed coat was the inhibiting factor in delaying germination and that the seed coat inhibition was due to restriction of gas exchange since restriction of water absorption was small. In California oat grass, Laude (1949) observed that hulling without seed coat injury was of little benefit in breaking

dormancy. Seed coat appeared to delay germination through mechanical restraint or restriction of gas exchange or both. It did not prevent water absorption. Ivanovskaja (1949) found that under certain conditions the seeds of wheat, barley, buck wheat, etc, enter a period of secondary dormancy brought about by a changed condition of their seed coats. Atwood (1914) suggested that seed coat restriction to oxygen entry probably played a role in dormancy.

Garber and Quisenberry (1923) observed that the germination of freshly harvested seeds of Avena fatua L, was increased by breaking of the seed coat. Johnson (1935-a) obtained evidence which strongly suggested that seed dormancy in Avena fatua L, is determined by a condition of the seed coat which developed after fertilization. Dormancy was more or less completely overcome by breaking the seed coat over the embryo or by soaking seeds in potassium nitrate solution. In wheat, Wellington (1956-b) found that embryos in white grains germinate immediately after harvest whereas those in red grains showed delayed germination. Removal of the covering layers of the seed eliminated this difference. The effect of covering layers did not appear to be related to their permeability to water or oxygen. Goodsell (1957) presumed that dormancy in Sorghum seeds was due to the presence of some inhibitory agents in the seed coat. Breaking seedcoat or hot water treatment permitted normal germination.

2) Plants belonging to families other than Gramineae : In this group of plants the distinction between two types of covering

structures such as the hull and seed coat, is absent. Seed coat here refers to the condensed tissues of the ovule outside the embryosac.

Crocker (1906) reported that germination could be induced in dormant iris seeds by removing the cap of tissue covering the radicle in the region of the hilum. Simpson et al (1940) showed that cotton seeds from which seed coats were removed had no tendency for dormancy. Eggers (1942) found that removal of seed coats from avocado seeds tended to hasten germination.

Crocker (1906) found that seed coat of cocklebur restrict oxygen supply to embryo below the minimum needed for germination. Kidd and West (1920) found in Brassica alba - Rahenh, and Pisum sativum L, that removal of testa from unripe seeds terminated their dormant condition. Dormancy in these cases was largely attributed to limitation of gaseous exchange by the living testa. Davis (1930) observed that in ambrosia seeds the nucellar tissue restricts oxygen supply and causes dormancy.

Cox et al (1945) found in cabbage that fresh seed coats inhibited germination by processes other than restricting gas exchange. Extracts from seed coats of partially dormant seeds retarded germination thus indicating the presence of germination inhibitors. Randalph and Cox (1943) also obtained similar results. Walhood (1956) reported the presence of germination inhibitors as the cause of dormancy in hard seeds

of cotton.

Crocker (1916) suggested that some seeds are held in a dormant state because the force of the expanding contents is not sufficient to rupture the coats. Crocker and Davis (1914) showed that the swelling embryos of seeds of water plantain pressed against the coat with considerable force which was still insufficient to break the coat. Croker et al (1946) experienced that removal of a portion of the shell over the radicle region allowed germination in walnuts which suggested that the mechanical strength of the coats prevented germination.

B. Role of embryo in seed dormancy.

Stokes and Hull (1930) found that seed dormancy in runner peanuts is inherent in the seed and not in the seed coat. Davis (1930) observed that dormancy of Ambrosia trifida is in the embryo eventhough the fruit and seed coats enforced on the embryo a period of induced or secondary dormancy more pronounced than the primary dormancy. Borthwick (1931) suggested that dormancy in carrot seed is caused by rudimentary embryos. Choate (1940) reported that in wild encumber dormancy is due to conditions within the embryo. Porter (1949) found that dormancy due to immature embryos can often be overcome by after ripening. Crocker and Barton (1957) are of opinion that in most cases of seeds which respond to moist low temperature pretreatments, dormancy is due to the embryo though in certain cases it is due to a combination of a hard coat and a dormant embryo. In a study of the inter-varietal reciprocal

hybrids of Papaver rhoeas L, Harper and McNaughton (1960) found that seed dormancy is determined by an interaction of embryonic and extra-embryonic factors.

Huntamer (1934) found low germination of new seed of Oryzopsis hymenoides (Roem. and Schult) Ricker, to be due to mechanical restraint by the seed coat and to embryo dormancy. Toole (1940) and Plummer and Frischknecht (1952) also obtained results indicating the existance of both seed coat and embryo dormancy in this grass. Dawson and Heinrichs (1952) in Stipa viridula Trin, found two kinds of dormancy. Physiological, which was largely overcome by prechilling moistened seed prior to germination and mechanical, which required a breaking down of the seed coat before germination took place. Sprague (1936) on the basis of observations made on maize kernels produced by hetero-fertilization suggested that the mechanism inhibiting normal germination of freshly harvested seeds is due to the geno-type of the scutellum.

Johnson (1935-a) made extensive studies on the nature of dormancy in oats. Whether the cause of delayed germination was embryonic or nonembryonic was attacked from three angles.

1) In crosses between Avena fatua L, and Avena sativa L, using the former as female parent, the hybrid seeds germinated much earlier than those on the parental stock of Avena fatua L. It was concluded that germinability was brought about through the influence of dominant sativa genes in the hybrid embryo.

2) Segregation for germinability was observed among

seeds of single F_1 plants.

3) Hulling grains of Avena fatua L, had no appreciable effect on germinability. But breaking seed coat over the embryo results in a marked stimulation of germination. On the basis of these evidences Johnson concluded that delayed germination was due to a condition of the seed coat which develops after fertilization under the influence of the genotype of the embryo.

Butany (1958) cultured under artificial conditions excised embryos of freshly harvested oak grains of 4 varieties of rice giving only 1 to 2% germination. These embryos germinated within 12 hours, thereby showing that dormancy is due to causes residing in parts of grains other than the embryo. Butany and Gangadharan (1958) found that eventhough hulling improved germination, it does not break dormancy in all varieties, thereby indicating that the embryo or seed coat is at least partly responsible for dormancy. On the other hand Namboodiri (1960) found that the hybrid grains behaved like those of the dormant parent as to germinability immediately after harvest and suggested that the cause of seed dormancy lies in the embryo.

(v) Stage of maturity in relation to seed dormancy.

Arber (1934) reported that grains of various cereals possessed the power of germination long before their maturity. Walker (1933) and Culpepper and Moon (1941) obtained satisfactory germination for immature seeds of sweet corn.

Sprague (1936) found that field corn seeds harvested 10 days after fertilization were capable of germination. Bartel(1941) recorded that seeds of a few wheat varieties and one barley variety germinated satisfactorily when collected 16 days after flowering. Harlan and Pope (1922) Harlan (1926) and Nutman (1941) reported that immature grains of barley removed from plants as early as five days after fertilization germinated readily. Similar results were obtained in rye by Gregory and Purvis (1938), Nutman (1941) and Hatcher and Purvis (1945). These investigators were interested only in finding out the earliest stage of development of the embryo for germination and so the extent of drying after harvest or the time elapse between harvest and germination test, were not taken into consideration.

Ponnaiya (1944) found that grains of Periamanjal - Cholam harvested during the early milk stage i.e. 12 to 16 days after flowering were capable of germination. Germination was obtained when the grains were dried and tested after a resting period of 7 months but not immediately after harvest. It was concluded that a minimum development period of 14 days after flowering is required by grains to germinate.

Titus (1940) found that seeds which normally require a low temperature pretreatment for germination or possessing impermeable coats failed to exhibit any dormancy when immature i.e. just past the milk stage. In sweet clover, Helgeson (1932) reported that slightly immature seeds have permeable seed coats and gave high percentage of germination.

But as a final step in maturity of seed, the seed coats became impermeable thus reducing germination in mature seeds. Conversely in wheat, Wellington (1956-a) found that no grain germinated so long as the layer in the pericarp containing chloroplast remained in tact. Germinability was brought about when this layer disintegrated during ripening.

According to Larson et al (1936) the period of dormancy in wheat, oats and barley is partly dependant on the stage of maturity of the seed. The period of dormancy was found to be longest in immature seeds. Cutting plants when seeds are unripe increased the dormancy period. McAlister (1943) showed in pasture grasses that both initial level and duration of dormancy are inversely related to degree of seed maturity at harvest. Differences of a few days in harvest date can make relatively large differences in the level of dormancy. Schaaf (1960) suggested that in Stipa viridula - Trin, dormancy is influenced by the stage of maturity of the seed at harvest. Schaaf and Rogler (1960) also obtained similar results. Pope and Brown (1943) showed that very dormant varieties of barley can be made to germinate in the head by placing moist filter paper on the embryo of the immature grain.

Crocker (1920) reported that drying hastens after ripening of rice grains collected at the milk or yellow ripe stage. Grains harvested at the milk ripe stage gave satisfactory germination only when dried for 15 days. Similar results were obtained by Koshimizu (1936) who reported that a decrease of

water content of unripe corn brought about germination. However, in wheat, Scholz (1933) found that after ripening is not associated with moisture content of the grain.

(vi) Variation in dormancy period.

Arber (1934) suggested that in grasses there is normally a period of seed rest before germination. Crocker and Barton (1957) are of opinion that after ripening period varies with the species. It is considered to be longest in oats, shorter in barley and wheat and shortest in rye. Early ripening varieties require a shorter period than late ripening ones. Generally for all varieties the period is shorter in dry than in wet seasons.

According to Larson et al (1936) the period of primary dormancy in wheat, oats and barley depends on the stage of maturity of seed, temperature of storage, winter or spring habit of plants and the variety used. Several workers, quoted by Christidis (1955), in their studies on dormancy in cereals also came to the same conclusion. Coffman and Stanton (1938) found that seeds of Avena sterilis L, and Avena fatua L, were slow in germination after harvest. Garber and Quisenberry (1923) found variation in degree of dormancy among different strains of Avena fatua L. Larsen et al (1936) suggested that in Avena sativa L, dormancy period of any considerable length was found only in late varieties and that winter wheats generally had a shorter rest period than spring wheats. But Scholz (1933) could not find

any relation between the length of afterripening period and spring or winter habit. Laude (1949) found that the intensity of delayed germination in the seeds of California oat grass varies from one seed crop to the next. Rogler (1960) observed that in Oryzopsis hymenoides (Roem. and Schult) Ricker, germination of seeds of individual plants within a geographic strain showed wide variation.

(Vii) Genetics of dormancy.

Stockes and Hull (1930) observed that in groundnut, dormancy of the runner type is incompletely dominant over nondormancy of the spanish type. The period of dormancy in the hybrid is intermediate between those of the two parental types. John et al (1948) also suggested that dormancy of spreading varieties is incompletely dominant over nondormancy of bunch varieties and that the character is governed by multiple factors. In interspecific hybrids of Papaver, Harper and McNaughton (1960) found that the hybrids lack dormancy even when both the parental species possess dormancy and suggested that the physiologic and genetic mechanisms for determination of dormancy in the parent species are different and neither complementary nor supplementary.

Crocker and Barton (1957) suggest that dormancy in grains of cereals is caused by genetic factors or by the environmental conditions at the time of growth and maturation of the fruit. Miller (1938) found it reasonable to consider that dormancy is the result of a combination of both hereditary and environmental factors. Schaaf (1960) observed that dormancy in Stipa viridula Trin. is heritable.

Dormancy in this grass was found to be influenced by the environment and also be the interaction of genotype and environment. Schaaf and Kegler (1960) also obtained similar results. They found that interpretation of segregation was difficult due to the relatively large genotype environment interaction involved.

Harrington and Knowles (1939-'40-b) suggest that inheritance of sprouting resistance in wheat is governed by more than one gene. They recorded transgressive segregation and obtained progenies more resistant to sprouting than the resistant parent. Crocker and Barton (1957) considered that maturing during rainy weather as the cause of dormancy in barley. But Brown at al (1948) demonstrated that barley dormancy is a genetic character when varieties from a world collection showed the same relative dormancy when grown under different climatic conditions and in different years. In a genetic analysis conducted by Freistedt (1935) on the F_2 of four crosses of spring barley, dormancy proved to be recessive. In one cross one factor seemed to be involved and in the other cross two factors.

Garber and Quisenberry (1923) found that in crosses between Avena sativa L., and Avena fatua L., dormancy of the latter species behaved as an inherited recessive. Johnson (1935-b) found in interspecific crosses of Avena that all the F_1 seeds germinated three months after harvest when seeds of Avena sativa L., parent gave practically 100% germination and seeds of Avena fatua L., parent failed to germinate.

These results suggested that dormancy of Avena fatua L; is genetically recessive to germinability of Avena sativa L. On the basis of further studies on the F_2 and F_3 embryo generations Johnson came to the conclusion that germinability is inherited as a dominant character on the basis of three factors of essentially equal potency. With the exception of the triple recessive all other genotypes are potentially germinable. Embryos having six dominent alleles (AAAAAA)-sativa type, germinate shortly after harvest. As time goes on embryos with a progressively smaller number of dominant alleles become germinable. Finally the triple recessive (aaaaaa)-fatua type will germinate. There would be considerable overlapping of periods when germination occurs in successive types. The germinative potentialities of different genotypes thus vary with time elapsing between harvesting and testing.

Mangelsdorf (1926) showed that a number of genetic factors are involved in the inheritance of premature germination in maize. These factors operate at various stages in the development of the seed and differ in some of their effects. All are alike, however, in forcing the seed to germinate before development has been completed. Mangelsdorf (1930) found that in all crosses the parental types reappeared in the F_2 endosperm generation. He suggested that at least 15 different genetic factors and 9 distinct characters are involved in the inheritance of premature germination. Six of the characters are the result of complementary factors involving two or three genes.

The remaining three characters are governed by duplicate triplicate and quadruplicate factors. In the first case seeds will germinate prematurely whenever any one of the dominants is lacking; in the latter case they will germinate only when all are lacking.

In rice only little is known on the inheritance of seed dormancy. Shanmugasundaram (1953) concluded that dormancy is a dominant character. Germinability of grains on F_1 plants was studied and found that 10 out of 13 F_1 groups gave a germination of less than 5% at harvest time. Parents involved in different crosses differed in the degree of resistance to sprouting. The F_2 and F_3 of different crosses also differed in germinability. So it was concluded that the inheritance is not simple and more than one gene and certain modifiers are involved. Namboodiri (1960) did extensive work on the genetics of seed dormancy in rice. He found that the hybrid grains behaved like those of the dormant parent with regard to germinability immediately after harvest, indicating that dormancy is inherited as a dominant character. However, the possibility of an intermediate nature of the grains for germinability was suggested. A study of the F_2 grains revealed significant differences between individual families in their initial sprouting values. This difference was attributed to the action of a system of modifiers. A clear cut segregation into two classes was not observed in the F_2. F_3 germinability showed continuous variation and no definite grouping of individuals into distinct classes was possible.

On the basis of these evidences it was concluded that dormancy is controlled by either multiple genes or by one or two major genes and a few modifers. Transgressive segregation was also indicated.

(viii) Dormancy in rice.

Most of the short duration varieties of rice do not require a period of dormancy as a prerequisite for proper germination.(Narasinga Rao and Shamugasundaram, 1951). Ramiah (1937) recorded with few exceptions that short duration varieties are capable of germinating immediately after harvest and that long duration varieties require a resting period. Mudaliyar and Sundararaj (1954) also obtained similar results. Lord and Fernando and Chalam (1954) found that the longer the duration of a variety the longer was its period of dormancy. Quick growing varieties may require no resting period. Parija et al (1940) stated that winter paddy do not germinate immediately after harvest. Dore (1955) could not find any correlation between duration and dormancy in the 21 varieties of Malaya tested. According to Sahadevan (1959) the association between dormancy and duration is not universally true. An association was found to some extent in the case of cultivated autumn rices but was practically absent in the winter varieties and also in wild rice - Oryza sativa var. fatua. He also recognised variation in dormancy period between dormant varieties. Matsuo (1957) suggested that Japanica type rice seeds require no dormant period.

Narasinga Rao and Shanmugasundaram (1951) tested 9 departmental strains and 140 types of duration 80 to 120 days and found that only 22 out of 149 gave below 5% germination immediately after harvest. These were considered as dormant varieties. Subsequent tests at periodic intervals revealed that among these dormant varieties themselves, there is variation for the period of dormancy. Such variations between dormant varieties was also noted by Namboodiri (1960).

PART. II.

ORIGINAL INVESTIGATION

I N T R O D U C T I O N

Induction of a short period of dormancy into the reputed short duration varieties of rice is a problem of current interest to rice breeders. An understanding of the causes, nature and genetics of dormancy is an essential prerequisite for an efficient breeding programme. The present investigation is directed to understand these basic aspects of the character.

Rice grain is a fruit consisting of the hull and seed coat of purely maternal origin and embryo and endosperm of biparental origin. In the selfed grain of a pure variety all these tissues are genetically identical. But in a grain of hybrid origin the hull and the seedcoat are of the maternal genotype, whereas the embryo and endosperm represent the F_1 generation. This difference by one generation will be repeated in subsequent segregating generations. The tissue actually responsible for dormancy is of paramount importance in fixing up generations in a hybridization programme.

Opinion differs as to which tissue in the rice grain is responsible for dormancy. Namboodiri (1960) gave a reasonable suggestion that dormancy is due to causes resident in the embryo. On the other hand Sahadevan (1959) considers that dormancy is a function of the hull. Butany and Gangadharan (1958) also suggested that the cause of seed dormancy lies to a great extent in the hull.

Moreover, Butany (1958) found in embryo culture studies that embryos of four types of rice are capable of germination under artificial conditions, when their grains gave only 1-2% germination. The causes of seed dormancy and the tissues responsible for it are to be understood clearly.

The delaying effect of hull on germination has been recorded by a number of investigators. (Parija et al 1940, Chalam, 1954, Chalam and Behera, 1956, Sahadevan, 1959). But whether this effect is due to the presence of inhibitory substances or purely mechanical, remains to be understood.

Previous investigators generally agree that seed dormancy in rice is complex in inheritance. Shanmugasundaram (1953) and Namboodiri (1960) suggested the operation of more than one gene and a set of modifiers. The latter author indicated the operation of multiple genes as an alternate possibility. The mode of inheritance and the number and nature of genes involved have to be established on the basis of detailed investigations.

Though the suggestion that dormancy follows a quantitative pattern in inheritance appears reasonable, the character is considered on a qualitative basis during investigations. The varieties and segregating populations have been classified into two groups viz.,dormant and nondormant or into three groups by introducing an intermediate semidormant class. This grouping into distinct alternate

classes is not in agreement with a quantitative idea. Again the basis on which these classifications are made differs with investigators. Shanmugasundaram (1953) considers varieties that show less than 5% germination at harvest time as dormant and others as nondormant. Butany and Gangadharan (1958) consider varieties that give upto 50% germination at harvest as dormant, those giving between 50 and 75% as semidormant and those giving more than 75% as nondormant. In all these cases the percentage of germination at the time of harvest forms the criterion for classification. A method for evaluation of dormancy and comparison of varieties in agreement with quantitative nature of the character is to be formulated.

In the present investigation, a method which estimates seed dormancy in terms of the number of days from flowering required for germination, is adopted. Such a method will provide data which could be subjected to biometric analysis. The varieties, hybrids and segregating generations are evaluated by this method.

M A T E R I A L A N D M E T H O D S

I. Material.

(i) Choice : This investigation is confined to the short duration (80 to 120 days) rice varieties. Shanmugasundaram (1953) and Namboodiri (1960) studied a number of varieties including both introduced types and local strains. On the basis of results obtained by them, three dormant and 3 nondormant varieties which showed maximum expression of the contrasting characters are selected for purpose of the present investigation.

Dormant types - T.568; T.1926; T.2105.

Nondormant strains - Co.10; Co.13; PTB.10.

The three nondormant varieties selected are reputed short duration strains. They are selected with the object of aiding the breeding programme for inducing dormancy now under progress in the various experimental stations. Seed samples obtained from the Paddy Breeding Station, Coimbatore formed the starting material.

(ii) Description of varieties : The salient features of the varieties selected for study are tabulated and given as Table I.

II. Methods.

A. Study of the six pure breeding varieties.

Period of dormancy : All the six varieties were raised during the crop season, October 1959 to February 1960 to

estimate the period from the date of flowering required by each variety for germination. Seedlings were planted in strips with spacing 1' x 6". At flowering, a large number of spikelets were marked for their flowering dates to get sufficient number of grains of the same stage of maturity for the conduct of germination tests. It takes 7 to 8 days for all the spikelets in a panicle to complete flowering. When germination of grains has to be studied at intervals of two days this variation in maturity of the spikelets within a panicle are likely to violate the results. To avoid this possible error, individual spikelets were marked for their flowering dates.

(1) Marking spikelets : Panicles in which a few spikelets at the top have flowered (usually on the second day of flowering of the panicle because a large number of spikelets open on the third day) were selected in the evening and all spikelets already opened were cut and removed. These panicles were then marked by blank labels. The next evening all spikelets that have not opened were removed from these panicles. The opened and unopened spikelets could be easily distinguished by holding the panicle against sunlight and seeing whether the anthers are present in side the glumes or not. Thus only spikelets opened on a particular day were retained on the panicle and these gave grains of the same stage of maturity. The blank labels were then replaced by date labels. About 100 panicles in each variety were so labelled to give sufficient

grains for periodic testing.

(ii) Germination tests : Germination tests commenced on the tenth day after flowering and continued at intervals of two days. A minimum number of 50 grains were tested every time. Panicles remaining on the plant at 30 days maturity were harvested and stored for further tests. Germination test in each variety was continued until 95% germination was attained. By this procedure, the period required from flowering to start germination and the total period required to give complete germination were obtained in respect of all the six varieties.

Germination tests were conducted on moist blotting paper kept in shallow zinc trays partially filled with sand. Grains were spread on the blotting paper and germination counts were taken daily upto ten days. A grain was considered to have germinated when the part of the lemma over the embryo ruptured and the radicle emerged out. All the grains that germinated upto the tenth day were taken to calculate the percentage of germination. A sample of 100% germinable grains of PTB.10 was kept in the tray to make sure that the conditions provided were favourable for germination.

The experiment was repeated with all the six varieties during the crop season, June to October 1960. Here germination was conducted on wet filter paper in petridishes. Germination counts were made only upto sevendays

because the previous season's work indicated that there is very little or no germination beyond seven days.

B. Hybridization programme :

(i) Crosses studied : Two sets of reciprocal crosses were made between nondormant and dormant varieties with the object of studying the inheritance of seed dormancy. In both the sets of crosses strain PTB.10 was used as the non-dormant parent. The two dormant parents were T.1926 and T.2105. The following crosses were effected.

Cross No.	♀ Parent.	♂ Parent.
I	PTB.10	T.1926
II	T.1926	PTB.10
III	PTB.10	T.2105
IV	T.2105	PTB.10

(ii) Technique of crossing :- The parental varieties were planted in alternate rows 2 feet apart. In each row the seedlings were planted in singles one foot apart. The wet cloth method of emasculation and hand pollination were adopted. A panicle which has started flowering the previous day was selected from the female parent line and all flowered spikelets were cut and removed. The wet cloth was then loosely wound round the panicle and hot air was blown down through the top hole of the cloth cylinder. The increase in temperature and humidity in the cloth chamber created a condition for the spikelets to open before the time of normal anthesis. After about 5 to 10 minutes a

large number of spikelets open and the cloth was then removed. The unburst anthers dangling outside were carefully removed with a pair of pointed forceps. About 20 to 25 emasculated spikelets were retained on the panicle and all the other spikelets removed. The panicle was covered by a thin cloth bag supported by bamboo stakes.

Two or three panicles from the male line were cut and removed into the wet cloth. The spikelets were opened by blowing. A few minutes after the panicles were taken out of the cloth, the anthers started dehiscing. The dehisced anthers were then removed by the forceps, directly brought inside the glumes of the emasculated spikelets and brushed over the stigma. The pollinated panicles were immediately bagged and labelled. After 3 to 4 days the cloth bag was removed to give normal conditions for healthy development of the grains.

(iii) Study of crossed grains : Crosses I to IV were made in October 1960 to produce hybrid seeds and to test their germination. The crossed grains were harvested at 30 days maturity and germination trials were conducted at intervals of 4 days, on moist filter paper in petridishes. Germination counts for the first two weeks were taken to calculate the percentage germination.

(iv) Study of grains on F_1 plants : Crosses I and II were made during the crop season July to November 1959 for the study of F_2 and F_3 generations. The crossed grains

were sown along with grains of the parent varieties in January 1960. The hybrid plants were identified and individually selfed. All panicles were marked for flowering dates. The date of flowering of a few panicles in the parent varieties was also marked.

Crosses III and IV were made during the crop season October 1959 to February 1960. Panicles on the F_1 plants and parental varieties were selfed and marked for flowering dates. Panicles from all hybrids and parents were harvested from the 20th day onwards and germination tests conducted at four days interval. Germination tests were made on wet blotting paper in zinc trays as before and daily counts made upto seven days. Tests were continued until all the hybrids and parents gave 95% germination.

(v) Study of grains on selected F_2 plants :- Three F_2 families in each of the crosses I and III were raised in strips along with the parental varieties. Within a strip, single seedlings were planted with a spacing of 1' x 6". When the plants have established well, one family each giving the maximum population in either of the crosses was selected. 30 plants were chosen from either of these families at random and labelled. All panicles on these 60 plants were marked for date of flowering. About 50 panicles each in the three parental varieties were also marked similarly. From the 20th day onwards one earhead each from from the sixty F_2 plants and the three parental varieties were collected at intervals of four days and their germination

tested. No earhead was given more than thirty days maturity. Tests were continued on each of the F_2 plants and the parental varieties until 95% germination was obtained.

As a general case whenever seeds were kept for germination a sample of 100 germinable seeds of PTB.10 was kept in the same tray to serve as a control.

C. Study of the role of hull :

(i) Effect of hulling : Hulled grains of all the six varieties were studied to understand the effect of hulling on germination. Spikelets were marked for flowering dates as done previously and germination tests started on the sixth day after flowering. AT this stage of maturity the endosperm was in the milky stage. Removal of glumes without injury to the kernal was difficult before six days of maturity and so tests could be done only from the sixth day onwards. Subsequent tests were conducted at two days interval until 95% germination was reached in each variety. Hulling was done with nails without injury to the embryo or the bran. Germination tests were conducted by placing hulled grains on wet filter paper in covered petridishes. A seed was considered germinated when the embryo showed visible expressions of expansion and emergence of radicle. Here also the experiment gave information on the period required from flowering to start germination, and the period required to give complete germination.

(ii) Nature of inhibition by the hull : Comparison of

the germination of normal (unhulled) and hulled grains gives an idea of the role of hull in delayed germination. The following two experiments were conducted to understand the nature of inhibition by the hull.

(a) Grains were selected at a stage of maturity when hulled kernals gave good germination but grains with hull gave only poor or no germination. A small portion of the lemma just above the region of the embryo was cut and removed. Germination percentage of such treated grains was compared with that of normal and hulled grains to know the effect of this treatment on germination. All the 3 nondormant and the 3 dormant varieties were subjected to this test.

(b) Hulls were collected from grains of the extreme dormant types, T.1926 and T.2105; Hulls of each type were mixed with hulled grains of Co.10, Co.13 and PTB.10 which were capable of good germination. Germination percentage of such kernals was estimated and compared with that of hulled grains of these varieties kept separately.

A combined study of the results of these two experiments would give clear indications as to the specific nature of the hull in delaying germination.

D. Analysis.

The data collected on germination of the pure breeding varieties and segregating populations were subjected to statistical analysis using the method of analysis of variance.

EXPERIMENTAL RESULTS

Results of work done to understand the nature, causes and mode of inheritance of seed dormancy in six varieties of short duration rice and their hybrids are presented here. Evaluation of the character is based on the percentage of germination estimated at periodic intervals from the date of flowering. Germinability is a character of the embryo and delayed germination may be due to causes resident within or outside it. As such it needs to specify correctly the generation of the embryo tested, to assess the character. This is more important in handling segregating generations.

A plant generation is commonly considered to constitute the different stages from seed to seed. But speaking strictly in terms of a sporophytic generation it is a matter of no controversy that a generation starts from the zygote and extends upto the formation of the spores through intermediate stages such as embryo, the vegetative phase and the flowering phase. So the embryo lodged in a seed does not belong to the same sporophytic generation as that of the plant bearing it but belongs to the next generation. Thus a seed is not bound to express a character similar to that of the sporophyte bearing it, when the character is dependant on the genotype of the embryo.

The importance of fixing generations while studying seed dormancy has been felt by previous workers such as Johnson (1935.b) in oats and Namboodiri (1960) in rice.

In the present work, reference to generations is made on the basis of the embryo generation. A seed and the plant it gives rise to, belong to the same generation in view of the fact that the active tissues of both share a common genotype without the intervention of a gametophytic generation. Thus a seed obtained by crossing belong to the F_1 generation; seeds borne on the F_1 plants represent the F_2 generation; seeds on F_2 plants represent the F_3 generation and so on.

A. <u>The period of dormancy in pure breeding varieties</u> :

Results of experiments conducted on germinability of grains of the six varieties under study in both the seasons are tabulated and given in table II. Any germination upto and including 5% is considered to be due to the operation of nongenetic factors and as such are taken as equivalent to no germination. For the same reason germination above 95% is taken to mean 100% germination. Thus in the table all germinations from 5 to 95% are recorded against the number of days after flowering. The starting point of germination in the table gives a direct information on the period of complete dormancy in respect of each variety. This period of complete dormancy is the period required to start germination over and above the normal maturity period of 30 days. Thus it can be seen that the three strains Co.10, Co.13 and PTB.10 do not possess any dormancy. (Plate I). Besides this, the type T.568 previously included in the dormant group does not show dormancy, eventhough it takes a

comparatively longer time to germinate than the 3 strains, in both the seasons. The remaining two types T.1926 and T.2105 are dormant in both the seasons, eventhough there is a seasonal variation for the period of dormancy.

Once germination is started all the varieties increase their percentage of germination in every successive test and sooner or later attain complete germination. This behaviour of slow but steady increase in germination percentage is characteristic of all the six varieties studied, irrespective of their being dormant or nondormant. This period, when falls outside the maturity level of 30 days, is referred to as the period of partial dormancy. It is interesting to note that this period of partial dormancy is comparatively longer in the dormant types T.1926 and T.2105 than in the nondormant ones in both the seasons.

The stage of complete germination lies outside the 30 days period of maturity for all the varieties in both the seasons. This cannot be taken as a criterion for classification or evaluation as it is of no practical significance.

In striking a comparison between the performance of the varieties in the two seasons, three features are apparent.

(1) The period from flowering to germination is more in the second season for the 3 types T.568, T.1926 and T.2105 whereas this period remains more or less the same in strains Co.10, Co.13 and PTB.10 in both the seasons.

(ii) The period to increase germination from 5 to 95% is slightly prolonged in the second season in all the varieties and the prolongation is more apparent in the case of PTB.10, T.1926 and T.2105

(iii) As a group the 3 strains Co.10, Co.13 and PTB.10 vary little between themselves in both the seasons. As regards the other 3 types, they differ among themselves within and between seasons in both complete and partial dormancy periods.

The germination data in both the seasons are subjected to a combined analysis adopting the analysis of variance method. Comparisons of varietal means are made within a season and between seasons. The interaction of varieties and seasons is also estimated. The varietal mean in this case denotes the average number of days from flowering required by one grain in a variety to germinate. The analysis of variance table is presented below :-

Analysis of variance.

Source.	D.F.	S.S.	M.S.	F.
Varieties	5	530266.87.	106053.37	1477.5**
Seasons	1	85210.45	85210.45	1188.5**
Interaction	5	67103.76	13420.75	187.0**
Error.	1188	85274.60	71.78	
Total.	1199	767855.68		

** Significant at 1% level of probability.

The varietal, seasonal and interaction effects are highly significant.

Summary of results.

i) Comparison of varieties.

Varieties.	Mean No.of days from flowering for one-grain to germinate.	S.E. of the Mean.	Critical difference ($P = 0.05$)
T. 2105	77.383		
T. 1926	67.583		
T. 568	37.478	0.5991	1.661
Co. 13	26.829		
Co. 10	26.227		
PTB. 10	25.860		

Conclusion:

T.2105 T.1926 T.568 Co.13 Co.10 PTB.10 .

T.2105, T.1926 and T.568 differ between themselves and from the other 3 strains. Co.13, Co.10 and PTB.10 do not show significant difference in germination. Considering the first 30 days from flowering as the period required for normal maturity, the first 3 types are dormant and the other 3 strains are nondormant. Among the 3 dormant types the period of dormancy varies.

ii) Comparison of seasons :

Season.	Mean No.of days from flowering for one grain to germinate.	S.E. of the Mean.	Critical difference. ($P = 0.05$)
Season II	51.987	0.3430	0.959
Season I	35.133		

Conclusion : In the second season the period for germination is prolonged. Environment influences the

period of dormancy.

(iii) Comparison of interaction effects :

Mean number of days from flowering for one grain to germinate.

Seasons. \ Varieties.	T.2105	T.1926	T.568	PTB.10	Co.13	Co.10
I	60.594	47.148	31.120	25.336	23.302	23.300
II	94.172	88.018	43.836	26.384	30.356	29.154

Critical difference (P= 0.05) = 2.348.

(a)

Season.	Varieties.					
I	T.2105	T.1926	T.568	PTB.10	Co.13	Co.10
II	T.2105	T.1926	T.568	Co.13	Co.10	PTB.10

In the first season the difference in germination between the three nondormant strains PTB.10, Co.13 and Co.10 is not significant, whereas the three dormant types differ significantly between themselves and from the nondormant strains. In the second season there is no change in the groups viz., nondormant and dormant. But the sequence of the three nondormant strains is different. Co.13 and Co.10 do not differ significantly and maintain the same relative status as in the first season. But PTB.10 differs significantly from both and is early in germination. The relative positions of the three dormant varieties remain the same in both the seasons. (Figure. I).

(b)

Varieties.	Seasons.	
T.2105.	II	I.
T.1926	II	I.
T. 568	II	I.
PTB.10	II	I.
Co. 13	II	I.
Co. 10	II	I.

Germination is delayed in the second season for all the six varieties but the difference is not significant in the case of PTB.10.

B. Dormancy in hybrid and segregating generations.

This part of the study serves a dual purpose. It gives information on :-

(a) the tissue responsible for dormancy, and

(b) the inheritance of dormancy.

i) F_1 generation : Details of hybrid grains obtained.

Cross No.	♀ Parent.	♂ Parent.	No.of spike-lets crossed	No.of grains obtained.
I	PTB. 10	T.1926	132	97
II	T. 1926	PTB.10	185	121
III	PTB. 10	T.2105	116	82
IV.	T. 2105	PTB.10	169	131

The percentage germination of crossed grains in these four crosses and that of the parents are presented in Tables III-A and III-B. In all the four crosses it can be seen that the periods required for germination by the crossed grains lie between the corresponding periods for the parental varieties.

Deviation of germinability in these crossed grains from the selfed ones on the parental varieties is a direct evidence for the fact that germinability of rice grains is governed by the genotype of the embryo. Again, the crossed grains are intermediate to the parental ones in germinability which means that there is no dominant recessive relationship between the contrasting characters. (Figure.III). It suggests either incomplete dominance or the quantitative nature of inheritence. An analysis of the F_1 data is not attempted because some of the crossed grains tested may not be hybrids.

ii) F_2 generation : Grains on each F_1 plant are tested for germination. Here the panicles instead of the spikelets are marked for flowering dates and germination tests conducted at intervals of 4 days. These two changes from the former procedure are made in view of the limited quantity of grains available when each plant is to be taken separately to determine the period of dormancy. The parental varieties are also evaluated on similar lines.

a) PTB.10 x T.1926 and reciprocal : The cross was successful only with PTB.10 as the female parent. Eleven grains were obtained. The hybrids were raised along with the parental varieties in January 1960. Nine out of the eleven plants were identified to be hybrids. By the end of the season there was scarcity of water in the field and so grains did not set properly. Germination of grains on these plants could not therefore be estimated.

b) PTB.10 x T.2105 and reciprocal : Nine crossed grains obtained were raised together with the parental varieties in July 1960. Seven out of the 9 plants proved to be hybrids.

No.of plants studied	PTB.10 x T.2105 ... 2 (Cross No.III)	
	T.2105 x PTB.10 ... 5 (Cross No. IV)	

Germination data obtained for these F_2 lines and the parental varieties are tabulated and given as table IV. The data can be interpreted on the following lines.

1. Comparison of the period from flowering to starting germination :

Period for parents.	PTB.10	... 20 days.
	T.2105	... 72 days.
Mid parental value.	...	... 46 days.
Mean of F_2 periods.	Cross No.III..	32 days.
	Cross No. IV..	37.6 "

2. Comparison of the period from flowering to complete germination :

Period for parents.	PTB.10	... 40 days.
	T.2105	... 120 days.
Mid parental value.	...	... 80 days.
Mean of F_2 periods.	Cross No.III..	88 days.
	Cross No. IV..	87.2 "

The mean value of F_2 lines is lower in the first comparison and higher in the second comparison than the corresponding

mid parental values. These comparisons, therefore, indicate that the grains on individual F_1 plants, representing the F_2 generation for germinability, show a greater variation than the mid parental limits. In all the lines the variation is more than that found in either of the parental varieties.

A comparison of the mean of F_2 lines to the general mean of the parents is also made adopting the analysis of variance method. Here the comparison is between the mean period required by one grain in the F_2 lines and in the parents for germination.

Analysis of variance.

Source.	D.F.	SS.	M.S.	F.
1. Parents vs F_2 lines	1	452.13	452.13	3.49
2. Between parents.	1	242040.99	242040.99	1866.30**
3. Between reciprocal F_2 lines.	1	250.08	250.08	1.93
4. Within the reciprocal F_2 lines.				
i) Cross No. III.	1	264.50	264.50	2.04
ii) Cross No. IV.	4	1020.26	255.06	1.97
5. Within groups (Error)	891	115549.88	129.69	
Total.	899	359577.84		

** Significant at 1% level of probability.

Conclusion :-

1) The general mean of the 7 F_2 lines is the same as the general mean of the parents.

2) The two parental means are different.

3) General mean of the F_2 lines in reciprocal crosses are the same.

4) Means of the F_2 lines within each of the reciprocal crosses are the same.

Thus the analysis of the F_2 data brings out two features. (Figure.III).

1) F_2 mean is the same as the general mean of the parents.

2) Variation in F_2 is more than that found in either of the parents.

iii) F_3 generation : Germination percentage of grains on randomly selected F_2 plants in one family each of the crosses I and III are tabulated along with the respective parental values and presented as tables V-A and V-B. It can be seen that all the 30 plants in either of the crosses lie in between the respective parental varieties for germinability. The F_3 lines show variation between themselves in the number of days required to start germination and also in the period required for complete germination. They show a continuous gradation bridging the gap between the parental varieties on either sides.(Plates II, III and IV). There is striking variation between these plants in their period of partial dormancy. In this sample of 30 F_3 lines each from either of the crosses, no single plant transgressed the parental limits for germinability.

C. Role of hull :

1) Effect of hulling : Germination percentages of grains of all the six varieties with and without hull are tabulated and presented as Table VI. The following informations are directly obtained from the table.

(a) Hulled grains germinate earlier than normal (unhulled) grains in all the six varieties irrespective of the variety being dormant or nondormant. (Plates V and VI). The earliness is apparent both for starting and completing germination. The starting point of germination in respect of strains Co.10 and Co.13 could not be traced because of the difficulty in removing the hulls, without injury to the kernal, prior to the six day period of maturity.

(b) There is not much difference between the six varieties in the period required by their hulled grains to start germination. The range of variation is 6 to 14 days, the extreme dormant type T.2105 requiring the maximum period. The small difference between varieties in this regard, though not apparent, is to increase the period in the same direction as the increase in dormancy period.

(c) The period between starting and completing germination of hulled grains is different in the six varieties. This period increases steadily from the nondormant to the dormant varieties. Even among dormant varieties the period is comparatively more in the extreme dormant ones.

(d) A comparison can be made between germinability of grains with and without hull in one and the same variety. (Figure.II). The period between starting and completing germination in the hulled grains is not in agreement with that in normal (unhulled) grains. In Co.10, Co.13 and PTB.10 the period required by hulled grains is less, in T.568 it is almost equal to, and in T.1926 and T.2105 it is greater than the corresponding period required by normal grains.

(e) In all varieties there is little or no difference in the time when the hulled grains give complete germination and normal grains start germination.

The data are analysed by adopting the analysis of variance method for comparison of varietal means.

Analysis of variance.

Source.	D.F.	S.S.	M.S.	F.
Varieties.	5	610704.35	122140.87	803.3**
Hull effect.	1	249846.80	249846.80	1643.2**
Interaction.	5	49823.12	9964.62	65.5**
Error.	1188	180637.79	152.05	
Total.	1199	1091012.06		

** Significant at 1% level of probability.

Summary of results.

1) The varietal means are significantly different.

2) Treatment	Mean No.of days from flowering for one grain to germinate.	S.E. of the mean.	Critical difference (P= 0.05).
With hull.	51.987	0.503	1.395
Without hull.	23.128		

Conclusion:

Hulled grains germinate much earlier than normal (unhulled) grains.

3) Comparison of interaction effects :

Mean number of days from flowering for one grain to germinate.

Varieties. / Treatment.	T.2105	T.1926	T.568	PTB.10	Co.13	Co.10
With hull.	94.172	88.018	43.836	26.384	30.356	29.154
Without hull.	56.398	35.192	17.462	12.962	8.694	8.060

Critical difference (P= 0.05) = 3.418.

(a)	Varieties.					
With hull.	T.2105	T.1926	T.568	Co.13	Co.10	PTB.10
Without hull.	T.2105	T.1926	T.568	PTB.10	Co.13	Co. 10

Hulled grains of Co.13 and Co.10 do not show significant difference in the period required for germination whereas the other four varieties are significantly different between themselves and ∕ from these two strains. The 3 dormant types have the same relative positions whether the grains ~~grains~~ are hulled or not. Hulled grains of PTB.10 changes its relative position in the series whereas Co.13

and Co.10 remain unchanged. This means that hulled grains of PTB.10 require a longer period for germination than those of Co.13 and Co.10 when normal grains of the same strain require only a shorter period than the other two.

(b) In all the six varieties, hulled grains require a significantly shorter period for germination than normal (unhulled) grains.

ii) Nature of inhibition by the hull : Germination data obtained from two experiments done in this connection are tabulated and presented as Table VII. The percentage germination of hulled grains and grains with glume cut over the embryo are practically the same in all the six varieties. (Plate VII). The small reduction in the latter case as compared to the former may be due to injury to the embryo during cutting of the glume. The percentage germination of hulled grains of the 3 nondormant strains remains practically the same whether mixed with hulls of dormant types such as T.2105 and T.1926 or not.

D I S C U S S I O N

Results obtained in the present investigation on the causes, nature and genetics of seed dormancy in six short duration varieties of rice and their hybrids may now be discussed.

i) Period of dormancy : Dormancy depends largely on the period between flowering and germination of grains and the different varieties show variation for this period. Grouping varieties into two distinct alternative classes such as dormant and nondormant eliminates the possible variation within the group. The period required for germination of a variety is subject to variation by environmental conditions. As such any grouping is only arbitrary and will not indicate the true relative positions of the varieties. Therefore, for purposes of estimation of dormancy and comparison of of varieties the period required by each variety for germination from flowering may serve as a useful criterion. A comparison of the six varieties taken up for the present investigation discloses the difficulty of grouping varieties into alternate classes for purposes of estimation of dormancy.

From a practical breeding point of view it is important to classify varieties as dormant or nondormant. This is usually done on the basis of the percentage of germination at the time of maturity. But this method of

estimation of the character will not provide information required for understanding the causes, nature and genetics of dormancy. So the period required for germination from the date of flowering is estimated. The data so collected will furnish information as to whether the variety is dormant or not. All varieties with the estimated period for germination less than the normal maturity period will be nondormant. Those which require a longer period for germination than the maturity period will not give any germination at harvest time and consequently will be dormant.

Apart from the intervarietal difference with regard to initial germination, the variation in germinability between grains of the same variety should also be taken into consideration for comparison of varieties. Germination data in Table II reveals that the intravarietal variation is not uniform in the different varieties studied. So the varietal mean which takes into account the inter and intravarietal variations will be a reliable estimate for comparison of varieties.

A comparison of the means, over the two seasons, of the six varieties reveals that the differences between the three nondormant varieties are not significant whereas the three dormant varieties differ among themselves and from the nondormant ones. But in the second season the nondormant strain PTB.10 shows a significant deviation from the other two strains of the same group. These results suggest that if a large number of varieties are evaluated on similar

lines there is the likelihood that the mean period for germination of those varieties show a continuous variation. For comparison of means, the inter and intravarietal variation in germinability have to be estimated and this points to the necessity of evaluating the character by tests at successive intervals from flowering, as adopted in the present investigation.

ii) Influence of environment on dormancy : It has been found that germination of all varieties except PTB.10 is influenced by seasonal conditions. In the second season, which is wet in comparison to the first dry season, all varieties except PTB.10 require a longer mean period for germination. The intravarietal variation is also more in the second season for all the varieties. This observation is in favour of the view expressed by Crocker and Barton (1957) that the period of dormancy is shorter in dry than in the wet seasons. Larson et al (1936) also recorded that when grains of cereals are stored under conditions of low temperature, the period of dormancy increased. But, in the present study it has been found that the period in the wet season is more irrespective of the variety being dormant or nondormant, eventhough the prolongation did not allow the nondormant varieties to get included into the dormant group. However, the seasonal influence does not appear to be uniform in all the varieties. The table for varietal means (page No.39) indicates that the differences observed in the periods required for germination in the dry and the wet

seasons is more in the three dormant varieties than in the two nondormant ones. Thus is appears that the dormant varieties show a differential response to seasonal variations.

iii) Role of the hull : A reference to table VI reveals that in all the varieties studied, hulled grains germinate earlier than the normal grains, thereby indicating that the hull by its presence imposes a delaying effect on germination. This delaying effect is present irrespective of the variety being dormant or nondormant. A comparison of the mean periods required by hulled and normal grains for germination also shows that hulling hastens germination in all the varieties.

Thus it may be concluded that the presence of hull in grains delays germination. This result is comparable to those obtained by previous workers such as Parija et al (1940) Chalam (1954), Chalam and Behera (1956), Narayanan and Lakshmanan (1952) and Sahadevan (1959). But the present investigations show that the delaying effect of hull on germination is not confined to dormant varieties but is present in all varieties irrespective of their being dormant or nondormant.

The nature of inhibitory action of the hull may now be discussed. Smith (1948) in wheat and Black (1959) in oats obtained evidence for the presence of germination inhibitors in the hull. In the present study it is seen that grains from which a small portion of the hull over the embryo ~~is~~

is removed give as good germination as the hulled grains. This is true in the case of all the varieties tested. The treatment effectively removes any mechanical resistance offered by the hull for the expansion of the embryo during germination. But the action of the hull through germination inhibitors, if any, will in no way be affected. Moreover, the presence of hull of the two dormant varieties did not influence the germination of hulled grains of the three nondormant varieties. These evidences suggest that the hulls of rice do not possess any water soluble germination inhibitors.

Butany and Gangadharan (1958) found that thickness of the hull did not influence dormancy. In rice the embryo has to press on the hull in the process of germination and actually the radicle finds its way out by piercing the hull. Germination of normal grains can take place only when the force exerted by the expanding embryo exceeds the breaking strength of the hull. The embryo, even when it is capable of germinating, may take some time to attain sufficient strength to rupture the hull in the normal process of germination. Removal of a small part of the hull over the embryo gives the same effect as removal of the whole hull from the point of view of this mechanical resistance. Thus it appears that the hull inhibits germination through mechanical resistance to expansion and growth of the embryo and this effect is present not only in the grains of dormant varieties but also in those of nondormant ones.

iv) Role of embryo : An intervarietal comparison of the mean periods required by hulled grains to germinate shows that all varieties except Co.13 and Co.10 are significantly different. Therefore, the embryos of different varieties require different periods for germination thereby indicating that they are mainly responsible for dormancy. This is contradictory to the views held by Ramiah (1937) and other early investigators who suggested that hulled grains have no dormancy.

The difference in periods required by hulled grains of dormant and nondormant varieties to start germination, is not apparent. But the period required by these varieties to give complete germination varies considerably. Hulled grains of dormant varieties, T.1926 and T.2105 require a comparatively greater period from start to complete germination than the corresponding periods in non-dormant varieties. This means that the intravarietal variation in germinability of grains is not uniform in the dormant and nondormant varieties. Therefore, the difference in mean period required by these varieties for germination is not due to a difference in initial germinability but is due to conditions brought about subsequently. As such the delayed germination of these dormant embryos is not due to their possessing any initial or primary dormancy but due to the slow progress in the changes to undergo before full germination is achieved. This may be comparable to the phenomenon of induced or secondary dormancy reported in other crop plants.

The role of embryo in dormancy can be further confirmed by the study of the behaviour of grains in the hybrid and in the segregating generations. Tables III-A and III-B show that germinability of hybrid grains obtained by crossing dormant and nondormant varieties differ from that of selfed grains on the female parental variety. Grains obtained in crosses using the dormant varieties T.1926 and T.2105 as female parents gave complete germination much earlier than the selfed grains on these parental varieties. Also grains obtained from crosses using the nondormant variety PTB.10 as the female parent gave little or no germination when selfed grains of this variety gave complete germination. These evidences strengthen the suggestion now offered that germinability of a grain is determined by the genotype of the embryo. Moreover grains on individual F_1 plants showed the characteristics of an F_2 population and those on selected F_2 plants behaved like F_3 lines for germinability. Thus pooling the informations obtained from the pure breeding varieties, the hybrids and segregating generations it is suggested that the embryos of grains are primarily responsible for germination and consequently dormancy. This finding is in agreement with the view of Namboodiri (1960) that the causes of dormancy are traceable to the embryo.

In hulled grains the seed coats remain in tact and therefore the performance of the varieties does not eliminate the possibility of a probable seed coat influence on dormancy. However, the information obtained from studies

on the hybrid and segregating generations clearly indicates the role of the embryo in determining dormancy. In the hybrid grain, the embryo represents the F_1 generation but the seed coat is maternal. These grains show germination characteristics different from that of the selfed grains on the female parent. In the F_2 and F_3 generations also germinability of grains behaves in accordance with the embryo generation. These evidences suggest that dormancy is determined by the embryo rather than by the seed coat.

It has been concluded that the differential behaviour of varieties as to germinability is controlled by the embryo. The cause of seed dormancy, therefore, lies primarily in the embryo and for purposes of the study of causes and inheritance of dormancy the embryo deserves greater attention. But it has also been pointed out that the hull by its mechanical obstruction imposes a delaying effect on germination in all varieties. The effects of the embryo and the hull work in an additive manner and the total effect thus produced decides whether the variety is dormant or nondormant. In a practical breeding programme, germination tests are made in grains with hull in tact and as such the delaying effect of hull may also be taken into consideration in such an investigation.

v) <u>Genetics of dormancy</u> : The dormant varieties taken up for the present work maintained the same relative status in both the seasons tried, thereby showing a genetic control over dormancy. Studies on hybrids and segregating popula-

-tions show that dormancy is heritable. But the period of dormancy varied between seasons suggesting the influence of environment over the character. It may be stated that dormancy in these short duration rice varieties is perhaps controlled by the genotype, environment and probaly also by the interaction of genotype and environment. This view may be likened to that expressed by Schaaf (1960) and Schaaf and Rogler (1960) on the basis of their studies on dormancy in grasses.

(a) Inheritance : The embryo being primarily responsible for the differential behaviour of varieties with regard to germination, the segregating generations for germinability may be fixed on the basis of embryo generations. Thus the hybrid grains represent the F_1 generation, grains on F_1 plants represent the F_2 generation, grains on F_2 plants represent the F_3 generation and so on.

Studies on the hybrid grains in two sets of reciprocal crosses between dormant and nondormant varieties reveal that the hybrid is intermediate to the parents with regard to germinability. Variation in germinability among hybrid grains of the same cross is not more than that found in selfed grains of the parental varieties. Hybrid grains in all crosses behaved uniformly with regard to their intermediate nature and restricted variability in germination. There is no appreciable difference in germiability between grains obtained in reciprocal crosses.

Grains representing the F_2 embryo generation of reciprocal crosses III and IV satify the requirements of F_2 populations in quantitative inheritance. The general mean of these F_2 families is the same as the general mean of the parents. General means of reciprocal F_2 families are the same and the means of individual F_2 families within a cross are also the same. Variability in the different F_2 families is almost the same but always more than that found in the parental varieties as well as in the F_1. The periods required for germination by grains representing the F_2 generation show continuous variation and cannot be grouped into distinct alternate classes. The F_2 variation overlaps with the parental values and actually bridges the gap between the two parental limits. Thus the F_1 and F_2 studies satisfy the criteria laid for quantitative factors and therefore dormancy in these varieties can be said to follow a quantitative pattern in inheritance.

The study of 30 F_3 lines each in crosses I and III further confirms the quantative nature of the character. The F_3 lines chosen at random, bridge the gap between the parental varieties and show some sort of a continuous variation. The difference in initial germinability and variance in these F_3 lines as found in tables V-A and V-B further strengthens the evidence presented for the inheritance of dormancy as a quantative character.

This finding that dormancy in these short duration rice varieties follows a quantitative pattern in inheritance is well in agreement with similar findings in oats by Johnson (1935-b).

Namboodiri (1960) observed that some of the F_3 lines gave a higher percentage of germination than the nondormant parent at the time of harvest. On the basis of this finding he suggested transgressive segregation. In the present investigation the germination percentage of grains of 7 F_2 families in reciprocal crosses III and IV have been estimated from start to complete germination at periodic intervals. The F_2 variation in all families overlapped with the parental variation but never exceeded the parental limits to give evidence for transgressive segregation. Moreover, germination of grains on 30 F_2 plants representing F_3 lines in each of crosses I and III is also estimated. The F_3 variability also extends well into the parental values but did not transgress the limits. The chances of expression of transgressive variation being much more in the F_2 than in the F_3 the evidence in the present study suggests that there is no transgressive segregation.

b) <u>Calculating the number of genes involved in dormancy</u> : The number of gene differences between two strains differing in a quantitative trait can be estimated by making assumptions that the multiple factors governing the character are independent in segregation, they show no dominance or epistatic

relations and have equal additive effects. The greater range of variability in the F_2 over that in the F_1 is taken as a measure in the estimation of the number of gene differences between the two parents. However, the assumptions such as equal additive effects of nonlinked genes, and their independence in action are not likely to be justified in actual cases. Moreover, homozygozity of all genes in one parental variety and of alleles of these in the other may not be valid in all cases. Therefore even the best calculations will give only a minimum estimate of the number of genes. An indirect method of calculation of the number of independently segregating factors through the estimation of heritability is also adopted in certain cases. A complex quantitative character may be governed in many cases by one or a few major genes whose action is modified by a set of modifying factors acting in a quantitative fashion. In any case the actual number of genes involved is difficult to calculate because of the complexity and interactions involved.

In the case of dormancy in short duration rice varieties, Shanmugasundaram (1953) suggested that the character is governed by more than one gene and possibly also by a set of modifiers. Namboodiri (1960) indicated that dormancy may be controlled by either multiple genes or by one or two major genes and a few modifiers. Evidence obtained in the present investigation suggest that the character is polygenic and its analysis is made difficult by the complex genotypic environ-

-mental interactions involved. The large seasonal variation for the period of dormancy is an indication of such interactions. However, the F_1 and F_2 of the cross T.2105 x PTB.10 and their parents being evaluated under the same set of environmental conditions, these data have been utilized for arriving at a minimum estimate for the number of gene differences between the two varieties. Following the method of calculation suggested by Sinnott, Dunn and Dobzhansky (1950) it has been found that a minimum number of three pairs of genes govern the inheritance of this character.

The chances of recovery of the parental forms in the F_2 population and F_3 lines can also be taken as an indication of the number of genes involved in a quantitative character. Even in the 30 F_3 lines in each of the crosses I and III, no parental forms are recovered. So it appears that atleast three pairs of genes are involved in both the dormant varieties.

Shanmugasundaram (1953) found variation in the degree of dormancy in the different varieties tested. Based on this evidence it was suggested that more than one gene and possibly also certain modifiers are involved in governing the character. Namboodiri (1960) also came to a similar conclusion on the basis of the variability observed in the different varieties and also the aberrant segregation observed in the F_2 families. The differences between F_2 families in initial sprouting values have been attributed to

the action of a system of modifers. But in the present study there is no significant difference in mean and variability between F_2 families of reciprocal crosses involving PTB.10 and T.2105 and also between families in the same cross. All the F_2 families more or less satisfy the requirements for the assumption of normality in distribution, characteristic of quantitative inheritance. The departure from normal distribution is not apparent in these F_2 families to suggest the operation of a few major genes and a set of modifiers.

S U M M A R Y

Work done in cereals and other crop plants on the factors related to seed dormancy (causes, tissues involved, stage of maturity at harvest, variation in period and genetics), which are important from a practical breeding point of view, has been critically reviewed with special reference to rice.

Studies were undertaken on six short duration varieties of rice and their hybrids to estimate the period of dormancy, to understand the relative roles of the hull and the embryo and also to understand the mode of inheritance of the character. A new method was adopted in the estimation of dormancy. The period required for germination from flowering, determined by germination tests at periodic intervals, rendered a reliable estimate of inter and intravarietal variability for germination and formed the criterion for comparison of varieties and hybrids.

The important results of the present investigation are summarised below :

i) Germinability of varieties of rice is subject to variation under the influence of seasonal conditions irrespective of the variety being dormant or nondormant. The period required for germination and consequently the period of dormancy is more in a wet harvest season than

in a dry season. The dormant varieties show a differential response to seasonal variation.

ii) Hulling reduces the period required for germination in grains of all varieties whether dormant or non-dormant. So, the hull by its presence imposes a delaying effect on germination. Hulling does not break dormancy always. The magnitude of the effect depends on the stage of afterripening of the grain.

iii) Hulls of the six varieties studied, do not contain any water soluble germination inhibitors. The delaying effect of hull on germination appears to be mechanical. The embryos require a certain period, probably to pick up sufficient strength to rupture the hull in the normal process of germination.

iv) Varieties differ in the mean periods required by their hulled grains for germination, thereby indicating that the embryo is primarily responsible for dormancy. But this differential behaviour of the embryos may probably be induced or secondary. The direct embryonic control over dormancy is confirmed by observations on the grains representing the F_1 and F_2 embryo generations.

v) Evidence from the F_2 and F_3 distributions does not suggest the possibility of transgressive

segregation. Neither there is any indication for the operation of a set of modifiers.

vi) Studies on the F_1, F_2 and F_3 embryo generations reveal that dormancy is polygenic in inheritance. The F_1 and F_2 distributions suggest such an assumption. A minimum number of 3 pairs of genes is estimated to be involved in the cross between T.2105 and PTB.10. These genes may possibly have equal additive effects.

vii) The cause of seed dormancy in rice can be said to reside both in the embryo and the hull. The differential germinability of varieties is primarily determined by the embryo. But the effects of the embryo and the hull act additively to determine whether the variety is dormant or nondormant.

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TABLES

TABLE - I. Description of varieties.

Variety.	Origin.	Duration in days. upto flowering	Apiculus pigmented or not.	Panicle type	Lemma and Palea colours. (Ripe).	Grain size.	Kernel colour (pericarp)	Period of Complete dormancy.	
								Shanmugasundaram, 1953	Namboodiri 1960.
T.568 Americano Italy	Introduced	113	G P T	Compact.	Straw.	Medium, Bold.	White.	45 days.	40 days.
T.1926 O.sativa. Orrisa.	Introduced	102	G T	Open	Blackish brown	Medium, Bold.	White.	30 days.	40 days.
T.2105 British Guiana.	Introduced	108	G T	Compact	Straw	Long, fine.	White.	60 days.	50 days.
Co.10 Gobikar.	Pure line selection	97	G P T	Compact	Straw	Medium, Bold.	White.	...	...
Co.13 Arupatham-kodai.	Pure line selection	93	G P T	Compact	Straw	Medium, Bold.	White.	...	...
PTB.10 Thekken-Cheera.	Pure line selection.	83	G T	Compact	Golden with dirty furrows.	Medium, Bold.	Red.	...	...

G P T = Green with a purple tip.

G T = Green throughout.

TABLE - II.

Germination percentage of grains of the six varieties.

No.of days after flower-ing.	Percentage of Germination.											
	I Season : October 1959 to Feruaby, 1960.						II Season : June to October, 1960.					
	Co.10.	Co.13.	PTB.10.	T.568.	T.1926.	T.2105.	Co.10.	Co.13.	PTB.10.	T.568.	T.1926.	T.2105.
16	6.0	...	...	...	...	...	...	...	...	...	...	...
18	27.8	11.7	...	...	...	...	6.8	...	14.7	...	...	...
20	21.2	40.6	...	...	...	...	14.5	9.5	28.6	...	...	...
22	28.9	27.5	14.3	8.1	...	...	22.5	14.8	38.6	...	...	...
24	84.4	66.1	49.3	11.1	...	...	34.9	21.2	60.0	...	...	...
26	70.5	92.9	87.9	13.2	...	...	49.1	25.8	41.5	...	...	...
28	93.3	94.0	90.0	36.0	...	...	41.1	33.9	71.1	...	...	...
30	94.0	93.8	91.7	36.9	...	...	49.3	61.6	68.4	...	...	...
32	91.7	95.0	96.7	85.5	...	...	66.4	50.0	63.0	5.3	...	...
34	94.4	97.9	...	80.0	7.1	...	76.3	81.4	86.2	7.1	...	...
36	97.1	....	...	88.0	10.2	...	81.1	84.0	88.2	18.5	...	...
38	...	...	...	86.8	18.0	...	92.3	88.4	91.2	32.3	...	...
40	...	...	...	91.7	24.0	...	96.5	95.9	96.8	41.4	...	...
42	...	...	...	100.0	37.8	...	...	...	...	50.8	...	...
44	...	...	...	...	53.3	...	...	...	...	57.5	...	...
46	...	...	...	...	53.3	...	...	...	...	62.5	...	...
48	...	...	...	...	56.3	...	...	...	...	70.0	...	...
50	...	...	...	...	68.0	...	...	...	...	81.8	...	...
52	...	...	...	...	41.7	11.9	...	...	...	88.8	...	...
54	...	...	...	...	80.8	32.6	...	...	...	92.2	...	...
56	...	...	...	...	87.9	20.7	...	...	...	95.7	...	...
58	...	...	...	...	93.8	56.5	...	...	...	...	...	...
60	...	...	...	...	94.7	70.3	...	...	...	...	...	...
62	...	...	...	...	78.3	79.3	...	...	...	...	...	...
64	...	...	...	...	93.8	80.3	...	...	....	...	...	...
66	...	...	...	...	96.6	71.1	...	...	...	...	...	...
68	...	...	...	...	...	75.0	...	...	...	...	...	...
70	...	...	...	...	...	80.4	...	...	...	...	...	...
72	...	...	...	...	...	83.9	...	...	...	....	....	...
74	...	...	...	...	...	90.2	...	...	...	...	5.2	...
76	...	...	...	...	...	91.7	...	...	...	...	8.5	...
78	...	...	...	...	...	96.1	...	...	...	...	19.2	...
80	...	...	...	...	...	...	...	...	...	...	34.3	9.4
82	...	...	...	...	...	...	...	...	...	...	42.9	22.9
84	...	...	...	...	...	...	...	...	...	...	46.8	18.5
86	...	...	...	...	...	...	....	...	...	...	53.4	30.6
88	...	...	...	...	...	...	...	...	...	...	55.2	35.6
90	...	...	...	...	...	...	...	...	...	...	60.5	39.3
92	...	...	...	...	...	...	...	...	...	...	62.2	57.9
94	...	...	...	...	...	...	...	...	...	...	62.5	54.2
96	...	...	...	...	...	...	...	...	...	...	67.0	67.6
98	....	...	...	...	...	...	...	...	...	...	70.8	68.8
100	...	...	...	...	...	...	...	...	...	...	75.0	70.1
102	...	...	...	...	...	...	...	...	...	...	79.8	78.0
104	...	...	...	...	...	...	...	...	...	...	78.9	82.9
106	...	...	...	...	...	...	...	...	...	...	87.5	86.0
108	...	...	...	...	...	...	...	...	...	...	93.8	84.5
110	...	...	...	...	...	...	...	...	...	...	94.7	87.5
112	...	...	...	...	...	...	...	...	...	...	98.1	93.5
114	...	...	...	...	...	...	...	...	...	...	...	88.6
116	...	...	...	...	...	...	...	...	...	...	...	96.4

TABLE - III-A.

Germination percentage of crossed grains and of selfed ones on Parental varieties.

Season : June to October 1960.

No.of days after flowering.	PTB.10.	PTB.10 x T.1926	T.1926 x PTB.10	T.1926.
20	28.6	...	...	...
24	60.0	...	...	...
28	71.1	...	...	...
32	63.0	5.0	...	...
36	88.2	38.9	...	...
40	96.8	66.7	10.5	...
44	...	60.0	43.8	...
48	...	58.8	40.0	...
52	...	83.3	70.6	...
56	...	100.0	86.7	...
60	...	...	88.2	...
64	...	...	...	...
68	...	...	...	...
72	...	...	...	...
76	...	...	...	8.5
80	...	...	...	34.3
84	...	...	...	46.8
88	...	...	...	55.2
92	...	...	...	62.5
96	...	...	...	67.0
100	...	...	...	75.0
104	...	...	...	78.9
108	...	...	...	93.8
112	...	...	...	98.1

TABLE - III-B.

Germination percentage of crossed grains and of selfed ones on Parental varieties

Season : June to October 1960.

No.of days after flowering.	PTB.10.	PTB.10 x T.2105	T.2105 x PTB.10	T.2105.
20	28.6	...	...	...
24	60.0	...	...	...
28	71.1	...	...	...
32	63.0	...	...	...
36	88.2	...	...	...
40	96.8	...	...	...
44	...	...	...	...
48	...	30.0	11.8	...
52	...	34.8	25.0	...
56	...	21.4	26.3	...
60	...	29.4	53.3	...
64	...	...	66.7	...
68	...	...	92.3	...
72	...	...	100.0	...
76	...	...	...	...
80	...	...	...	9.4
84	...	...	...	18.5
88	...	...	...	35.6
92	...	...	...	57.9
96	...	...	...	67.6
100	...	...	...	70.1
104	...	...	...	82.9
108	...	...	...	84.5
112	...	...	...	93.5
116	...	...	...	96.4

TABLE - IV.

Germination percentage of grains representing the F_2 families and those of parental varieties.

Season : June to October 1960.

No.of days after flower-ing.	PTB.10.	PTB.10 x T.2105.		T.2105 x PTB.10.					T.2105
		F_2.I	F_2.II.	F_2.III.	F_2.IV.	F_2.V.	F_2.VI.	F_2.VII.	
20	16.7	...	...	...	...	...	...	...	...
24	47.6	...	...	...	...	...	...	...	...
28	86.6	...	...	...	...	...	...	...	...
32	87.6	9.2	5.3	...	...	...	...	...	...
36	92.6	9.4	12.9	...	12.8	...	9.6	8.9	...
40	97.9	8.8	30.3	19.0	14.5	17.6	11.6	19.6	...
44	...	15.6	29.0	22.0	25.9	14.3	14.5	29.8	...
48	...	21.2	24.7	13.9	43.5	30.0	27.6	24.8	...
52	...	29.3	30.0	22.7	33.3	47.6	51.6	43.4	...
56	...	58.0	46.3	29.8	30.8	40.9	43.3	45.9	...
60	...	63.5	63.2	36.1	42.0	61.7	50.0	59.6	...
64	...	63.1	69.3	41.1	62.5	64.5	54.2	77.6	...
68	...	69.8	73.6	69.6	71.2	78.0	60.2	70.3	...
72	...	78.3	76.5	75.0	69.3	80.4	71.8	81.8	7.2
76	...	82.7	86.7	83.9	78.3	89.5	78.0	86.7	19.3
80	...	77.9	86.3	91.5	88.4	90.8	92.7	80.9	24.7
84	...	83.0	91.4	98.6	88.7	93.9	88.1	90.8	23.1
88	...	95.7	96.0	...	98.9	86.6	96.0	95.5	31.4
92	...	...	...	...	...	...	...	...	47.9
96	...	...	...	...	...	...	...	...	56.1
100	...	...	...	...	...	...	...	...	59.2
104	...	...	...	...	....	...	...	...	62.3
108	...	...	...	...	...	...	...	...	74.6
112	...	...	...	...	...	...	...	...	91.1
116	...	...	...	...	...	...	...	...	93.3
120	...	...	...	...	...	...	...	...	96.6

TABLE - V-A.

Germination data of grains on individual F_2 plants (F_3 generation)

Cross : PTB.10 x T.1926. Season : June to October 1960.

No.of days after flower-ing.	Parent PTB.10	F_2 plant numbers									
		I	II	III	IV	V	VI	VII	VIII	IX	X
		Percentage of germination.									
20	16.7	...	...	...	...	...	...	...	...	...	...
24	47.6	6.7	6.2	6.0	5.1	6.2	5.2	...	...	...	...
28	86.6	14.0	21.9	11.2	13.0	33.3	9.8	9.9	6.8	8.2	...
32	87.7	23.9	41.9	17.5	32.0	50.4	8.2	20.6	15.9	13.9	10.5
36	92.6	34.6	43.4	12.1	47.0	46.0	30.1	33.5	22.8	33.9	57.6
40	97.9	73.1	53.2	37.2	45.8	50.4	42.9	33.3	9.4	23.6	42.7
44	...	79.8	56.1	47.3	51.0	66.7	51.9	42.2	38.4	40.0	69.0
48	...	91.7	74.7	49.6	57.4	78.2	50.0	38.5	54.4	46.0	68.8
52	...	96.1	81.2	69.2	79.1	59.5	63.1	72.1	62.6	52.6	90.4
56	...	...	92.4	69.1	71.0	84.8	72.0	80.9	77.4	64.9	94.4
60	...	...	96.3	72.2	79.6	69.6	73.3	90.8	79.3	69.2	95.7
64	...	...	...	81.8	86.2	82.1	88.2	97.1	81.4	79.6	...
68	...	...	...	89.5	90.1	88.0	68.5	...	90.1	88.4	...
72	...	...	...	96.0	96.6	92.9	92.4	...	96.6	97.1	...
76	...	...	...	...	...	96.6	96.1	...	...	...	...
80	....	...	...	...	...	...	...	...	...	...	...
84	...	...	...	...	...	...	...	...	...	...	...
88	...	...	...	...	...	...	...	...	...	...	...
92	...	...	...	...	...	...	...	...	...	...	...
96	...	...	...	...	...	...	...	...	...	...	...
100	...	...	...	...	...	...	...	...	...	...	...
104	...	...	...	...	...	...	...	...	...	...	...
108	...	...	...	...	...	...	...	...	...	...	...
112	...	...	...	...	...	...	...	...	...	...	...
116	...	...	...	...	...	...	...	...	...	...	...
120	...	...	...	...	...	...	...	...	...	...	...
124	...	...	...	...	...	...	...	...	...	...	...

TABLE - V-A (continued)

Germination data of grains on individual F_2 plants (F_3 generation)

Cross : PTB.10 x T.1926. Season : June to October 1960.

F_2 plant numbers (F_3 lines).											
XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII
Percentage of germination.											
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
12.0	8.9	9.0	9.5	5.2	18.1	6.5	15.4	5.8	...	...	...
26.2	20.1	14.1	20.7	7.2	24.1	17.4	4.1	11.8	7.2	5.7	...
42.4	11.0	15.4	24.5	11.6	30.9	33.0	11.0	13.5	13.5	12.2	9.6
65.3	57.8	22.1	58.6	16.8	53.5	21.3	34.1	26.1	26.4	13.9	27.4
69.7	60.0	26.9	48.9	21.6	55.2	30.1	37.1	40.6	38.9	25.0	33.7
74.1	73.6	40.9	52.6	33.3	59.8	25.8	39.8	37.0	42.1	38.3	47.9
86.5	78.8	57.3	64.4	68.5	79.2	45.3	35.5	38.2	58.6	85.2	64.8
95.1	87.1	70.6	72.3	68.6	67.7	32.5	31.6	44.3	37.2	47.9	80.4
...	95.9	80.6	76.6	73.9	73.3	77.9	57.9	56.9	81.1	53.3	86.4
...	...	90.5	73.7	82.3	77.6	83.2	79.0	61.2	84.5	62.4	88.6
...	...	96.9	90.3	91.8	80.1	88.6	78.9	67.4	91.3	70.9	92.2
...	...	...	96.9	95.5	89.5	89.3	74.3	76.8	97.3	78.4	97.9
...	...	...	...	...	96.2	97.8	79.4	78.6	...	91.0	...
...	...	...	...	...	...	...	89.7	85.3	...	88.6	...
...	...	...	...	...	...	...	87.9	90.5	...	96.2	...
...	...	...	...	...	...	...	91.8	89.4	...	...	...
...	...	...	...	...	...	...	95.3	93.9	...	...	...
...	...	...	...	...	...	...	...	97.3	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...

TABLE - V-A (continued)

Germination data of grains on individual F_2 plants (F_3 generation).

Cross : PTB.10 x T.1926. Season : June to October 1960.

No.of days after flower-ing.	F_2 plant numbers (F_3 lines).								Parent T.1926
	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX.	
	Percentage of germination.								
20	...	...	...	...	...	...	...	...	...
24	...	...	...	...	...	...	...	...	...
28	...	...	...	...	...	...	...	...	...
32	...	...	...	...	...	...	...	...	...
36	...	...	...	...	...	...	...	...	...
40	11.9	5.3	...	...	...	...	...	...	...
44	32.3	19.5	8.3	14.1	6.1	...	...	...	...
48	44.9	32.0	16.4	43.5	11.9	5.7	...	...	...
52	26.4	41.3	33.0	34.0	23.8	13.6	9.3	6.9	...
56	61.1	51.0	71.0	40.6	42.9	17.5	16.1	12.4	...
60	72.2	57.3	60.2	57.2	48.8	41.2	20.8	17.1	...
64	76.9	61.2	68.0	64.8	54.7	67.5	19.0	27.6	...
68	78.0	79.3	73.2	74.5	63.0	63.6	30.2	30.1	...
72	83.9	78.9	80.0	77.8	74.1	69.6	43.9	28.1	...
76	88.7	88.5	91.1	91.8	68.9	78.5	58.1	29.1	6.3
80	95.6	96.9	96.5	97.1	75.3	90.3	58.8	59.2	9.6
84	...	...	...	...	79.6	96.9	69.8	81.7	18.9
88	...	...	...	...	82.5	...	71.9	83.9	24.1
92	...	...	...	...	85.2	...	77.6	82.2	40.7
96	...	...	...	...	92.5	...	80.8	76.5	40.8
100	...	...	...	...	97.2	...	90.4	81.3	44.8
104	...	...	...	...	...	...	95.7	91.7	59.0
108	...	...	...	...	...	...	...	96.2	63.7
112	...	...	...	...	...	...	...	...	75.1
116	...	...	...	...	...	...	...	...	89.6
120	...	...	...	...	...	...	...	...	92.7
124	...	...	...	...	...	...	...	...	96.6

TABLE - V-B.

Germination data of grains on individual F_2 plants (F_3 generation)

Cross : PTB.10 x T.2105. Season : June to October 1960.

No.of days after flowering	Parent PTB.10	F_2 plant numbers (F_3 lines).								
		I	II	III	IV	V	VI	VII	VIII	IX
		Percentage of germination.								
20	16.7	5.8	...	...	...	...	...	...	...	...
24	47.6	24.3	6.1	6.9	...	...	...	...	...	...
28	86.6	...	20.4	13.3	12.4	8.7	7.7	7.6	7.4	9.4
32	87.7	46.3	29.3	21.2	42.4	...	17.0	19.1	20.7	10.8
36	92.6	50.0	42.3	23.6	54.0	12.1	21.4	26.4	...	6.0
40	97.9	44.4	54.3	30.4	32.9	42.2	48.1	31.0	42.7	19.1
44	...	55.0	70.3	34.0	57.3	31.9	48.1	43.6	61.6	23.1
48	...	67.0	84.3	37.4	55.6	38.8	49.6	41.7	58.6	36.9
52	...	67.8	88.8	64.7	79.7	47.1	58.2	63.5	60.9	48.4
56	...	81.7	96.9	69.7	84.5	48.6	62.5	59.8	61.9	...
60	...	77.2	...	50.5	96.5	54.2	72.7	60.2	...	...
64	...	76.7	...	90.3	...	80.9	78.8	73.9	68.5	71.0
68	...	86.5	...	96.3	...	80.6	80.2	82.5	71.0	75.9
72	...	88.8	...	...	...	89.7	86.8	85.4	83.3	...
76	...	97.8	...	...	...	97.1	92.9	89.0	87.4	79.3
80	...	...	...	...	...	...	97.8	96.9	90.3	83.7
84	...	...	...	...	...	...	...	...	97.9	92.9
88	...	...	...	...	...	...	...	...	...	96.1
92	...	...	...	...	...	...	...	...	...	...
96	...	...	....	...	...	...	...	...	...	...
100	...	...	...	...	...	...	...	...	...	...
104	...	...	...	...	...	...	...	...	...	...
108	...	...	...	...	...	...	...	...	...	...
112	...	...	...	...	...	...	...	...	...	...
116	...	...	...	...	...	...	...	...	...	...
120	...	...	...	...	...	...	...	...	...	...
124	...	...	...	...	...	...	...	...	...	...
128	...	...	...	...	...	...	...	...	...	...

TABLE - V-B (continued).

Germination data of grains on individual F_2 plants (F_3 generation)

Cross : PTB.10 x T.2105. Season : June to October 1960.

F_2 plant numbers (F_3 lines).											
X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
Percentage of germination.											
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
5.3	...	...	...	...	...	...	...	..	...	...	...
11.2	8.2	5.7	...	...	...	...	...	...	...	...	...
12.7	13.5	10.1	5.2	17.4	5.5	8.7	...	...	...	...	...
...	12.4	14.2	15.7	20.9	8.6	22.7	6.7	6.1	7.3	9.9	6.3
18.8	30.3	...	22.4	18.7	15.8	27.8	24.1	11.7	6.8	15.5	12.5
18.9	41.7	33.7	19.3	25.7	8.3	11.3	32.1	24.1	...	14.8	18.3
26.3	38.6	35.3	38.9	48.2	20.2	39.3	51.1	43.9	17.1	28.3	32.6
20.0	50.4	39.2	43.8	38.6	26.2	27.9	54.0	50.4	30.9	32.9	35.2
36.3	59.8	41.9	60.2	55.3	...	28.9	58.1	56.1	41.3	58.4	41.7
48.3	67.6	...	77.6	68.4	57.8	41.5	72.9	61.2	...	51.5	50.6
61.1	69.9	47.6	86.6	72.4	64.1	50.0	76.1	77.8	57.3	57.6	61.6
...	76.7	...	90.5	79.0	69.5	58.1	84.2	78.8	68.0	60.7	72.3
74.0	76.9	62.4	97.8	84.9	86.0	72.4	88.5	83.5	77.6	69.3	78.5
84.3	83.7	77.5	...	91.2	83.0	81.0	98.1	88.1	80.4	73.8	82.3
93.5	89.6	87.3	...	96.6	91.0	91.7	...	93.8	91.2	76.4	84.2
90.9	72.9	...	...	...	96.8	98.9	...	97.2	87.1	87.1	86.5
98.9	92.3	94.5	...	...	...	...	...	...	96.2	95.1	90.8
...	96.4	90.0	...	...	...	...	...	...	...	...	96.7
...	...	92.8	...	...	...	...	...	...	..	...	...
...	...	97.3	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	..	...	...	...	...	...	...	...	...	...
...	...	....	...	...	...	...	...	...	...	..	...

TABLE - V-B (continued).

Germination data of grains on individual F_2 plants (F_3 generation)

Cross : PTB.10 x T.2105. Season : June to October 1960.

No.of days after flower-ing.	F_2 plant numbers (F_3 lines).									Parent T.2105
	XXII	XXIII	XXIV	XXV	XVI	XVII	XVIII	XXIX	XXX	
	Percentage of germination.									
20	...	...	...	...	...	...	...	...	...	...
24	...	...	...	...	...	...	...	...	...	...
28	...	...	...	...	...	...	...	...	...	...
32	...	...	...	...	...	...	...	...	...	...
36	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...
44	7.3	6.3	7.5	7.0	...	...	...	...	...	...
48	15.6	8.1	...	...	...	...	...	...	...	...
52	32.5	18.2	10.2	14.9	16.5	...	...	...	...	...
56	39.1	25.9	5.1	22.1	27.7	6.7	...	...	...	...
60	45.0	41.1	19.6	...	33.9	10.7	...	...	...	...
64	47.8	52.6	32.0	37.4	50.5	24.7	6.5	5.1	...	...
68	54.2	67.2	...	50.6	63.4	45.3	10.3	6.6	5.1	...
72	64.5	71.8	56.8	...	68.8	63.4	21.5	13.8	12.1	7.2
76	74.4	75.8	61.2	43.7	76.4	52.2	...	17.8	...	19.3
80	79.8	78.9	...	78.8	77.4	71.4	42.7	25.0	26.5	24.7
84	85.4	84.9	75.6	...	85.0	81.0	31.3	28.2	31.1	23.1
88	91.8	88.5	84.8	73.1	89.0	86.5	61.4	35.1	...	31.4
92	97.1	91.1	91.4	87.5	92.3	90.5	77.1	51.9	31.1	47.9
96	...	97.1	97.8	88.6	94.2	96.1	...	52.7	...	66.1
100	...	...	...	92.7	97.8	...	87.1	58.1	58.5	59.2
104	...	...	...	97.2	...	...	88.3	65.3	49.0	62.3
108	...	...	...	...	...	...	90.3	72.4	72.2	74.6
112	...	...	...	...	...	...	96.5	79.3	75.6	91.1
116	...	...	...	...	...	...	...	91.0	81.7	93.3
120	...	...	...	...	...	...	...	97.3	...	96.6
124	...	...	...	...	...	...	...	...	93.9	...
128	...	...	...	...	...	...	...	...	95.7	...

TABLE - VI.

Germination percentage of normal (unhulled) and hulled grains.

No.of days after flower-ing.	Percentage of germination.											
	Normal (unhulled) grains.						Hulled grains.					
	Co.10.	Co.13.	PTB.10	T.568.	T.1926.	T.2105	Co.10.	Co.13.	PTB.10.	T.568.	T.1926.	T.2105.
6	...	...	...	...	...	...	37.0	32.0	...	...	...	...
8	...	...	...	...	...	...	60.0	63.3	7.7	...	...	...
10	...	...	...	...	...	...	96.3	70.0	28.0	16.7	...	...
12	...	...	...	...	...	...	...	96.7	50.0	42.5	6.1	...
14	...	...	...	...	...	...	...	...	83.1	44.7	15.8	10.3
16	...	...	...	...	...	...	...	...	82.3	55.6	37.9	11.1
18	6.8	...	14.7	...	...	...	...	...	96.7	66.1	49.3	15.0
20	14.5	9.5	28.6	...	...	...	...	...	...	69.4	60.0	15.4
22	22.5	14.8	38.6	...	...	...	...	...	...	84.8	53.8	13.5
24	34.9	21.2	60.0	...	...	...	...	...	...	78.2	23.2	14.5
26	49.1	25.8	41.5	...	...	...	...	...	...	81.7	36.2	7.6
28	41.1	33.9	71.1	...	...	...	...	...	...	86.4	37.2	8.6
30	49.3	61.6	68.4	...	...	...	...	...	...	91.1	35.6	16.0
32	66.4	50.0	63.0	5.3	...	...	...	...	...	96.7	22.2	18.8
34	76.3	81.4	86.2	7.1	...	...	...	...	...	...	32.1	25.0
36	81.1	84.0	88.2	18.5	...	...	...	...	...	...	40.3	19.2
38	92.3	88.4	91.2	32.3	...	...	...	...	...	...	46.4	18.8
40	96.5	95.9	96.8	41.4	...	...	...	...	...	...	45.8	10.7
42	...	...	...	50.8	...	...	...	...	...	...	52.9	17.3
44	...	...	...	57.5	...	...	...	...	...	...	60.0	25.9
46	...	...	...	62.5	...	...	...	...	...	...	58.3	30.8
48	...	...	...	70.0	...	...	...	...	...	...	60.3	37.7
50	...	...	...	81.8	...	...	...	...	...	...	64.2	37.5
52	...	...	...	88.8	...	...	...	..1	...	...	66.7	38.9
54	...	...	...	92.2	....	....	...	...	...	...	72.2	41.1
56	...	...	...	95.7	...	...	...	...	...	...	67.2	40.3
58	...	...	...	...	...	...	...	...	...	...	75.4	45.2
60	...	...	...	...	...	...	...	...	...	...	76.9	47.5
62	...	...	...	...	...	...	...	...	...	...	62.7	48.5
64	...	...	...	...	...	...	...	...	...	...	78.8	52.8
66	...	...	...	...	...	...	...	...	...	...	80.5	57.8
68	...	...	...	...	...	...	...	...	...	...	81.1	55.2
70	...	...	...	...	...	...	...	...	...	...	91.2	60.3
72	...	...	...	...	...	...	...	...	...	...	93.9	65.2
74	...	...	...	...	5.2	...	...	...	...	...	97.0	73.2
76	...	...	...	...	8.5	...	...	...	...	...	...	79.2
78	...	...	...	...	19.2	...	...	...	...	...	...	82.4
80	...	...	...	...	34.3	9.4	...	...	...	...	...	87.9
82	...	...	...	...	42.9	22.9	...	...	...	...	...	98.5
84	...	...	...	...	46.8	18.5	...	...	...	...	...	...
86	...	...	...	...	53.4	30.6	...	...	...	...	...	...
88	...	...	...	...	55.2	35.6	...	...	...	...	...	...
90	...	...	...	...	60.5	39.3	...	...	...	...	...	...
92	...	...	...	...	62.2	57.9	...	...	...	...	...	...
94	...	...	...	...	62.5	54.2	...	...	...	...	...	...
96	...	...	...	...	67.0	67.6	...	...	...	...	...	...
98	...	...	...	...	70.8	68.8	...	...	...	...	...	...
100	...	...	...	...	75.0	70.1	...	...	...	...	...	...
102	...	...	...	...	79.8	78.0	...	...	...	...	...	...
104	...	...	...	...	78.9	82.9	...	...	...	...	...	...
106	...	...	...	...	87.5	86.0	...	...	...	...	...	...
108	...	...	...	...	93.8	84.5	...	...	...	....	...	...
110	...	...	...	...	94.7	87.5	...	...	...	...	...	...
112	...	...	...	...	98.1	93.5	...	...	...	...	...	...
114	...	...	...	...	...	88.6	....	...	...	...	...	...
116	...	...	...	...	...	96.4	...	...	...	...	...	...

TABLE - VII.

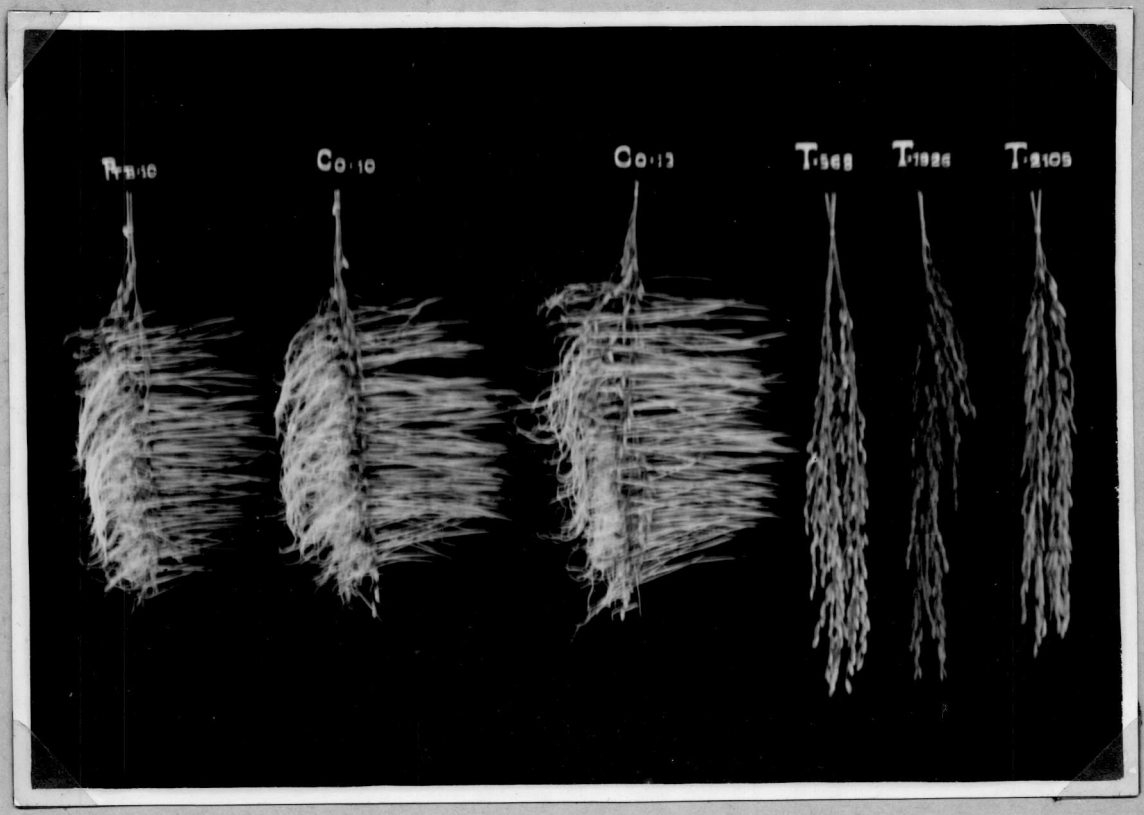
Germination data to show the nature of inhibition by the hull.

Variety.	No. of days after flower-ing.	Percentage of germination.				
		Normal grain.	Hulled grain.	Part of glume over embryo cut	Hulled grains mixed with hull of:-	
					T.1926.	T.2105.
Co.10	16	nil	96	94	92	94
Co.13	16	nil	98	96	96	94
PTB.10	16	nil	80	76	78	74
T.568	30	2	88	84	..	..
T.1926	70	nil	90	82	..	..
T.2105	70	nil	66	62	..	..

ILLUSTRATIONS

P L A T E. I.

Comparison of germinability of the six varieties.
(Germination tested 30 days after flowering).



PTB. 10 Co. 10 Co. 13. T.568. T.1926. T.2105.

PLATE. I.

P L A T E. II.

Comparison of germinability of earheads on parents,

F_1 and F_2 s.

Cross :--- PTB.10 x T.1926.

(Period from flowering to testing ... 40 days)

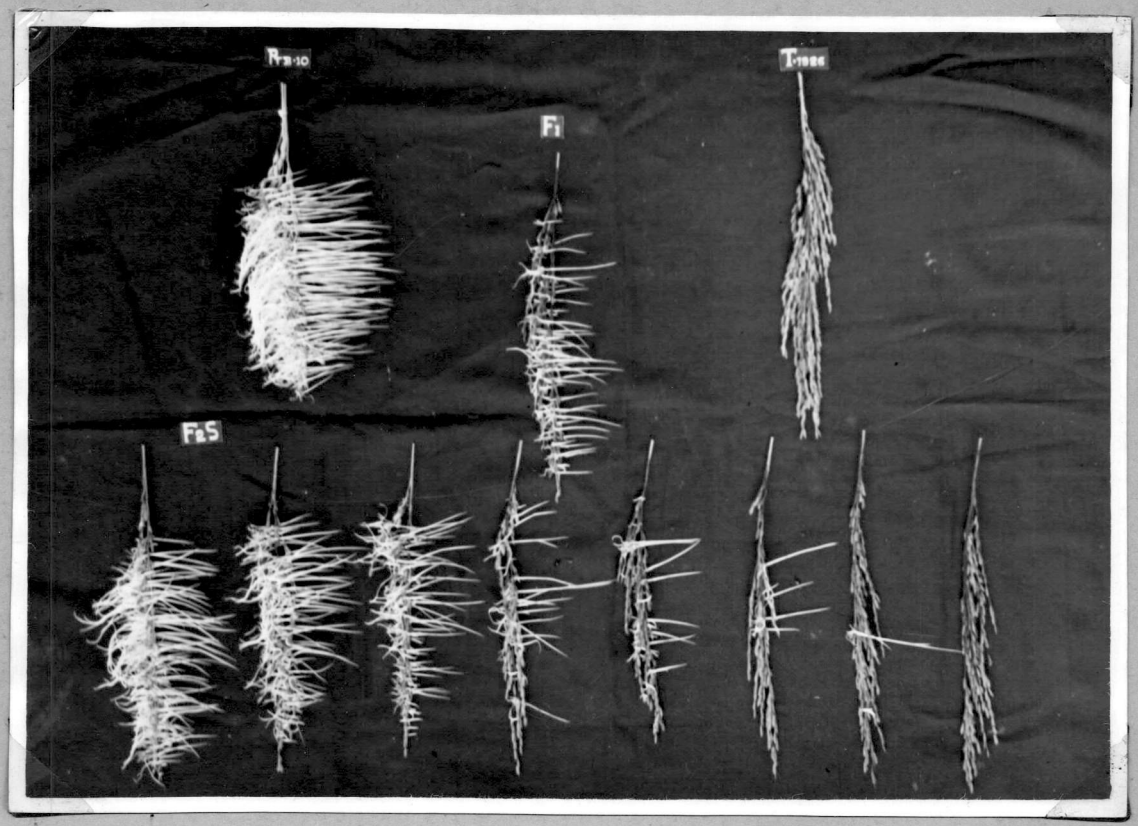


PLATE. II.

P L A T E. III.

Comparison of germinability of earheads on parents,

F_1 and F_2 s.

Cross :—— PTB.10 x T.2105.

(Period from flowering to testing ... 60 days).

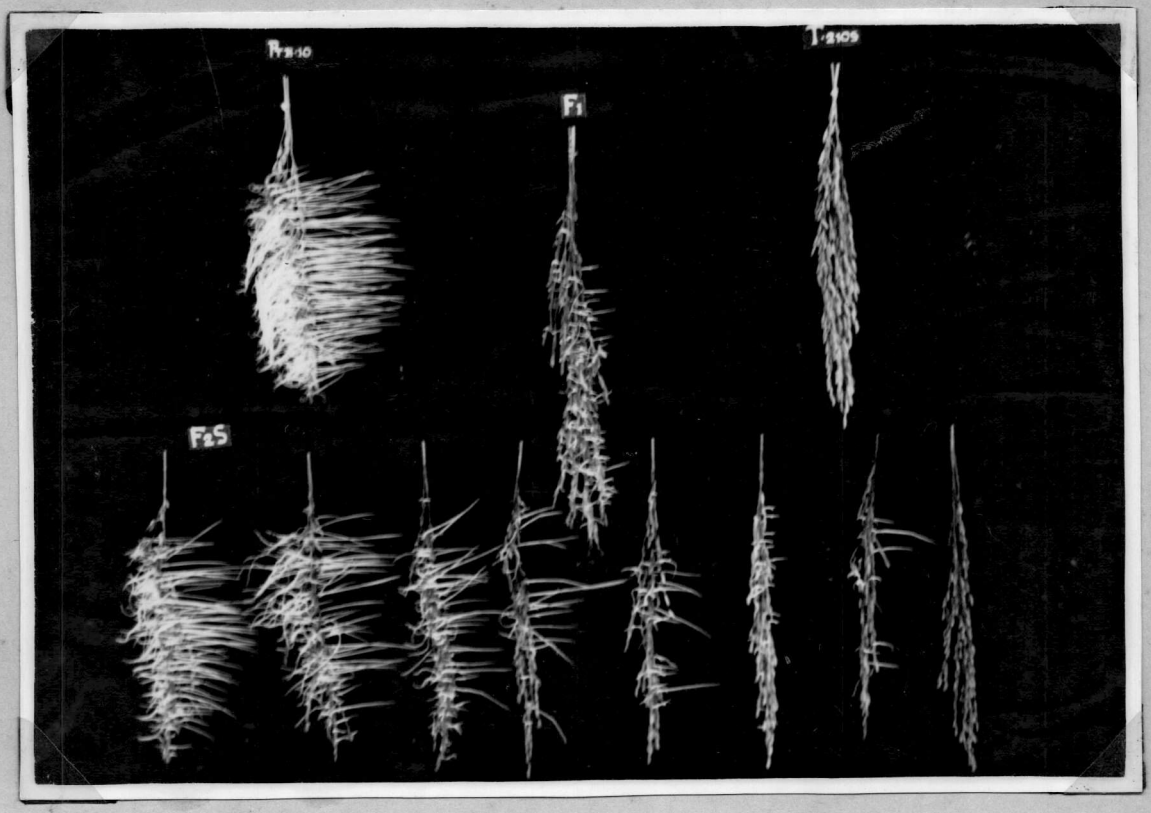


PLATE. III.

P L A T E. IV.

Variation in germinability and colour of grains from F_2 plants.

Cross :---- PTB.10 x T.2105.

(Period from flowering to testing ... 60 days)

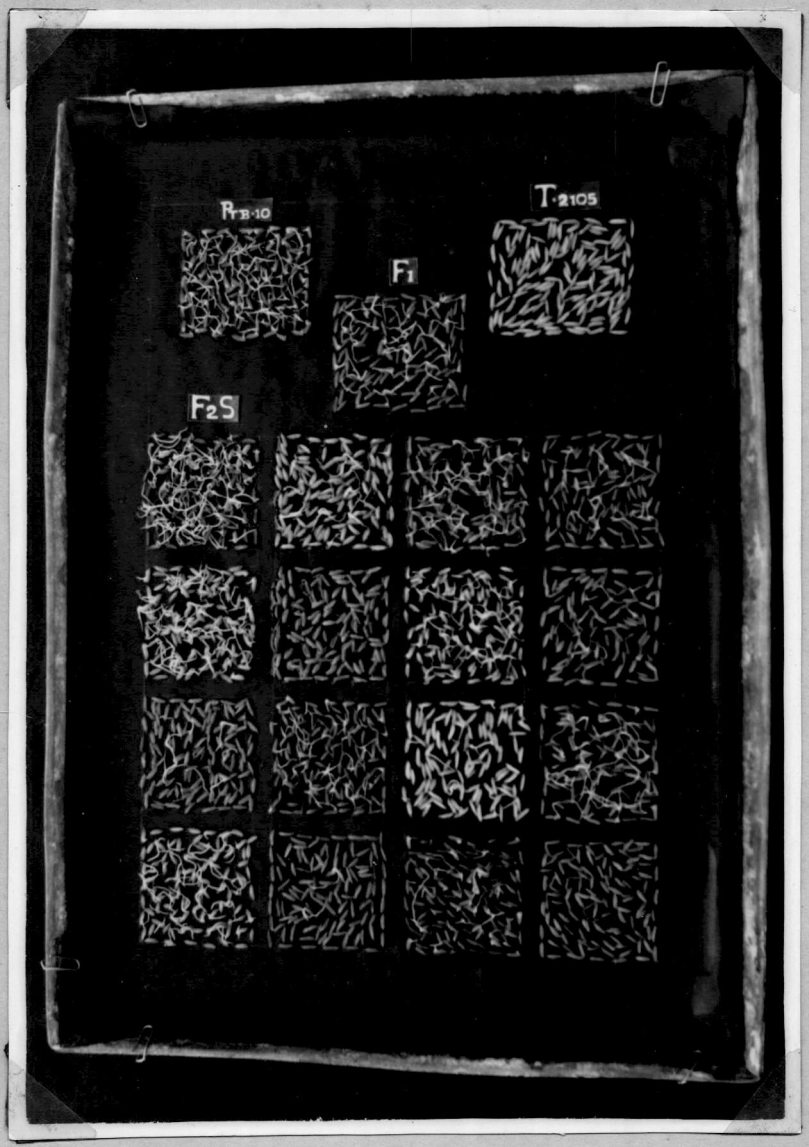


PLATE. IV.

P L A T E. V.

Comparison of germinability of hulled and normal (unhulled) grains of the six varieties.

(Delaying effect of hull on germination)

(Period from flowering to testing ... 14 days)

A -	PTB.10.	Hulled.	Good germination.
B -	CO.10.	Hulled.	Good germination.
C -	CO.13.	Hulled.	Good germination.
D -	PTB.10.	Unhulled.	No germination.
E -	CO.10	Unhulled.	No germination.
F -	CO.13	Unhulled.	No germination.
G -	T. 568	Hulled.	Little germination.
H -	T.1926	Hulled.	Little germination.
I -	T.2105	Hulled.	Little germination.
J -	T. 568	Unhulled.	No germination.
K -	T. 1926	Unhulled.	No germination.
L -	T . 2105	Unhulled.	No germination.

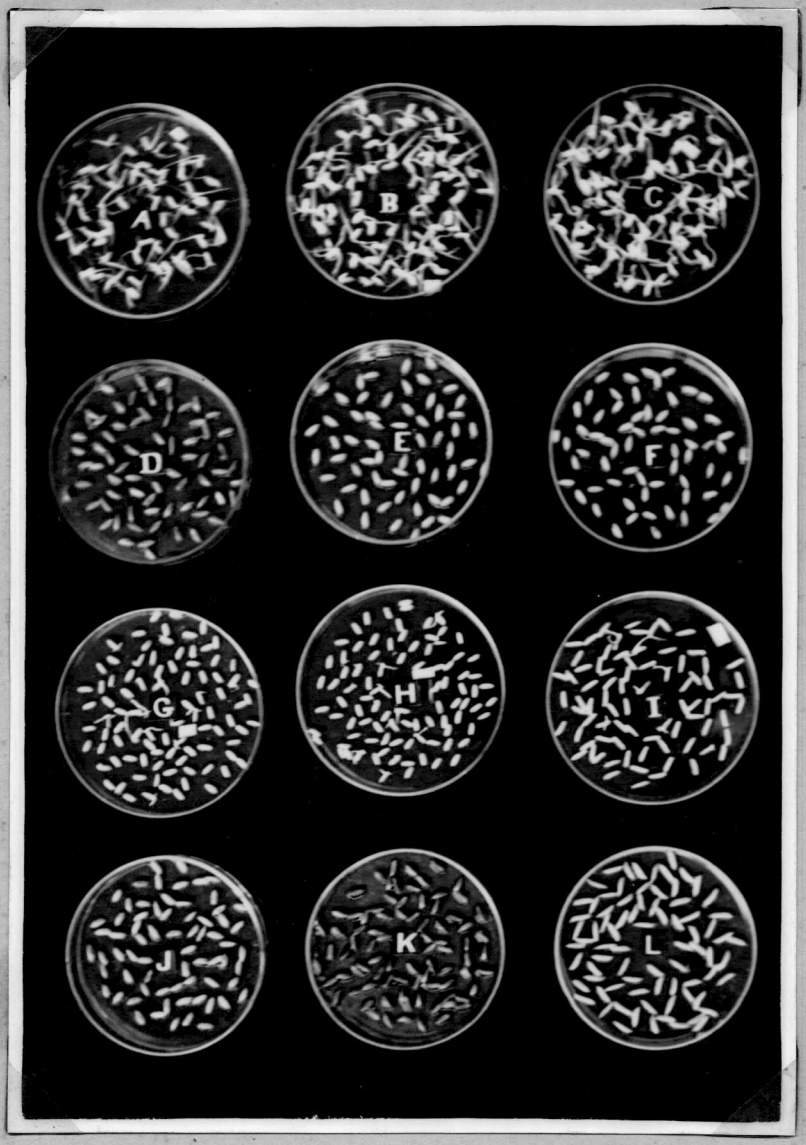


PLATE. V.

P L A T E. VI.

Comparison of germination of hulled and normal (unhulled) grains of six varieties.

(Difference in period required by varieties for germination).

			Period from flowering to testing.
A - PTB. 10.	Unhulled.	Complete germination.	40 days.
B - Co. 10	Unhulled.	complete germination.	40 days.
C - Co. 13	Unhulled.	Complete germination.	40 days.
D - T. 568	Unhulled.	No germination.	30 days.
E - T.1926	Unhulled.	No germination.	70 days.
F - T.2105	Unhulled.	No germination.	70 days.
G - T. 568	Hulled.	Complete germination.	30 days.
H - T.1926	Hulled.	Complete germination.	70 days.
I - T.2105	Hulled.	Complete germination.	70 days.

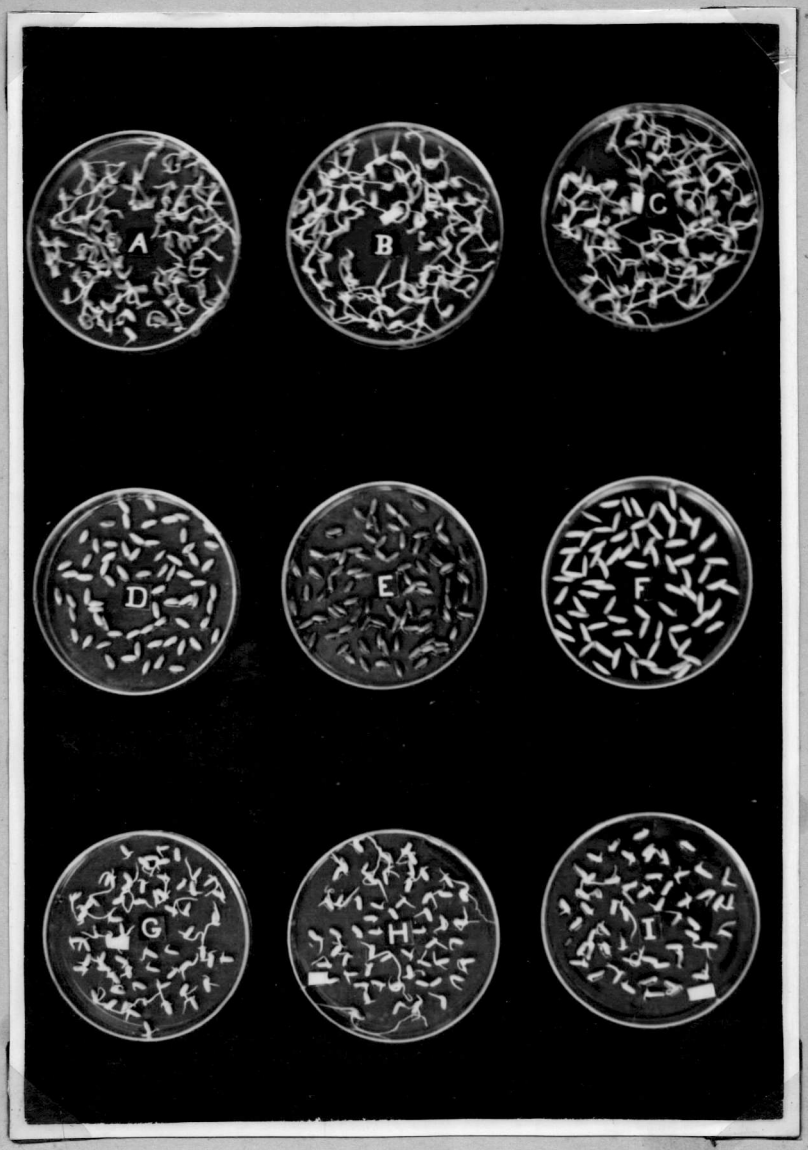


PLATE. VI.

P L A T E. VII.

Nature of the delaying effect of hull on germination.

(T.1926 and T.2105 tested).

A - Co. 10.	Hulled grain.	FUll germination.	Co.10 of same maturity.
B - A + hull of T.1926.		Full germination.	
C - A + hull of T.2105.		Full germination.	
D - T.1926.	Glume over embryo cut.	Full germination.	Same maturity.
E - T.1926	Unhulled grain.	No germination.	
F - T.1926	Hulled grain.	Full germination.	
G - T.2105	Glume over embryo cut	Full germination.	Same maturity.
H - T.2105	Unhulled grain.	No germination.	
I - T.2105	Hulled grain.	Full germination.	

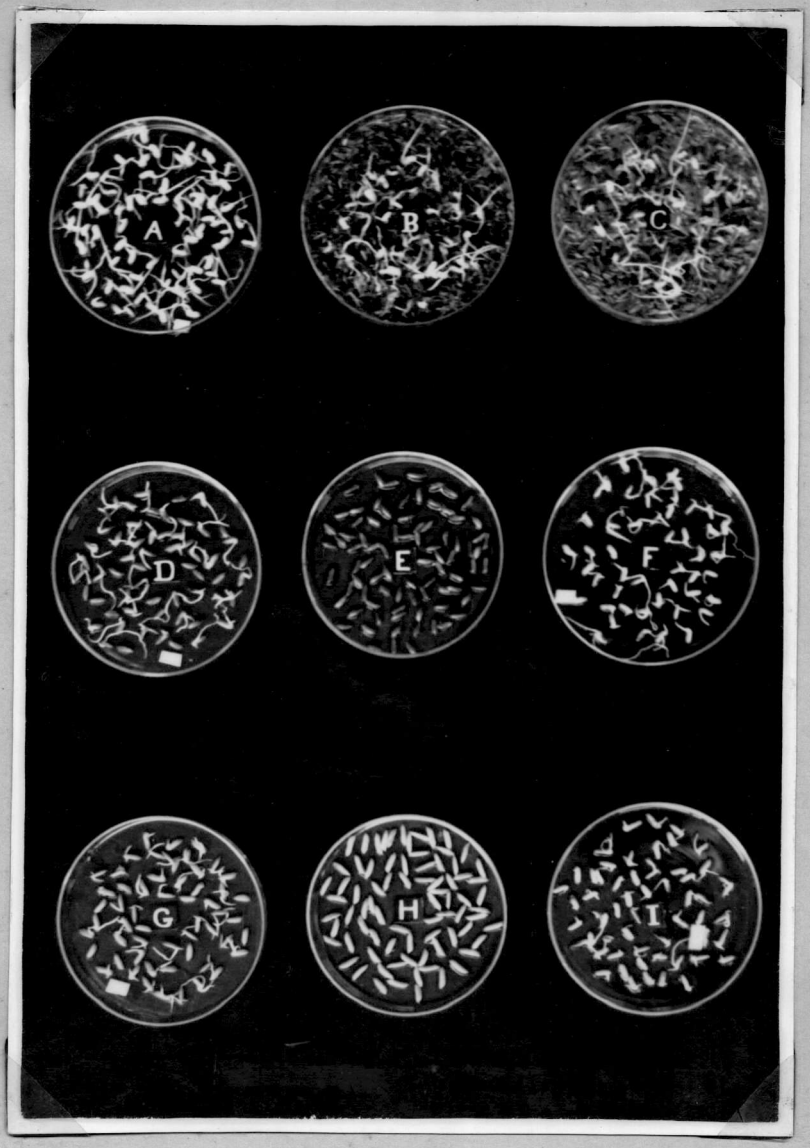


PLATE. VII.

F I G U R E. I.

Influence of seasonal variations
on germination.

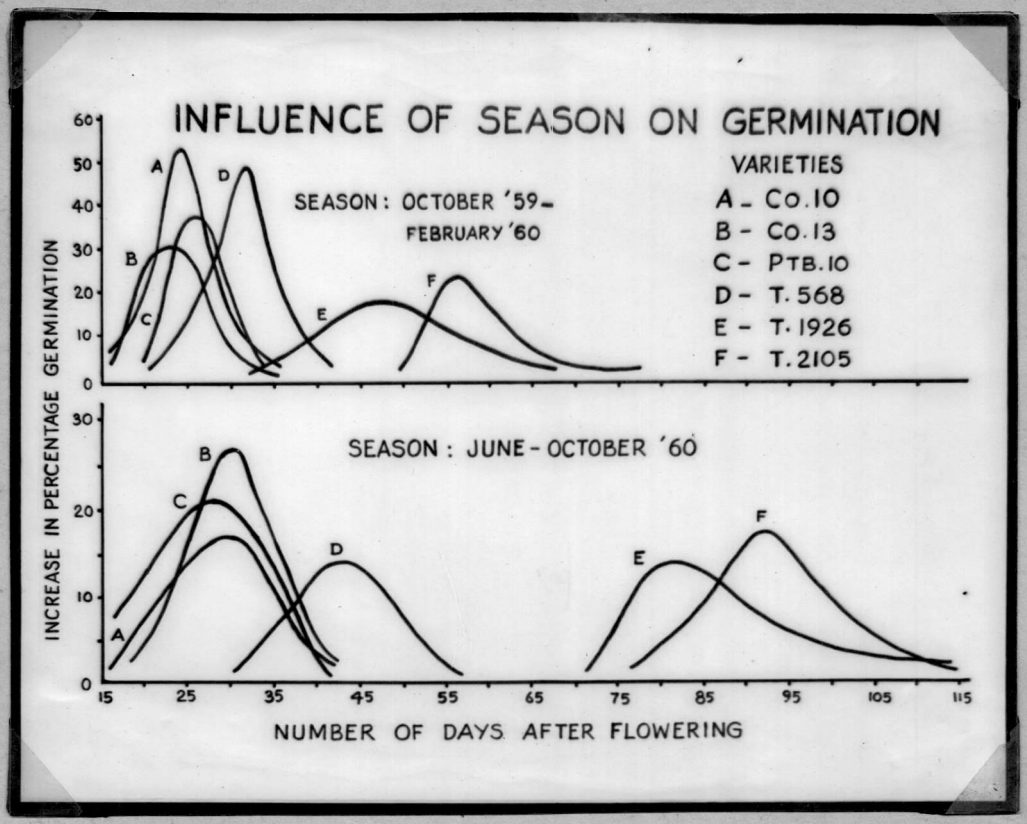

INFLUENCE OF SEASON ON GERMINATION
VARIETIES
A - Co.10
B - Co.13
C - PTB.10
D - T.568
E - T.1926
F - T.2105
SEASON: OCTOBER '59 - FEBRUARY '60
SEASON: JUNE - OCTOBER '60
INCREASE IN PERCENTAGE GERMINATION
NUMBER OF DAYS AFTER FLOWERING
0
10
20
30
40
50
60
15
25
35
45
55
65
75
85
95
105
115

FIGURE. I.

F I G U R E. II.

Effect of hulling on germination.

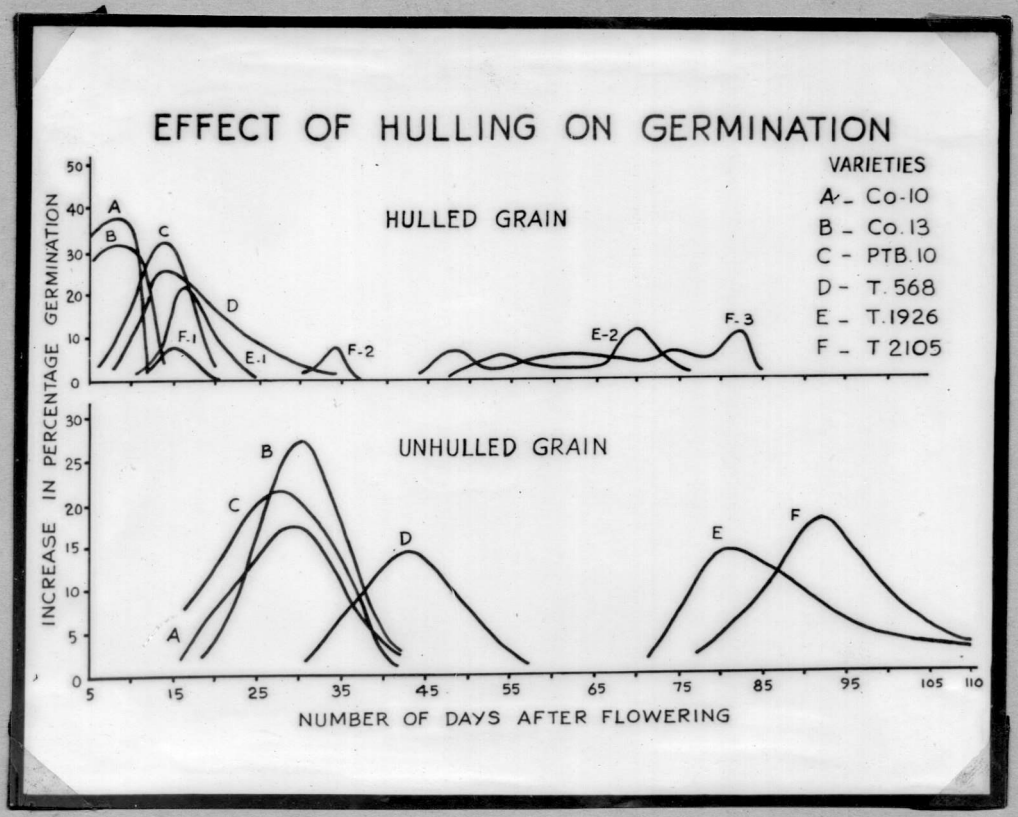

EFFECT OF HULLING ON GERMINATION
VARIETIES
A - Co-10
B - Co. 13
C - PTB. 10
D - T. 568
E - T. 1926
F - T 2105
HULLED GRAIN
UNHULLED GRAIN
INCREASE IN PERCENTAGE GERMINATION
NUMBER OF DAYS AFTER FLOWERING
A
B
C
D
E
F
F-1
E-1
F-2
E-2
F-3
0
10
20
30
40
50
5
15
25
35
45
55
65
75
85
95
105
110

FIGURE. II.

F I G U R E. III.

Inheritance of seed dormancy.

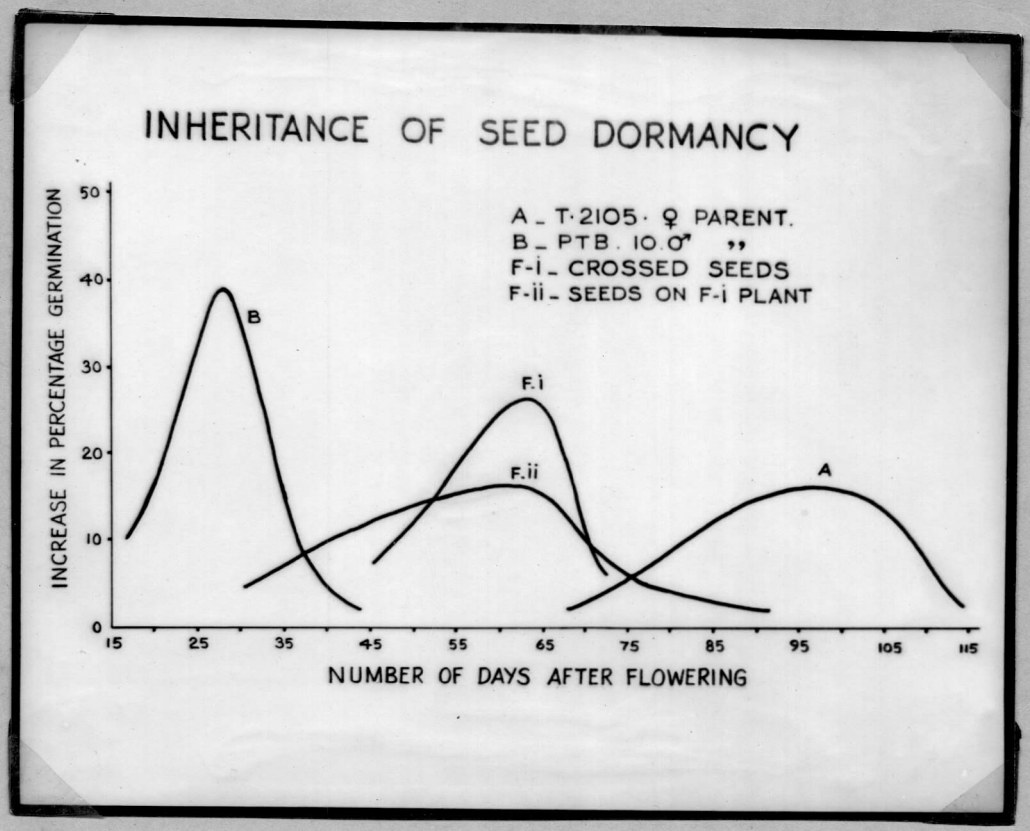

INHERITANCE OF SEED DORMANCY
A _ T·2105· ♀ PARENT.
B _ PTB. 10.0♂ ,,
F-i _ CROSSED SEEDS
F-ii _ SEEDS ON F-i PLANT
INCREASE IN PERCENTAGE GERMINATION
0
10
20
30
40
50
B
F.i
F.ii
A
15
25
35
45
55
65
75
85
95
105
115
NUMBER OF DAYS AFTER FLOWERING

FIGURE. III.