PROGRESS REPORT ON RUBBER SEED INVESTIGATIONS

G. P. KELENY* AND
ANTON J. H. VAN HAAREN†

ABSTRACT

The literature on the storage of rubber, Hevea brasiliensis *seed is reviewed.*

Details are given of a series of experiments intended to determine the optimum packing methods for the preservation of rubber seed viability.

Germination figures are presented to show the changes in seed quality during different stages of the rubber seedfall, and in the clonal composition of seed produced in a young polyclonal rubber seed garden.

It is evident that seed of the clone PR 107 *is generally of poor viability, while seed of the clone BR* 2 *(female parentage) produced by young trees has apparently a low viability and is slow in germinating during the early stages of the development of the seed garden. Details are given of treatments applied in an effort to break the possible impermeability of the seedcoat and dormancy of the BR* 2 *seed.*

INTRODUCTION.

The rubber tree, *Hevea brasiliensis,* is a native of Brazil. The species was introduced into the Far East during the late 1870s and early 1880s, the expeditions of Cross to Panama and Wickham to Brazil both having taken place in 1876. Some small plantings were made by the turn of the century, but large scale plantation establishment did not commence until about 1910. The plants for these early plantings were, naturally, raised from seed. The selection of high yielding rubber trees commenced at an early date and was followed by experiments on the vegetative propagation of *Hevea.* The first handbook on the subject was published in 1918 and the "budgrafting" of buds of superior clones onto ordinary root stock became the general practice about ten years later. In view of the very considerable improvement in yields obtained from vegetative propagation, it is not surprising that little attention was paid to the rubber seed and to preserving seed viability. Although some practical methods were evolved for storing the seed for short periods, it was only following the development of the so called 'clonal' seed that some work was commenced in the 1950's and 1960's to study methods of maintaining the viability of rubber seed.

Kidd (1914) attributed the prolongation of the life of otherwise rapidly deteriorating *Hevea brasiliensis* seed to the presence of 40 per cent. carbon dioxide produced by the seed in a closed flask. He assumed that the gas will induce narcosis and a state of dormancy.

Dijkman (1951) summed up the general position by stating that *Hevea* seed loses its viability quite rapidly and that stored without protection, germination drops within a month to less than 45 per cent. He also states that reasonable viability may be maintained for a period of six to eight weeks, if the seed is packed in a mixture of damp charcoal powder and sawdust (in equal parts). The seed should be packed in layers, in cases with air-vents, the damp sawdust-charcoal mixture being in layers of at least 2 cm. between the seed.

* Plant Introduction Officer, Department of Agriculture, Stock and Fisheries, Port Moresby.
† Officer in Charge, Bisianumu Rubber Centre, Sogeri, via Port Moresby.

Maas (1950) suggests that when packing rubber seed, it must be protected from drying out. Small quantities can be sent over a distance without any additional packing material under cool conditions, such as in the cool storage chambers of ships.

Edgar (1958) mentions that it has been found that freshly gathered rubber seed can lose 50 per cent. of its moisture in three days and most of the remainder in the following ten days, and that the percentage germination curve closely follows the curve for loss of moisture. He considered that fresh ungerminated rubber seed could be packed in gunny bags without any other packing material, but such seed may be stored for a longer period in damp charcoal (adding 20 per cent. of water by weight to the dry charcoal). If germinated seed has to be kept for a longer period he recommends that it should be packed in moist sawdust in sealed tins.

Experiment work on solving some of the storage problems of *Hevea brasiliensis* seed carried out at the Rubber Research Institute of Malaya is only briefly reported in successive Annual Reports of the Institute. No comprehensive account of the experiments appears to have been published.

A small scale trial of coating fresh seed of *Hevea brasiliensis* with shellac, wax and latex concentrate indicated that there is little promise of such treatments prolonging the viability of the seed under normal storage conditions. Fresh untreated seed had a 60 per cent. germination, but failed to germinate after four, and eight weeks' storage. Treated seed gave 1-2 per cent. germination following four weeks' storage and none germinated after eight weeks (RRIM 1958).

The following year seed of the clone Tjirandji 1 was stored in polythene bags in a cold store at 40 degrees F and at room temperatures. After 12 weeks' storage, 68 per cent. of the seed germinated in the former treatment and 62 per cent. in the latter. Initial viability was 89 per cent. (RRIM 1959).

In a storage test with seed having a poor initial viability of 34 per cent. (from the February harvest), seed kept in small polythene bags at room temperature failed to germinate after one month's storage;—seed left at a temperature of 40 degrees F had a 10 per cent. germination after eight weeks. In another experiment rubber seed with an initial viability of 69 per cent. was kept for 12 weeks in polythene bags at a temperature of 40 degrees F. Germination was 60 per cent. When stored at room temperatures for the same period, germination fell to 17 per cent. The viability of seed stored in hessian bags, at both temperatures, fell below 10 per cent. after six weeks (RRIM, 1960).

It was then reported that evidence was increasing that the storage of rubber seed at a low temperature (40 degrees F) in sealed polythene bags is effective for a limited period only. A severe drop in germination was experienced in two experiments after fourteen weeks of storage. Storage at room temperatures in charcoal or sawdust having a 20-30 per cent. moisture content maintained a high germination for a longer period (RRIM 1961).

Variable germination results have been obtained with different batches of rubber seed kept in different storage conditions, in polythene bags, with and without packing material. In some trials seed stored well for up to four months when packed with moist sawdust in polythene bags and kept at room temperature (RRIM 1962).

Later experiments were concentrated on the aeration factor in rubber seed storage. Seed was stored for two months in small polythene bags with and without perforations, using sand or sawdust media with three levels of moisture content, and at 4 degrees C or ambient temperatures. It was found that the viability after storage was often much more affected by the physiological conditions of the seed at the time of collection than by the treatments. However, there was no loss of viability after two months' storage at ambient temperatures in aerated sand or sawdust. Storage at 4 degrees C resulted in germination losses ranging from 20-80 per cent. with little evidence of any effect of aeration or medium, but there was an indication that the highest moisture content, especially with sand, was the least favourable. Storage in sawdust in unperforated bags at ambient temperatures resulted in total loss of viability

but seed survived in perforated bags. When using sand as a medium in the bags, perforations were of no benefit. There were also indications that the size of the container or the number of seeds in a sample may affect results, therefore results obtained from small samples may not be applicable to large scale storage (RRIM 1964).

The effect of the number of seeds per container on the viability of the seed stored at ambient temperatures was also investigated. Perforated polythene bags containing 200, 500, 900, 1,400 and 2,000 seeds were used for storage. The seed was mixed with sawdust containing 15 per cent. moisture. The moisture content was found to be excessive. Germination figures showed that after two months, viability was lower in the larger seed samples. There was an approximate 20 per cent. germination loss in sample of up to 900 seeds per bag and a 40-50 per cent. loss in bags with 1,400 and 2,000 seeds. After two months, viability decreased more markedly in the smaller samples, so that after four months' storage the loss in germination was 68-70 per cent. in all containers. In no case was there a total loss of germination (RRIM 1965).

Van Haaren (1963) reported that at Prang Besar Estate near Kajang in Selangor in Malaysia, a well known producer of polyclonal rubber seed, surplus seed is stored at a temperature of 40-50 degrees F. Under these storage conditions seed was said to maintain its viability for up to six months. Van Haaren (1963) also reported that at the Experiment Station of the Rubber Research Institue of Malaya at Kuala Lumpur, rubber seed for despatch to various parts of the country was packed in polythene bags with a few breathing holes. Ten lb. of seed per bag is mixed with an equal quantity of moist sawdust (10 lb. dry sawdust with 3 lb. of water). The rubber seed so treated was claimed to remain viable for up to three months.

Comprehensive trials on the storage of rubber seed were reported by Ong Thian Pa and Lauw Ing Koen (1963). Their results indicated the following:

(a) There is a relationship between moisture content and germination. Rubber seed with a moisture content above 20 per cent. has the best germination; the death point seems to be at 12 per cent. moisture content.

(b) Coating the seed with paraffin wax, varnish and animal glue had an unfavourable effect on the viability.

(c) Seed stored in a refrigerator in an open container did not germinate after one month's storage, while seed stored in sealed plastic bags had a germination of 88 per cent. and 80 per cent. after one and two months' storage respectively. The moisture content of the seed was considered to be the determining factor.

(d) Seed kept in 100 per cent. carbon dioxide did not germinate after one months' storage. In 50 per cent. carbon dioxide viability fell after one month from 96 per cent. to 72 per cent. in one replicate and to 17 per cent. in another.

(e) Although packing rubber seed in damp quicklime powder prevented mould development, viability declined.

(f) Seed stored in water for 30 days can be destroyed by bacterial action. The surviving seed germinates rapidly.

(g) Stored rubber seed requires an atmospheric moisture content in excess of 40 per cent. R.H. in the storage chamber.

(h) Rubber seed stored in sealed plastic bags at atmospheric temperatures suffered no decline in viability after 30 days.

(i) Further elaboration of method (h) indicated the need for some ventilation, as oxygen in the bags was rapidly exhausted and the seed perished. At the same time the hole or holes must be small enough to prevent a significant loss of moisture in the rubber seed. Provided these two conditions were met, rubber seed could be stored for 60 days at room temperatures without loss of viability.

(j) Further experiments confirmed that the successful storage of *Hevea* seed in an airtight container is only possible if there is enough oxygen available within the container during the period of storage.

(k) Plastic bags with one or two small holes (½ mm to 1 mm in diameter) gave good results and the viability of the rubber

seed remained unchanged after four months storage at room temperatures. The insertion of wet filter paper in the bag had a harmful effect by causing high humidity and encouraging fungal development which spread from the paper to the seed.

(l) 50-180 seeds is the optimum amount per bag.

(m) It is advisable to treat the seed with an organic mercurial fungicide.

(n) Seed of different clones had a similar response to methods of storage.

PART I

RUBBER SEED PACKING TESTS.

The Department of Agriculture, Stock and Fisheries is distributing a large quantity of rubber seed each year for planting in various parts of the Territory of Papua and New Guinea. Despite air transportation, delays frequently occur at transhipment points, which can have a deleterious effect on the viability of the seed. Therefore, simple tests were carried out to determine the efficacy of various packing methods in preventing a decline in the viability of rubber seed in the course of delays that may occur, in a humid tropical lowland environment, between seed collection and planting at the place of destination.

The seed for these tests was collected from a 30 acre area of 25 years old "Tjikadoe" seedling trees growing at the Bisianumu Rubber Centre at Sogeri in the Central District of Papua.

The following packing treatments were applied:

(1) Seed in a hessian bag.

(2) Seed in a sealed plastic bag.

Table I.—RUBBER SEED PACKING TEST 1964.

TREATMENT	No. of days after collection	No. of seed used in test	Percentage seed germinated at unpacking	Percentage germination weeks after planting				
				1	2	3	4	5
Control	2 (at 1800 ft.)	200	—	7.5	21	75	84.5	86
Hessian bag	9	100	1	1	28	57	69	79
Hessian bag + moist sawdust	9	100	8	10	55	90	94	97
Plastic bags, no holes	9	100	—	1	18	47	61	69
Plastic bags, no holes + moist sawdust	9	100	1	2	51	80	84	91
Plastic bag and few holes	9	100	—	—	46	80	83	87
Plastic bag, few holes + moist sawdust	9	100	10	10	48	65	74	84
Plastic bag, many holes	9	100	—	—	17	56	76	83
Plastic bag, many holes + moist sawdust	9	100	4	5	45	76	85	89
Plywood box + moist sawdust	9	100	2	2	59	82	87	93
Hessian bag	21	100	—	—	27	45	49	53
Hessian bag + moist sawdust	21	100	2	7	64	72	78	78
Plastic bag, no holes	21	100	—	—	78	89	90	90
Plastic bag, no holes + moist sawdust	21	100	3	10	77	84	87	88
Plastic bag, few holes	21	100	—	2	61	76	84	87
Plastic bag, few holes + moist sawdust	21	100	6	19	77	83	90	90
Plastic bag, many holes	21	100	—	—	28	59	66	67
Plastic bag, many holes + moist sawdust	21	100	5	16	83	91	93	93
Plywood box + moist sawdust	21	100	16	29	79	84	89	89

(3) Seed in a plastic bag with few breathing holes (40-50 holes).

(4) Seed in a plastic bag with many breathing holes (160-200 holes).

(5) Seed in plywood box, packed in moist sawdust.

Treatments 1-4 were divided into two groups (A) seed only and (B) seed packed in moist sawdust.

The moist sawdust was prepared by mixing 10 lb. of dry sawdust with 3 lb. of water. Approximately 1 lb. of moist sawdust was used per 100 seeds. The size of the plastic bags was 16" x 12" and the breathing holes were 6 mm. in diameter. There were 100 seeds per bag.

Two days after collection, the seed, packed as above, was taken to Port Moresby which is in the tropical lowlands and kept there under atmospheric conditions for 5 and 17 days respectively, before being returned to the nurseries for planting. A control lot of 200 seeds was planted 2 days after collection i.e. was stored for 2 days without treatment at an altitude of approximately 1,800 ft. in a cool environment.

The germination results over a five weeks' period are recorded in *Table* 1.

The above experiment indicated that the storage of rubber seed under atmospheric conditions in the tropical lowlands can result in a decline of seed viability from 86 per cent. to 79 per cent. after 7 days and to 53 per cent. after 19 days' storage. The addition of moist sawdust had improved the storability of the seed in all treatments except in the case of sealed plastic bags. It also showed that the customary method of packing rubber seed in Malaysia in moist sawdust in plywood boxes was efficient in maintaining seed viability for up to 21 days' storage. The results using plastic bags were not as clearcut as those reported by Ong Thian Pa and Laum Ing Koen possibly because (a) the shorter duration of the tests (b) the sealed bags were probably not absolutely airtight and (c) the perforations were more numerous and of larger diameter.

The experiment was repeated in 1966. Moist sawdust was obtained by mixing eight lb. of dry sawdust with four lb. of water. Two lb. of moist sawdust was used to 200 rubber seeds. The results appear in *Table* II.

Table II. RUBBER SEED PACKING TESTS 1966.

TREATMENT	No. of days after collection	No. of seed used in test	Percentage seed germinated at unpacking	Percentage germination weeks after planting					
				1	2	3	4	5	6
Control	4 (at 1,800 ft)	100	—	1	67	75	76	76	76
Hessian bag	9	200	—	—	15.5	47.0	55.5	56.5	60.0
Hessian bag + moist sawdust	9	200	6.0	22.0	47.0	52.5	56.5	58.0	60.5
Plastic bag, no holes	9	200	—	3.0	45.0	77.5	79.5	79.5	79.5
Plastic bag, no holes + moist sawdust	9	200	—	11.0	51.00	59.0	60.5	60.5	62.5
Plastic bag, many holes	9	200	—	—	20.0	58.5	65.5	66.0	66.5
Plastic bag, many holes + moist sawdust	9	200	29.5	46.5	65.5	70.0	71.0	71.0	71.5
Hessian bag	21	200	—		1.5	5.0	7.0	7.0	7.0
Hessian bag + moist sawdust	21	200	19.5	19.5	28.5	30.0	30.0	30.0	30.0
Plastic bag, no holes	21	200	—	2.5	74.0	81.5	82.0	82.0	82.0
Plastic bag, no holes + moist sawdust	21	200	—	—	26.5	29.0	35.5	38.0	40.0
Plastic, bag, many holes	21	200	—	—	13.0	24.5	29.5	30.0	30.0
Plastic, bag, many holes + moist sawdust	21	200	45.5	49.0	64.0	65.5	66.0	66.0	66.0

This experiment confirmed previous results that when rubber seed is stored in the hot humid tropics, a rapid decline in viability may take place unless special measures are taken to prevent the drying out of the seed. When the seed was packed in hessian bags only, germination declined from 76 per cent. to 60 per cent. after seven days storage in the lowlands, then to 7 per cent. after 21 days' storage, but it was possible to slightly arrest this decline by the addition of moist sawdust (which however was already dry by the time the seed was unpacked). When using plastic bags with many holes, seed desiccation took place during the period of storage, depressing the germination during the 21 day period. The addition of moist sawdust helped to maintain viability, although the sawdust was already dry on conclusion of the 21 days' storage. Rubber seed packed in plastic bags with no holes, but not sealed airtight, maintained a high level of viability even after 21 days' storage. In this treatment the addition of moist sawdust depressed the germination, possibly due to excess moisture in the bags. It is noteworthy that despite this fact, in this treatment no germination took place prior to planting inside the bags which had no punched holes, either with or without the addition of moist sawdust (the sawdust was still moist on unpacking these treatments). As against this, germination commenced in the other treatments having moist sawdust.

The above tests confirm the validity of storage practices reported by van Haaren (1963) namely that in Malaysia rubber seed for despatch was packed in polythene bags with a few breathing holes, but did not contribute any data to support some recent commercial practice in Malaysia of despatching rubber seed for export in perforated cardboard boxes without moist sawdust as a packing medium. The experiments upon which this new practice were based (private communication 1965) involved storage for four to six days, thus would probably only apply to conditions where it would be certain that the seed would reach its destination and be planted within a matter of a few days. The value of packing rubber seed in plastic bags which are not hermetically sealsed, was also indicated.

PART II — THE EFFECT ON THE GERMINATING MEDIUM.

In respect of germinating beds Dijkman (1951) recommends as the generally used method to lay out specially prepared beds in which the ground is loosened to a depth of 15 cm. Maas (1950) suggested a layer of 5 cm. of sand over ordinary nursery soil. However, in the course of raising rubber seedlings at Bisianumu, a differential effect of the germinating medium was noted. Therefore a small test was set out, using polyclonal seed imported from Malaysia, which was planted three days after despatch from Singapore.

The results are shown in *Table* III.

The above tests confirm the superiority of medium to coarse river sand over soil as a medium in germination beds and indicate that better results may be obtained by pregerminating rubber seed between two layers of wet bags (the bags to be kept moist by frequent sprinkling of water).

Table III. THE EFFECT OF GERMINATING MEDIUM.

Treatment (germinating medium)	No. of seeds in test	Percentage germination—weeks after planting					
		1	2	3	4	5	6
Soil	200	0	14.5	28.5	30.5	40.0	41.0
Sand	300	0	35.0	58.3	63.7	66.0	67.0
Bags	200	0	5.5	41.5	70.5	75.5	75.5

Table IV. GERMINATION OF COMMON RUBBER SEED.

Year	Period of seedfall	No. of seed in test	Percentage germination weeks after planting					
			1	2	3	4	5	6
1964	Early seedfall (May)	700 (400, 200, 100)	12.6	51.4	73.4	81.4		
	Peak seedfall (June)	10 x 200	8.2	76.8	90.0	92.6		
	Late seedfall (July)	2 x 200	3.0	27.5	44.7	61.2		
1965	Late seedfall (June, July)	3 x 100			14.0	19.0		27.0
1966	Early seedfall (early June)	2 x 100	0	28.0	37.0	38.5	40.5	41.5
	Peak seedfall (June-July)	5 x 100	0	31.6	65.2	74.8	77.4	79.4
	Later seedfall (July-August)	2 x 100	0	49.5	66.0	69.0	71.5	71.5

PART III — QUALITY OF RUBBER SEED DURING THE SEEDFALL.

The Department of Agriculture, Stock and Fisheries is selling considerable quantities of rubber seed each year from a 30 acre area of 25 year old trees originating from a "Tjikadoe" seedling plantation. This so called "common seed" is used for the raising of seedling rootstock for budgrafting. The seeding season varies from year to year, but occurs generally from March to July. Seed samples were taken from the above area throughout several seasons. These tests indicate that seed collected during the early and late fall has a tendency towards lower viability than seed from the main or peak fall. Typical results are shown in *Graph* I. Some of the results are tabulated in *Table* IV.

In 1965, only the seed produced at the end of the seed fall was tested due to the absence on leave of one of the authors. In 1966, seed collection was discontinued shortly after the end of the peak seedfall.

PART IV — CHANGES IN THE CLONAL COMPOSITION OF SEED PRODUCED IN A YOUNG POLYCLONAL SEED GARDEN AND THE DIFFERENTIAL GERMINATION OF CLONAL RUBBER SEED.

A polyclonal rubber seed garden was established at the Bisianumu Rubber Centre in 1958-1959 for the production of 'clonal' seed. The seed garden is 40 acres in extent and consists of the clones Tjir. 1, AVROS 157, RRIM 501, PR 107 and BR 2. The clones are randomized so as to give maximum cross pollination.

The first seed was collected from this area in 1964 when the trees were six years old. Seedfall commenced early in June and was practically finished by the end of July. The main fall occurred from 20th to 30th June. The clonal composition of the seed collected varied at different times of collection, but BR 2 predominated, particularly towards the end of the seedfall. It is evident that the BR 2 trees matured earlier and were more prolific seed producers at this early stage of the development of the garden. The clonal composition of the seed produced in 1964 is shown in *Table* V.

The 1965 seedfall was rather prolonged due to unseasonal weather conditions in 1964. Seedfall commenced near the end of March and finished in the first week of September. Flowering, which is usually during August-October, extended from August 1964, to January 1965. The main flowering was in September 1964, and all five clones flowered again during January 1965. Consequently there were two peak falls, one in April 1965, and the other in August 1965. The clonal composition (female parentage) of the seed collected during this prolonged seedfall is set out in *Table* VI.

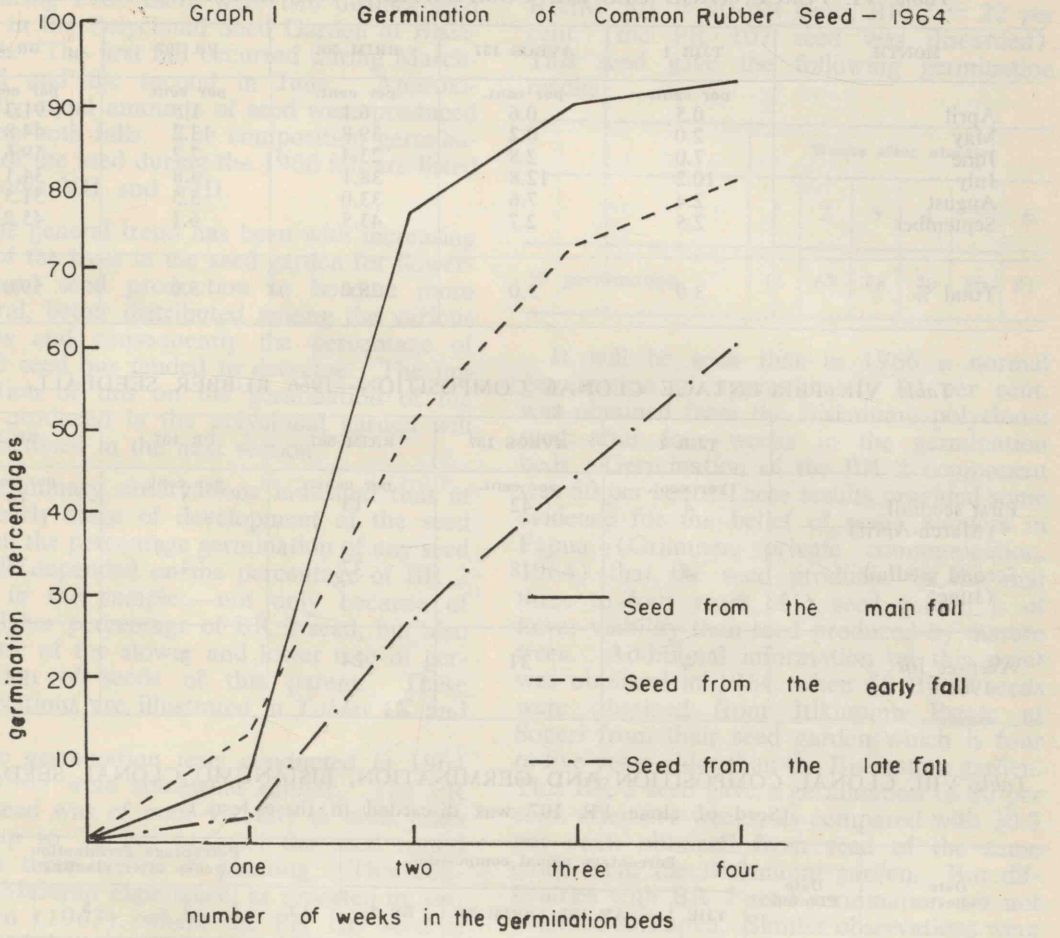

Table V. CLONAL COMPOSITION OF RUBBER SEED 1964.

Clone	Per cent. of seed		
	main seedfall (sample of 1118 seeds)	late seedfall (sample of 1928 seeds)	Average for the year (total 44,179 seeds)
TJIR 1	17.0	3.1	13.0
AVROS 157	8.0	2.6	7.0
RRIM 501	13.0	10.1	14.0
PR 107	7.0	4.2	7.0
BR 2	55.0	80.0	59.0
	100.0 per cent.	100.0 per cent.	100.0 per cent.

Table VI. PERCENTAGE CLONAL COMPOSITION—1965 RUBBER SEEDFALL.

MONTH	TJIR 1	AVROS 157	RRIM 501	PR 107	BR 2
	per cent.	per cent.	per cent.	per cent.	per cent.
April	0.5	0.6	6.1	1.5	91.3
May	2.0	0.2	39.8	13.2	44.8
June	7.0	2.8	23.4	7.2	59.6
July	10.2	12.8	38.1	4.8	34.1
August	2.4	7.6	33.0	5.5	51.5
September	2.5	2.7	43.5	6.1	45.2
Total %	3.0	5.0	28.0	5.0	59.0

Table VII. PERCENTAGE CLONAL COMPOSITION—1966 RUBBER SEEDFALL.

	TJIR 1	AVROS 157	RRIM 501	PR 107	BR 2
	per cent.	per cent.	per cent.	per cent.	per cent.
First seedfall (March-April)	4	42	13	2	39
Second seedfall (June)	4	18	37	4	37
Average for 1966	4	31	24	3	38

Table VIII. CLONAL COMPOSITION AND GERMINATION, BISIANUMU CLONAL SEED 1966.
(Seed of clone PR 107 was discarded in these tests.)

	Date Collected	Date Planted	Percentage clonal composition				Percentage germination weeks after planting			
			TJIR 1	AV 157	RRIM 501	BR 2	1	2	3	4
First seedfall	14.3.66	21.3.66	3	91	5	1	0	51	78	85
	19.3.66	24.3.66	5	91	3	1	0	16	47	73
	21.3.66	28.3.66	6	66	15	13	0	24	58	68
	24.3.66	1.4.66	7	50	19	24	0	18	19	24
	28.3.66	4.4.66	3	16	15	66	0	3	3	17
Second seedfall	2.4.66	7.4.66	2	16	10	72	8	10	18	23
	27.5.66	31.5.66	6	32	40	22	15	67	78	79
	1.6.66	6.6.66	10	20	40	30	0	39	64	65
	17.6.66	23.6.66	5	25	30	40	0	41	79	80
	30.6.66	7.7.66	4	28	38	30	0	26	51	69

During 1966 there were two distinct seed falls in the Polyclonal Seed Garden at Bisianumu. The first fall occurred during March-April and the second in June. Approximately equal amounts of seed were produced during both falls. The composition germination of the seed during the 1966 fall are listed in *Table* VII and VIII.

The general trend has been with increasing age of the trees in the seed garden for flowering and seed production to become more general, better distributed among the various clones and consequently the percentage of BR 2 seed has tended to decrease. The implication of this on the germination of the seed produced in the polyclonal garden will be discussed in the next section.

Preliminary observations indicated that at this early stage of development of the seed garden the percentage germination of any seed sample depended on the percentage of BR 2 seed in the sample;—not only because of the higher percentage of BR 2 seed, but also because of the slower and lower rate of germination of seeds of this parent. These observations are illustrated in *Tables* IX and X.

The germination tests conducted in 1964 and 1965 were somewhat similar. The PR 107 seed was of poor viability in both years and up to 75 per cent. of the seed rotted within three weeks of planting. This confirms Malayan experience, as reported by van Haaren (1963), where the PR 107 seed is removed from polyclonal rubber seed sold, as it tends to go mouldy rapidly. It is evident that the inclusion of this clone in a polyclonal garden must be due to its quality as a pollen parent. It also constitutes only a small percentage of the total seed produced.

In both years seed of the clone BR 2 was slow in germinating and generally only about 50 per cent. of the seed germinated even after eight weeks in the seedbed. There was, however, a marked improvement in 1966, in both the speed and rate of germination of seed of all the clones in the seed garden (*Table* VIII). A bulk sample of 6,062 seeds collected during the peak of the seedfall in 1966 had a clonal composition of Tjir 1 = 6 per cent., AVROS 157 = 32 per cent., RRIM 501 = 40 per cent., BR 2 = 22 per cent. (the PR 107 seed was discarded). This seed gave the following germination results:

	Weeks after planting					
	1	2	3	4	5	6
% germination	15	67	78	79	80	81

It will be seen that in 1966 a normal germination of approximately 80 per cent. was obtained from the Bisianumu polyclonal seed after four weeks in the germination beds. Germination of the BR 2 component was 50 per cent. These results provided some evidence for the belief of some planters in Papua (Grimmer, private communication, 1964) that the seed produced in the first three to four years of a seed garden is of lower viability than seed produced by mature trees. Additional information on this point was obtained in 1964, when 50 BR 2 seeds were obtained from Itikinumu Estate at Sogeri from their seed garden which is four to five years older than the Bisianumu garden. This BR 2 seed gave a germination of 80 per cent. after five weeks, as compared with 30.3 per cent. obtained from seed of the same clone from the Bisianumu garden. But difficulties with BR 2 seed germination are not confined to Papua. Similar observations were made in Malaysia (Rubber Research Institute of Malaya, private communication, 1964). There, it was considered that the plumule does not easily pierce the seed coat of BR 2 seed and therefore cracking the seed coat or widening the micropyle would improve the rate of germination.

GERMINATION OF SEED OF OTHER CLONES.

Maas (1950) reported that seed viability depends on the genetic origin, quite apart from outside factors (such as method of storage and planting techniques). Seed of the clones included in the Bisianumu Seed Garden also exhibited widely differing viability and rate of germination.

Table IX. GERMINATION OF BISIANUMU POLYCLONAL SEED. JUNE-JULY SEEDFALL 1964.

Clone (female parent)	No. of seed in test	Percentage germination—weeks after planting							
		1	2	3	4	5	6	7	8
TJIR 1	3 x 100) 1 x 200)	1.8	27.2	57.8	68.8	50.4	84.0	86.0	87.0
AVROS 157	,,	1.0	34.8	55.2	63.4	67.2	67.5	69.5	70.0
RRIM 501	,,	1.4	41.8	69.4	81.4	84.8	90.0	91.7	92.0
PR 107	,,	0.8	21.2	30.6	32.2	32.6	33.0	33.0	33.0
BR 2	,,	0.0	1.2	18.2	25.4	34.8	46.4	52.8	57.0

Table X. GERMINATION OF BISIANUMU POLYCLONAL SEED. JULY-SEPTEMBER SEEDFALL 1965 (Summary of five tests).

Clone (female parent)	Seed in test		Percentage germination—weeks after planting			
	No.	per cent.	2 weeks	4 weeks	6 weeks	8 weeks
TJIR 1	95	10	1.0	40.0	59.0	65.0
AVROS 157	100	11	2.0	39.0	54.0	59.0
RRIM 501	209	22	0.0	31.0	49.0	57.0
PR 107	81	9	0.0	10.0	14.0	14.0
BR 2	449	48	0.0	12.0	30.0	42.0
TOTALS	934	100	0.3	22.0	38.0	47.0
Comparable figure for 1964	500	—	2.0	22.8	34.5	45.7

Table XI. PERCENTAGE GERMINATION OF SEED OF FIVE ADDITIONAL CLONES. 1964.

Clone (female parent)	No. of seed in Test	Percentage germination—weeks after planting							
		1	2	3	4	5	6	7	8
PB 5/51	300	7.0	67.6	76.3	77.0	77.3	77.6	77.6	77.6
Koitaki 1	300	0.0	5.3	15.3	26.0	39.0	49.0	54.3	58.3
PB 12/127	300	2.0	16.7	45.3	58.3	65.3	79.0	91.3	95.3
NAB 12	300	0.0	0.0	4.3	10.3	20.3	34.3	49.0	54.0
LCB 1320	300	0.0	12.0	44.0	50.7	55.0	61.0	67.3	68.0

A further check on clonal variations in seed viability was made in 1964, with seed collected from the Museum Plot No. 1 at Bisianumu. This is an eight acre plot planted in 1955-1956 comprising 24 clones, but is not planted as a seed garden. Seed was collected from five clones which were noted for their prolific seed production. Two tests were carried out (1 x 200 and 1 x 100 seed per clone). The results are shown in *Table* XI. Comparable figures for seed for the Polyclonal Seed Garden can be found in *Table* IX. It will be noted that the rate of seed germination of these clones from the Museum Plot was generally similar to that from the Seed Garden.

Table XII. BREAKING OF IMPERMEABILITY OF BR 2 SEED, 1965.

Treatment	No. of seed in test	Percentage germination, weeks after planting							
		1	2	3	4	5	6	7	8
Control	100	0	0	5	19	45	48	50	50
Micropyle roughened with file	100	0	1	42	51	54	54	54	54
Seed cracked	100	0	0	8	19	39	42	46	47
Hot water on seed left seeping 12 hours	100	0	0	0	0	—	—	—	—
BR 2 seed from Itikinumu seed garden	100	0	0	7	39	68	79	81	81

PART V — EXPERIMENTS TO IMPROVE THE GERMINATION OF BR 2 SEED BY SEED TREATMENT.

The slow and low rate of germination of seed of the clone BR 2, as reported earlier in this paper, led to experiments to try to break this apparent hard seededness or dormancy of the seed. The fact that seed of some clones was slow in germinating was recognised though not widely reported. Dijkman (1951) mentioned that : 'viable seed germinates (depending on the percentage) between 3 and 25 days. Seeds which germinate slowly, like AV 163 ill. should be pretreated by removing the micropylar cap to speed germination'. The Rubber Research Institute of Malaya (private communication, 1964) also suggested that cracking the seed coat of BR 2 seed or widening the micropyle before setting in the beds may improve the germination.

The first approach was made on the assumption that perhaps BR 2 seed had a hard impermeable seed coat which prevented the absorption of moisture in the seedbed or admitted it only rather slowly, resulting in a delayed and prolonged germination period. Seed from the August 1965 seedfall was given various treatments and planted in a sand germination bed. The results are shown in *Table* XII. Unfortunately in the second treatment (filing the micropyle) ants entered the seed through the micropyle and destroyed the embryo in 41 seeds, while rodents ate 10 seeds in the treatment with the cracked seed coat. Thus results must remain inconclusive although a promising start was made in the germination. The hot water treatment resulted in the death of the seeds, which rotted in four weeks. The BR 2 seed from Itikinumu Estate again gave satisfactory results.

The treatment of roughening the micropyle with a file was repeated, using sand and soil as germinating medium. The sand gave superior results, compared with soil. The test had to be discontinued after four weeks, due to losses from rodents and rotting of the seed (old seed). At this stage, filing the micropyle resulted in 18 per cent. germination, as against 5 per cent. in the control.

In 1966 experiments were based on the possibility that difficulties experienced in germinating BR 2 seed may be caused through an impermeable seed coat or the need for an after-ripening period. The treatments applied and germination results obtained in a series of tests are recorded in *Table* XIII.

Contrary to the general indications obtained in previous years, the results of the tests in 1966 (*Table* XIII) gave largely inconclusive results, but are given in detail in order to record the treatments applied. It is evident that both the hot water and the sulphuric acid treatment resulted in the death of the embryo. Neither rendering the seed coat more permeable by means of filing, nor exposure of the seed to the sun while enclosed in clear plastic, gave consistent results, except perhaps in one series of experiments.

Table VIII. TESTS ON BREAKING THE IMPERMEABILITY AND DORMANCY OF BR 2 SEED, 1966.

Date collecting seed	Date planted	TREATMENT	No. of seed in test	Percentage germination—weeks after planting					
				1	2	3	4	5	6
4.6.66	9.6.66	Seed for ½ hour in the sun under clear plastic	200	0	0	15.0	26.5	34.0	38.0
,,	,,	Seed for 1 hour in the sun under clear plastic	200	0	1	16.5	21.0	26.0	34.5
,,	,,	Seed for 2 hours in the sun under clear plastic	200	0	0	12.0	21.0	27.5	34.0
,,	,,	Seed for 5 min. in hot water	200	0	0	0	0	0.5	0.5
,,	,,	Seed for 10 min. in hot water	200	0	0.5	1.0	1.0	1.0	1.0
,,	,,	Seed coat filed	200	0	0	44.5	51.5	54.0	57.5
,,	,,	Control	200	0	1	54.0	65.5	67.0	74.5
7.6.66	10.6.66	Seedcoat filed	200	0	0	46.5	61.0	62.0	63.5
,,	,,	Seed soaked for 10 min. in hot water	200	0	0	0	0	0	0
,,	,,	Seed for 10 min. in hot sun under clear plastic	200	0	0.5	39.0	53.5	58.0	63.0
,,	,,	Seed for 2 min. in conc sulphuric acid	200	0	0	0	0	0.5	0.5
,,	,,	Seed for 5 min. in conc sulphuric acid	200	0	0	0	0	0	0
,,	,,	Seed for 10 min. in conc sulphuric acid	200	0	0	0	0	0	0
,,	,,	Control	200	0	0	51.5	69.0	69.5	70.5
10.6.66	17.6.66	Seed for 5 min. in the sun under clear plastic	100	0	0	24.0	33.0	38.0	40.0
,,	,,	Seed for 10 min. in the sun under clear plastic	100	0	2	26.0	44.0	48.0	50.0
,,	,,	Seed for 15 min. in the sun under clear plastic	100	0	0	15.0	30.0	35.0	35.0
,,	,,	Seed for 20 min. in the sun under clear plastic	100	0	0	24.0	38.0	47.0	48.0
,,	,,	Seed for 25 min. in the sun under clear plastic	100	0	3.0	34.0	52.0	59.0	59.0
,,	,,	Seed for 30 min. in the sun under clear plastic	100	0	0	23.0	47.0	49.0	51.0
,,	,,	Seed for 45 min. in the sun under clear plastic	100	0	0	21.0	35.0	44.0	45.0
,,	,,	Seed for 60 min. in the sun under clear plastic	100	0	0	25.0	45.0	49.0	50.0
,,	,,	Control	100	0	2.0	19.0	47.0	53.0	55.0
17.6.66	17.6.66	Seed for 15 min. in the sun under clear plastic	100	0	2.0	28.0	45.0	50.0	54.0
,,	,,	Seed for 25 min. in the sun under clear plastic	100	0	2.0	29.0	42.0	49.0	57.0
,,	,,	Seed for 35 min. in the sun under clear plastic	100	0	1.0	24.0	49.0	54.0	59.0
,,	,,	Seed for 45 min. in the sun under clear plastic	100	0	0	22.0	38.0	47.0	52.0
,,	,,	Control	100	0	4.0	15.0	31.0	37.0	38.0

Table XIII. (Continued).

Date collecting seed	Date planted	TREATMENT	No. of seed in test	Percentage germination—weeks after planting					
				1	2	3	4	5	6
24.5.66	5.7.66	Seed untreated, planted 11 days after collection	400	0	0	1.25	16.75	23.75	26.0
30.6.66	5.7.66	Seed untreated, planted 5 days after collection	400	0	0	9.75	33.25	48.75	54.5
24.6.66	5.7.66	Seed untreated, planted 11 days after collection	200	0	0	1.0	6.0	9.0	13.5
,,	,,	Seed coat filed, planted 11 days after collection	200	0	0	0.5	1.5	3.0	3.5
,,	,,	Seed for 15 min. in the sun under clear plastic, planted 11 days after collection	200	0	0	1.0	13.0	17.5	21.5
30.6.66	,,	Seed untreated, planted 5 days after collection	200	0	0	9.5	24.5	33.5	39.5
,,	,,	Seed coat filed, planted 5 days after collection	200	0	0	11.0	23.0	32.5	40.0
,,	,,	Seed for 15 min. in the sun under clear plastic, planted 5 days after collection	200	0	0	13.5	33.5	48.5	51.0

NOTES

(1) In experiments planted on 10.6.66 all the seed treated with sulphuric acid became mouldy within five days; on the seventh day the seed was washed in a solution of copper oxychloride, then dipped in copper oxychloride powder before replanting. The mould re-occurred within a few days.

(2) Heat treatment in the sun was carried out by placing not more than 200 seeds in a closed clear plastic bag 15" x 12", the seed being in a single layer. Treatment was carried out between 10 a.m. and noon.

(3) The hot water treetment consisted of placing the seed in hot, but not boiling, water.

(4) In the sulphuric acid treatment the seed was washed in clear running water immediately after removal from the acid.

(5) When filing the seed coat, 'flat' side of the seed, i.e. not the micropyle, was rubbed on a metal file until the shiny dark brown colour of the epidermis disappeared.

On the other hand, it seems evident that delaying the planting of the seed from 5 to 11 days resulted in a considerable drop of the viability (20 per cent.) even in the cool environmental conditions at Bisianumu. It would seem that the somewhat poor and slow germination of BR 2 seed could not be substantially improved by making the seed coat more permeable or by providing some after-ripening treatment or period. Rather, it must be due to physiological conditions in the endosperm which corrects itself when the trees of this clone reach mature age, as evidenced by the satisfactory germination of BR 2 seed from the older trees at Itikinumu Plantation situated only a few miles from Bisianumu. A similar trend towards improved germination was observed in the BR 2 seed produced at Bisianumu in 1966. (*See Note.)

CONCLUSIONS.

(1) Seed of *Hevea brasiliensis* retains its viability for only a relatively short period following maturity and seedfall, particularly when the seed is stored or is in transit in a humid tropical coastal environment. However, the seed maintains its viability well for nine days following harvest and this period is ample to effect delivery to most centres in Papua and New Guinea requiring rubber seed, provided no undue transit delays take place. Packing the seed in moist sawdust helped reduce the decline in viability even when stored for 21 days. When using moist sawdust, it may be necessary to prevent its drying out e.g. by packing the seed in plywood boxes or in perforated plastic bags. Plastic bags without ventilation holes, but not hermetically sealed, were also effective in preserving viability; in this treatment the addition of moist sawdust appeared to be disadvantageous.

(2) Sand was a superior germinating medium to soil in nursery beds and pre-germination in wet bags produced better results.

(3) The quality of the rubber seed collected from the main seedfall period was superior to that collected either early or late during the seeding season.

(4) The rubber trees in the Bisianumu Polyclonal Seed Garden are not yet mature. During this early period the clonal composition of the seed produced varied from year to year and from season to season. Trees of the clone BR 2 are more advanced and are prolific seed producers. Therefore early seed crops were dominated by seed of BR 2 female parentage. As the trees of other clones in the seed garden are approaching maturity the percentage of BR 2 seed tends to decline.

(5) Seed of PR. 107 female parentage has only a low percentage of germination, therefore the principal use of this clone in a seed garden must be as a pollen parent. At an early stage of the development of the seed garden, seed produced by the BR 2 trees had a lower and slower rate of germination than seed of the clones Tjirandji 1, AVROS 157 and RRIM 501. There is evidence from the performance of BR 2 seed in 1966 and from another somewhat older seed garden in the Sogeri area that this is likely to be only a temporary effect.

(6) There is evidence of variation among rubber clones in the quality of the seed produced and the length of time required for germination.

(7) Tests were carried out to try to break any hardseededness or dormancy that may occur in seed of the rubber clone BR 2. Hot water or acid treatment resulted in the immediate death of the seed. Roughening the micropyle or the seedcoat with a file or cracking the seedcoat did not improve the rate of germination, but resulted in losses from ants entering the micropyle and rodent damage. Similarly, the exposure to hot sun of the rubber seed packed in clear plastic for varying periods did not produce improved germination. It is concluded that physiological conditions other than impermeability of the seedcoat or dormancy must be responsible for the slow and relatively low rate of germination of seed produced by rubber trees of the clone BR 2 during the early years of seed production.

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*NOTES.

Germination results of BR 2 ill. seed from the 1967 seedfall are becoming available at the time of writing and confirm the above observations. The germination of seed collected the Polyclonal Seed Garden at Bisianumu during the 1967 seedfall was as follows:

Seed collection date	Clone	No. of seed in test	Percentage germination—weeks after planting					
			1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks
3.3.67	TJIR 1	1674	13	60	94	96	96.4	96.4
	AVROS 157	1502	12	64	81	83	83.8	83.8
	RRIM 501	618	14	40	65	73	77	77
	BR 2	5740	0.3	16	70	80	83	84
15.3.67	TJIR 1	170	0	44	84	87	87	87
	AVROS 157	961	2	84	87	87	87	87
	RRIM 501	954	6	94	96	96	96	96
	BR 2	6806	0.1	15	42	45	46	51
18.3.67	TJIR 1	92	0	16	82	85	87	87
	AVROS 157	507	0.5	60	85	86	86	86
	RRIM 501	538	0.9	78	96	96	96	96
	BR 2	4347	0.2	3	68	79	84	85
5.4.67	polyclonal sample	100	9	39	60	62	64	64
11.4.67	polyclonal sample	100	19	70	84	89	89	89

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