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DISEASE in Farm and Garden Seeds

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DESPITE recognition of the desirability of using good quality seed, inadequate attention tends to be paid to the presence of disease in what is otherwise regarded as sound seed. Fungi and bacteria are present on or within all seeds (in rare instances viruses also persist) but most of these have no ill effect. The significance of others may be expressed in several ways. Root nodule-forming bacteria essential for normal lucerne growth are conveniently established by the well known seed-inoculation technique. In other instances fungi are known to exist in a commensal manner within seed tissues with no ill effect on the latter. Increasing information is being obtained on the relation of such endophytes to problems of temperature control in stored grain. Endangered stock health may follow use of feed grains contaminated with mould fungi. Fermentation processes, induced by the ingested fungi after mouldy grain is mashed, can produce substances particularly harmful to pigs. The objective of this bulletin is to deal with basic characteristics of seed-carried organisms which impair development of plants grown from diseased seed. The supplementary tabulation aims to present a general summary of seed-carried diseases of major importance in New Zealand arable farming. As details of disease life histories can be obtained from other sources, the available space in this account is concentrated on recent developments in control and prevention.

Principles of disease prevention.

Where seed transmission is important, possibilities of applying the following broad principles of prevention within which many techniques have been developed, should be examined:

1. Exclusion of parasite from the host plant.
2. Reduction of inoculum or infective matter.
3. Breeding or selecting disease-resistant plants.

1. EXLUSION OF PARASITE. The possibilities here include **Quarantine** or prohibition of import, pending assurances of disease freedom. **Notification.** Several countries list certain plant diseases whose occurrences must be notified in order that preventive measures can be organised. Onion smut for example is a notifiable crop disease in England. **Eradication.** This principle may be applied successfully in eliminating carriers from a seed-producing crop as for instance the removal of mosaic-infested bean plants at the green-leaf stage when disease symptoms are well defined. **Prevention of sale.** In England it is an offence to offer for sale plant material carrying any of the several notifiable diseases. **Certification.** Official supervision to ensure that disease-free material is retained for seed production and carefully harvested, is a form of control which farmers can willingly accept. The New Zealand Department of Agriculture has been conspicuously successful in maintaining varietal type, improving yields and checking virus disease within potatoes and among seed crops there are other possibilities in respect to disease prevention. The example of dry-rot disease is a case in point.

Brassica seed and dry rot. Tests made by the Plant Diseases Division on turnip and swede seed produced under Department of Agriculture supervision show that seed produced in New Zealand is, in general, freer from dry-rot disease than imported seed similarly tested. Features of the programme include careful selection of seed plants based on a progeny test principle and choice of a planting area with a view to securing isolation from other brassica crops and likely inter-pollination. Seed production is favoured in the dry areas of Central Otago where among other things there exists a good measure of natural control against dry-rot disease. Officers of the Department of Agriculture make field inspections and the contracting firm may thereafter be required to rogue the seed crop to remove off-type plants. Additional care is exerted in the processes of harvesting and packeting the seed. The overall objective is to preserve agronomic value unimpaired by admixture. Dry-rot disease is only one of several limiting factors involved but it is clear that the use of "Government approved" turnip and swede seed will ensure the best prospect of disease avoidance to the extent that the disease problem has been combated by "supervision of seed production." It is significant that bacterial soft-rot decay is now less widespread, at least through parts of the South Island. Formerly very severe losses occurred when swede roots disintegrated into a pungent decay brought about by soil bacteria which had entered the dry-rot cankers. This secondary bacterial decay has been noticeably less severe in the last few years as "approved seed" has become increasingly used. In the presence of uninjured canker-free stem tissue, bacteria are unable to produce the ruinous soft rot. An early expansion of the Government Approved Seed scheme can be hoped for in respect to production of cabbage, cauliflower, carrot, celery and other horticultural seeds. Seed disinfection is discussed later but it should be noted that any line of brassica seed can be largely freed of dry-rot infection by a hot water treatment. This is not practicable however under farm conditions. The College is in a position to do the treatment whenever necessary, involving a tap-water soak of 15 minutes, followed by transfer of seed to water held strictly at 122 deg. F. for 30 minutes after which it must be quickly dried.

2. REDUCTION OF INOCULUM. If this principle could be applied in a practicable way to reduce infective material rife at any one time, an improvement could be expected in respect to several diseases. A notable example is discussed as follows:

(a) Ryegrass blind-seed disease. Continued failure to control this disease in New Zealand can be partially attributed to the fundamental weakness lying in reluctance or inability to grapple the problem from the diseased seed angle. This has been done in the ryegrass seed-producing districts of Oregon, U.S.A., and it is significant that the disease there is under good field control. The causal fungus at a certain stage in its life history is confined to the seed. Further, although it may be carried over on the other grass hosts, it is not a soil-inhabiting organism. At each pasture sowing a proportion of "blind" or diseased seeds are sown, or others are "inoculated" into the soil when premature diseased seeds are shaken to the ground during harvesting. In either event this fungus-infested seed produces the reproductive apothecia from which primary (ascospore) infection is established in the grass flower heads in the following spring. Secondary (macro-conidia) infection will follow, especially when damp weather conditions occur in October-November, after the disease has been established in the grass heads. If truly disease-free ryegrass seed crops are required some attempt must be made to eliminate primary infection from dead seeds on the soil surface. Neill has shown that infected seed stored or aged for two years, or oven dried, can be thus disinfected and the internally-established fungus destroyed. In fact, there is little possibility of the fungus being vigorous if seed more than a year old is sown. Hot water treatment at 122 deg. F. for 30 minutes, followed by drying, has also been proved effective in eradicating the blind seed fungus. These treatments may reduce field germination even further but so long as heavier seeding rates are possible the reduced germination will not matter in terms of grass pasturage. The important thing is that no diseased seed should be re-established in a field. Many difficulties can be imagined in organising a universal scheme of disinfection of ryegrass seed either by hot water or by ageing treatment but the task should be faced. So long as there is a proportion of diseased seed in every pasture sowing, primary infection will occur in grass heads next spring and the disease will rise or fall in severity depending on the way in which weather conditions then assist or inhibit the build up of secondary infection. Meanwhile the College has secured success in keeping initially good germinating crops at a high level of disease avoidance by sowing the seed on fallowed ground, with fields so located as not to be surrounded by other ryegrass areas. Other ryegrass in the near vicinity of the seed crop is topped by mower—especially "foreign" ryegrass in field corners. The objective has been to "reduce the inoculum" or the amount of infective material from which the disease starts.

(b) Hot water treatments. The essential difference between loose and covered smut of barley and wheat is that sooty-black smut spores in the former are shed when the crop is still green and enter unaffected flowering heads to become established within the developing grain. Covered smut remains intact and held by the chaff or glumes until the spore balls are shattered during threshing with consequent external contamination of healthy seed by the spore dust. The hot water treatment for loose-smut eradication is not feasible on a farm, for a strict control of temperature for a definite time is essential—a pre-soak in tapwater 5 hours, followed by soaking in water at 127 deg. F. for 10 minutes (wheat) or 5 minutes (barley). Hot water treatments against loose smut and leaf stripe were developed in New Zealand under the initiative of Messrs Neill and Hewlett and the Canterbury (N.Z.) Seed Co. That organisation distributed H.W.T. barley seed to contract growers with noticeable improvement in crop yields and disease eradication. At the present time the Department of Agriculture administers within its seed-certification organisation a pure wheat scheme entailing hot water treatment, which is commendable in its simplicity and efficiency of operation. The department arranges for multiplication of pure lines of nucleus wheat under strict observation at the Crop Research Division. In the case of the main variety, Cross 7, the department then supplies Canterbury Agricultural College with stock seed. This is hot-water treated with the equipment at the Crop Research Division, grown as a field crop by the College and distributed to merchants as certified mother seed, available then to farmers as seed treated against loose smut. The resulting crop may then be certified by the department as standard seed. It must be noted that some wheat varieties are susceptible to germination injury under hot-water treatment. Black has shown that Dreadnought wheat may be partially dormant in some seasons requiring a period of post-harvest ripening before it will germinate fully. Hot water treatment of Dreadnought seed during this dormant period is likely to be injurious.

Good results are being obtained by the use of hot water treated celery and tomato seed. The celery leaf spot disease (see table) is devastating in its effects on plant vigour and hot water alone seems effective in eliminating seed infection. The treatment requires a temperature of 136 deg. F. for 10 minutes and during the past few years the College has offered to do the treatment for commerial growers. It has been very noticeable how much less copper spraying of foliage is necessary on celery plants grown from hot-water-treated seed. Tomato seed hot-water treated at 122 deg. F. for 10 minutes is now generally sought by glass-house producers in the Christchurch area who have been impressed by the vigour and initial freedom from disease of seedling plants grown from treated seed. What the undoubted beneficial effects of the hot-water treatment of tomato seed can be attributed to is not clear, but it does seem that a disease factor established in the seed coat is effectively eliminated. Furthermore the heat treatment appears to be selective and to eliminate weak seeds. Certainly tomato plants grown from hot-water-treated seed are characteristically uniform in size and vigour with a conspicuous absence of weak seedlings.

(c) Dust disinfection.

(i) **Peas.** Pre-germination losses of garden and field peas reach surprisingly high levels, especially when the seed is germinating in wet, cold soil. Germination loss is attributable to seed decay caused by a complex of soil fungi normally present in arable soils but whose destructive propensity is encouraged by soil conditions unfavourable to quick plant growth. Additional to the soil fungi **Rhizoctonia** and **Pythium** others are carried on seed which has become infected during crop growth, for ex-

In the diseases summarised below infected seed is the vital link in the life cycle. Aspects of prevention merely referred to in the last column are discussed in the text of the Bulletin.

Host Plant	Disease	Causal Organism	Distinctive Appearances	Prevention relating to seed
Oats	1. Leafspot and Seedling Blight	Helminthosporium avenae	Brown spotted leaves; germination loss.	Organic-mercury dust disinfection 2ozs/bushel
	2. Loose Smut	Ustilago avenae	Sooty spore mass, loose	Dust disinfection as for 1.
	3. Covered Smut	Ustilago Kolleri	Sooty spore mass held by glumes	
Barley	4. Footrot	Fusarium culmorum	Stunted seedlings	Dust disinfection as for 1.
	5. Earblight (Scab)	Fusarium graminearum	Sterile ears or shrivelled grain	
	6. Leaf Stripe	Helminthosporium gramineum	Brown streaks on leaves	Tap water 5 hours: Hot water 127deg.F., 5mins.
	7. Loose Smut	Ustilago tritici and U. nuda	Smutted head in green crop	Tap water 5 hours: Hot water 127deg.F., 5mins.
	8. Covered Smut	Ustilago Jensenii	Smutted head intact until threshing	Dust disinfection as for 1.
Wheat	9. Footrot and Earblight—as for Barley (above 4).			
	10. Loose Smut	Ustilago tritici	Smutted heads in green crop	Tap water 5 hours; Hot water 127deg.F., 10mins.
	11. Covered Smut	Tilletia caries; T. foetens	Smutted heads intact until threshing	Dust disinfection as for 1.
	12. Ergot	Claviceps purpurea	Purple black sclerotia in ripe ear	Removed by seed dressing
Swedes, Turnips and related crops	13. Dry rot	Phoma lingam	Spotted seedling leaves. Canker and dry rot of stem	Hot water treatment 122 deg.F., 30mins, or use "Government approved" seed.
	14. Stem blight	Alternaria spp.	Black spots on stems and pods	Use "Government approved" seed.
	15. Bacterial soft rot	Bacillus campestris, etc.	Soft pungent internal decay	If Dry Rot is controlled this secondary soft rot is restricted.
Ryegrass	16. Blind Seed	Phialea temulenta	Seed embryo shrivelled and sterile	Use 2-year-old seed or sow high germinating seed in isolation.

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APPENDIX TABLE

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Host Plant	Disease	Causal Organism	Distinctive Appearances	Prevention relating to seed
Beans (Dwarf)	17. Haloblight and wilt	Phytomonas medicaginis	Water soaked spots and wilting	Foliage spray Bordeaux 3.4.50 and resistant varieties.
	18. Anthracnose	Colletotrichum lindemuthianum	Oval brown cankers on pods and stems	Foliage spray Bordeaux 3.4.50 and resistant varieties.
	19. Mosaic	A virus	Green yellow leaf mottle and stunted growth.	Remove infected plants before harvesting seed.
Peas	20. Collar rot and pod blight	Ascochyta species **etal.**	Purplish-black spots	Seed disinfection using TMTD dusts at 2ozs/bushel.
	21. Pre emergence decay	Rhizoctonia, Pythium and other soil fungi	Failure to emergence from soil	Seed disinfection using TMTD dusts at 2ozs/bushel.
	22. Wilt	Fusarium orthoceras var. pisi.	Brown dead patches; rolled brittle leaves	Use resistant varieties.
Linseed and Flax	23. Seedling blight	Colletotrichum linicola	Brown leaf spots and seedling collapse	Disinfection using organic mercury or TMTD dusts
	24. Stembreak-Browning	Polyspora lini	Brown stem lesions and breaking	Dust hydrated lime followed by 10mins. hot water 126 deg.F. with 1% hydrated lime.
	25. Pasmo	Sphaerella linorum	Spherical lesions with black pinpoint dots.	Avoid seed from diseased crops.
	26. Wilt	Fusarium lini	Seedling blight and wilting	Conc. Sulphuric Acid 3-5 mins., followed by washing.
Celery	27. Leaf Spot	Cercospora apii; Septoria apii	Small brown spots on leaves and stems	Hot water treatment 136 deg.F., 10mins.
Onions	28. Leaf Smut	Urocystis cepulae	Cracked stems and leaves filled with sooty black spores.	Formalin 1-1½% in water applied by drip tank when seed is sown.

ample, the species **Ascochyta pisi** and related forms (table) causing pod leaf spotting and collar rot. These also contribute to germination losses and everything is to be gained by effective seed treatment. Throughout several years of successive sowings at Lincoln the field germination of the standard varieties Massey and Onward has averaged no more than 60 per cent in untreated sowings. When the sowings coincided with adverse soil conditions losses were even higher. Experiments with approved pea-seed disinfectants have shown that at least 15 per cent improvement can be expected where the chemical protection is given. Spergon containing Tetrachloro-para-benzoquinone, Fernasan or Premasan both containing Tetramethyl thiuramdisulphide are recommended, used at the rate of 2 ounces per bushel and machine applied during commercial seed cleaning.

(ii) Flax and Linseed. It is indicated in the Table that certain flax diseases are preventable by seed disinfection and the organic-mercury dusts such as Ceresan have been especially effective. In Northern Ireland, Muskett has calculated that by introducing a certification scheme for flaxseed, whereby the health of seed was checked and the whole of seed stocks disinfected, the fibre crop alone was increased by the value of £2,000,000 during the 1939-45 war period. Special note should be made of the Baylis method of eliminating seed-carried **Polyspora** stem break and browning. This can be eliminated by a 10 minute hot-water (126 deg. F.) steep. Baylis observed though that the mucilaginous flaxseed coating swelled during H.W.T. and in consequence seed dried too slowly and tended to coalesce in lumps. This gumming was reduced during H.W.T. when 5 per cent potash alum was added to the steep and entirely avoided when the seed was first dusted with 4 ounces per bushel of hydrated lime and then added to the hot-water steep, also containing 1 per cent of hydrated lime.

(iii) Cereal seed. Wheat and barley seed are almost universally dust-disinfected during the post-harvest seed-cleaning operations. It is unfortunate that the same situation has not developed in New Zealand with oats in which crop smut diseases are very prevalent. Disinfection of seed wheat against covered smut must continue for, despite absence of heavy disease outbreaks, the author found that **Tilletia**-covered smut spores were present in 17 per cent and 9 per cent of wheat seed samples examined in two successive years. Justification for the organic-mercury dust treatment resides also in the benefit conferred on cereal seed germinating in soil highly charged with **Fusarium** foot-rot fungi. The problem here is of the same nature and degree as that discussed in connection with peas. Counts of field emergence of wheat reveal germination losses of up to 40 per cent and an appreciable improvement has been demonstrated at Lincoln by using dust-disinfected seed. A poor strike sometimes follows the sowing of dusted wheat which has been stored for a long period before sowing. Baylis has shown that wheat slightly out of condition may be dust-disinfected in autumn and safely sown the following spring. Injury through dusting can be expected, however, when wheat seed with a moisture content exceeding 16 per cent is treated and stored before sowing.

(iv) Recent seed-disinfection developments. The case has been made that proper seed treatment offers an inexpensive method of controlling certain seed-carried diseases and of protecting germinating seeds against some soil organisms. The dry-dusting method as at present applied in New Zealand, however, has been found inadequate in many respects. The problem is not one of what chemical to use. Over the years liquid steeps like formalin and bluestone and copper carbonate and organic-mercury dusts have been all proved effectively fungicidal though the latter materials have prevailed on account of their ease of application. The problem exists in securing adequate and efficient dust-coverage of treated grain. From the evidence of an investigation reported by the author (N.Z. Jour. Science and Technology 32A. 1-21, 1950) it may be concluded that many machines are mechanically incapable of ensuring proper disinfectant coverage.

Among commercial wheat samples from 185 sources only 11 carried the 2 ounce per bushel dust load claimed for all. The dominant faults in so many dusting machines include inadequate agitation of dust and seed in the mixing cylinders, loss of dust by draught and faulty dust-supply devices. Fortunately machines are now available which have been proved completely efficient, notably the

Stickland type of machine used in England and the Hannaford machine of South Australia.

New Methods. A trend in the United States is definitely away from dust treatments and towards slurry or "semi-wet" methods where small amounts of liquid serve as a carrier of the dust and are mixed in a fully enclosed system with a large volume of seed. One type of slurry is prepared by adding a specially formulated powder Arasan S.F. containing 75 per cent T.M.T.D. to water, 1 lb per gallon. When used in the patented machine, flying dust, both offensive and poisonous to operators, is eliminated while coverage of seed is complete. The Panogen treatment of Swedish origin is of a similar nature. A continuous-spray method may also be used entailing application of a wettable fungicide as a spray to seed passing through a conical enclosed and fast-revolving cylinder. Another new method of disinfecting seed involving application of heat in a manner intermediate between hot water and heated dry air, is accomplished by introducing steam into a current of air, with mechanical arrangements to maintain desired temperature and moisture levels. The term "Vapour heat" is used to describe this method which eliminates seed diseases and which has become popular as the difficulty of drying normally H.W.T. seed is overcome.

Pelleted seed. In the table it has been indicated that onion smut can be controlled by the formalin drip method, with the solution (1.0-1.5 per cent strength) applied as the seed is deposited in the coulter row. A more convenient alternative worthy of trial consists of first moistening onion seed with methyl cellulose and then coating with an equal weight of a suitable fungicide active against the onion smut fungus. Pelleted seed has of course many promising possibilities such as ensuring more even sowing by adding bulk to small seed, a method of securing close contact between seed, fertiliser, growth substance or insecticide-fungicide.

Disinfection of vegetable seed. It has been proved that most vegetable seeds derive benefit from disinfection, notably in avoidance of heavy preemergence soil losses caused by the **Fusarium, Rhizoctonia** and **Pythium** fungi. T.M.T.D. dusts have been proved strikingly beneficial against "damping off" in sowings of tomato, beet, lettuce, peas, beans, radish, cabbage, cauliflower, carrot and flower seeds. In the interest of home and market gardeners, seed distributors might well examine their obligation in having the seed disinfected at the time it is packeted for sale.

3. BREEDING OR SELECTING DISEASE RESISTANT PLANTS. Selection of healthy plants has been operated from early times in securing plant improvement and disease avoidance. Resistant varieties developed by hybridisation techniques in crop research centres are now being sought in respect of many diseases, especially those arising from invasion of leaf tissues by the air-carried pathogens which produce rust and mildew types of disease. Meanwhile among the seed diseases listed in the table, the example of dwarf beans warrants mention merely as an illustration of possibilities within the above-defined principle of disease prevention. Although the worst effects of Halo-blight and Anthracnose can be limited by spraying the plants with 3-4-50 strength Bordeaux mixture, note should be taken of the measure of resistance within certain varieties. Reid, of the Plant Diseases Division, has shown that the white-seeded types and the runner-beans are highly resistant, though none of the available material is entirely immune against Halo-blight and Anthracnose.

At the Crop Research Division, Cruickshank has shown that useful material exists on which breeding work against pea wilt can be based. Among garden peas, English Wonder, Quartermaster, Stratagem, Yorkshire Hero, Laxton's Progress and Senator have been shown to be wilt resistant. This character is possessed among field peas by Marathon, Mammoth Blue, Harrison's Glory and Prussian Blue. It is noteworthy also that there are prospects of securing a measure of dry rot resistance within some lines of swede seed.

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