PEANUT PRE-EMERGENCE AND CROWN ROT INVESTIGATIONS.

R. B. MORWOOD, M.Sc., formerly Senior Pathologist, Science Branch, Division of Plant Industry.

SUMMARY.

The results of investigations covering a number of years are reported.

Crown rot is caused by Aspergillus niger. Pre-emergence rot is due to Rhizopus arrhizus, Aspergillus niger and probably other organisms.

Seed treatment, particularly with organic mercurial fungicides and the organic fungicide thiram, improves field emergence, sometimes to a remarkable extent.

The previous cropping history of the soil has a marked influence on losses from pre-emergence and crown rots.

INTRODUCTION.

Shortly after the development of an extensive peanut industry in the South Burnett district of Queensland, growers met with serious difficulties in establishing good stands of this crop (Fig. 1). Losses occurred in several ways. Numbers of the kernels merely swelled and rotted in the soil. Evidence has been obtained that many of these were viable. Other kernels germinated but failed to emerge, having rotted below ground level. Still more emerged but failed to survive to maturity due to the development of the disease now known as crown rot. It was these losses which led to the investigations reported in this paper.

SYMPTOMS AND ASSOCIATED ORGANISMS.

Crown rot may affect peanut plants at any stage from the seedling to the mature plant, but is most common in the former. The first obvious symptom is a wilt of the whole plant, or in the case of large individuals a wilting of one or more branches. The stalk and root tissues of affected plants, just below the ground, are dark and shrunken and have a somewhat shredded appearance. Black masses of spores of *Aspergillus niger* Van Tieghem can usually be readily seen on the surface of the affected area. Most wilted plants soon die but some maintain a precarious existence on adventitious roots sent out from the stem above the affected area.

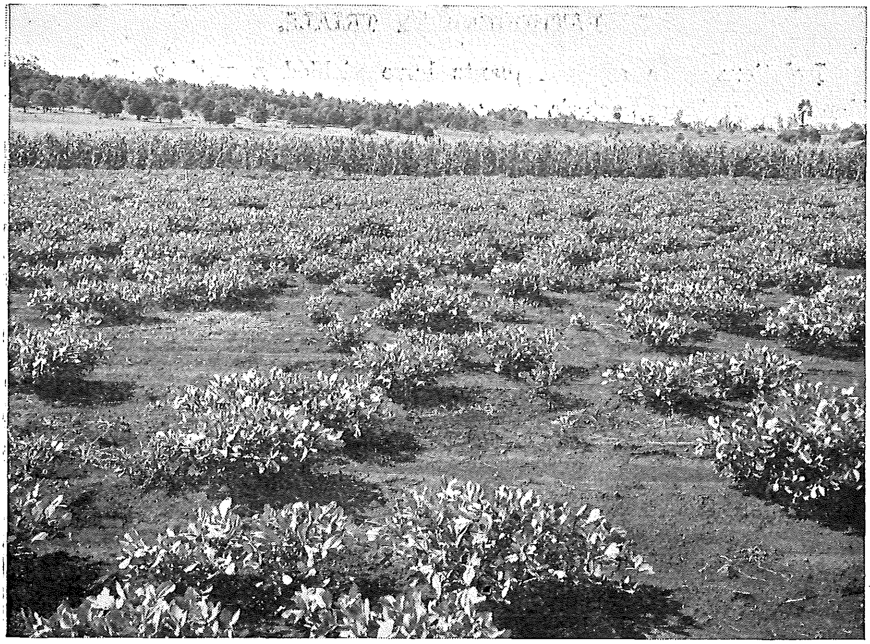


Fig. 1.

A Peanut Crop in which the Stand has been Thinned Out by Crown Rot.

Associated with crown rot there is a pre-emergence rot in which rotting of the seed or hypocotyl kills the plant before it appears above the ground. This is often due to the same fungus that causes crown rot, but frequently a type of pre-emergence rot with somewhat different symptoms is found. This is distinguished by the presence on the rotting seed of a loose mat of mycelium in which is incorporated a mass of soil particles. The mycelium is that of a species of *Rhizopus* corresponding closely to *R. arrhizus* Fischer, as described by Hildebrand and Koch (1943). (G. D. Bowen, Queensland Department of Agriculture and Stock unpublished records, 1953). It is also found occasionally on the rotted hypocotyl of plants which have the aboveground symptoms of crown rot.

Observations and inoculations reported later indicate that in the disease complex plants showing crown rot symptoms are usually infected with *A. niger* with an occasional *R. arrhizus* infection. In pre-emergence rot, either organism can be involved; the evidence suggests that *Rhizopus* occurs more frequently in this phase of the disease. In a few instances other organisms may be involved.

PATHOGENICITY TRIALS.

Isolations from affected plants have yielded a variety of organisms. Unidentified species of bacteria are common, while the most frequently occurring fungus is the one responsible for the black spore masses, namely *A. niger*. *R. arrhizus* and *Pencillium* spp. appear on numerous occasions and *Botrytis* sp. and *Fusarium* sp. occasionally.

Whole nuts were selected for freedom from injury and surface sterilized by soaking for 30 minutes in 1–400 commercial formalin. They were then hand-shelled carefully to avoid contamination. Before planting the seed in autoclaved soil, the appropriate inoculum was applied either as a fragment of an agar culture or as a water suspension of spores. Some of the kernels were first injured with a small cut or abrasion.

Attempts to reproduce the disease with various unidentified bacteria were all negative. An occasional lesion was found after inoculation with *Penicillium* sp. but not consistently enough to warrant any conclusions on the pathogenicity of this organism.

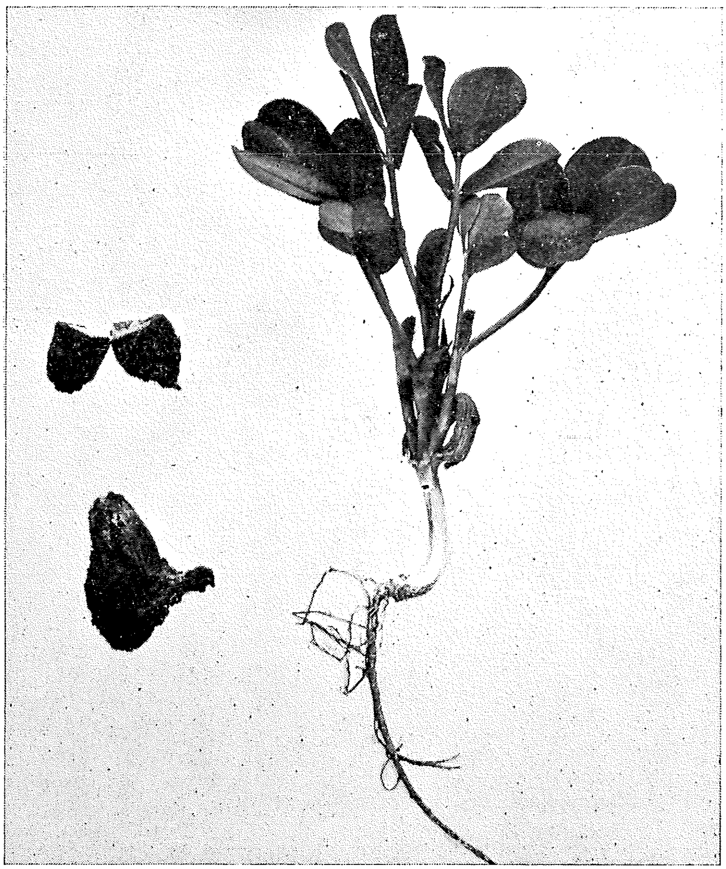
Very few peanut kernels germinated after inoculation with *R. arrhizus*, the seed usually rotting without any growth (Fig. 2, B and C). It developed the mat of mycelium and adhering soil characteristic of this type of pre-emergence rot. The fungus was re-isolated from affected seed. Under moist conditions in the plant house, *R. arrhizus* spreads rapidly through and over the surface of the soil. In one series of inoculations with various organisms, in which tins of soil were used and placed close together in an incubator, the spread of this fungus to adjacent tins spoiled the trial. No sudden wilt of established plants has been obtained by inoculation of seed with *R. arrhizus.*

Typical symptoms of crown rot were produced only when *A. niger* was used as inoculum (Figs. 2A, and 3). The organism was readily re-isolated from affected plants. However, the disease could not be induced at will. Only a small proportion of the seed inoculated developed into diseased plants, the majority producing normal plants. Attempts to increase the amount of disease by varying the soil moisture content were not successful. Field observations indicate that soil texture influences the development of the disease, but this aspect has not been fully explored in the laboratory.

Figures from inoculation experiments are given in Table 1.

The isolates of *R. arrhizus* used consistently reduced emergence and few plants survived after infection. These few did not subsequently develop crown rot. Emergence was variable after infection with *A. niger*, and usually a few

A B



C D

Fig. 2.

Artificial Inoculation of Peanut Kernels with the Organisms Responsible for Pre-emergence Rot and Crown Rot. A, *Aspergillus niger*. B, *Rhizopus arrhizus* ex Peanut. C, *R. arrhizus* ex Apricot. D, uninoculated.

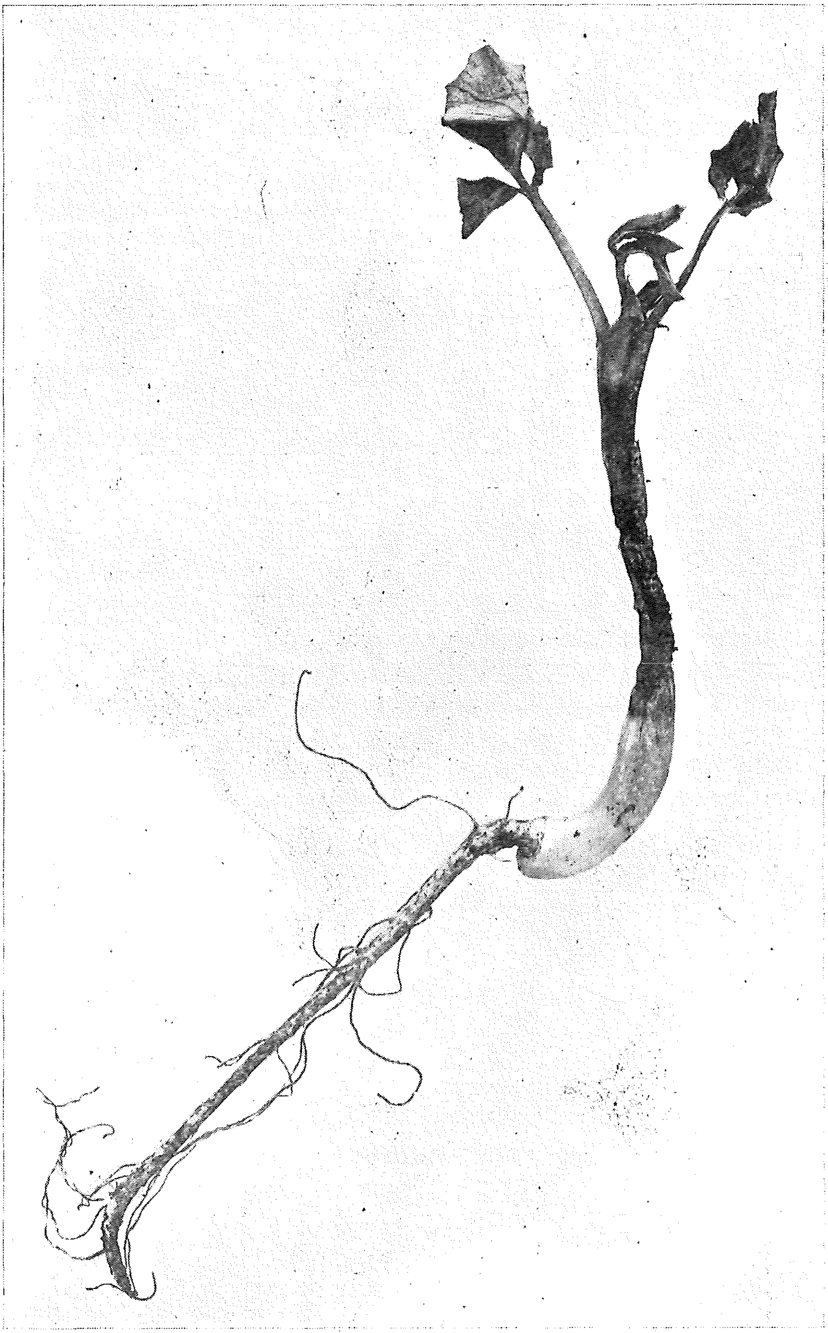


Fig. 3.

Crown Rot Resulting from Artificial Inoculation of Peanut Kernels with *Aspergillus niger*.

Table 1.

EMERGENCE OF PEANUT KERNELS INOCULATED WITH VARIOUS ORGANISMS.
(MEAN EMERGENCE PER 10 PLANTS.)

Organism.	Experiment A.		Experiment B.	
	Injured.	Uninjured.	Injured.	Uninjured.
Aspergillus niger	1·1	0·5	7·8	7·4
Rhizopus arrhizus from peanut ..	0·3	0·0	1·0	2·0
Rhizopus arrhizus from apricot fruit ..	0·1	0·1	..	..
Penicillium sp.	..	..	7·8	7·8
Unidentified bacteria	..	..	6·2	7·6
Not inoculated	4·0	4·0	6·8	7·2

of the surviving plants wilted and died with the development of stem lesions in the cotyledonary region. These carried the spores of *A. niger*. The evidence suggests that *Rhizopus arrhizus* is responsible for most of the pre-emergence rot and that *Aspergillus niger* is the cause of crown rot.

KERNEL INJURY.

A suggestion was prevalent at one time that injury to the kernels was directly responsible for the failure to emerge and loss of seedlings. Self-sown peanuts are generally not affected with crown rot nor are plantings of whole nuts. Exceptionally the disease may be found in such plants but the amount is usually small. Furthermore, carefully hand-shelled and hand-planted kernels develop little if any crown rot. Figures comparing hand-shelled with machine-shelled kernels taken from an experiment described later are given in Table 2.

Table 2.

PERCENTAGE EMERGENCE OF HAND-SHELLED AND MACHINE SHELLED KERNELS.

Treatment.	Trial A.	Trial B.
Hand-shelled	70	76
Machine-shelled	44	49

It is evident that injury to kernels by the shelling machinery has a considerable bearing on the disease, although this has not always been verified when deliberate injuries were induced in the laboratory.

Investigation of planting machinery indicated that it did in fact visibly damage a number of kernels. However, it has been found that machine-shelled and hand-planted kernels are affected to an extent comparable with that of machine-shelled and machine-planted kernels. This indicates that the injury occurring in the sheller predisposes the kernel to the troubles under consideration but that injury in the planter has little if any further effect.

Consideration of the injury factor leads to several solutions of the crown rot problem but considerations of cost and other difficulties have precluded their adoption. Whole nuts could be used for seed. However, the distribution of plants in the row is poorer with whole nuts and they require more moisture for germination. This can only be partly overcome by pre-soaking the nuts. The objection to hand-shelling is the labour involved in the operation.

SEED TREATMENT.

It was considered that machine-shelled kernels would germinate more satisfactorily if chemically treated, and trials to determine a suitable treatment were started. Early trials consisted of laboratory plots using small quantities of seed. It was found that applications of formalin for 12 hours at strengths of 1 part of formaldehyde to 4,000 parts of water and stronger seriously reduced germination of peanut kernels. A 10-minute dip with a strength of 1 part to 500 parts of water or weaker was without deleterious effect, and the shorter dipping period was adopted for further trial. Bluestone and corrosive sublimate were tried at various strengths and the 1 per cent. and 0·1 per cent. dilutions respectively were adopted as the rates most likely to be useful. Mercury and copper dusts were most promising, particularly organic mercury dust.

The seed treatments were then field-tested using single drills 2½ chains long with eight replications. Except where otherwise indicated, the plots were planted with a double-row planter, using weighed amounts of seed. By weighing the excess seeds from each row and counting the kernels per pound, the number of seeds per row was estimated. The stands were counted and results are reported in Table 3 as percentage emergence. Figures for the laboratory germination are also given.

Table 3.

SEED TREATMENT TRIAL, No. 1.

Treatment.	Laboratory Germination.	Field Emergence.
	%	%
Mercurial dust A	96	81
Mercurial dust B	93	74
Corrosive sublimate—		
1 : 1000 for 3 minutes ..	87	68
Bluestone—		
1 : 100 for 3 minutes	72	60
Formalin—		
1 : 240 for 10 minutes ..	55	44
Copper carbonate dust	83	68
Untreated	74	48
Untreated hand-planted	..	51
Necessary differences for significance:		
5% level	..	6·2
1% level	..	8·3

The two mercurial dusts were experimental fungicides containing organically combined mercury in undisclosed proportions. The dusts were applied at the rate of 1 oz. to 20 lb. of seed. For the corrosive sublimate treatment, kernels were dipped in a solution of 1 part per 1,000 for three minutes, then rinsed in water. For the bluestone dip the rinsing was omitted. After dipping, the seed was dried and stored till required.

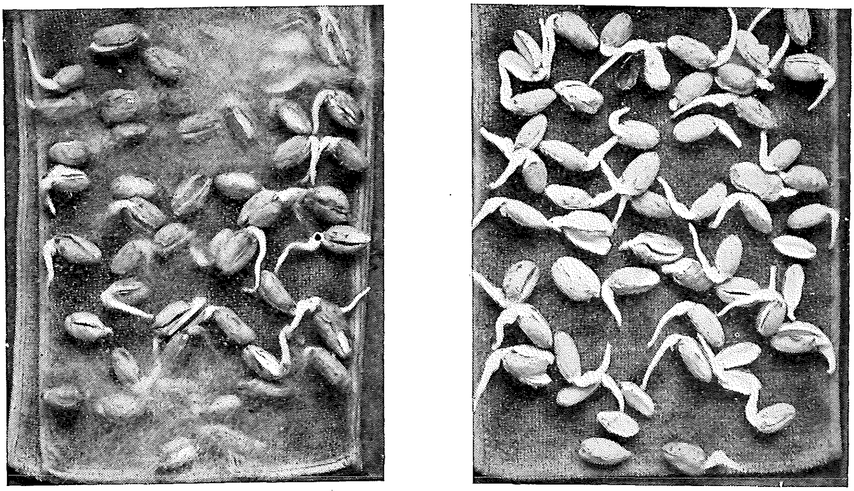


Fig. 4.
Effect of Mercurial Dusts on the Germination of Peanut Kernels. Untreated seed on left.

The mercury dusts were outstanding and this type of dust has since proved most consistent in improving field emergence.

The corrosive sublimate and bluestone dips resulted in delayed germination and the formalin in seriously delayed germination. On account of this effect and their inferiority to the organic mercury materials, they were not again tested. The copper dust was somewhat inferior to the mercurials but was considered to warrant further testing.

A further field trial of treated peanuts consisted of short drills in which 25 kernels were planted per drill and subsequent emergence counted. Four treatments were tested against untreated in four randomised blocks. The results obtained are shown in Table 4.

The two organic mercury dusts were again superior to the copper dusts and the latter were not given further consideration.

Following this work, seed treatment with mercury dusts was adopted as a standard practice in the industry in 1937, with marked reduction in disease incidence. The treatment is applied in bulk by the Queensland Peanut Marketing Board, which handles practically all the peanut seed in the State.

Table 4.

SEED TREATMENT TRIAL, No. 2.

Treatment.	Field Emergence.
	%
Ceresan (1·5% Hg)	67
Agrosan (1·5% Hg)	65
Cuprocide	52
Copper carbonate	41
Untreated	33
Necessary differences for significance :	
5% level	11·5
1% level	16·8

Seed Treatment with New Organic Fungicides.

When new organic fungicides became available, two of them were compared with the standard treatment, and a mercury dust containing only 0·5 per cent. Hg was included. The results from 12 replications in single drills with 100 seeds per drill were as shown in Table 5.

Table 5.

SEED TREATMENT TRIAL, No. 3.

Treatment.	Field Emergence.
	%
Ceresan (1·5% Hg)	72
Ferbam (80% dust)	73
Mercury dust (0·5% Hg)	59
Thiram (50% dust)	75
Untreated	60

The dust with the lower percentage of mercury was unsatisfactory but the organic preparations were among the best. Arrangements were made for a further trial of thiram, which was considered to have the most desirable properties. In these trials some new materials were incorporated and various amounts of dusts were tested on three different kinds of soil. The same seed was used throughout. The results are given in Table 6. A discussion of the effect of different types of soil will be found in a later section.

Table 6.

PERCENTAGE FIELD EMERGENCE IN A RATE-OF-TREATMENT AND ROTATION TRIAL.

Previous Crops.	Rhodes Grass.			Peanuts with Cover Crops.			Peanuts without Cover Crops.			Mean.
Oz. per 100 Lb. Kernels.	10.	5.	2·5.	10.	5.	2·5.	10.	5.	2·5.	
Ceresan	68	76	76	66†	62†	55	78†	69†	58†	68
Agrosan	76	73	77	71†	67†	65†	71†	73†	66†	71
Thiram	72	74	77	67†	64†	60†	51	54*	49	63
Hexachlorbenzene	76	67	62	49	43	48	39	38	35	49
Untreated	..	71	..	..	47	..	..	38	..	49

* Significantly better than untreated at 5% level.

† Significantly better than untreated at 1% level.

Ceresan and Agrosan, the two organic mercury dusts, again proved superior to the other fungicides. Hexachlorbenzene, which is a highly efficient preventive of wheat bunt, was useless for peanuts. The performance of thiram varied somewhat, and as this material was at the time much more expensive than the mercurials, its commercial use could not be recommended. There appeared to be rather less post-emergence loss of plants after treatment with thiram than after treatment with Ceresan or Agrosan.

The use of 10 oz. of dust per 100 lb. of seed did not result in any improvement over the standard rate of 5 oz. per 100 lb. With half this rate ($2\frac{1}{2}$ oz. per 100 lb.) there was still a high degree of disease control but not as high as with the standard rate.

A 5 x 4 randomised block trial was laid down to test two brands of chloranil (tetrachloroparabenzoquinone). Each plot comprised five rows of 50 kernels each. The results as percentage field emergence are given in Table 7.

Table 7.

SEED TREATMENT TRIAL, No. 4.

Treatment.	Field Emergence.
	%
Ceresan	81
Agrosan	77
Tetroc (chloranil 98%)	72
Spergon (chloranil 98%)	68
Untreated	60
Necessary differences for significance :	
5% level	7·2
1% level	10·3

The two brands of chloranil (Tetroc and Spergon) both had some beneficial effect but neither was as good as the organic mercurial preparations. Chloranil was therefore not considered further.

It is interesting to note the rather high figures for field emergence of the untreated plot in this trial. This is accounted for by the use of good seed in a paddock newly ploughed after being for several years under Rhodes grass. The trials with seed lots of varying germinability reported in Table 11 were planted at the same time and place. Even the poorest of these seed lines showed a 60 per cent. emergence.

Four of the replications in the first treatment trial were planted with seed which had been recently shelled, the other four with kernels which had been shelled from two to four weeks before treatment and sowing. There were indications that the delay in planting after shelling somewhat reduced the emergence of untreated seed, but this effect, if real, was nullified by the best treatments.

Figures for selected treatments are given in Table 8.

Table 8.

EFFECT OF TIME OF SHELLING ON FIELD EMERGENCE.

Treatment.	"New" Seed.	"Old" Seed.
	%	%
Mercurial A	79	82
Mercurial B	75	73
Untreated	55	44
Untreated, hand-planted	57	38

Effect of Seed Treatment on Yield.

Any increase of yield from seed treatment may be due to improved stand or to increased average yield per plant. In an experiment planned to obtain information on these points untreated and Ceresan-treated seed was planted at from 22 lb. to 56 lb. of kernels per acre. Two randomised blocks using six seeding rates and split plots for the treatment were planted. The sub-plots were six rows wide and ran right across a paddock in order to facilitate planting. A 10-chain length was marked off for harvesting and threshing and weights were taken for the total yield of nuts from the 10 chain x 18 feet sub-plots. Stand counts at various intervals and other data were also recorded and are summarised in Table 9.

The treatment had a marked beneficial effect on yield. This appeared to be only partly due to increased stand, and in fact there was no statistically significant increase in yield with increasing planting rate. Under the conditions of this experiment a stand of one plant per foot of row could be achieved by planting about 30 lb. of treated seed per acre. It could with difficulty be approached by planting 56 lb. of untreated seed. Seed treatment is considerably less costly than increasing rate of seeding and results in a more uniform stand ; this could account in part for the higher yields from treated seed.

Table 9.

SEED TREATMENT AND YIELD.

Planting Rate.	Stand (Plants per Chain Row).		Yield (Lb. per Acre).	
	Ceresan.	No Dust.	Ceresan.	No Dust.
22 lb. per acre	42	25	1,260	970
26 ,, ,, ,, ...	54	31	1,150	1,060
30 ,, ,, ,, ...	69	40	1,310	1,010
36 ,, ,, ,, ...	71	39	1,340	1,170
44 ,, ,, ,, ...	79	50	1,240	1,100
56 ,, ,, ,, ...	102	55	1,120	1,090
Mean	69	40	1,230	1,070
Necessary differences for significance :—				
Between planting rate means with same sub-plot treatment :				
5% level	..	..	230	230
1% level	..	..	350	350
Between marginal treatment means :				
5% level	2·8		86	
1% level	4·3		130	

Seed Treatment and Germination Tests.

The growth of *Rhizopus* sp. and *Aspergillus niger* on peanut kernels seriously interferes with the laboratory determination of percentage germination. *Rhizopus* sp. in particular tends to spread on the germination tray and affect considerably more kernels than those originally infected. Because of this it is difficult to obtain reproducible results, but the difficulty is overcome by treating the seed with an organic mercury dust. Table 10 illustrates the variation in tests of two samples of the same seed lots.

Table 10.

VARIABLE PERCENTAGE GERMINATION IN LABORATORY TESTING.

Untreated.		Treated.	
1st Test.	2nd Test.	1st Test.	2nd Test.
39	92	98	95
58	90	97	97
57	87	97	96
6	89	96	97

In practice, peanut kernels intended for seed are after shelling submitted for germination test and those seed lots which fail to reach the required standard of 80 per cent. after treatment are discarded. However, emergence in the field varies with many other factors besides laboratory germination of the seed. When planted in unsuitable soil, treated seed giving a good laboratory germination may still show a poor field emergence. When planted in soil of a good type this difference is less marked, as can be seen from Table 11. Under these circumstances laboratory germination of treated seed gives a satisfactory prediction of field performance.

Table 11.

LABORATORY GERMINATION COMPARED WITH FIELD EMERGENCE IN A SCRUB SOIL OF GOOD TYPE.

Untreated.		Treated.	
Germination (%).	Emergence (per 100 Seeds).	Germination (%).	Emergence (per 100 Seeds).
73	34	94	68
74	38	94	78
61	36	93	70
78	28	96	62
71	52	91	84
76	32	95	64
76	52	97	80
Mean 73	39	94	72

It is obvious that, while conditions in the field modify the laboratory performance of seed, it is still very important to have seed of a high standard of germination. It is not possible to test this standard with reasonable accuracy unless the seed is first treated with an efficient fungicide.

CROP ROTATION AND CROWN ROT.

Reference has been made to the influence of soil type and crop rotation on crown rot and associated diseases of peanuts. This influence is very marked. Direct evidence on this point was obtained and is shown in the figures of Table 6.

On a good scrub soil newly ploughed after several years under Rhodes grass, there was little benefit from seed treatment. On a scrub soil cropped to peanuts each year and on which a winter crop was ploughed in between peanut crops, the overall stand was poorer and differences due to treatment were marked. On a forest soil under continuous peanut culture, the differences were greater still.

Numerous observations support the claim that crown rot is more prevalent when the organic matter of the soil has been depleted. The high incidence of disease in old peanut lands could be explained therefore on the basis of either the depletion of organic matter or a build-up of pathogens in such land. However, in many such paddocks good stands of peanuts are frequently to be found only on areas where peanuts have been stacked and threshed in previous seasons. These areas should carry larger rather than smaller concentrations of pathogens, and in fact wilt diseases occur more frequently in them than elsewhere. Pre-emergence rotting and crown rotting are conspicuously less prevalent in soil containing the peanut debris from the old stacks. The evidence all points to a lower incidence of these diseases when humus is abundant, however it is derived.

DISCUSSION.

Crown rot of the peanut due to *Aspergillus niger* does not appear to have assumed the serious proportions in other parts of the world that it has in Queensland. Jochems (1926) recorded the fungus in peanuts in the East Indies and reported positive results on inoculation but dismissed the disease as unimportant. Gibson (1949) reported the disease as locally severe in East Africa and has since (1950) obtained successful inoculations with *A. niger*. He also recorded *Rhizopus arrhizus* among the fungi found in typical diseased material. Crosier (1944) recorded *Rhizopus nigricans* as severely injuring peanut seedlings in the germinator.

The incidence of crown rot in the South Burnett district in Queensland can be such as to constitute a serious threat to the peanut industry there, while more recently the disease has appeared to a serious extent in some North Queensland peanut crops. However, with adequate precautions of seed treatment and crop rotation as outlined previously (Morwood, 1946) the disease may be kept down to small proportions.

In the field there is inevitable confusion between crown rot and pre-emergence rot caused by *R. arrhizus*. The two diseases combine to reduce stands and the benefit of seed treatment is attained by a degree of control of both troubles.

Seed treatment of peanuts has been widely adopted for the improvement of field emergence. Gibson (1950) in East Africa and Prevot and Commun (1951) in French Equatorial Africa found that seed treatment increased establishment by up to 50 per cent. and the latter workers stated that seed disinfection is one of the most effective means of developing ground nut production. Hopkins (1945) refers to additional control of root rot caused by *Sclerotium rolfsii* by seed disinfection with mercurial dusts. This effect has not been observed in Queensland.

Reference to control measures for crown rot and pre-emergence rot has already been made and it is now only necessary to reiterate the salient points. Machine-shelled kernels should be treated before planting with an organic mercury dust with a minimum mercury content of 1·5 per cent. at the rate of 5 oz. per 100 lb. kernels. With Red Spanish kernels the rate should be reduced to $2\frac{1}{2}$ oz.

per 100 lb. Peanuts should be sown in a rotation that ensures ample organic matter in the soil. This is most likely to be attained by including several years of Rhodes grass pasture in the rotation. Peanuts should be the first crop sown following the ploughing out of the Rhodes grass. Crop residues should be incorporated in the soil and not burnt (Kerr and Cartmill, 1951).

ACKNOWLEDGMENT.

The experimental work reported in this article has only been possible with the co-operation of numerous officers of the Queensland Department of Agriculture and Stock and of peanut growers. The Queensland Peanut Marketing Board made available facilities and provided materials and assistance.

REFERENCES.

CROSIER, W. F. 1944. Seed-borne microorganisms. *In* N.Y. St. Agric. Exp. Sta. Rep. 1942–43 : 56–7.

GIBSON, I. A. S. 1949. *In* Overseas Food Corporation Scientific Dep. E. Afr. Rep. 1948–49 : Sect. 18.

————————. 1950. *In* Overseas Food Corporation Scientific Dep. E. Afr. Rep. 1949–50 : Sec. 19.

HILDEBRAND, A. A., and KOCH, L. W. 1943. Rhizopus root rot of sugar beet. Canad. J. Res. 21 (C) : 235–48.

HOPKINS, J. C. F. 1945. The importance of seed disinfection of ground nuts. Rhod. Agric. J. 42 : 432–3.

JOCHEMS, S. C. J. 1926. *Aspergillus niger* op katjang tanah. Ind. Cult. Teysm. 11 : 325–6.

KERR, J. A., and CARTMILL, W. J. 1951. Peanut growing in Queensland. Qd. Agric. J. 72 : 63–76.

MORWOOD, R. B. 1946. Peanut crown rot. Qd. Agric. J. 63 : 18–19.

PREVOT, P., and COMMUN, R. L. 1951. Desinfection des semences d'arachide. Oleagineaux 6 : 1–10.

WILSON, C. 1950. Peanut seed treatment. Plant Dis. Reptr. 34 : 87–95.

(Received for publication, Aug. 13, 1953.)