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# STUDIES ON THE DISINFECTION OF SEED POTATOES

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## SUMMARY

1. Experiments to compare the effect of drying washed and disinfected seed tubers in ventilated stacks of 10 cwt. boxes with drying in seed chitting trays indicated that, in general, there were no marked differences produced by the two methods with respect to control of storage disease, crop growth and yield. However, there was a tendency for condensation moisture to form on the top boxes of the stacks which was probably associated with a slight increase in soft rot in 1965 and blackleg in 1966-67 and 1967-68. Covering boxes with straw was found to apparently reduce condensation.

2. Commercial washing and disinfection increased the incidence of blackleg in the field despite modifications aimed at reducing damage before disinfection. The washing machine was shown to assist in some way the entry of the blackleg organism into the potato tissues beyond the reach of the disinfectant. Disinfection of unwashed tubers reduced the level of the disease to below that found in untreated tubers.

3. Some evidence was given to account for the generally higher incidence of blackleg in the trials in 1968 than in 1967. Although experiments were planted in different fields in the same area in the two years, it is suggested that the difference in blackleg incidence was the result of the

rainfall pattern.

4. Using hot air drying apparatus, it was shown that disinfected and washed and disinfected tubers could be dried satisfactorily with air temperatures up to 212°F when exposed to the hot air stream for up to $3\frac{1}{2}$ min. There was no evidence that the hot air affected control of storage diseases, growth of crop, blackleg or yield.

5. Disinfection of unwashed tubers in a prototype disinfection tank for $\frac{1}{2}$ - $\frac{3}{4}$ min. with an EEMC concentration of 150 ppm showed that storage disease could be reduced and blackleg controlled in the field. However, the presence of soil slightly affected the efficiency of the disinfection process.

6. In the trials over the three years disinfection usually reduced the incidence of skin spot, dry rot and gangrene to a satisfactory level. When this was not the case, delay in applying the treatment of more than three days after lifting was usually the reason.

7. Generally, disinfected tubers gave sprout stimulation, earlier emergence, greater number of stems and tubers than undisinfected tubers.

8. Despite the higher level of blackleg in crops grown from

washed and disinfected seed compared with untreated tubers, the yield was not significantly reduced. Unwashed, disinfected tubers produced yields which compared favourably with untreated tubers, showing that plants grown from undisinfected seed were probably more vigorous.

# 1. INTRODUCTION

## 1.1. General

Interest in seed tuber disinfection as a means of controlling diseases which cause losses in storage, or which adversely affect growth or quality of the subsequent crop, dates back to the end of the last century, when Bolley (1891) suggested the use of mercuric chloride for the control of the transmission of common scab (*Streptomyces scabies*). Since this date, a wide range of chemicals and techniques of application have been investigated in an attempt to reduce particular disease problems against which other means of control are inadequate. The purpose of seed tuber disinfection has tended to vary in practice with the problems prevalent in different countries, emphasis having been given to the control of seed piece decay caused by *Erwinia* spp. and *Fusarium* spp. and common scab in the U.S.A. (Clayton, 1929), *Rhizoctonia solani* in the Netherlands (van Emden, 1958) and latent tuber diseases in the British Isles (Todd, 1963; Hirst, 1967).

One of the first compounds shown to control a wide range of tuber diseases was a 0.1 per cent solution of mercuric chloride used as a 1½ hour steep (Bolley, 1891; Clayton, 1929; Greeves, 1937; Greeves and Muskett, 1939; Graham *et al*., 1957; Robinson *et al*., 1960). The main disadvantage of this compound is the length of time required for effective control (Clayton, 1929; Greeves and Muskett, 1939). Hot mercuric chloride treatment was shown to require less time and was used effectively to a small extent in the U.S.A. (Chupp, 1925) but had the disadvantage of involving the farmer with the need for special heating equipment. The use of a 1-2 per cent solution of formaldehyde, introduced by Arthur in 1897, has given generally only limited success in controlling tuber diseases (Arthur, 1897; Small, 1935; Greeves and Muskett, 1939; Boyd, 1957; Gray and Malcolmson, 1967) although a hot formaldehyde treatment developed by Melhus and Gilman (1919) proved highly effective against both common scab and *Rhizoctonia*.

Claus *et al*. (1923) and Appel (1923), in Europe, and Clayton (1929), in the U.S.A., were amongst the first workers to report on the use of organo-mercury compounds. Similar compounds are now widely used for seed potato disinfection and are recognised as the most effective chemicals available for the control of a wide range of common tuber diseases. Although they are highly toxic to mammals (Graham, 1964), they have the advantage that good disease control may be obtained with a disinfection time of as little as ½-1 minute with 100-150 ppm solution.

In the British Isles, the use of ethoxyethylmercury chloride (EEMC) or methoxymethylmercury chloride (MEMC) solutions has proved effective against skin spot (*Oospora pustulans* (Greeves and Muskett, 1939), dry rot (*Fusarium caeruleum* (Foister, 1940), *Rhizoctonia* (Graham *et al*., 1957) and gangrene (*Phoma* spp.) (Boyd, 1960), although Gray and

Malcolmson (1967) concluded that organo-mercurial compounds did not always give good control of gangrene in N.E. Scotland.

In the U.S.A., Guthrie (1959) found the organo-mercurial Semesan Bel (hydroxymercurinitrophenol 12.5 per cent : hydroxymercurichlorophenol 3.8 per cent) controlled seed piece decay in the soil better than, or as well as, other compounds tested, and Robinson *et al*. (1960) reported that it controlled *Verticillium* wilt (*Verticillium albo-atrum*).

In Holland, organo-mercurials are widely used to control *Rhizoctonia* (van Emden, 1958) while, in Russia, Manturova (1960) and Znamenskya (1960) have found NIUIF solution (1-4000 basic solution containing 1-3 per cent ethylmercury phosphate) controls skin spot on several varieties of potato.

Among other chemicals which have been developed to some extent commercially, may be included some of the antibiotics and phenol compounds. Variable results have been obtained from the use of antibiotics. Bonde (1953) introduced streptomycin for the control of bacterial rot of seed pieces and a reduced incidence of seed piece decay and blackleg (*Erwinia carotovora* var. *atroseptica*) from the use of this compound has been reported (Bonde and de Souza, 1954; Bonde, 1955), although Graham and Volcani (1961) could not obtain a consistent reduction.

Oligomycin has been shown to reduce the incidence of gangrene but was phytotoxic (Gray and Malcolmson, 1967). Antibiotics have been used in conjunction with other compounds by Bonde and Hyland (1960), using either dieldrin or captan with agrimycin, and Duncan and Galligby (1962) using captan with streptomycin, but little or no benefit was reported from the treatments.

Of the phenol based compounds, Warren and Potter (1961, 1962) suggested the possibility of orthophenylphenol and 2,4,5-trichlorophenol for the control of a range of common pathogenic organisms on potatoes. Using chlorophenol solution, Gray and Malcolmson (1967) controlled Rhizoctonia but found an increase in the incidence of wet rot. However, in the Netherlands, phenol compounds are used commercially to control Rhizoctonia.

Despite the wide range of other compounds tested as seed tuber disinfectant solutions, none have been developed extensively for this purpose in practice.

Treatment with thiram (tetramethyl thiuram disulphide) did not satisfactorily control gangrene or Rhizoctonia (Gray and Malcolmson, 1967) or skin spot (Lennard, 1967). However, McKee and Boyd (1962) found control of dry rot in a small scale trial and Førsund (1968) recorded a reduction in degree of attack by Oospora pustulans on the underground parts of potato plants. McKee and Boyd (1962) tested diphenyl for dry rot control but found control erratic and sometimes the compound was phytotoxic. Gray and Malcolmson (1967) also found this chemical unsatisfactory for gangrene control.

The application of disinfectant dusts has fewer practical difficulties than solutions in spite of the difficulties of ensuring good coverage of the tuber surface (Boyd, 1957; Gray and Malcolmson, 1967). Tecnazene (5 per cent 6-tetrachloronitrobenzene) has been successfully used to control dry rot (Foister and Wilson, 1950; McKee and Boyd, 1962) and gangrene (Harrison and Downie, 1960). However, there were severe gangrene outbreaks in stocks that had been treated with tecnazene in N.E. Scotland (Gray and Malcolmson, 1967). Thymol has been shown to reduce dry rot infection (Foister, Wilson and Boyd, 1945) but did not control skin spot (Boyd, 1957). Using a dust form of Semesan Bel, Clayton (1929) reported satisfactory control of Rhizoctonia, common scab and seed piece decay. However, apart from the organo-mercury dusts, no dust compounds are available which give control of a range of common diseases.

Although most dusts that have been used for disinfection of tubers rely on the volatility of the active ingredient for effect, there is, at present, little published work on the process of fumigation itself. Gray and Malcolmson (1967) found that fumigation with trioxymethylene was only moderately effective in controlling Rhizoctonia if tubers were washed before treatment.

Other chemicals which have been used for disease control include sulphur for common scab control (Butler and Jones, 1955), yellow oxide of mercury for seed piece decay control (Cunningham and Reinking, 1946), maneb for seed piece decay (Line and Eide, 1960) and skin spot control (Lennard, 1967; McGee, 1967; Førsund, 1968), captan for skin spot (Bonde and Hyland, 1960; Lennard, 1967) and bacterial seed piece decay control (Bonde, 1960) and copper sulphate for skin spot control (Lennard, 1967) but none have become commercially important.

Graham (1964) tested a variety of organo-tin compounds but found that the only one which controlled some of the important tuber diseases was phytotoxic and reduced emergence and yield. He concluded that there was little prospect of the organo-tin compounds superseding the organo-mercury compounds as potato tuber treatments in Scotland in the near future.

In the widespread use of organo-mercurial disinfectants, the time of application of the treatment is found to vary depending upon the existing disease problems. This becomes apparent on consideration of the diseases prevalent in different countries.

In the U.S.A., seed tubers or seed pieces are disinfected immediately before planting, to control 'seed piece' decay which can cause extensive blanking when cut seed is used. Control of common scab (Clayton, 1929), Rhizoctonia (Clayton, 1929) and Verticillium wilt and blackleg (Robinson et al., 1960) has also been obtained by disinfection in this way. Tubers are disinfected either in piles, when the organo-mercurial solution is sprinkled over them until they are thoroughly wetted, or in dipping tanks (Clayton, 1929).

In Holland, where Rhizoctonia can cause considerable damage to young sprouts, tubers are disinfected during the storage period, usually in autumn before boxing (van Emden, 1958). Tubers are disinfected in baskets or boxes in tanks, in mobile disinfection plants or at large scale static continuous plants.

A process of disinfection within 72 hours of lifting has been used, particularly in seed growing areas of the British Isles, for the control of latent diseases which now form one of the major problems associated with seed potato production in these regions. At present, organo-mercury disinfection at lifting represents the only practical means of effectively controlling some of these diseases and preventing them causing extensive losses during the storage period and blanking in the subsequent crop. It has been reported that disinfection at this time also reduces the incidence of latent diseases in the subsequently harvested crop. The process is also important to the potato export trade where losses due to some latent diseases have adverse economic repercussions and, in addition, disease free seed is often necessary to overcome importing difficulties (Graham, 1960; Gray and Malcolmson, 1967).

Three methods of organo-mercury seed-tuber disinfection are being used in Scotland at present:

1) Small scale disinfection by immersing unwashed tubers in baskets or boxes in a solution of the organo-mercurial for ½-1 minute.
2) Disinfection of unwashed tubers for 12 minutes in mobile, continuous units.
3) Disinfection of washed tubers for 12 minutes at large, static plants.

Approximately 7000 tons of seed tubers are disinfected annually in Scotland, most of which are washed before disinfection.

## 1.2. Disease Incidence in Relation to Potato Seed Tuber Disinfection

In Scotland, organo-mercurial disinfection of seed tubers has been applied in particular against latent disease problems, and there is a considerable amount of evidence of its effectiveness in the control of skin spot, gangrene and dry rot.

Skin spot has been found to be amenable to control by organo-mercury disinfection at lifting with unwashed seed tubers (Greeves and Muskett, 1939; Foister, 1943; Boyd, 1957; Manturova, 1960; Znamenskya, 1960; Edie, 1964; Edie and Boyd, 1966; McGee, 1967) and with washed tubers (Boyd, 1960). However, if disinfection is delayed, it is less effective (Greeves and Muskett, 1939; Boyd, 1960; Edie and Boyd, 1966; McGee, 1967). Edie and Boyd (1966) found that the effectiveness of treatment further depended on the time of lifting, earlier lifting resulting in greater control.

Disinfected tubers are usually kept in trays after treatment which itself reduces skin spot infection compared with that in bulk stored tubers (Boyd, 1960; Boyd and Lennard, 1961a; Edie and Boyd, 1966; McGee, 1967). Washing alone reduces the level of infection (Boyd, 1957, 1960) and Boyd (1960) concluded that each part of the commercial disinfection process that he examined, that is, washing, disinfection and boxing, played some part in skin spot control.

There is evidence that infected seed can transmit the disease to the crop (Boyd and Lennard, 1961a; Edie, 1964), whereas there is a reduction in crops grown from disinfected seed. (Edie, 1964).

Good control of gangrene has been reported by several workers when tubers were washed and disinfected (Boyd, 1960; Todd, 1963; Jennings et al., 1964; Graham, 1964; Logan, 1964) or disinfected only (Anon, 1962; Todd and Adams, 1967; Logan, 1967b) at lifting. However, Gray and Malcolmson (1967) did not always obtain effective control and occasionally found an increase in incidence of the disease with disinfection. The failure of treatment, in these instances, was attributed to pre-harvest infection. The state of maturity of the crop at the time of disinfection was considered to be another factor determining the effectiveness of the disinfection treatment (Gray and Malcolmson, 1967). Todd (1963) has suggested that failure of disinfection to control gangrene can also be due to infection in storage as well as before harvest and delay in applying treatment for 6 weeks or more after lifting (Boyd, 1960) or until January (Gray and Malcolmson, 1967) has been found to give inadequate control.

There are conflicting results on the effects of washing without disinfection on the incidence of gangrene. Boyd (1960) and Graham (1964) have shown that washing alone reduces the incidence of the disease, although Gray and Malcolmson (1967) recorded an increase after washing compared with riddled only tubers.

Little information is available on the effects of disinfection treatment of seed tubers on the incidence of gangrene in the subsequent crop. In trials carried out by Logan (1967b), the incidence of gangrene in the progeny of washed and disinfected seed was found to be lower than that in the progeny from untreated seed, which he suggested may have been due to stem infection from planting infected seed (Logan, 1967a). Gray and Malcolmson (1966), Boyd and Logan (1966) and Boyd and O'Donnell (1967) have indicated that planting infected tubers can lead to an increase in the level of infection in the crop, but Rosser and Jones (1956) and Todd and Adam (1967) did not always find that the level of gangrene in the crop was related to the health of the mother tuber.

Good control of dry rot was given by organo-mercurial disinfection of unwashed tubers (Foister, 1940; Foister and Wilson, 1943; Small, 1945; Harrison and Downie, 1960; Logan, 1967b; Logan, 1967c) and by disinfection after washing (Boyd, 1960; Todd, 1963; Graham, 1964; Jennings et al., 1964).

Foister and Wilson (1943) found that the incidence of the disease was never reduced to below about 4-5 per cent which they attributed to the penetration of the fungus into cracks in the tuber surface beyond the reach of the disinfectant, or to infection in the field before lifting. A similar percentage infection has been found in tubers that have been artificially bruised before disinfection (Small, 1945). Satisfactory control of the disease is not obtained if disinfection is not carried out at lifting (Foister and Wilson, 1943; Small, 1945;

Boyd, 1960).

Washing without disinfection has reduced the incidence of dry rot (Boyd, 1960; Jennings *et al*., 1964; Graham, 1964). Boyd (1960) suggested the reduction was due to removal of inoculum by the washing process.

It has been shown that planting disinfected seed free from dry rot infection reduces soil contamination and, therefore, the incidence of disease in the subsequent crop compared with untreated seed (Boyd and Logan, 1966; Boyd and O'Donnell, 1967).

Among other diseases controlled to some extent by organo-mercury disinfection at lifting may be included *Rhizoctonia* and blight (*Phytophthora infestans*).

*Rhizoctonia* is satisfactorily controlled by organo-mercury disinfection at lifting of washed (Graham *et al*., 1957; Graham, 1960; Jennings *et al*., 1964) and unwashed tubers (Gray and Malcolmson, 1967). Control is also effected during the storage period (van Emden, 1958). However, Graham (1960) found that disinfection did not prevent germination of all sclerotia, but that when a wetting agent was added, the effectiveness of the solution was greatly enhanced. While washing alone has been shown to have no effect on the germination of sclerotia (Gray and Malcolmson, 1967), it produced a reduction in the number of plants with infection at the stem bases (Jennings *et al*., 1964).

Greeves (1937) showed that organo-mercury disinfection at lifting reduced the incidence of late blight but that disinfection 3-4 days after lifting the crop gave little or no control. However, more recently, both with unwashed (Logan, 1967b) and washed tubers (Graham, 1964) little control of the disease by disinfection was reported and this was attributed to infection already being established in the tuber.

The coiled sprout condition of potatoes associated with infection by Verticillium nubilum has been found to be controlled by disinfection at planting (Pitt et al., 1965).

For the control of common scab, Jennings et al. (1964) found organo-mercury disinfection at lifting was ineffective, but Cairns et al. (1936) indicated that the disease could be controlled by disinfection of tubers just before planting and by planting in soil apparently free of the pathogen.

One of the serious disadvantages of washing and disinfection is the increase in the incidence of blackleg in the subsequent crop, while inadequate drying may result in soft rot development during storage.

In Scotland, there appears to have been no published data on the effect of blackleg in the field, until interest was stimulated by the introduction of the commercial process of seed tuber washing and disinfection.

Evidence for a higher level of blackleg in washed than unwashed tubers has been obtained by Graham and Volcani (1961), Gray (1962), Jennings et al. (1964), Graham (1964), Logan (1964, 1969), and Gray and Malcolmson (1967), and although disinfection after washing has sometimes led to an even greater increase (Gray, 1962; Gray and Malcolmson, 1967) it usually reduces the level, at least in part (Graham and Volcani, 1961; Graham, 1963; Jennings et al., 1964; Logan, 1964, 1969).

With seed grown and washed and disinfected in Scotland, and subsequently planted in Israel, Graham and Volcani (1961) found that disinfection increased the level of disease compared with washed only treatments in one experiment, had no effect in three others, and in the only case where the disease was 'epidemic', led to a significant reduction. They concluded that EEMC did not satisfactorily control blackleg and suggested that this was due, in part, to the poor penetration of the disinfectant through the surface of the tuber and also to the systemic nature of the infection, bacteria having entered the heel end of the mother tuber into the vascular system. There was undoubtedly bacterial contamination at the tuber surface, since the blackleg organism had been found in the soil surrounding the plants in the field and was occasionally isolated from washings from skin scrapings. It was further suggested that the bacteria may have been in a physiological resting state and would not have been susceptible to the disinfectant.

That mechanical damage was in any way associated with blackleg infection was first recorded by Smith and Ramsay (1947) when they suggested that tubers with large proliferated lenticels, through which bacteria can easily enter from the soil, may develop soft rot or latent infection as a result of rubbing off of the tissue in the washing process, producing a wound which is readily infected by bacteria. Graham (1963) suggested that the bacteria enter lenticels and abrasions, partly under the influence of water pressure, and remain latent until the following season. Graham (1967) also indicated that the pintle rollers of the washing and grading machinery were responsible for damage to lenticels. The reduction in damage when pintle rollers were removed was demonstrated by Hamilton and Ruthven (1967) who showed that the uptake of the organo-mercurial EEMC was greater after washing in a machine with this type of roller than in one with smooth sponge rollers. Further evidence that infection is closely associated with the washing process was provided when Graham (1963) showed that blackleg can be markedly reduced if tubers are dipped in a bactericide before, as well as after, washing.

Logan (1964) described a gangrene-like symptom in seed tubers which had been washed in machines equipped with pintle rollers, and this he called 'bacterial hard rot'. After washing, and storage for 5 days in humid conditions, a bacterial rotting developed although there was a lower incidence in tubers which had previously been disinfected. He attributed this condition partly to the effect of the high pressure water jets impinging upon the surface of the tuber and causing entry of blackleg bacteria into tissues, beyond the influence of the mercury solution. If tubers with 'hard rot' symptoms were planted, blackleg developed in 76 per cent of the plants. Hard rot is to some extent similar to the phenomenon found by Rudd Jones and Dowson (1950) where the spread of the bacteria was limited by the formation of a retarding barrier under low relative humidity and temperature, and development of soft rot in high humidity and temperature.

Recently Logan (1969) investigated the effect of disinfecting unwashed tubers on the incidence of blackleg in the crop, and found that the level of disease was reduced to the same level as the untreated control tubers in one trial, and almost to this level in another. However, if tubers were brushed on pintle rollers before disinfection, the incidence of the disease was considerably increased and hard rot found during the storage phase. He concluded that all treatments in which soil was removed from the tuber surface by washing or brushing, increased blackleg level whether tubers had been disinfected or not.

It has been suggested that drying tubers after disinfection is the most important part of the process and, unless this is done thoroughly before they are bagged, boxed or clamped, large losses from soft rot result (Foister, 1940; Foister and Wilson, 1943). Immediate drying of washed ware can give almost complete control of soft rot (Ruehle, 1940; Twiss, 1960). More recently, soft rot has been further associated with washed and washed and disinfected seed, and has been attributed, at least in part, to slow drying (Boyd, 1960; Jennings et al., 1964; Logan, 1964). Boyd (1960) suggested that the small size of seed tubers in sprouting boxes did not permit adequate ventilation, causing slow drying, and Logan (1964) stated that under such environmental conditions favourable conditions for bacterial multiplication could be produced in the tissue, resulting in soft rot under humid conditions or hard rot under cold, dry conditions.

It is generally held that the most important factor causing soft rot in moist tubers is a film of water between tubers at the points of contact. This is thought to lead to the death of the tissue at these points which may subsequently become infected with soft rot bacteria (Burton, 1963).

## 1.3. The Effect of Organo-mercurials on Growth

The effects of disinfection with organo-mercurials at lifting are not restricted to disease control, changes in the pattern of growth and yield having been frequently observed, particularly in stocks that have been washed and disinfected. There are no indications that disinfection is injurious to sprout growth (Greeves, 1937) although, after washing, disinfection has been occasionally associated with failure to sprout (Gray and Malcolmson, 1967). It is generally accepted, however, that washed and disinfected seed produces a higher number of sprouts with a faster growth rate (Boyd, 1960; Jennings et al., 1964). Boyd (1960) suggested that this stimulation might be due partly to the effect of washing and disinfection on pathogenic organisms in the eyes of tubers or to the stimulative effect of EEMC on sprout growth. Seed tubers that have been washed without disinfection show only slight stimulation compared to riddled tubers (Boyd, 1960; Jennings et al., 1964) but sometimes sprout growth is inhibited (Jennings et al., 1964), possibly as a result of a bacterial infection which weakened or killed the buds.

Organo-mercurial disinfection has been found, in general, to have no effect on rate of plant emergence (Gray and Malcolmson, 1962, 1967; Jennings et al., 1964), although Boyd (1960) had some indication that seed tubers which had been washed and disinfected at lifting showed a more rapid rate of plant emergence than untreated tubers, thus reflecting differences in the vigour of sprouting. An increase in number of stems from tubers which were washed and disinfected has been observed by Jennings et al. (1964).

It is evident that washing and disinfection at lifting has no consistent effect on total yield of the tubers, sometimes producing increases (Boyd, 1960), sometimes decreases (Gray and Malcolmson, 1967), while more usually there have been no obvious effects (Boyd, 1960; Jennings et al., 1964; Graham, 1964; Gray and Malcolmson, 1967). However, a more detailed analysis of the ware, seed and chat fractions has indicated differences that were attributed to the greater number of stems in plants from disinfected seed (Jennings et al., 1964). Thus plants from disinfected seed produced a lower ware weight and increases in the weights of seed and chat fractions associated with a greater number of stems per plant. Graham (1964) has also reported higher seed yields from organo-mercurial disinfection.

### 1.4. Commercial Seed Tuber Disinfection in Scotland

In Scotland, a commercial seed tuber disinfection process was developed as a result of much initial work by Sir Thomas Wedderspoon of Eassie, Angus. Disinfection was at first carried out in a concrete tank containing a solution of the organo-mercurial in which tubers in baskets were immersed for ½-1 minute (Foister and Wilson, 1943). Although the strength of the solution was maintained by periodically topping up with concentrated organo-mercurial solution, it soon lost its activity if tubers were very dirty. Immediately after disinfection tubers were put into sprouting trays to dry.

In 1956, Sir Thomas Wedderspoon introduced the first continuous disinfection plant in Britain, at Eassie, Angus (Muskett, 1960; Boyd, 1960), and, in 1958, a second plant was installed at Limavady, Northern Ireland (Jennings *et al*., 1964). At these plants, tubers were first washed to remove adhering soil, including eelworm cysts, in particular *Heterodera rostochiensis* (Mabbott, 1960). They were then passed over a spool type grader to remove ware and chats. The seed was carried to the disinfection tank where the tubers were moved through the organo-mercurial solution by a system of paddles, the period of immersion lasting 12 minutes. Tubers were partially dried on sponge roller driers, final drying being achieved in seed sprouting trays in a well ventilated building.

One advantage of large static plants for disinfection is that, by careful co-ordination, large quantities of seed potatoes can be disinfected within a short time of harvesting. On an average farm it would be difficult to undertake the additional work necessary for the process at a time when there would be little surplus labour (Small, 1944; Boyd, 1960; Lennard, 1967). In view of the toxic nature of the disinfectant, there is a further advantage that only trained and experienced operatives are involved in the process. The Advisory Committee on Pesticides and Other Toxic Chemicals has recently recommended that commercial disinfection using organomercurials be only carried out in premises covered by the Factories Act (Recommendation Sheet No. 279, issued 1 July 1967) and further emphasises the necessity for central plants for the purpose, where the use of the disinfectant is carefully controlled and the safety regulations can be enforced.

In recent years, the seed washed and disinfected at these plants has been open to criticism because of the associated increase in the incidence of blackleg in the subsequent crops. This increase has been documented by several workers and represents a major disadvantage of the process as operated at present. Another problem is that of efficient drying:

although disinfected and washed and disinfected tubers have been found to dry satisfactorily in seed trays under most conditions, their use involves excessive labour and an alternative means of large scale drying would be advantageous.

In the present work, investigations have been carried out on commercial washing and disinfection with special reference to a) efficiency of drying in boxes using forced air ventilation and b) the problem of blackleg (Section 3). A study was also made of the effects of hot air drying of tubers after disinfection (Section 4) and finally the efficiency of a small scale continuous disinfection machine was also investigated (Section 5).

# 2. GENERAL MATERIALS AND METHODS

## 2.1. Introduction

In the experiments it was aimed to apply the disinfection treatments within 3 days of lifting, although this was not possible in all cases. Following the imposed disinfection and drying treatments for each experiment, tubers were subsequently stored in chitting trays. During the storage period records were made of sprout growth characteristics and disease development. In the following spring apparently sound tubers from each treatment were selected and planted in the field for studies on the rate of plant emergence, field growth characteristics, the incidence of blackleg and tuber yield. In 1967, plant samples were taken after sprout emergence, and examined for symptoms of coiled sprout and of seed tuber decay.

## 2.2. Storage Method and Observations

### 2.2.1. Storage method

Following all disinfection and other experimental treatments, tubers were placed in trays measuring 18 in. x 30 in. The trays had an open, slatted structure designed to allow a rapid drying of tubers (Plate 2). Each tray was filled to a depth of two layers of tubers, at the rate of about 150 tubers per tray, and then stacked in an insulated shed. Lighting was provided in 1966-67 and 1967-68 by means of 5 ft. fluorescent strip-lights (warm white) and the trays were moved at weekly intervals in order to reduce positional effects due to variations in light intensities. The air in the shed was kept circulated by means of fans to minimise temperature differences at different heights in the store.

### 2.2.2. Sprout growth observations

At intervals during storage, samples of 10 apparently healthy tubers were taken at random from each tray for assessments of the number of sprouts per tuber and the length of sprouts. In making the count only the main sprout over $\frac{1}{16}$ in. of each eye was considered in 1965-66, while in 1966-67 and 1967-68 all eyes showing sprout growth were counted.

### 2.2.3. Disease assessments

Any obviously damaged or diseased tubers were rejected at the time of applying the experimental treatment or within the first week of tray storage. Observations were made at weekly intervals on any subsequent storage rot development. At usually three dates during storage, tubers showing rot symptoms were counted and removed, only tubers showing lesions of at least $\frac{3}{4}$ in. being considered on the first two dates. All tubers showing any rot symptoms were removed at the final date before planting. Diseased tubers were examined and classified by visual symptoms but, in doubtful cases, diagnoses were confirmed by isolation tests.

At the time of the final storage rot assessments, 50 tubers were taken at random from the trays of each treatment and assessed for skin spot according to the method of Boyd (1957). The surface infection index (Boyd, 1957) was calculated after tubers had been divided into the following categories:

Severe (S) - $\frac{1}{4}$ or more of the surface area covered by skin spot pustules.

Moderate (M) - between $\frac{1}{10}$ and $\frac{1}{4}$ of the surface area affected.

Slight (L) - from a trace up to $\frac{1}{10}$ of the surface area.

Trace (T) - up to 10 pustules per tuber.

The surface infection index (S.I.I.) can then be found by multiplying the number of tubers in each category by the average percentage area affected, i.e.

Severe x 62.5

Moderate x 17.5

Slight x 5

Trace x 1

The total is then divided by the number of tubers examined (N) and multiplied by 100/62.5 to give a mean percentage area infected.

The calculation is summed up by the formula:

$$\text{S.I.I.} = 1.6\frac{(62.5 \times S + 17.5 \times M + S \times 5 + T)}{N}$$

Samples that had not been washed as part of the seed treatment were washed in a washing machine before the assessment was made.

## 2.3. Field Studies

### 2.3.1. Planting method

Sprouted tubers of uniform size and apparently free from rot and obvious skin spot symptoms were selected from each treatment at the end of the storage period and planted in 28 in. drills. The tubers were planted by hand at a uniform spacing, care being taken to avoid damage to the sprouts. After the initial earthing up, no further cultivations were carried out and weed control was by chemical means.

### 2.3.2. Emergence counts

Counts of the number of tubers showing first leaf emergence were made, usually at 3-7 day intervals after planting and the rate of emergence calculated by multiplying the number of newly emerged plants at each count by the number of days since planting, and dividing the sum of these products by the final number of plants emerged. Emergence failures were recorded as tubers which did not show emergence approximately 12 weeks after planting.

### 2.3.3. Stem number and height assessments

In all years the numbers of stems at soil level and height from soil level to the tip of the tallest stem were assessed on samples of 10 apparently healthy plants per plot.

### 2.3.4. Assessments of the condition of the mother tuber after planting, and of the incidence of coiled sprout

In the 1967 field trials, 8 plants per plot were sampled 12 weeks after planting. The seed tuber from each plant was classified as sound, rotted, or decomposed, according to the degree of soft-rotting. Also at this time, in two of the trials, the stems below soil level were examined and the number of plants showing complete coiling symptoms was recorded.

### 2.3.5. Blackleg counts

Apart from 1966, when only one count was made in August, all experimental plots were periodically examined for the incidence of blackleg in the crop, from the time of emergence until senescence. All plants showing any blackleg symptoms were marked and, if identification of the disease was difficult, parts of the infected plants were taken to the laboratory for confirmation of symptoms by Dr D.C. Graham, Agricultural Scientific Services, East Craigs, Edinburgh.

## 2.4. Yield

In 1966, haulms were cut down to facilitate lifting by hand. The tubers from individual plots were hand riddled into the size fractions: ware (more than 2¼ in.), seed (1¼-2¼ in.) and chats (less than 1¼ in.), and counted and weighed. In

1967 and 1968, the haulms were destroyed by chemicals applied approximately 2 weeks before lifting. The plots were lifted with an elevator digger, the produce from each plot riddled on a spool grader, and the number and weight of ware, seed and chats recorded.

# 3. EFFECT OF COMMERCIAL WASHING AND DISINFECTION OF SEED TUBERS ON SUBSEQUENT DISEASE DEVELOPMENT, CROP GROWTH AND YIELD

## 3.1. Introduction

The first commercial system of continuous disinfection to handle large quantities of seed potatoes was developed by Sir Thomas Wedderspoon in 1956 at Eassie, Angus. The essential difference between this process and that described by previous workers was the inclusion of washing before riddling and disinfection to remove soil and eelworm cysts (Mabbott, 1960). Boyd (1960) at Eassie and Jennings et al. (1964) in Northern Ireland have examined this process of washing and disinfection and reported a satisfactory control of the storage diseases: skin spot, dry rot and gangrene. They also noted a sprout stimulation during storage following disinfection, and Jennings et al. (1964) recorded an increase in the number of stems per plant and a greater number of tubers from plants grown from washed and disinfected seed tubers.

Since the work of Boyd (1960), the plant at Eassie has been extensively modified. These changes were aimed mainly at increasing the capacity of the plant and reducing handling costs. The main purpose of the experiments was to examine the efficiency of the modified process in controlling storage diseases and to determine the effects of any change in the method of treatment on subsequent crop growth.

A general criticism of the washing and disinfection treatment is that it is associated with an increase in the incidence of blackleg (Graham and Volcani, 1961; Graham, 1963; Jennings et al., 1964; Logan, 1964, 1969; Gray and Malcolmson, 1967). The experiments were, therefore, also designed to introduce modifications in the disinfection treatment which might reduce the level of blackleg development.

A series of three experiments was carried out in 1965-66, 1966-67 and 1967-68 respectively and the details and results of each experiment are considered in the following three sections. In addition, a survey of disease development in two washed and disinfected stocks, which had been sent to farms in England, was carried out in 1968.

## 3.2. Experimental Studies - 1965-66

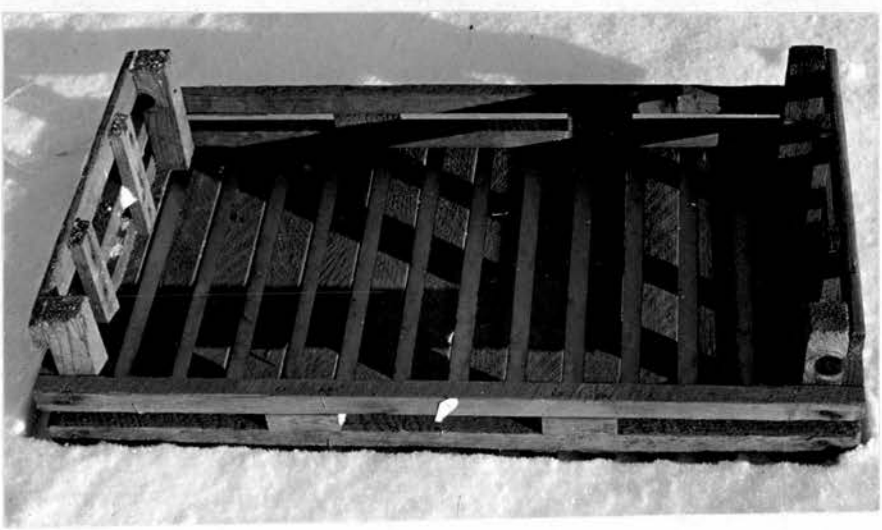
### 3.2.1. Introduction

It has been found that tubers can be satisfactorily dried in most conditions in seed chitting trays (Boyd, 1960). This was the drying method first employed at the plant at Eassie but, due to the high handling costs, this was replaced in 1965 by a system using 10 cwt. boxes. The main objective of the trial in 1965-66 was to make a comparative study of the effects of bulk drying in 10 cwt. boxes (Plate 1) and tray drying (Plate 2) on the incidence of storage rots, skin spot and blackleg and of growth characteristics in storage and in the field.

In order to assess the level of disease control of both

Plate 1. A 10 cwt. box as used for final drying of washed and disinfected seed tubers at the commercial plant.

Plate 2. A seed chitting tray of the type used for drying tubers at the commercial plant before the use of 10 cwt. boxes.



methods, hand riddled, undisinfected tubers, stored in trays, were included as a third treatment.

### 3.2.2. Materials and methods

Disinfection at the commercial plant at Eassie involves a highly automated, continuous process with a capacity of about 75 tons per day. With the procedure employed in 1965, the crops were brought to the plant in 10 cwt. boxes which were subsequently emptied into hoppers. Tubers were conveyed to the washing machine where they were rotated over sponge rollers and a bank of 5 pintle rollers (Plates 3 and 4), and cleaned by the action of oscillating water jets at a pressure of 70 lb. per square inch.

From the washing machine tubers were passed on to a spool grader and separated into three size grades: under $1\frac{1}{4}$ in., $1\frac{1}{4}$-$2\frac{1}{4}$ in. and $2\frac{1}{4}$ in. and over.

From the grader, the seed tubers were conveyed to the disinfection tanks after stones, damaged and diseased tubers had been removed. The disinfection tanks contained a solution of EEMC (100-120 ppm mercury) with 200 ppm of a proprietary wetting agent. Tubers took 12 minutes to pass through the solution by the action of paddles. They were then partially dried on a sponge roller drying table set under a fan delivering air at 10,000 c.f.m. and, finally, carefully placed into 10 cwt. boxes with slatted sides for adequate ventilation (Plate 5).

Plate 3. A sponge roller and a pintle roller from a potato washing machine.

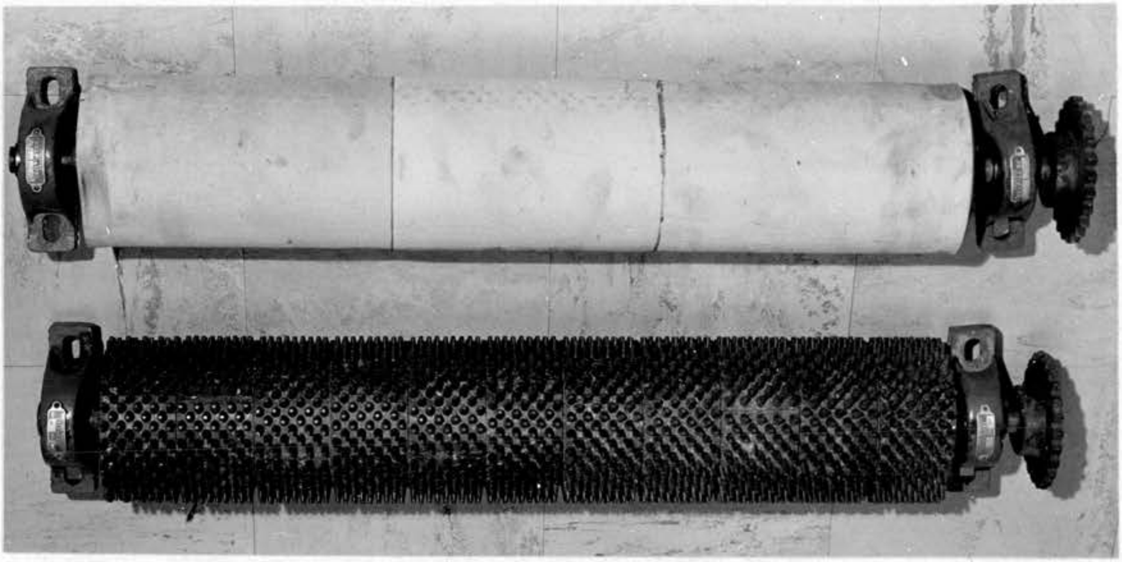


Plate 4. Detail of a Pintle roller from a potato washing machine.

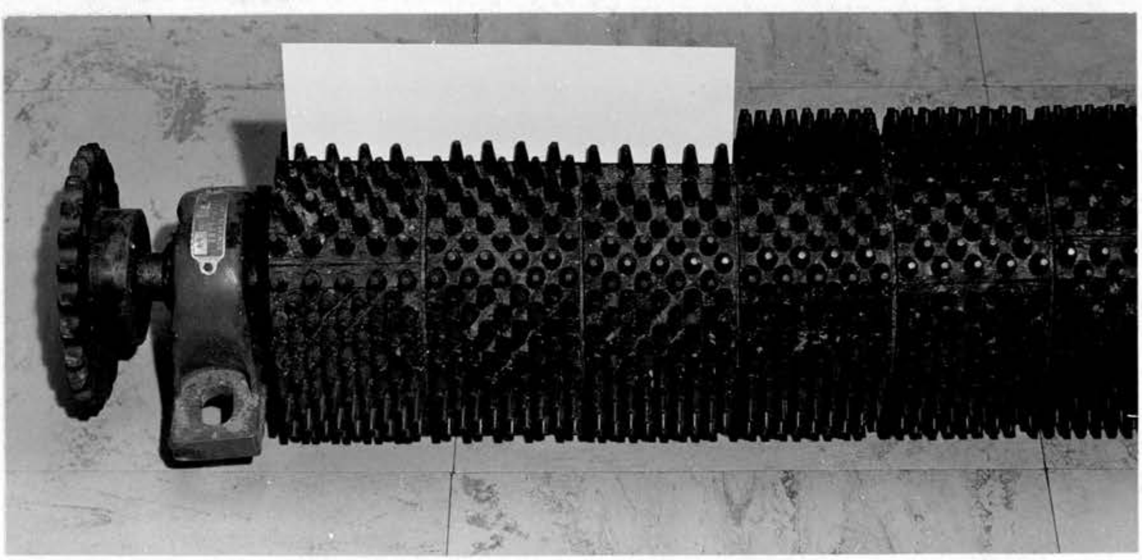


Plate 5. Part of a sponge roller drying table under a high capacity fan at the point where tubers enter the 10 cwt. boxes.

The boxes were stacked in a large shed where they were ventilated with forced air circulation from a fan for 2-3 days until they appeared dry. Usually tubers remained in the boxes for about 10 days after which they were sorted and bagged for despatch to the grower. The grower was recommended to empty the bags into chitting trays as soon as they were received, so that, ideally, tubers remained in bags for only 3 to 6 days.

In the experiment carried out in 1965-66, tubers of the varieties Majestic and King Edward were subjected to the following treatments on 23 October, 1965, within 48 hours of lifting:

1) Hand riddled into seed trays (H Rid).
2) Washed, machine riddled, disinfected and dried in seed trays (WMDT).
3) Washed, machine riddled, disinfected and dried in 10 cwt. boxes (WMDB).

The crops of both varieties had been burned down at least one month before lifting.

The hand riddled treatment was made up of tubers that had been taken by potato fork from the 10 cwt. boxes in which the crops had been transported from the field and then riddled over a 1¼ in. mesh hand riddle (using about 30 shakes). They were then put into seed trays.

Treatment 2 consisted of tubers that were collected in trays at the end of the conveyor belt at the point where they normally enter the 10 cwt. boxes. They had been partially dried on the sponge roller table but were still moist at this time.

The washed, disinfected and box-dried treatment represented tubers that had received the modified, commercial drying technique. The boxes of tubers were built into stacks 6 boxes high and in 5 rows each of about 30 boxes. The middle row of the bottom tier was replaced by a steel framework, forming a tunnel through which air was forced from a high capacity electric fan (10,000 c.f.m.). The end of the tunnel opposite to where the fan was positioned was blocked by one box. The stack was ventilated until the tubers appeared to be dry.

On 2 November, 1965, samples were taken from various parts of the stack as follows:

a) 3-9 in. below the top layer of tubers of 3 top boxes.
b) From 3-9 in. below the top layer of tubers of 3 bottom boxes.
c) From the top and sides of 3 outside boxes.

About 200 tubers were taken from each box and put into hessian bags. The object of this sampling method was to see if there was any difference in the efficiency of drying in the different parts of the stacks which might be reflected in the subsequent observations. At the same time, tubers from the other treatments were put into bags. All the treated tubers were stored in an unheated building for one week to simulate the time of transport to the grower. After this period the bags of all treatments were transported to a shed where the tubers were put into chitting trays for storage until planting. The temperature of storage was maintained at a minimum of 42°F and there was no illumination.

During the storage period, sprout counts were made on 10 January and 10 February, and a skin spot assessment on 31 March. Storage rots were removed and counted periodically up to the date of planting. Samples of sound tubers from the three treatments were planted on 5 April in 28 in. drills at 9 in. spacing in 2 separate trials for the 2 varieties. The treatments were arranged in a randomised block layout with 6 replicates and 15 tubers per plot. Emergence counts were made every 3 days. The number of stems and their maximum height per plant were recorded on 8 August and a blackleg count was also made on this date.

The King Edward plots were lifted on 17 August and the Majestic on 21 September and the weight and number of seed, ware and chats recorded. Plots were lifted early because blight seriously attacked a part of the trials.

In addition, a small scale trial was carried out with tubers of Majestic showing varying levels of severity of lenticel pitting and hard rot (Logan, 1964). Tubers were divided into 4 categories as follows:

1) Mild pitting.
2) Severe pitting (blackened lenticels).
3) Severe pitting + small hard rot lesions.
4) Severe pitting + large hard rot lesions (over ¾ in.).

Thirty tubers of each were planted and counts of emergence and blackleg subsequently made.

### 3.2.3. Results

a) Sprout growth in storage

The disinfected treatments showed, in general, a greater mean number of eyes with sprouts over $\frac{1}{16}$ in. per tuber than the hand riddled treatments but significant differences were only found in the results for Majestic. The data for Majestic also showed that tray dried, disinfected tubers had a significantly higher number of sprouts over $\frac{1}{16}$ in. than any of the box dried treatments in February (Table 1).

Table 1

The mean number of sprouts over $\frac{1}{16}$ in. per tuber on 10 January and 10 February, 1966.

| Treatment | Mean number of eyes with sprouts over $\frac{1}{16}$ in. per tuber | | | |
|---|---|---|---|---|
| | Majestic | | King Edward | |
| | 10 January | 10 February | 10 January | 10 February |
| H Rid | 0.1 | 2.1 | 4.7 | 5.9 |
| WMDT | 1.3 | 5.9 | 4.9 | 6.1 |
| WMDB (a) | 0.8 | 3.4 | 6.7 | 7.5 |
| WMDB (b) | 1.3 | 3.2 | 5.6 | 6.9 |
| WMDB (c) | 0.5 | 4.2 | 5.4 | 5.7 |
| S.E. ± | 0.24 | 0.39 | 0.57 | 0.49 |

The results for the mean number of sprouts in different size categories for the different dates showed a gradual increase in sprout length throughout the storage season for each treatment (Appendix 1). The longest sprouts were generally of the order of 1 in. at the time of planting.

b) Skin spot development

There was a low overall incidence of skin spot but in both varieties the disinfection treatments showed less infection compared with the hand riddled treatments.

Table 2

The effect of different disinfection treatments on the incidence of skin spot - 31 March, 1966.

| Treatment | Percentage number of tubers with infection at some eyes | Surface infection index | Percentage number of tubers free from obvious infection |
|---|---|---|---|
| Majestic | | | |
| H Rid | 9 | 1.0 | 69 |
| WMDT | 3 | 0.4 | 81 |
| WMDB (a) | 1 | 0.3 | 82 |
| WMDB (b) | 1 | 0.3 | 83 |
| WMDB (c) | 0 | 0.3 | 84 |
| King Edward | | | |
| H Rid | 22 | 1.2 | 51 |
| WMDT | 2 | 0.3 | 80 |
| WMDB (a) | 1 | 0.2 | 90 |
| WMDB (b) | 2 | 0.2 | 89 |
| WMDB (c) | 4 | 0.3 | 84 |

c) Tuber rots

The results for the effects of the different disinfection treatments on the incidence of tuber rots are shown in Table 3.

Compared with hand riddled treatments, disinfection gave a reduction in the number of tubers infected by gangrene and dry rot in both varieties. This effect was more marked for Majestic, where the incidences of both diseases in hand riddled tubers were higher than that for King Edward.

Hard rot was observed in a proportion of tubers from all washed and disinfected treatments except the King Edward tray dried tubers. The symptoms were identical to those described by Logan (1964), commencing with a blackening of the pitted lenticels and the gradual development during the storage season of superficial, black, corky lesions sometimes exceeding 1 inch in diameter. The incidence and severity of symptoms were more marked in Majestic tubers, the incidence being highest in the box dried tubers from the top layer and sides of the stack (Treatments WDBD (a) and (c)).

Soft rot was present in both stocks to a very small degree. There was a slightly higher incidence in the Majestic box dried (a) treatment than in the other treatments. It was observed that condensation moisture was present on the top layers of boxes of tubers of this variety at the time of sampling on 2 November, whereas all other tubers were dry.

Table 3

The effect of different disinfection treatments on the incidence of tuber rots - Final counts taken 31 March, 1966.

| Treatment | Total number of tubers | Gangrene per cent | Dry rot per cent | Hard rot per cent | Soft rot per cent | Other rots per cent | Total rots per cent |
|---|---|---|---|---|---|---|---|
| Majestic | | | | | | | |
| H Rid | 738 | 65.2 | 5.2 | 0.0 | 0.5 | 0.0 | 70.9 |
| WMDT | 1020 | 3.0 | 0.1 | 6.3 | 0.2 | 0.0 | 9.6 |
| WMDB (a) | 654 | 4.4 | 0.5 | 8.4 | 1.7 | 0.0 | 15.0 |
| WMDB (b) | 716 | 2.7 | 0.0 | 2.4 | 0.0 | 0.0 | 5.1 |
| WMDB (c) | 630 | 2.7 | 0.0 | 8.9 | 0.4 | 0.0 | 12.0 |
| King Edward | | | | | | | |
| H Rid | 714 | 6.3 | 0.6 | 0.0 | 0.0 | 0.0 | 6.9 |
| WMDT | 1002 | 1.0 | 0.2 | 0.0 | 0.1 | 0.0 | 1.3 |
| WMDB (a) | 517 | 1.6 | 0.0 | 1.2 | 0.0 | 0.0 | 2.8 |
| WMDB (b) | 668 | 2.0 | 0.5 | 0.2 | 0.2 | 0.0 | 2.9 |
| WMDB (c) | 562 | 1.8 | 0.0 | 0.7 | 0.2 | 0.0 | 2.7 |

d) Emergence in the field

In the Majestic trial, all disinfected treatments showed an earlier emergence than the hand riddled with significant differences in early counts (Appendix 2), with box dried (a) tubers emerging slightly faster than other disinfected treatments (Table 4). In the case of King Edward, there were no significant differences in the percentage plant emergence at different dates between any of the treatments (Appendix 2) but disinfected tray dried and box dried (b) treatments tended to emerge slightly earlier than other treatments (Table 4). Blanking was negligible in the plots of each variety.

Table 4

The effect of seed treatment on the average number of days to plant emergence and the percentage blanking in the field - 1966.

| | Majestic | | King Edward | |
|---|---|---|---|---|
| Treatment | Average number of days to emergence | Per cent blanking | Average number of days to emergence | Per cent blanking |
| H Rid | 57.7 | 1 | 51.9 | 1 |
| WMDT | 54.0 | 1 | 47.9 | 1 |
| WMDB (a) | 51.8 | 1 | 51.9 | 1 |
| WMDB (b) | 54.0 | 0 | 48.8 | 1 |
| WMDB (c) | 53.2 | 1 | 51.5 | 0 |

e) Stem number

In Majestic there was a tendency for more stems to develop from disinfected tubers compared with hand riddled, although there were no significant differences. With King Edward, however, there was a significant reduction in the stem number of some of the disinfected treatments compared with the hand riddled treatment (Table 5).

Table 5

The mean number of stems per plant counted on 8th August 1966.

| Treatment | Number of stems Majestic | King Edward |
|---|---|---|
| Untreated | 5.4 | 4.7 |
| WDTD | 5.5 | 3.6 |
| WDBD (a) | 6.6 | 4.2 |
| WDBD (b) | 5.7 | 3.6 |
| WDBD (c) | 6.7 | 4.1 |
| S.E. ± | 0.36 | 0.21 |

f) Blackleg

The incidence of blackleg was generally higher in Majestic than in King Edward. In both varieties, there was evidence of an increased level of blackleg associated with washed and disinfected treatments, although the data showed no significant differences (Appendix 4). With Majestic, disinfected, tray dried tubers appeared to have a higher level of blackleg than box dried tubers (Table 6).

Table 6

The incidence of blackleg in relation to different disinfection treatments. - 8 August 1966.

| Treatment | Blackleg per cent Majestic | King Edward |
|---|---|---|
| H Rid | 5.6 | 0.0 |
| WMDT | 25.6 | 4.4 |
| WMDB (a) | 15.6 | 2.2 |
| WMDB (b) | 15.6 | 6.6 |
| WMDB (c) | 17.8 | 3.3 |

g) Yield

Although no significant differences were found in yield data for the different treatments, the hand riddled treatments gave a heavier yield than disinfected treatments in both varieties. There was a tendency in Majestic for disinfected, box dried treatments to give a greater number of tubers associated with an increased seed and chat number (Table 7, Appendix 5).

Table 7

Yield (tons per acre) and number of tubers (thousands per acre) in relation to different disinfection treatments. - 1966.

| Treatment | Ware (tons) | Seed (tons) | Chats (tons) | Total (tons) | Total No. (thousands) |
|---|---|---|---|---|---|
| **Majestic** | | | | | |
| H Rid | 6.6 | 16.2 | 1.7 | 24.5 | 282.6 |
| WMDT | 4.9 | 13.9 | 1.1 | 19.9 | 262.4 |
| WMDB (a) | 5.7 | 16.1 | 1.3 | 23.1 | 309.7 |
| WMDB (b) | 5.1 | 15.0 | 1.5 | 21.6 | 294.2 |
| WMDB (c) | 6.6 | 14.7 | 1.5 | 22.8 | 322.8 |
| S.E. ± | 0.99 | 1.04 | 0.16 | 1.33 | 16.54 |
| **King Edward** | | | | | |
| H Rid | 2.2 | 17.7 | 2.2 | 22.1 | 417.8 |
| WMDT | 2.5 | 17.2 | 1.8 | 21.5 | 386.3 |
| WMDB (a) | 2.2 | 15.8 | 1.9 | 19.9 | 373.6 |
| WMDB (b) | 1.2 | 16.7 | 2.1 | 20.0 | 403.1 |
| WMDB (c) | 2.0 | 15.6 | 2.3 | 19.9 | 407.0 |
| S.E. ± | 0.61 | 1.23 | 0.19 | 1.28 | 21.87 |

h) Plant emergence and blackleg incidence in relation to lenticel pitting and hard rot of the seed tuber

The rates of plant emergence and incidence of blackleg in relation to the level of severity of lenticel pitting and hard rot of the seed tuber are shown in Table 8.

Table 8

The effects of different levels of severity of lenticel pitting and hard rot of the seed tuber in relation to the rate of plant emergence, blanking and blackleg - 1966.

| **Seed tuber** symptoms | Rate of emergence (days) | Blanking (per cent) | Blackleg 25 August (per cent) |
|---|---|---|---|
| **Mild pitting** | 53.4 | 0 | 13 |
| **Severe pitting** | 56.0 | 0 | 10 |
| **Severe pitting** + small lesions | 55.4 | 0 | 27 |
| Severe pitting **+ large lesions** | 55.7 | 27 | 32 |

Plant emergence was found to be slower from tubers with severe pitting and planting tubers with large hard rot lesions gave rise to considerable blanking due to soft rot. The incidence of blackleg was higher in plants grown from tubers with hard rot symptoms (Table 8).

### 3.2.4. Discussion

The results of this preliminary trial did not indicate any marked differences between tray and box drying. Tubers dried by both methods after disinfection showed, to varying degrees, the known growth responses to disinfection with organo-mercury solutions, namely, sprout simulation (Boyd, 1960; Jennings *et al.*, 1964), earlier emergence (Boyd, 1960) and, with Majestic, greater stem and tuber numbers (Jennings *et al.*, 1964). The effects of growth characteristics were generally more marked in Majestic than in King Edward, but in both varieties differences in method of drying produced no differences of practical significance. All disinfection treatments irrespective of drying method successfully controlled skin spot, gangrene and dry rot and confirmed previous work (Boyd, 1960; Jennings et al., 1964; Graham, 1964; Logan, 1967).

Although box drying had no serious disadvantages, the incidence of both hard rot and soft rot appeared to be slightly increased. The former occurred in box dried but not tray dried King Edward tubers, and was more prevalent in boxes than trays of the Majestic tubers. Tubers with soft rot symptoms occurred in all treatments but with Majestic the incidence was higher in the boxes at the top of the stacks. The increases in both types of rot associated with box drying may be attributed in part to the presence of condensation moisture which was sometimes observed on the tubers under such storage conditions. The connection between bacterial soft rotting and slow drying has been suggested also by other workers (Boyd, 1960; Jennings et al., 1964; Logan, 1964).

The level of blackleg in the subsequent crops was increased by all disinfection treatments compared with undisinfected treatments, the increase being most marked in the Majestic tray dried treatment. But, because of plot variations, the increases were not statistically significant and there were no significant differences in the yields between any of the treatments.

The results of experiments where hard rot affected tubers were planted confirmed those of Logan (1964). There was an increase in blanking due to soft rotting of the sett in the soil and a higher incidence of blackleg in the crop.

### 3.3. Experimental Studies - 1966-67

#### 3.3.1. Introduction

Several modifications were made to the equipment of the commercial disinfection plant before disinfection commenced in Autumn 1966. All pintled rollers were removed from the washing machine (Plate 7) and replaced by sponge rollers, and the spool grader was replaced by a reciprocating type of riddle (Plate 8) consisting of horizontal, plastic coated wire grading screens arranged one above the other. These moved forwards and backwards through an angle of $45^{o}$ in the vertical plane so that the tubers were moved across the surface and passed either through each screen or along on to conveyor belts depending upon their size. These changes aimed at reducing damage possibly associated with the development of hard rot symptoms and blackleg infection in the disinfected seed.

A further change was the removal of the paddles from the disinfection tanks and the tubers instead moved through the solution on a conveyor belt (Plate 9).

The method of drying was also improved by the addition of another sponge roller and a fan drier (Plate 10) at the end of

Plates 6 - 12. Equipment involved at the washing and disinfection plant in 1966-67.

Plate 6. The hopper into which tubers are emptied before entering the washing machine.

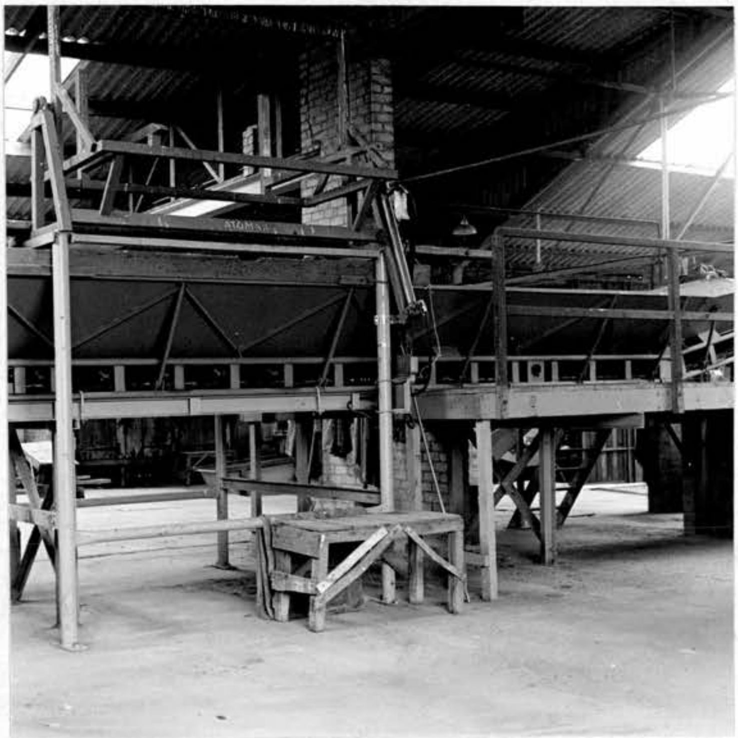


Plate 7. The potato washing machine.

"reverberating"

Plate 8. The reciprocating type riddle.

Plate 9. A disinfection tank showing the conveyor belt which moves tubers through the solution.

Plate 10. The sponge roller drying tables under the high capacity fans.

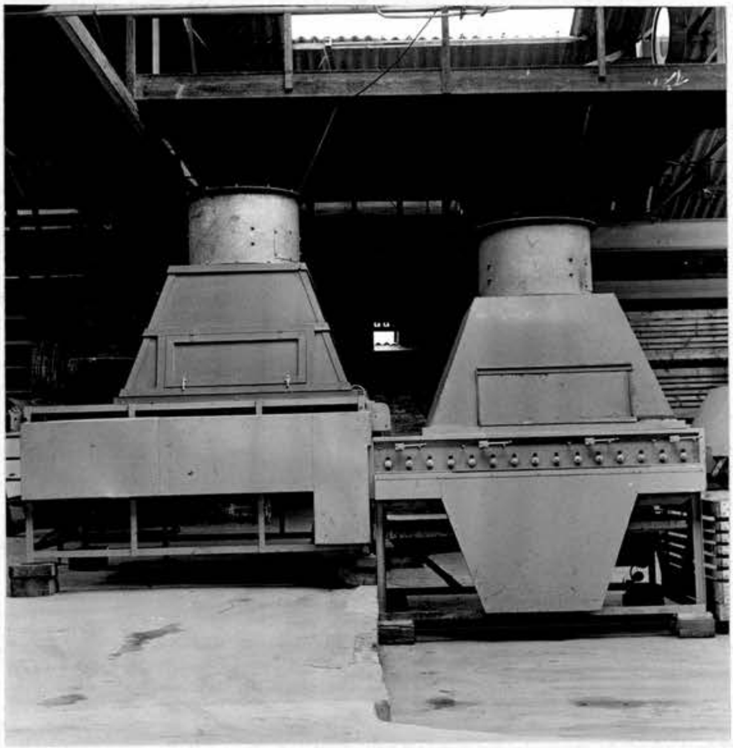
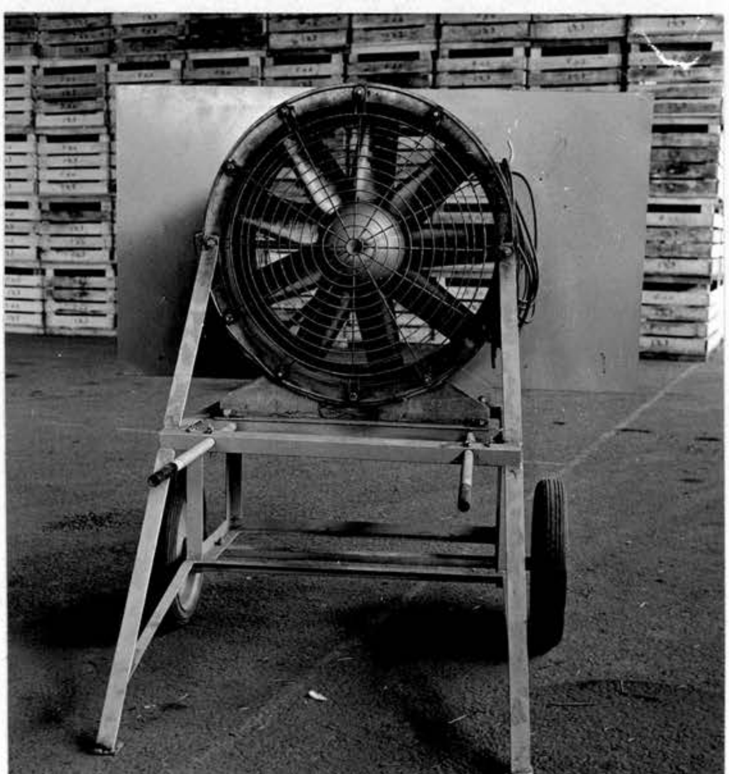


Plate 11. A fan used for blowing air into the stacks of 10 cwt. boxes which results in the final drying of seed tubers.



the conveyor system before tubers entered the 10 cwt. boxes. The size of the stacks of 10 cwt. boxes was reduced to 5 high and 3 boxes wide with the metal frames forming the ventilating tunnel, moved up one tier from the ground.

A comparison was again made in 1966-67 between tray and box drying. A washed and machine riddled treatment was also included to assess the influence of washing without disinfection on tubers, particularly with respect to the incidence of blackleg. In order to examine the effect of the machine riddle, a treatment of riddled only tubers was included.

A further experimental treatment involved putting a 6 in. layer of straw on the top of each box of a column of boxes in the stacks in an attempt to reduce condensation on the tubers.

### 3.3.2. Materials and methods

A King Edward stock was treated on 26 October and Majestic on 7 November, 1966. Both stocks had been burned down at least a month before lifting, and lifting was within 3 days of the day of treatment. The following treatments were applied:

1) Reciprocating plant riddled (M).
2) Hand riddled (H Rid).
3) Washed, and machine riddled (WM).
4) Washed, machine riddled, disinfected, tray dried (WMDT).
5) Washed, machine riddled, disinfected, dried in boxes (WMDB (a), (b) and (c)).
6) Washed, machine riddled, disinfected, dried in boxes but

with a 6 in. layer of straw over each box (WMDB (sa), (sb) and (sc)).

Treatment 1 was applied to Majestic only. Tubers were taken from the hopper and riddled on the plant riddle after the washing machine had been temporarily stopped. Although these tubers were not washed they were unavoidably moistened by the riddling due to the proximity of the riddle to the washing machine in the process.

Treatment 2 was almost the same as the hand riddled treatment in 1965 but tubers were taken from the hopper after they had been tipped out of the boxes in which they had been brought from the field.

Treatment 3 consisted of tubers that had been through the washing and riddling part of the process only. Tubers were collected from the conveyor belt before they entered the disinfection tanks and were left to dry in sprouting trays.

Treatment 4 was applied to tubers that were tray dried after disinfection as in 1965 but with the previously described modifications in the process.

Treatment 5 was the same as the box dried treatment in 1965, apart from the changes to the plant, and was again sampled in the three different areas of the boxes.

Treatment 6: A column of five outside boxes in the stack of each variety, each covered with a 6 in. layer of straw, was sampled in a similar way to that in treatment 5, i.e.

(a) 3-9 in. below top layer of tubers of the top box;

(b) 3-9 in. below the top layer of tubers of the bottom box; and

(c) the tops and sides of the three other outside boxes.

Sampling was carried out on 4 November with King Edward and 16 November for Majestic tubers. Also on these dates the other treatments of each variety were put into hessian sacks and taken to the potato store where they were put into chitting trays after one week.

Throughout the storage period trays were illuminated and the store thermostatically controlled to a minimum temperature of $37^{o}C$.

During storage, sprout counts were made and treatments were also assessed for skin spot and tuber rots.

Treatments of each variety were planted on 14 April with the exception of the strawed, box dried treatments. The Majestic tubers were planted in a 7 x 7 Latin square and the King Edward in a 6 x 6 Latin square. Tubers were planted at a 12 in. spacing in 28 in. drills with each plot consisting of 8 drills of 10 tubers.

Counts of emergence, stem number, height and blackleg were made throughout the growing season. On 25 July 8 plants per plot were sampled and the state of the mother tuber recorded as either apparently sound or soft rotted.

Haulm destruction was carried out on 27 September in the King Edward plots and on 23 October in the Majestic plots. The corresponding dates of lifting were 5 and 30 October, blocks of 40 plants being lifted from each plot.

After lifting, the tubers from each plot were riddled and the ware, seed and chats fractions weighed and counted.

### 3.3.3. <u>Results</u>

a) Sprout growth in storage

The mean number of sprouted eyes per tuber was found to be generally greater in the disinfected than the undisinfected treatments of both varieties, the difference being significant with most of the treatments at each date of assessment (Table 9, Appendix 6). No consistent trend is detectable between any of the disinfected treatments but washed and machine riddled tubers of both varieties tended to show a larger number of sprouting eyes than the riddled only treatments. In the Majestic March count there were significantly more sprouting eyes in the hand riddled than the machine riddled only treatment (Table 9).

There was a progressive increase in the lengths of sprouts throughout the storage period although, at planting, sprouts were only about $\frac{1}{4}$ in. long with Majestic and $\frac{1}{2}$ in. with King Edward. The slight reduction in the mean number of sprouts per tuber in some of the King Edward treatments of the March count was probably due to handling of tubers for disease assessments during this period (Table 9, Appendix 6).

Table 9

The mean number of sprouting eyes in relation to seed treatment. 1967

| Treatment | Majestic | | | King Edward | | |
|---|---|---|---|---|---|---|
| | 10 Jan. | 10 Feb. | 10 Mar. | 10 Jan. | 10 Feb. | 10 Mar. |
| Graded | | | | | | |
| M | 0.0 | 3.6 | 8.0 | - | - | - |
| H Rid | 0.0 | 3.2 | 9.4 | 2.7 | 6.8 | 7.6 |
| Washed | | | | | | |
| WM | 0.1 | 6.6 | 9.7 | 3.5 | 7.6 | 7.6 |
| Disinfected | | | | | | |
| WMDT | 0.1 | 9.7 | 10.8 | 5.7 | 8.8 | 9.0 |
| WMDB (a) | 0.3 | 9.2 | 11.4 | 5.8 | 8.9 | 8.7 |
| WMDB (b) | 0.3 | 9.5 | 11.1 | 4.9 | 8.4 | 8.4 |
| WMDB (c) | 0.3 | 9.4 | 10.8 | 5.2 | 9.0 | 8.6 |
| WMDB (sa) | 0.1 | 9.0 | 11.1 | 5.7 | 8.8 | 8.9 |
| WMDB (sb) | 0.4 | 9.5 | 10.3 | 4.8 | 9.1 | 8.6 |
| WMDB (sc) | 0.2 | 8.7 | 11.5 | 6.5 | 9.5 | 8.8 |
| S.E. ± | 0.07 | 0.54 | 0.28 | 0.35 | 0.30 | 0.21 |

b) Skin Spot

In general, disinfected treatments showed a reduction in the skin spot level compared to undisinfected treatments. However, the incidence of the infection was low with the exception of the washed only treatments (Table 10).

Table 10

The effect of the different treatments on the incidence of skin spot - 1967.

| Treatment | Percentage tubers with infection at some eyes | Surface infection index | Percentage tubers free from obvious infection |
|---|---|---|---|
| Majestic | | | |
| Graded | | | |
| M | 8 | 2.3 | 52 |
| H Rid | 36 | 3.7 | 60 |
| Washed | | | |
| WM | 44 | 6.8 | 20 |
| Disinfected | | | |
| WMDT | 0 | 1.0 | 54 |
| WMDB (a) | 6 | 1.3 | 68 |
| WMDB (b) | 8 | 1.1 | 64 |
| WMDB (c) | 2 | 0.6 | 76 |
| WMDB (sa) | 0 | 0.6 | 76 |
| WMDB (sb) | 0 | 0.7 | 68 |
| WMDB (sc) | 0 | 0.6 | 76 |
| King Edward | | | |
| Graded | | | |
| H Rid | 8 | 2.1 | 32 |
| Washed | | | |
| WM | 48 | 5.4 | 4 |
| Disinfected | | | |
| WMDT | 0 | 0.7 | 77 |
| WMDB (a) | 16 | 1.0 | 77 |
| WMDB (b) | 0 | 0.1 | 96 |
| WMDB (c) | 0 | 0.2 | 88 |
| WMDB (sa) | 4 | 1.6 | 32 |
| WMDB (sb) | 8 | 1.7 | 60 |
| WMDB (sc) | 8 | 0.6 | 76 |

c) Tuber rots

All washed and disinfected treatments of each variety gave a marked reduction in the incidence of gangrene and dry rot. Both diseases were increased in the washed treatment compared to the hand riddled treatment in King Edward but decreased in Majestic. Machine riddling in Majestic produced a higher level of the diseases than hand riddling.

Blight was found in both stocks but an apparent reduction was shown by all disinfected treatments. Blight was also found associated with some of the dry rot and gangrene lesions, but its positive identification in some of these lesions was so difficult that they were all considered due to dry rot or gangrene (Table 11).

There was no soft rot associated with box dried tubers this year. The only tubers found to be moist when sampled were those in the top unstrawed boxes of the King Edward stock.

Table 11

The effect of the various treatments upon the incidence of tuber rots: final counts taken 30 March 1967.

| Treatment | Total No. of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Other rots per cent | Total rots per cent |
|---|---|---|---|---|---|---|
| Majestic | | | | | | |
| Graded | | | | | | |
| M | 819 | 23.2 | 13.2 | 2.8 | 0.1 | 39.3 |
| H Rid | 1050 | 17.2 | 8.5 | 3.9 | 0.4 | 30.0 |
| Washed | | | | | | |
| WM | 767 | 9.4 | 6.9 | 1.2 | 0.3 | 17.8 |
| Disinfected | | | | | | |
| WMDT | 1118 | 1.7 | 1.2 | 0.6 | 0.6 | 4.1 |
| WMDB (a) | 701 | 1.7 | 0.9 | 0.3 | 0.4 | 3.3 |
| WMDB (b) | 613 | 1.6 | 1.5 | 0.3 | 0.0 | 3.6 |
| WMDB (c) | 562 | 2.0 | 0.9 | 0.4 | 0.2 | 3.7 |
| WMDB (sa) | 750 | 3.5 | 1.2 | 0.8 | 0.0 | 5.5 |
| WMDB (sb) | 300 | 2.3 | 0.7 | 0.0 | 0.0 | 3.0 |
| WMDB (sc) | 417 | 3.1 | 1.4 | 1.4 | 0.2 | 6.1 |
| King Edward | | | | | | |
| Graded | | | | | | |
| H Rid | 1062 | 16.9 | 3.2 | 3.5 | 1.5 | 25.1 |
| Washed | | | | | | |
| WM | 1227 | 28.0 | 6.9 | 4.2 | 0.8 | 39.9 |
| Disinfected | | | | | | |
| WMDT | 600 | 4.0 | 0.2 | 2.0 | 0.2 | 6.4 |
| WMDB (a) | 907 | 3.2 | 0.1 | 1.1 | 0.8 | 5.2 |
| WMDB (b) | 866 | 1.5 | 0.1 | 2.4 | 0.7 | 3.7 |
| WMDB (c) | 875 | 1.3 | 0.2 | 1.5 | 0.8 | 3.8 |
| WMDB (sa) | 465 | 2.8 | 0.2 | 0.2 | 0.0 | 3.2 |
| WMDB (sb) | 712 | 2.0 | 0.4 | 1.0 | 0.8 | 4.2 |
| WMDB (sc) | 835 | 0.8 | 0.3 | 0.8 | 0.8 | 2.7 |

d) Emergence in the field

All disinfected treatments tended to emerge at a significantly faster rate than the other treatments (Table 12, Appendix 7). Washed only and hand riddled treatments emerged at the same rate. The machine riddled only treatment in the Majestic trial showed the slower rate of plant emergence. Blanking was negligible in both varieties (Table 12).

Table 12

The effect of treatment on the average number of days to emerge and the percentage blanking in the field. - 1967.

| Treatment | Majestic | | King Edward | |
|---|---|---|---|---|
| | Average No. of days to emerge | Per cent Blanking | Average No. of days to emerge | Per cent Blanking |
| Graded | | | | |
| M | 54.0 | 1 | - | 1 |
| H Rid | 48.1 | 0 | 45.0 | 1 |
| Washed | | | | |
| WM | 48.4 | 2 | 46.0 | 0 |
| Disinfected | | | | |
| WMDT | 45.4 | 0 | 39.7 | 0 |
| WMDB (a) | 42.4 | 0 | 41.4 | 0 |
| WMDB (b) | 43.3 | 0 | 42.0 | 0 |
| WMDB (c) | 44.7 | 1 | 40.8 | 0 |

e) Number of stems

In both varieties the disinfected treatments tended to produce more stems than undisinfected tubers but significant differences were only present in Majestic treatments (Table 13). The Majestic washed only treatments had significantly fewer stems compared with the hand riddled treatment (Table 13).

Table 13

The effect of the various treatments on the average number of stems per plant on 4 July, 1967.

| Treatment | No. of stems Majestic | King Edward |
|---|---|---|
| Graded | | |
| M | 3.3 | - |
| H Rid | 3.7 | 4.9 |
| Washed | | |
| WM | 2.8 | 5.1 |
| Disinfected | | |
| WMDT | 4.6 | 6.0 |
| WMDB (a) | 4.7 | 5.3 |
| WMDB (b) | 5.3 | 5.3 |
| WMDB (c) | 5.2 | 5.4 |
| S.E. ± | 0.27 | 0.45 |

f) Examination of the mother tuber

In the Majestic machine riddled treatment there were significantly more soft rotted mother tubers recovered and fewer sound than for any of the other treatments. The washed only and hand riddled treatments of both varieties tended to have more soft rotted and fewer sound mother tubers than the disinfected treatments (Table 14, Appendix 9).

Table 14

The effect of seed treatment on the condition of seed tubers after planting - 1967.

| Treatment | Percentage of affected tubers<br>Sound | <br>Soft rotted | | <br>Sound | <br>Soft rotted | |
|---|---|---|---|---|---|---|
| | Majestic | | | King Edward | | |
| Graded | | | | | | |
| M Rid | 33.9 | 28.6 | 62.5 | - | - | |
| H Rid | 58.9 | 14.3 | 73.2 | 45.8 | 12.5 | 68.3 |
| Washed | | | | | | |
| W only | 55.4 | 17.9 | 73.3 | 62.5 | 16.7 | 79.2 |
| Disinfected | | | | | | |
| WMDT | 69.6 | 7.1 | 76.7 | 70.8 | 2.1 | 72.9 |
| WMDB (a) | 64.3 | 8.9 | 73.2 | 66.7 | 8.3 | 75.0 |
| WMDB (b) | 80.4 | 1.8 | 82.2 | 77.1 | 8.3 | 85.4 |
| WMDB (c) | 67.9 | 8.9 | 76.8 | 81.3 | 4.2 | 85.6 |

g) Blackleg

There was a progressive increase in the number of plants showing symptoms of blackleg throughout the growing season for all treatments. In the case of hand riddled treatments this increase was very slight but reached relatively high levels in all machine riddled treatments. The highest incidence of blackleg was consistently found from tubers which were washed but not disinfected and the reduction from disinfection was most marked where tubers were tray dried. In Majestic, machine riddling without washing gave only slightly less blackleg than with washing (Table 15, Appendix 10).

Table 15

The incidence of blackleg in relation to different disinfection treatments - 1967.

| Treatment | Date of Count<br>14 June<br>per cent | 25 June<br>per cent | 24 July<br>per cent | 4 September<br>per cent |
|---|---|---|---|---|
| | | Majestic | | |
| Graded | | | | |
| M | 3.6 | 7.5 | 8.2 | 18.3 |
| H Rid | 1.3 | 2.0 | 2.2 | 3.8 |
| Washed | | | | |
| WM | 4.8 | 9.3 | 9.9 | 21.0 |
| Disinfected | | | | |
| WMDT | 2.9 | 3.8 | 4.2 | 11.5 |
| WMDB (a) | 4.6 | 7.3 | 7.7 | 15.5 |
| WMDB (b) | 4.3 | 6.3 | 6.6 | 19.8 |
| WMDB (c) | 4.5 | 8.6 | 8.8 | 17.4 |
| | | King Edward | | |
| Graded | | | | |
| H Rid | 0.0 | 0.0 | - | 2.3 |
| Washed | | | | |
| WM | 2.1 | 4.6 | - | 20.5 |
| Disinfected | | | | |
| WMDT | 0.0 | 1.0 | - | 13.9 |
| WMDB (a) | 0.8 | 0.8 | - | 19.2 |
| WMDB (b) | 0.4 | 0.4 | - | 14.9 |
| WMDB (c) | 0.4 | 0.6 | - | 17.9 |

h) Yield

In Majestic machine riddled tubers gave a higher yield than washed and machine riddled tubers, while both treatments were associated with significantly lower yields than all other treatments except the washed and disinfected box dried (a) treatment. In King Edward hand riddled tubers produced a heavier yield than washed only and disinfected box dried (a) tubers (Table 16).

Disinfected treatments produced a significantly higher number of tubers than other treatments in both varieties. Hand riddled treatments yielded a significantly greater ware weight and also a greater number than any other treatment while disinfected treatments gave a significantly heavier seed yield and a tendency with Majestic to give an increase in the weight and number of chats (Table 16, Appendix 11).

In relating total yield and percentage blackleg of individual plots a significant negative correlation was found between yield and blackleg of -0.55 with Majestic and -0.40 with King Edward.

Table 16

Yield (tons/acre) and total number (thousands/acre) of tubers in relation to different disinfection treatments. - 1967.

| Treatment | Yield (tons) Ware | Seed | Chats | Total | Number (thousands) Total |
|---|---|---|---|---|---|
| Majestic | | | | | |
| Graded | | | | | |
| M | 14.2 | 5.9 | 0.5 | 20.8 | 127.9 |
| H Rid | 17.8 | 6.0 | 0.5 | 23.7 | 138.8 |
| Washed | | | | | |
| WM | 12.6 | 5.8 | 0.5 | 18.9 | 129.5 |
| Disinfected | | | | | |
| WMDT | 13.1 | 9.9 | 0.8 | 23.9 | 191.1 |
| WMDB (a) | 13.1 | 8.7 | 0.6 | 22.4 | 176.3 |
| WMDB (b) | 13.5 | 9.5 | 0.8 | 23.8 | 192.8 |
| WMDB (c) | 13.7 | 8.7 | 0.7 | 23.1 | 180.4 |
| S.E. ± | 0.62 | 0.36 | 0.04 | 0.63 | 6.17 |
| King Edward | | | | | |
| Graded | | | | | |
| H Rid | 16.0 | 8.1 | 0.4 | 24.5 | 185.7 |
| Washed | | | | | |
| WM | 12.3 | 8.3 | 0.6 | 21.2 | 186.3 |
| Disinfected | | | | | |
| WMDT | 11.6 | 10.0 | 0.6 | 22.2 | 214.8 |
| WMDB (a) | 10.4 | 10.7 | 0.7 | 21.8 | 223.4 |
| WMDB (b) | 11.8 | 9.6 | 0.5 | 22.0 | 208.8 |
| WMDB (c) | 11.0 | 10.9 | 0.6 | 22.5 | 208.4 |
| S.E. ± | 0.56 | 0.45 | 0.07 | 1.09 | 7.00 |

3.3.3. Discussion

In general, the 1966-67 results confirmed those of the previous year, indicating no marked differences between box and tray drying following disinfection in their effects on growth characteristics. There were no differences in the number or length of sprouts, number of stems in the field or the number and yield of tubers between the two methods of drying. Skin spot, dry rot, gangrene and blight were satisfactorily controlled by all treatments where disinfection was involved.

Hard rot was absent in all the 1966-67 treatments and this may be attributed to the removal of the pintled rollers from the washing and grading machinery (Graham, 1967). In contrast to the previous year, there was no increase in the incidence of soft rot associated with washed, disinfected and box dried treatments, although the boxes on top of the King Edward stacks were found to be moist when sampled, while boxes which had been strawed were dry.

As in the previous year, the incidence of blackleg after planting was higher in all disinfection treatments than in the hand riddled treatments. Tray drying tended to reduce blackleg compared with box drying.

The effects of washing only on the growth, disease development, and yield of tubers were found in some cases to be similar to those reported by other workers. A slight sprout stimulation was seen with each variety as observed by Boyd

(1960) but not to the extent of that in disinfected treatments. There was, however, a slower initial emergence after planting washed King Edward seed and a decrease in stem number in Majestic, compared with all other treatments, and washed only tubers of both varieties gave a smaller yield than all other treatments, and a lower number of tubers than the disinfected treatments.

Washing only was found to increase the incidence of skin spot compared with all other treatments. These results do not support those of Boyd (1960) who found that washing reduced the level of infection. The effects of washing on the incidence of dry rot and gangrene compared with the riddled only treatment were different for the two varieties. The incidence of both diseases was increased with King Edward and decreased with Majestic. After planting washed only seed the incidence of blackleg was higher than with hand riddled treatments or disinfected, tray dried seed, but only slightly higher than with box dried treatments.

Machine riddling without washing resulted in decreased sprouting, slower emergence, lower total yield and a higher incidence of gangrene and dry rot compared with hand riddled tubers. It has been shown that gangrene and dry rot are associated with tuber damage, particularly on the grader (Foister, Wilson and Boyd, 1952; Malcolmson, 1958, Kranz, 1958; Harrison and Downie, 1960; Gray, 1965). The decreased sprouting reflected in slower emergence is possibly also connected with the apparently higher level of damage found in the machine riddled treatments.

Machine riddling gave a much higher incidence of blackleg than hand riddled tubers, and approximately as much as the machine riddled and washed treatment. It is probable that, in addition to damage to the tuber, the film of moisture from the washing machine on the machine riddle had the same influence as washing on the occurrence of blackleg and that infection largely depends on two factors, damage and the presence of water.

## 3.4. Experimental Studies - 1967-68

### 3.4.1. Introduction

Modifications to the process since 1966-67 were aimed at reducing damage to tubers at all points on the conveyor system. Baffles were put into the riddle, the speed of rollers in the washing machine was reduced, and changes in level of the conveyor belt were eliminated wherever possible. It was thought that these changes, by reducing the damage before disinfection, would decrease the incidence of blackleg in the crop.

In view of the association found between washing and the incidence of blackleg in washed and washed and disinfected seed it was decided to examine experimentally the effect of disinfection without previous washing to find whether the level of blackleg in the field could be reduced without loss of control of storage diseases. A similar method has been used for many years and involves a $\frac{1}{2}$ - 1 minute disinfection of unwashed tubers. Many workers have reported obtaining satisfactory control of various storage diseases using this method (Greeves and Muskett, 1939; Foister, 1940; Foister and Wilson, 1943; Logan, 1967b). There is, however, only one account of the effect on blackleg, this indicating that the level of blackleg would be reduced to the level found in the equivalent riddled treatment when washing was omitted (Logan, 1969).

Several methods of grading were used in this year's trials in order to examine the effect of different levels of damage on the development of storage diseases and blackleg in the field. Various combinations of riddling with washing or disinfection were also used to give an indication of their influence on subsequent disease development. A comparison was again made this year between tray and box drying techniques.

## 3.4.2. Materials and methods

Treatment was carried out on 1 November with King Edward and on 10 November with Majestic.

The treatments were as follows:

1. Reverberating plant riddled (M)
2. Reciprocating bare wire riddled (Recip Rid)
3. Hand riddled (H Rid)
4. Hand picked (H Pick)
5. Washed and plant riddled, tray dried (WM)
6. Washed and hand picked, tray dried (WH Pick)

7. Washed, plant riddled, disinfected, tray dried (WMDT)
8. Washed, plant riddled, disinfected, box dried (WMDB)
9. Machine riddled, disinfected, tray dried (MD)
10. Hand picked, disinfected, tray dried (DH Pick)

<u>Treatment 1</u> was a repeat of treatment 1 in the case of Majestic in 1966. However, this year, tubers of both varieties were riddled on the plant riddle. An attempt was made to prevent tubers from becoming moistened on the riddle by passing about 1 cwt. of unwashed tubers over it before any were removed for the experimental treatment.

<u>Treatment 2</u> consisted of tubers taken from the hopper and passed over a normal bare wire reciprocating riddle. In the case of the King Edward stock it was done the day after other treatments were carried out.

<u>Treatment 3</u> corresponded to the hand riddled treatment in 1966-67.

<u>Treatment 4</u> was applied to tubers that had been taken from the hopper after grading by hand and transferred to trays without any form of riddling.

<u>Treatment 5</u> consisted of tubers that had been taken off the conveyor belt after the riddle, as in 1966.

<u>Treatment 6</u> was of tubers that had been washed and collected before they went on to the riddle, seed sized tubers picked out by hand and put into trays.

<u>Treatment 7</u> was similar to the washed and disinfected,

tray dried treatments of 1965-66 and 1966-67.

Treatment 8 consisted of box dried, washed and disinfected tubers as in the previous two years' experiments.

Treatment 9 consisted of unwashed tubers that had been riddled on the plant riddle (as in treatment 1) and then disinfected in a small tank of EEMC solution that had been drawn off the main disinfection tanks of the plant. Tubers remained submerged for 12 minutes after which they were left to dry in seed trays.

Treatment 10: Tubers that had been hand picked were disinfected as in treatment 9.

A para-cresol test (Robertson, 1961) was carried out on Majestic tuber samples immediately after the various treatments in order to assess levels of damage.

As in the previous years, the trays were stored in the same building as the 10 cwt. boxes until sampling on 9 November in the case of King Edward and 20 November for Majestic. Sampling of the stacks of boxes was the same as in 1965-66 and 1966-67 but the samples from different parts of the stack were mixed and considered as a single treatment. The samples were held in bags until they were put into trays in the potato store on 17 November and 27 November respectively.

Sprout counts and storage rot and skin spot assessments were made during the storage period. Apparently healthy tubers were planted on 29 April. Tubers were planted in a split plot design with varieties as main plots. Each sub-plot consisted of 5 drills of 10 tubers at a 15 in. spacing and there were four replicates of each treatment.

Counts of emergence, stem number, height and blackleg were made during the season. Plots were sprayed to destroy foliage on 16 September and lifted on 17 October. The weights and numbers of the various fractions were found after the tubers were riddled.

### 3.4.3. Results

a) Incidence and severity of mechanical damage

From Table 17 it may be seen that hand picked tubers showed a high level of damage before any grading treatment was applied. Hand riddling caused a higher degree of cracking than machine riddling. The washing process caused no increase in cracking (Table 17).

Table 17

Damage incidence in relation to various grading and washing treatments in Majestic - November 1967.

| Treatment | No. of tubers with cracks Per cent | | | | Free (per cent) |
|---|---|---|---|---|---|
| | 1" | ½" | ¼" | Total | |
| H Rid | 13 | 22 | 55 | 90 | 1 |
| H Pick from box | 5 | 9 | 38 | 52 | 8 |
| WM | 17 | 22 | 37 | 76 | 2 |
| WH Pick | 18 | 10 | 20 | 48 | 6 |

b) Sprout growth

Tubers disinfected after machine riddling and washed and disinfected tubers had a significantly greater number of sprouting eyes than the machine riddled only treatments. Disinfected hand picked tubers showed a significantly greater number of sprouting eyes compared to hand picked only tubers, but in the 1 March count only. Washed and machine riddled treatments also had a significantly higher sprout number than the machine riddled treatments, while washed and hand picked tubers showed an initial tendency for sprout stimulation which was only significantly higher than hand picked only tubers in the Majestic trial (Table 18).

Table 18

1968

The mean number of sprouting eyes in relation to seed treatment.

| Treatment | Majestic 1 March | Majestic 1 April | King Edward 15 February | King Edward 1 April |
|---|---|---|---|---|
| Graded | | | | |
| M | 2.0 | 10.0 | 4.0 | 6.6 |
| Recip Rid | 2.6 | 10.6 | 5.1 | 7.3 |
| H Rid | 4.3 | 10.8 | 4.6 | 7.3 |
| H Pick | 5.7 | 10.9 | 5.0 | 8.0 |
| Washed | | | | |
| WM | 6.7 | 11.2 | 5.5 | 8.1 |
| WH Pick | 7.2 | 11.5 | 6.0 | 7.5 |
| Disinfected | | | | |
| WMDT | 9.1 | 11.9 | 7.3 | 10.0 |
| WMDB | 8.5 | 12.4 | 7.0 | 9.6 |
| MD | 3.5 | 12.1 | 7.9 | 9.3 |
| H Pick D | 7.2 | 10.8 | 7.0 | 8.3 |
| S.E. ± | 0.38 | 0.30 | 0.58 | 0.49 |

There was a gradual increase in the length of sprouts throughout the storage phase and at planting the longest sprouts in each variety for all treatments were of the order of $\frac{1}{4}$ - $\frac{1}{2}$ in. (Appendix 12).

c) Skin spot

The incidence of the disease was very low in the Majestic tubers in all treatments and no differences were evident between any treatments. In King Edward some degree of control was given by all the disinfected treatments but not to a satisfactory level and there was a poorer control given by the washed and disinfected, box dried tubers compared with other disinfected treatments. The unwashed, disinfected treatments gave a similar degree of control to the washed and disinfected, tray dried treatments of both varieties (Table 19).

Table 19

The effect of different treatments on the incidence of skin spot - 10 May 1968.

| Treatment | Percentage of tubers with infection at some eyes | Surface infection index | Percentage of tubers free from obvious infection |
|---|---|---|---|
| Majestic | | | |
| Graded | | | |
| M | 4 | 0.2 | 88 |
| Recip Rid | 0 | 0.2 | 88 |
| H Rid | 4 | 0.5 | 88 |
| H Pick | 0 | 0.1 | 94 |
| Washed | | | |
| WM | 0 | 0.1 | 96 |
| WH Pick | 1 | 0.1 | 92 |
| Disinfected | | | |
| WMDT | 0 | 0.1 | 98 |
| WMDB | 0 | 0.1 | 96 |
| MD | 1 | 0.1 | 94 |
| H Pick D | 1 | 0.2 | 90 |
| King Edward | | | |
| Graded | | | |
| M | 70 | 6.2 | 4 |
| Recip Rid | 42 | 4.5 | 6 |
| H Rid | 62 | 6.3 | 0 |
| H Pick | 88 | 6.5 | 10 |
| Washed | | | |
| WM | 78 | 7.3 | 12 |
| WH Pick | 42 | 10.1 | 10 |
| Disinfected | | | |
| WMDT | 24 | 1.8 | 56 |
| WMDB | 30 | 2.8 | 28 |
| DM | 22 | 1.4 | 50 |
| DH Pick | 28 | 0.9 | 46 |

d) Tuber rots

Gangrene was markedly reduced by all disinfection treatments in both varieties. The level of disease in the untreated tubers was much higher in the King Edward tubers than in Majestic but the degree of control was not so satisfactory. In comparing the various disinfection treatments, in Majestic box dried tubers and the unwashed, disinfected treatments tended to give slightly less effective control but this was not evident in King Edward where the hand picked and disinfected tubers had least gangrene. Washing alone appeared to reduce gangrene before mechanically riddling in the Majestic stock and hand picking in the King Edward. All forms of riddling increased the level of the disease considerably (Table 20).

In both varieties disinfection gave a satisfactory control of dry rot. The disease was increased by riddling, particularly in Majestic, but washing alone reduced the incidence after machine riddling in Majestic and hand picking in King Edward, while with Majestic the level of the disease was increased by washing after hand picking.

The development of blight was negligible in Majestic and was reduced by disinfection in King Edward (Table 20).

Hard rot was again absent this year and tubers in the top boxes of the stacks were dry at the time of sampling.

Table 20

The effect of the various treatments upon the incidence of tuber rots: Final counts taken 28 April 1968.

| Treatment | Total No. of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Other rots per cent | Total rots per cent |
|---|---|---|---|---|---|---|
| Majestic | | | | | | |
| Graded | | | | | | |
| M Rid | 978 | 29.1 | 11.7 | 0.0 | 0.3 | 41.1 |
| Recip Rid | 996 | 27.5 | 13.9 | 0.0 | 0.4 | 41.8 |
| H Rid | 1024 | 29.3 | 7.4 | 0.0 | 0.4 | 37.1 |
| H Pick | 971 | 17.3 | 2.8 | 0.0 | 0.2 | 20.3 |
| Washed | | | | | | |
| WM | 1340 | 17.1 | 4.5 | 0.0 | 0.3 | 21.9 |
| WH Pick | 1035 | 16.4 | 5.1 | 0.1 | 0.2 | 21.9 |
| Disinfected | | | | | | |
| WMDT | 863 | 1.5 | 0.6 | 0.2 | 0.0 | 2.3 |
| WMDB | 912 | 4.8 | 1.0 | 0.0 | 0.0 | 5.8 |
| DM | 624 | 6.4 | 2.9 | 0.0 | 0.0 | 9.3 |
| DH Pick | 555 | 4.7 | 1.4 | 0.0 | 0.0 | 6.1 |
| King Edward | | | | | | |
| Graded | | | | | | |
| M Rid | 1117 | 44.9 | 3.3 | 1.2 | 0.0 | 49.3 |
| Recip Rid | 1402 | 71.5 | 4.4 | 1.5 | 0.0 | 77.4 |
| H Rid | 1018 | 62.6 | 2.8 | 1.7 | 0.0 | 67.1 |
| H Pick | 1071 | 42.4 | 2.5 | 1.6 | 0.0 | 46.5 |
| Washed | | | | | | |
| WM | 1465 | 43.1 | 3.2 | 1.4 | 0.0 | 47.7 |
| WH Pick | 1321 | 21.8 | 1.7 | 0.8 | 0.0 | 24.3 |
| Disinfected | | | | | | |
| WMDT | 831 | 13.9 | 1.0 | 0.6 | 0.0 | 15.5 |
| WMDB | 1061 | 13.9 | 0.9 | 0.1 | 0.0 | 14.8 |
| DM | 690 | 13.5 | 0.9 | 0.6 | 0.0 | 14.9 |
| DH Pick | 587 | 9.0 | 0.7 | 0.3 | 0.0 | 10.1 |

e) Emergence

Disinfected Majestic tubers emerged at a significantly faster rate, and the washed only tubers at a slightly faster rate, than the equivalent graded treatments. With King Edward graded and washed only treatments emerged at approximately the same rate while disinfected treatments sometimes showed a significantly higher number of emerged plants (Table 21, Appendix 13).

Table 21

The effect of treatment on the average number of days to emergence and the percentage blanking in the field.

| Treatment | Majestic | | King Edward | |
|---|---|---|---|---|
| | Emergence rate (days) | Blanking (per cent) | Emergence rate (days) | Blanking (per cent) |
| Graded | | | | |
| M | 42.6 | 2 | 42.2 | 5 |
| Recip Rid | 41.6 | 1 | 43.9 | 2 |
| H Rid | 41.8 | 0 | 42.2 | 2 |
| H Pick | 41.9 | 0 | 41.9 | 0 |
| Washed | | | | |
| WM | 41.0 | 1 | 44.2 | 5 |
| WH Pick | 40.3 | 2 | 42.4 | 3 |
| Disinfected | | | | |
| WMDT | 39.3 | 5 | 42.8 | 0 |
| WMDB | 40.3 | 1 | 41.4 | 0 |
| DM | 40.3 | 1 | 42.1 | 2 |
| DH Pick | 40.4 | 0 | 41.4 | 0 |

f) Number of stems

Disinfected treatments showed a slight tendency for more stems in both varieties compared to equivalent graded only treatments. The only significant differences, however, were with King Edward where washed, disinfected and box dried tubers produced more stems than machine riddled only, and disinfected after hand picking had a greater number than hand picked only (Table 22).

Table 22

The effect of the various seed treatments on the average number of stems per plant. - 8 July 1968.

| Treatment | Majestic | King Edward |
|---|---|---|
| Graded | | |
| M | 4.7 | 6.0 |
| Recip | 4.4 | 7.0 |
| H Rid | 4.2 | 6.8 |
| H Pick | 4.6 | 6.3 |
| Washed | | |
| WM Rid | 4.4 | 7.1 |
| WH Pick | 4.6 | 7.1 |
| Disinfected | | |
| WMDT | 5.0 | 7.0 |
| WMDB | 5.1 | 7.8 |
| DM | 4.8 | 6.8 |
| DH Pick | 5.6 | 8.1 |
| S.E. diff. 1 | 0.56 | |
| S.E. diff. 2)<br>S.E. diff. 3) | 0.26 | |

S.E. diff. 1. For comparison between treatments within the same varieties.
S.E. diff. 2. For comparison between varieties within the same treatments.
S.E. diff. 3. For comparison between different treatments within different varieties.

g) Blackleg

There was a progressive development of blackleg symptoms throughout the season with a considerable increase during August. The washed only treatments were associated with the highest levels of blackleg in Majestic. Disinfection after washing tended to slightly decrease this level although differences were not significant. Although differences between box and tray drying were only slight and non-significant, there was a tendency for more blackleg to develop from box dried tubers. Tubers that were disinfected without washing produced significantly less blackleg than any treatment that included washing. Of the graded only treatments, reciprocating riddled tubers gave rise to a similar level of blackleg to the washed and disinfected treatments. Machine riddled and hand riddled tubers produced approximately the same levels of blackleg and, while these were generally less than that for washing and disinfection treatments, the differences were only significant in the September count. Hand picked tubers produced less blackleg than other graded treatments in Majestic but not in King Edward (Table 23, Appendix 15).

Table 23

The incidence of blackleg in relation to different disinfection treatments - 1968.

| Treatment | 24 June | 1 July | 23 July | 1 August | 4 September |
|---|---|---|---|---|---|
| | Date of Count | | | | |
| **Majestic** | | | | | |
| Graded | | | | | |
| M | 2.0 | 8.0 | 10.0 | 18.5 | 30.5 |
| Recip Rid | 2.5 | 3.5 | 6.5 | 19.0 | 37.0 |
| H Rid | 3.0 | 5.5 | 6.5 | 14.5 | 27.0 |
| H Pick | 1.5 | 3.0 | 4.0 | 9.0 | 18.0 |
| Washed | | | | | |
| WM | 4.5 | 9.5 | 12.0 | 28.5 | 52.0 |
| WH Pick | 3.0 | 7.0 | 10.0 | 24.5 | 45.0 |
| Disinfected | | | | | |
| WMDT | 2.0 | 3.5 | 5.5 | 15.5 | 42.0 |
| WMDB | 1.0 | 5.0 | 10.0 | 23.0 | 40.0 |
| DM | 0.5 | 1.5 | 2.0 | 4.0 | 17.5 |
| DH Pick | 0.5 | 2.0 | 2.0 | 3.0 | 12.5 |
| **King Edward** | | | | | |
| Graded | | | | | |
| M | 2.5 | 2.5 | 3.5 | 8.0 | 20.5 |
| Recip Rid | 0.5 | 2.0 | 8.5 | 20.0 | 31.0 |
| H Rid | 1.0 | 1.5 | 3.5 | 9.0 | 19.0 |
| H Pick | 0.0 | 1.5 | 2.5 | 12.0 | 25.0 |
| Washed | | | | | |
| WM | 0.0 | 2.0 | 4.5 | 16.0 | 33.5 |
| WH Pick | 1.0 | 3.0 | 4.5 | 17.5 | 35.5 |
| Disinfected | | | | | |
| WMDT | 0.0 | 2.5 | 3.5 | 11.5 | 33.0 |
| WMDB | 1.0 | 2.0 | 2.5 | 14.5 | 39.0 |
| DM | 0.0 | 0.0 | 0.0 | 1.0 | 15.5 |
| DH Pick | 0.0 | 0.0 | 0.0 | 1.0 | 13.0 |

h) Yield

Of the graded only treatments the reciprocating riddled treatment with King Edward produced a significantly lower yield than the other graded only treatments. Washed only treatments produced a lower yield than equivalent graded treatments but a significant difference was only present with the washed and machine riddled treatment in Majestic.

Although there were no significant differences between different disinfected treatments or between disinfected treatments and the equivalent riddled only tubers, the washed and disinfected treatments yielded less than the machine riddled only treatments and disinfected only tubers (Table 24).

No significant differences were found between treatments of Majestic with respect to the total number of tubers produced, but with King Edward reciprocating riddled tubers gave a significantly lower number than hand riddled and hand picked treatments and machine riddled and disinfected tubers (Table 24). Graded only treatments tended to produce more ware tubers than the equivalent washed only or disinfected treatments with Majestic but the only significant difference was between hand riddled and washed machine riddled tubers. With King Edward hand picked tubers produced a significantly greater number of ware than washed, disinfected and box dried tubers. There were no significant differences in the number of seed and chats between treatments of Majestic but in King Edward reciprocating riddled tubers produced a significantly lower number than hand riddled, hand picked and machine riddled disinfected tubers (Appendix 16).

A significant negative correlation was found between yield and blackleg of -0.55 with Majestic and -0.50 with King Edward.

Table 24

Yield (tons/acre) and number of tubers (thousands/acre) in relation to treatment - 1968.

| Treatment | Ware (tons) | Seed (tons) | Chats (tons) | Total (tons) | Total No. (thousands) |
|---|---|---|---|---|---|
| Majestic | | | | | |
| Graded | | | | | |
| M | 3.9 | 10.6 | 0.6 | 15.1 | 142.6 |
| Recip Rid | 3.3 | 10.4 | 0.8 | 14.5 | 155.7 |
| H Rid | 4.0 | 10.1 | 0.8 | 15.9 | 147.8 |
| H Pick | 3.9 | 9.5 | 0.6 | 14.0 | 136.5 |
| Washed | | | | | |
| WM Rid | 1.6 | 8.2 | 1.0 | 10.8 | 142.4 |
| WH Pick | 3.1 | 9.3 | 0.8 | 13.2 | 137.0 |
| Disinfected | | | | | |
| WDT | 2.2 | 10.3 | 1.0 | 13.5 | 146.2 |
| WDB | 2.3 | 10.1 | 0.8 | 13.2 | 148.0 |
| DM Rid | 2.3 | 12.8 | 0.8 | 15.9 | 165.8 |
| DH Pick | 3.0 | 12.2 | 0.8 | 16.0 | 178.8 |
| S.E. diff. 1 | 0.59 | 1.01 | 0.11 | 1.23 | 19.33 |
| S.E. diff. 2)<br>S.E. diff. 3) | 0.31 | 0.49 | 0.05 | 0.58 | 7.19 |

Table 24 (contd.)

| Treatment | Ware (tons) | Seed (tons) | Chats (tons) | Total (tons) | Total No. (thousands) |
|---|---|---|---|---|---|
| King Edward | | | | | |
| Graded | | | | | |
| M | 1.7 | 11.7 | 0.9 | 14.3 | 196.5 |
| Recip Rid | 0.9 | 9.0 | 0.9 | 10.8 | 154.0 |
| H Rid | 1.6 | 12.5 | 1.1 | 15.2 | 226.3 |
| H Pick | 1.9 | 12.0 | 0.9 | 14.8 | 211.3 |
| Washed | | | | | |
| WM Rid | 0.9 | 10.6 | 1.0 | 12.5 | 170.8 |
| WH Pick | 1.4 | 11.2 | 1.0 | 13.6 | 196.5 |
| Disinfected | | | | | |
| WDT | 0.6 | 10.7 | 1.2 | 12.5 | 191.7 |
| WDB | 0.4 | 10.2 | 0.9 | 11.5 | 186.2 |
| DM Rid | 0.5 | 12.3 | 1.0 | 13.8 | 217.8 |
| DH Pick | 0.6 | 12.3 | 1.0 | 13.9 | 195.7 |
| S.E. diff. 1 | 0.59 | 1.01 | 0.11 | 1.23 | 19.33 |
| S.E. diff. 2) S.E. diff. 3) | 0.31 | 0.49 | 0.05 | 0.58 | 7.19 |

## 3.4.4. Discussion

As in the previous two years there were again no outstanding differences between box and tray drying following washing and disinfection. Both treatments showed the growth responses associated with the disinfection of tubers with organo-mercury solutions to a similar extent with respect to sprouting, emergence, stem number, tuber number and yield. Skin spot, dry rot and gangrene were controlled also to a similar degree, although there was a slightly higher level of gangrene in the box dried tubers than in tray dried tubers of Majestic. In King Edward, where the incidence of gangrene was very high in undisinfected tubers, the level of control after both disinfection treatments was not satisfactory. A possible explanation for this failure of treatment is given in Section 3.6.

As in 1966-67, no hard rot was observed in 1967-68, and soft rot was also absent in both varieties. Tubers from the top boxes in the stacks were dry on the day of sampling but this may indicate merely that the climatic conditions were not conducive to condensation at that time. As in the previous two years, treatments which included washing and disinfection gave rise to relatively high levels of blackleg with a slight tendency for less blackleg to develop in tray dried compared with box dried tubers as found in 1966-67.

The omission of washing from the complete washing and disinfection process did not affect to any degree the typical growth characteristics on the subsequent crop. However, there was a tendency for heavier yield production, especially with Majestic, where washing was omitted. Skin spot in both varieties, and tuber rots in King Edward, were reduced to the level found in the washed and disinfected tubers but, with Majestic, the incidence of gangrene and dry rot were slightly higher than in washed and disinfected, tray dried treatments.

Disinfection without washing was consistently associated with a low incidence of blackleg and this was significantly less in any treatments which included washing. This agrees with the results of Logan (1969).

The effects of washing alone were in most cases similar to those found in 1966-67. Sprout stimulation was slight but, again, not so extensive as that given by washed and disinfected treatments. A slightly delayed emergence with King Edward and slight tuber yield reduction in Majestic followed the planting of washed and machine riddled treatments. In 1967-68, washing tubers had no definite effect on skin spot in either variety but reduced the level of gangrene and dry rot in both the machine riddled Majestic and hand picked King Edward tubers. Seed which had been washed only produced, in general, the highest incidence of blackleg in the growing crop.

A high incidence of damage was found in hand picked tubers after harvesting and transport operations, but this level was considerably increased in the size-grading process and this was associated with a corresponding increase in the incidence of gangrene and dry rot. In a comparison of hand picked and machine riddled treatments, there was also some evidence that increased damage of the Majestic seed tubers was associated with a higher incidence of blackleg in the subsequent crop.

Evidence for a direct relationship between tuber damage and blackleg incidence was conflicting but in both varieties washing was the major factor in the subsequent development of the disease. Thus washing alone, in spite of the method of handling beforehand, gave the highest level of blackleg, and disinfection after washing gave no evidence of a significant reduction in disease level. However, where washing was omitted, disinfection caused a substantial reduction, irrespective of the method of grading. This suggests that the washing process in some way allows an establishment of the organism in the tuber in such a way that subsequent disinfection is not effective.

The organism is undoubtedly on the surface of tubers at the time of lifting (Graham and Volcani, 1961; Logan, 1964) and it is probable, as suggested by Graham (1963) and Logan (1964), that the pressure of the water jets pushes the organism below the level to which the disinfectant can penetrate.

## 3.5. Commercial Assessment of the Stocks used in the 1967-68 Trials

### 3.5.1. Introduction

A comparison was made between the washed, machine riddled, disinfected and box dried (WMDB) treatments of the 1967-68 trials and similarly treated parts of the same stocks which had been despatched to English farms as commercial consignments purchased through a seed potato merchant. This was to assess how washed and disinfected seed tubers reacted under normal farm conditions with respect to storage rots, skin spot and blackleg.

3.5.2. Materials and methods

The stacks of 10 cwt. boxes in which the Majestic and King Edward tubers were dried at the Eassie disinfection plant were emptied and sorted as part of the commercial process before being put into sacks on 20 November, 1967, and 9 November, 1967, respectively. They were despatched from the plant and, after a few days, received on the farms where they were placed in chitting trays within 3 weeks.

On 6 March, 1968, 4 farms to which part of the Majestic stock had been sent and 3 which had bought some of the King Edward stock, were visited and a storage rot assessment made. At each store, 10 trays were thoroughly examined for the incidence of tuber rots. In addition, 50 tubers were taken at random from several trays at each store, for a skin spot assessment.

On 29-30 July the crops grown from the treated seed were inspected for the incidence of blackleg, the number of diseased plants in 5 blocks of 50 plants throughout the crop being recorded.

## 3.5.3. Results

a) Skin spot

The incidence of skin spot in commercial stores was similar to that in the experimental treatments except for the farm at West Dereham where there was a lower level (Table 25).

Table 25

The effect of seed treatment on the incidence of skin spot. 1968

| Farm No. and Locality of store | Percentage tubers with infection at some eyes | Surface infection index | Percentage tubers free from obvious infection |
|---|---|---|---|
| Majestic | | | |
| WMDB (Experimental) | 0 | 0.1 | 96 |
| 1. Scunthorpe | 2 | 0.2 | 78 |
| 2. Scunthorpe | 0 | 0.3 | 72 |
| 3. Knaith | 4 | 0.3 | 70 |
| 4. Worksop | 2 | 0.3 | 82 |
| King Edward | | | |
| WMDB (Experimental) | 30 | 2.8 | 28 |
| 5. West Dereham | 4 | 0.4 | 56 |
| 6. Pondersbridge | 28 | 1.8 | 16 |
| 7. Warboys | 24 | 1.7 | 8 |

b) Tuber rots

The results of storage rot assessments with both stocks were essentially similar in the ratios of the different diseases to those found in the experimental treatment, washed, disinfected and box dried. There was a lower incidence of disease in the Majestic commercial stocks, probably because the total in the experimental treatments consisted of all rots which had developed up to 28 April while the commercial stocks were assessed on 6 March. The stock at West Dereham showed a lower incidence of gangrene than at other stores (Table 26).

Table 26

The effect of the various treatments on the incidence of tuber rots - 1968.

| Farm No. and Locality of store | Total number of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Soft rot per cent | Pink rot per cent | Total rots per cent |
|---|---|---|---|---|---|---|---|
| Majestic | | | | | | | |
| WMDB (Experimental) | 912 | 4.8 | 1.0 | 0.0 | 0.0 | 0.0 | 5.8 |
| 1. Scunthorpe | 1248 | 1.3 | 0.5 | 0.0 | 0.0 | 0.0 | 1.8 |
| 2. Scunthorpe | 2265 | 0.9 | 0.6 | 0.0 | 0.0 | 0.0 | 1.5 |
| 3. Knaith | 2125 | 1.0 | 0.2 | 0.0 | 0.0 | 0.0 | 1.2 |
| 4. Worksop | 2259 | 0.8 | 0.4 | 0.0 | 0.0 | 0.0 | 1.2 |
| King Edward | | | | | | | |
| WMDB (Experimental) | 1061 | 13.9 | 1.0 | 0.6 | 0.0 | 0.0 | 14.8 |
| 5. West Dereham | 2200 | 9.0 | 0.1 | 0.3 | 0.0 | 0.3 | 9.7 |
| 6. Pondersbridge | 2046 | 13.4 | 0.5 | 1.4 | 0.1 | 0.0 | 15.4 |
| 7. Warboys | 2372 | 17.0 | 0.6 | 0.9 | 0.0 | 0.1 | 18.6 |

c) Blackleg

The incidence of blackleg in the commercial stock of Majestic was much lower than in the experimental treatment, although the levels were similar in King Edward (Table 27).

The commercial crops were planted earlier and plants were in a much more advanced state of growth. The size of these plants was never reached by the experimental treatments at Edinburgh.

Table 27

The incidence of blackleg in commercial stocks of Majestic and King Edward - 30 July 1968.

| Farm No. and locality where planted | Blackleg (per cent) |
|---|---|
| Majestic | |
| WMDB (Experimental) | 23.0 (1 August) |
| 1. Scunthorpe | 10.8 |
| 2. Scunthorpe | 10.4 |
| 3. Knaith | 7.6 |
| 4. Worksop | 9.6 |
| King Edward | |
| WMDB (Experimental) | 14.5 (1 August) |
| 5. West Dereham | 9.0 |
| 6. Pondersbridge | 10.5 |
| 7. Warboys | 16.0 |

3.5.4. Discussion

With each variety, the incidence of rots in the commercial stores was generally of the same order as that of the experimental treatments. The slightly more variable results from different farms in King Edward may relate to the original stock having been grown in two fields, thus introducing possible effects of soil variations and slightly different times of lifting with respect to different samples.

In Majestic stocks, the incidence of blackleg was markedly lower in the English crops than in the experiments. It is suggested that this difference was due to the higher levels of fertiliser used in England for potato growing, Graham and Harper (1966) having shown that high levels of nitrogen tend to mask the expression of symptoms in the field. Observations of the state of the English crops, which all showed more luxuriant growth than the crop in Scotland, supported this view, although blackleg was still conspicuous. The effect was not seen to the same extent in King Edward which might again be attributed to variation in the source of samples.

3.6. General Discussion and Conclusions

The results of the three years' experiments confirmed those of Boyd (1960), Jennings et al. (1964) and Graham (1964) in demonstrating the effectiveness of commercial washing and disinfection in controlling certain latent tuber diseases and indicated that changes in the process over the period did not markedly affect the efficiency of treatment. There was, however, some evidence that the omission of paddles from the disinfection tanks in 1966 and 1967 allowed higher levels of gangrene and dry rot to develop than were commercially acceptable and this may be related to a poor circulation of EEMC in the disinfection solution. As a result, in subsequent work a pump installation has been introduced in order to overcome this problem.

There was generally no obvious clear disadvantage associated with box drying compared with tray drying in the experiments. In some cases, however, condensation of moisture on the tubers in the top boxes was associated with slightly more soft rot development and there are suggestions from unpublished data in subsequent work that atmospheric conditions which give rise to excessive condensation can seriously aggravate this problem.

Blackleg continued to be a problem associated with the commercial washing and disinfection process despite attempts to reduce the incidence of the disease by the removal of the pintled rollers, and to reduce tuber damage during the process. It was observed, however, that the problem was present to a lesser extent in the commercial crops grown in England than in the equivalent crops in Scotland and this may be due, in part, to the greater quantities of fertiliser used in England, which has been shown to reduce the symptom expression of the disease (Graham and Harper, 1966).

It is clear from the trials 1966-68, that washing is associated with an increase in blackleg, and the results are in agreement with the work of Logan (1969) and support the suggestion that the problem of blackleg increase could be solved by the omission of the washing process.

There was no significant difference in the total yield of washed and disinfected seed compared with riddled only tubers despite the higher incidence of blackleg in treated stocks and the negative correlation found between blackleg incidence and yield. Washing alone, however, tended to depress yield, while disinfection without washing tended to produce higher yields.

# 4. THE EFFECT OF HOT AIR DRYING ON SEED-TUBERS AFTER DISINFECTION

## 4.1. Introduction

Whereas the necessity for rapid and efficient drying of seed-tubers after disinfection has been recognised on several occasions (Foister and Wilson, 1943; Boyd, 1960; Jennings *et al*., 1964; Logan, 1964) there are no data on the effect of hot air drying on seed-tubers. In America, hot air drying of washed ware is an established practice, aimed partly at reducing soft rot in storage (Ruehle, 1940). In Britain, Twiss (1960) suggested times and temperatures for drying ware tubers to prevent the development of extensive soft rotting in badly dried, washed tubers. He found that, despite temperature rises in the tuber, of from 67-95$^{o}$F at a depth of 1 mm., there appeared to be no heat damage to the tubers, either immediately or after storage, and, at the same time, soft rot was eliminated. Ruehle (1940) suggested that drying ware tubers for 3 minutes at 130$^{o}$F was adequate; providing there was good air circulation. He found that, when a pointed thermometer was plunged into the flesh of a tuber, which had been exposed to air at 150$^{o}$F, for 4 minutes, the temperature rose only by 6$^{o}$F, and after 2 minutes only by 2$^{o}$F. This is an indication that the effect of hot air on tuber temperature is much less than might be expected because heating of tuber tissue is prevented by the cooling effect of evaporation of the surface moisture. Rose and Schomer (1944) found that if the temperature $\frac{1}{16}$ in. below the surface of tubers rose to 135-140°F and was maintained for 10 minutes, the skin blackened and oozing took place from the lenticels. Nielsen (1946) reported that if tubers were held at 113°F for more than an hour, they became more susceptible to soft rot, but later recovered from this in store. Nielsen and Todd (1946) indicated that this phenomenon could be due to the effect of heat in increasing the permeability of the cells, allowing sugars to pass into the cell walls and intercellular spaces where they are more accessible to soft rot bacteria.

There was a reduction in yield from plants grown from tubers held in water at 43-45°C for an hour to control blight (van der Zaag, 1956) although Førsund (1960) found no effect when tubers were kept in water at 40-45°C for 1-8 hours. He later reported a slight decrease in vigour of seed that had been heated to 43°C, and 4-5% yield reduction compared with untreated seed (Førsund, 1968). There is evidence, therefore, that prolonged heating can cause damage to seed-tubers, but no results are available which show the effect of a short exposure time using similar temperatures.

In the present trials, washed only, hot air dried treatments were included to determine any biological effect of heat on tubers, and also for a comparison with washed and disinfected, hot air dried treatments, to determine any deleterious effects which might have been produced by the action of heat on the surface film of EEMC solution. It was considered possible, firstly, that significant amounts of EEMC might have been lost from the surface of the tuber by rapid drying in a stream of hot air, because of the volatility of EEMC (Graham, 1964). Secondly, since it might be necessary for a solution of the disinfectant to be present on the tuber surface for a minimum period to enable the disinfection process to be effective, rapid drying might remove EEMC from solution too quickly, thus reducing its efficiency. In Holland, tubers are kept moist after the start of disinfection for 30 minutes, for effective Rhizoctonia control.

In the trials in 1966-67 and 1967-68, the apparatus used for drying the seed-tubers was designed so that it was possible to subject small numbers of tubers to a current of air at various temperatures for precise lengths of time. The object of the trials was to assess whether the lengths of time necessary for drying had any effect on the efficiency of disinfection and the growth, blackleg development, and yield of the subsequent crop. In 1966-67, a preliminary trial was carried out to examine any effects on tubers, using air temperatures in the range $73^{o}$ - $126^{o}$F. This was followed in 1967-68 by a more detailed trial, using the temperature range $122^{o}$ - $212^{o}$F.

## 4.2. Experiments in 1966-67

### 4.2.1. Materials and methods

Seed stocks of the varieties Majestic and King Edward were used in these trials and lifted, spool graded and the treatments applied on the following dates shown in Table 28.

Table 28

The date of lifting, grading and the application of treatments to the varieties Majestic and King Edward - 1966.

| Variety | Date of lifting | Date of grading | Date of treatment |
|---|---|---|---|
| Majestic | 6-8 October | 28 October | 29 October |
| King Edward | 6 November | 9 November | 10 November |

The treatments applied to each variety were as follows:

1. Spool graded (M)
2. Spool graded, washed and dried in trays (placed in the drying apparatus for 1 minute) (MWT)
3. Spool graded, washed and dried in trays at 126°F ($MWH_3$)
4. Spool graded, washed, disinfected and dried at 73°F ($MWDH_1$)
5. Spool graded, washed, disinfected and dried at 99°F ($MWDH_2$)
6. Spool graded, washed, disinfected and dried at 126°F ($MWDH_3$)

Spool graded only treatments of each variety were kept in sprouting trays from the beginning of the experiment.

Washing was carried out in a modified Cooch washing machine containing a set of 34 smooth rollers and 6 pintled rollers, and with jets with a water pressure of 70 lbs./square inch. The potatoes were then disinfected for 12 minutes in 100-120 ppm EEMC and 200 ppm of a non-ionic wetting agent, in 20 gallons of solution contained in a stainless steel tank.

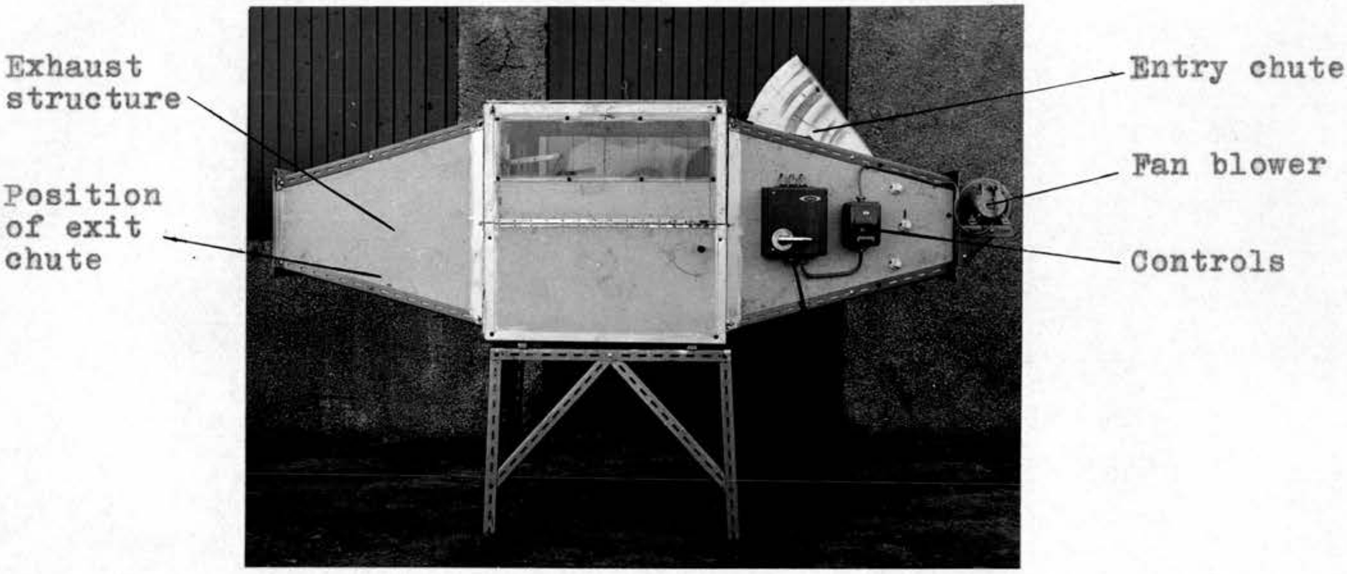
Tubers were placed in small, plastic, perforated containers and dipped into the tank.

The potatoes were dried in an experimental drying apparatus which had been constructed at the National Institute of Agricultural Engineering (Scottish Station). This has a basically simple design with a high versatility. It consists of a roller table, approximately 18 in. x 18 in., made up of 6 banks of intermeshing, rubber disc-rollers, mounted in a cube frame, the asbestos sides of which are interchangeable (Plates 12 and 13). Two truncated structures fit any sides of the cube and diminish in size from 1 square yard to 1 square foot. One contains the heating fixtures, a fan and three heating elements and the other joins a flue for exhaust gases. The aperture of the fan intake may be changed using special discs of known area, and each of the heating elements can be altered independently by means of a simmerstat control so that when the fan blower directs air through the heating elements the drying current produced is varied from ambient to 126°F.

Tubers enter the apparatus through a chute at one end of the roller table and leave by a chute at the opposite end. The disc rollers are manually cranked so that the speed of rotation and movement of the tubers can be varied, and at the same time air is directed by the fan through one side of the table and directed to the outside of the building.

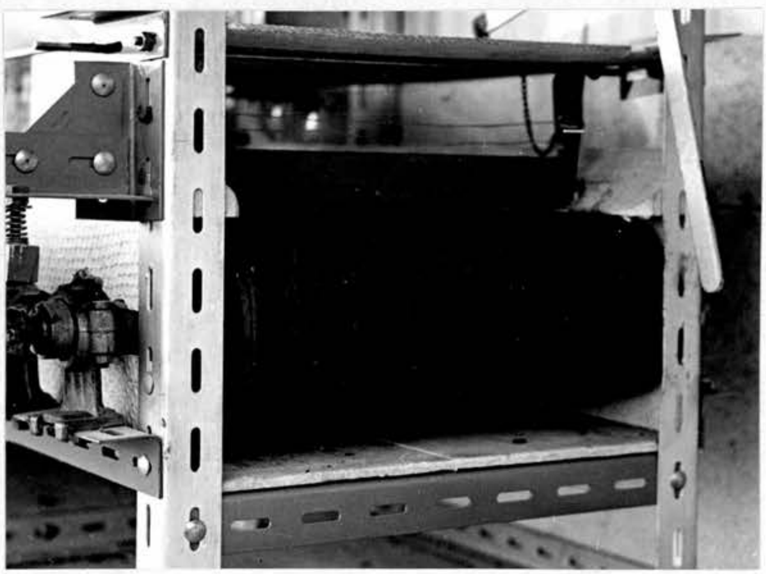
An electronic hygrometer (Type: Shaw-Multirange Hygrometer) was used to test the relative humidity of air in the

Plate 12. General view of hot air drying machine.




Cube frame containing disc roller bed

Plate 13. Detail of the intermeshing rubber disc roller bed.



ducting since it was anticipated that this would be a reliable method of determining when tubers had dried by detecting a fall in relative humidity of the outflowing air. The instrument uses small capacitance type elements. These consist of a wire, coated with a hygroscopic di-electric layer, which is specific to water vapour, and varies with the humidity and the variable capacitance is indicated on the hygrometer dial. The probe of the instrument was hung at the exhaust end of the roller table but it was found that, to obtain a scale deflection, tubers had to be placed in the machine without first passing them over the sponge rollers. They were merely shaken to remove excess water or EEMC solution and then tipped into the machine in lots of approximately 6 lbs. (25-35 tubers). A hygrometer reading of the empty machine was always taken after it had been running at a particular temperature for a few minutes to reach equilibrium. The time taken for tubers to dry was calculated from the time the entry chute was closed after they were in the machine, until the scale reading had almost returned to its original position. At this point tubers were found to be completely dry except for the presence of a trace of moisture in the eyes. The temperatures and approximate drying times are shown in Table 29.

Table 29

The temperature and approximate drying times of tubers in the hot air drying apparatus.

| Temperature $^{o}F$ | Average time (minutes) King Edward | Majestic |
|---|---|---|
| 73 | 3.0 | 3.5 |
| 99 | 2.5 | 3.0 |
| 126 | 2.0 | 2.5 |

Ambient temperature at both treatment dates was fairly low being 40-42$^{o}$F.

The use of the hygrometer was not very satisfactory and only an approximate guide to the necessary drying time was obtained. The reason for this was that the difference in relative humidity between air passing over moist tubers and air passing over dried tubers was almost undetectable and was probably due to the large volume of air flowing.

All treatments were trayed and kept in a potato store where sprout counts and disease assessments were made before planting. This took place on 6 April in the case of Majestic and 7 April with King Edward. Tubers were planted in 6 x 6 Latin squares with 8 drills of 15 tubers in each plot and with tubers 1 foot apart in the rows. During the growing season, emergence, height, stem number and blackleg counts were made, and an assessment of stem coiling (associated with *Verticillum nubilum*) and examination of mother tubers was also carried out.

The foliage was chemically destroyed on 3 October and plots lifted on 26-27 October. The weights and numbers of ware, seed and chats were determined for each plot.

4.2.2. Results

There appeared to be no increase in the temperature of tubers during drying at any of the temperatures used in these trials. The moisture in the eyes disappeared almost immediately and the only visible effect was a slight bluish tinge on the Majestic tubers which disappeared when the tubers greened.

a) Sprout growth

Table 30

The mean number of sprouting eyes per tuber in relation to seed treatment - 1967.

| Treatment | Mean number of sprouts per tuber | | | | | |
|---|---|---|---|---|---|---|
| | 10 Jan. | 10 Feb. | 10 Mar. | 10 Jan. | 10 Feb. | 10 Mar. |
| | Majestic | | | King Edward | | |
| Graded | | | | | | |
| M | 0.0 | 4.3 | 9.0 | 0.9 | 7.8 | 7.6 |
| Washed | | | | | | |
| MWT | 0.5 | 10.4 | 10.3 | 2.3 | 9.0 | 8.5 |
| $MWH_3$ | 0.1 | 6.1 | 9.9 | 2.6 | 8.7 | 9.4 |
| Disinfected | | | | | | |
| $MWDH_1$ | 0.2 | 8.9 | 10.6 | 2.4 | 9.3 | 9.3 |
| $MWDH_2$ | 0.2 | 9.3 | 10.2 | 2.7 | 9.8 | 9.5 |
| $MWDH_3$ | 0.2 | 9.1 | 10.6 | 2.4 | 9.7 | 9.1 |
| S.E. ± | 0.11 | 0.52 | 0.42 | 0.50 | 0.33 | 0.37 |

Washed and washed and disinfected treatments usually had significantly more sprouts per tuber than the riddled only treatments. There were significantly less sprouts in the washed only, dried at 126°F, treatment than in the washed and tray dried treatment with Majestic in January and February but this was not reflected in King Edward treatments. No differences were apparent between the disinfected treatments dried at the various temperatures (Table 30).

The lengths of sprouts increased gradually throughout the storage period and at planting sprouts were of the order of $\frac{1}{4}$ - $\frac{1}{2}$ in. in length. The mean numbers of sprouts of different lengths per tuber for each treatment are shown in Appendix 17.

In some treatments there was a reduction in the number of sprouts per tuber shown by the March count compared with the February count which was probably the result of handling when making disease assessments (Table 30, Appendix 17).

b) Skin spot

Infection was negligible in the Majestic tubers but with King Edward it was much higher although it was successfully controlled in all disinfected treatments. Differences between the riddled only and washed treatments were small (Table 31).

Table 31

The effect of seed treatment on the incidence of skin spot - assessed 3 May 1967.

| Treatment | Percentage tubers with infection at some eyes | Surface infection index | Percentage tubers free from obvious infection |
|---|---|---|---|
| Majestic | | | |
| Graded | | | |
| M | 0 | 0.3 | 84 |
| Washed | | | |
| MWT | 0 | 0.0 | 100 |
| $MWH_3$ | 0 | 0.0 | 100 |
| Disinfected | | | |
| $MWDH_1$ | 0 | 0.0 | 100 |
| $MWDH_2$ | 0 | 0.0 | 100 |
| $MWDH_3$ | 0 | 0.0 | 100 |
| King Edward | | | |
| Graded | | | |
| M | 36 | 2.2 | 28 |
| Washed | | | |
| MWT | 24 | 2.9 | 44 |
| $MWH_3$ | 36 | 3.6 | 20 |
| Disinfected | | | |
| $MWDH_1$ | 0 | 0.0 | 100 |
| $MWDH_2$ | 0 | 0.0 | 100 |
| $MWDH_3$ | 0 | 0.0 | 100 |

c) Tuber rots

The level of disease was low in both varieties and no differences were apparent between tubers dried at different temperatures. Disinfection reduced the level of disease in the King Edward but not the Majestic trial.

Hard rot symptoms were present in all treatments which included washing, with the exception of the washed and disinfected King Edward tubers (Table 32).

d) Emergence

Significant differences in the rates of emergence between the different treatments were present only in the Majestic trial (Appendix 18). In this trial, the riddled only control tended to emerge more slowly than other treatments (Table 33). The disinfected tubers dried at $99^{o}F$ showed a slower emergence than all other washed, and washed and disinfected treatments. The washed only, tray dried, and washed and disinfected dried at $126^{o}F$ emerged more quickly than did other treatments. Blanking was negligible with each variety (Table 33).

Table 32

The effect of various treatments on the incidence of tuber rots - 1966-67.

| Treatment | Total No. of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Hard rot per cent | Soft rot per cent | Total rot per cent |
|---|---|---|---|---|---|---|---|
| Majestic | | | | | | | |
| Graded | | | | | | | |
| M | 912 | 1.2 | 0.0 | 0.7 | 0.0 | 0.2 | 2.1 |
| Washed | | | | | | | |
| MWT | 753 | 1.5 | 0.2 | 0.4 | 0.9 | 0.4 | 3.4 |
| $MWH_3$ | 741 | 1.2 | 0.7 | 0.5 | 0.3 | 0.0 | 2.7 |
| Disinfected | | | | | | | |
| $MWDH_1$ | 715 | 0.8 | 0.3 | 0.7 | 0.1 | 0.4 | 2.3 |
| $MWDH_2$ | 693 | 1.4 | 0.8 | 0.3 | 0.0 | 0.3 | 2.8 |
| $MWDH_3$ | 647 | 0.9 | 0.6 | 0.7 | 0.6 | 0.2 | 3.0 |
| King Edward | | | | | | | |
| Graded | | | | | | | |
| M | 943 | 0.4 | 0.2 | 1.6 | 0.0 | 0.2 | 2.4 |
| Washed | | | | | | | |
| MWT | 898 | 1.0 | 0.0 | 0.8 | 0.3 | 0.2 | 2.3 |
| $MWH_3$ | 757 | 1.2 | 0.0 | 0.9 | 0.1 | 0.0 | 2.2 |
| Disinfected | | | | | | | |
| $MWDH_1$ | 735 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| $MWDH_2$ | 867 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_3$ | 850 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |

Table 33

The average number of days for emergence and percentage blanking - 1967-67.

| Treatment | Majestic | | King Edward | |
|---|---|---|---|---|
| | Rate of emergence (days) | Blanking (per cent) | Rate of emergence (days) | Blanking (per cent) |
| Graded | | | | |
| M | 49.6 | 1 | 47.0 | 1 |
| Washed | | | | |
| MWT | 45.6 | 0 | 46.5 | 1 |
| $MWH_3$ | 47.2 | 0 | 47.4 | 0 |
| Disinfected | | | | |
| $MWDH_1$ | 47.4 | 1 | 47.6 | 0 |
| $MWDH_2$ | 48.8 | 0 | 47.4 | 1 |
| $MWDH_3$ | 45.9 | 1 | 46.5 | 1 |

e) Number of stems

Disinfected treatments, except $MWDH_3$ with King Edward, produced a significant increase in the number of stems compared with graded only treatments. Washing alone without heat drying was also associated with significantly more stems than graded only with Majestic (Table 34).

Table 34

The effect of seed treatment on mean number of stems per plant - 8 July 1967.

| Treatment | Majestic | King Edward |
|---|---|---|
| Graded | | |
| M Rid | 3.5 | 5.0 |
| Washed | | |
| MWT | 4.4 | 5.4 |
| $MWH_3$ | 3.9 | 5.4 |
| Disinfected | | |
| $MWDH_1$ | 4.2 | 5.9 |
| $MWDH_2$ | 4.3 | 5.8 |
| $MWDH_3$ | 4.2 | 5.1 |
| S.E. ± | 0.19 | 0.21 |

f) Stem coiling

Table 35

The effect of seed treatment on stem coiling.
8 July 1967

| Treatment | Per cent tubers showing stem coiling Majestic | King Edward |
|---|---|---|
| Graded | | |
| M | 11.5 | 2.1 |
| Washed | | |
| MWT | 11.5 | 8.3 |
| $MWH_3$ | 14.6 | 10.4 |
| Disinfected | | |
| $MWDH_1$ | 8.3 | 6.3 |
| $MWDH_2$ | 4.2 | 4.1 |
| $MWDH_3$ | 9.4 | 4.1 |
| S.E. ± | 2.74 | 2.34 |

There was no significant difference between any of the treatments with respect to the incidence of stem coiling symptoms (Table 35).

g) The incidence of soft-rotted and healthy mother tubers

In each variety there were more healthy and fewer soft-rotted mother tubers in the disinfected treatments (Table 36, Appendix 20). In about 25 per cent of the plants examined in each trial the remains of the original setts were unidentifiable and the cause of the breakdown could not definitely be diagnosed.

Table 36

The effect of seed treatment on the condition of the seed tuber after planting - 8 July 1967.

| Treatment | Majestic Healthy (per cent) | Majestic Soft-rotted (per cent) | King Edward Healthy (per cent) | King Edward Soft-rotted (per cent) |
|---|---|---|---|---|
| Graded | | | | |
| M | 50.0 | 13.5 | 39.6 | 36.5 |
| Washed | | | | |
| MWT | 57.3 | 14.6 | 27.1 | 49.0 |
| $MWH_3$ | 52.1 | 15.6 | 38.5 | 38.5 |
| Disinfected | | | | |
| $MWDH_1$ | 75.0 | 9.4 | 78.1 | 5.2 |
| $MWDH_2$ | 59.4 | 3.4 | 66.7 | 8.3 |
| $MWDH_3$ | 66.7 | 8.3 | 66.7 | 8.3 |

h) Blackleg incidence

Washed with both varieties, and washed and disinfected treatments with Majestic, showed significantly higher levels of blackleg than the riddled only controls. With King Edward disinfected tubers there was a reduction in the incidence of the disease compared with washed only treatments, which was not seen with Majestic. The temperature of drying did not have a marked influence on the incidence of blackleg except with washed only treatments where drying at 126$^{o}$F was associated with a lower level of the disease in each variety than tray drying temperature (Table 37, Appendix 21).

Table 37

The incidence of blackleg (per cent) in relation to seed treatment - 1967.

| Treatment | Date of count<br>13 June | 24 June | 24 July | 25 August and 1 September |
|---|---|---|---|---|
| Majestic | | | | |
| Graded | | | | |
| M | 0.6 | 1.8 | 3.0 | 4.6 |
| Washed | | | | |
| MWT | 4.3 | 7.9 | 8.6 | 15.2 |
| $MWH_3$ | 3.3 | 4.5 | 5.5 | 13.7 |
| Disinfected | | | | |
| $MWDH_1$ | 3.5 | 5.6 | 5.7 | 14.3 |
| $MWDH_2$ | 3.5 | 5.7 | 6.7 | 13.1 |
| $MWDH_3$ | 6.0 | 6.7 | 7.0 | 11.2 |

Table 37 (contd.)

| Treatment | 13 June | 24 June | 24 July | 25 August and 1 September |
|---|---|---|---|---|
| | | Date of count | | |
| King Edward | | | | |
| Graded | | | | |
| M | 0.0 | 0.0 | - | 5.8 |
| Washed | | | | |
| MWT | 0.3 | 0.3 | - | 22.1 |
| $MWH_3$ | 0.3 | 0.6 | - | 17.4 |
| Disinfected | | | | |
| $MWDH_1$ | 0.0 | 0.1 | - | 10.6 |
| $MWDH_2$ | 0.0 | 0.1 | - | 9.3 |
| $MWDH_3$ | 0.0 | 0.0 | - | 12.5 |

i) Yield and number of tubers

There were no differences between the yield of any of the disinfected treatments of either variety or between disinfected tubers and graded only tubers. However, in King Edward, the washed only, tray dried tubers produced a significantly lower yield than all other treatments (Table 38). Disinfected treatments produced a significantly greater total number of tubers than graded treatments. With Majestic there was a significant reduction in the weight but not number of ware produced in disinfected treatments compared to the graded only treatment and a similar trend was seen with King Edward although differences were significant for number in the case of $MWDH_1$ only. Disinfected treatments also showed a significantly greater number, and sometimes weight, of seed and there was a tendency for a greater chat weight than in graded only treatments (Table 38, Appendix 22).

With Majestic there was a positive correlation between yield and blackleg of individual plots of 0.308 while with King Edward there was a significant negative correlation of -0.426.

Table 38

Yield (ton/acre) and number of tubers (thousand/acre) in relation to seed treatment - 1967.

| Treatment | Yield (ton/acre) Ware | Seed | Chats | Total | Total No. (thousand/acre) |
|---|---|---|---|---|---|
| Majestic | | | | | |
| Graded | | | | | |
| M | 15.6 | 5.8 | 0.4 | 21.8 | 134.7 |
| Washed | | | | | |
| MWT | 12.9 | 7.5 | 0.5 | 20.9 | 155.1 |
| $MWH_3$ | 12.7 | 5.0 | 0.5 | 19.2 | 131.9 |
| Disinfected | | | | | |
| $MWDH_1$ | 12.9 | 7.0 | 0.6 | 20.5 | 159.0 |
| $MWDH_2$ | 12.6 | 8.0 | 0.5 | 21.0 | 166.2 |
| $MWDH_3$ | 11.3 | 7.3 | 0.5 | 19.0 | 152.6 |
| S.E. ± | 0.72 | 0.74 | 0.05 | 0.90 | 5.74 |

Table 38 (contd.)

| Treatment | Yield (ton/acre) | | | | Total No. |
|---|---|---|---|---|---|
| | Ware | Seed | Chats | Total | (thousand/acre) |
| King Edward | | | | | |
| Graded | | | | | |
| M | 12.1 | 8.2 | 0.5 | 20.8 | 190.8 |
| Washed | | | | | |
| MWT | 8.4 | 9.3 | 0.7 | 18.4 | 198.0 |
| $MWH_3$ | 11.8 | 9.8 | 0.7 | 22.2 | 207.3 |
| Disinfected | | | | | |
| $MWDH_1$ | 9.8 | 11.6 | 0.7 | 22.0 | 231.1 |
| $MWDH_2$ | 10.7 | 10.6 | 0.7 | 21.9 | 221.4 |
| $MWDH_3$ | 10.9 | 10.1 | 0.7 | 21.7 | 221.8 |
| S.E. $\pm$ | 0.99 | 0.30 | 0.05 | 0.48 | 6.46 |

### 4.2.3. Discussion

Some of the known effects on growth and disease associated with washed and disinfected seed, i.e. an increase in number of sprouts, greater number of stems, decreased weight of ware and increase in the total number of tubers produced, as well as control of storage rots and skin spot and greater evidence of blackleg in washed only treatments compared with washed and disinfected tubers, were observed in King Edward. There was no indication that drying of tubers between 73-126$^{\circ}$F resulted in a loss of control of the latent diseases by the organo-mercurial solution.

In the Majestic trial some of the "characteristic" effects were not so evident. There was no reduction of storage rots nor a tendency for decrease in the blackleg level in disinfected treatments compared with washed only tubers. This is almost certainly due mainly to the interval of three weeks between lifting and treatment, rather than to the effect of the drying temperature. With respect to sprouting, stem number and yield, tubers responded in a similar way to the King Edward variety but in Majestic there was also an earlier emergence from disinfected tubers.

The hard rot symptoms in the treatments that included washing were most probably due to the presence of the six pintle rollers in the washing machine and possibly to the pintles on the spool grader. There was generally a lower incidence of hard rot in disinfected treatments compared with washed only tubers (Logan, 1964).

There was no evidence that hot air drying increased the incidence of blackleg which was found to be characteristically higher than graded only tubers in the washed only, and washed and disinfected treatments.

The difference in the time taken to dry Majestic and King Edward tubers may be due to two factors: firstly, the Majestic tubers were badly damaged at lifting and therefore might have retained moisture at points of damage, and, secondly, the King Edward tubers, being somewhat rounder, it appeared that a larger part of the surface was coming into contact with the rollers of the drying machine which were probably responsible for the removal of much of the moisture.

It may be concluded from the results of storage and field assessments that tubers of the varieties Majestic and King Edward can be satisfactorily dried with hot air within the range 73-126°F for from 2 to 3.5 minutes when this is done without increasing the temperature of the flesh of the tuber.

## 4.3. Experiments in 1967-1968

### 4.3.1. Introduction

As there was apparently no detectable damage to tubers by drying them with temperatures up to 126°F, it was decided to use a higher range for experiments in 1967-68 to cover a wider range of temperatures which might have some commercial application. The drying apparatus was modified to produce air temperatures of up to about 212°F, and a wider range of treatments was used so that a more detailed investigation of any effects of drying temperature was possible. In addition, unwashed disinfection treatments were included. Since a suitable stock of Majestic was not available the variety Pentland Dell was used.

### 4.3.2. Materials and methods

The experimental drying apparatus was modified to work at a higher temperature range by adding two extra heating elements and by insulating the roller bed with an asbestos and perspex tunnel (Plates 14 and 15). The latter also had the effect of increasing the air speed over the tubers which itself led to a much quicker drying time. Stocks of the varieties Pentland Dell and King Edward, which had both been burned down at least one month before lifting with an elevator digger, were used in the trials in 1967-68. The dates at which the stocks were riddled, lifted and treated are given in Table 39.

Table 39

The date of lifting, grading and the application of treatments to the varieties Pentland Dell and King Edward - 1967.

| Variety | Date of lifting | Date of grading | Date of treatment |
|---|---|---|---|
| Pentland Dell | 22-23 November | 22-23 November | 23-24 November |
| King Edward | 31 September | 10 October | 12 October |

The washing, disinfection and drying were carried out as in 1966. No attempt was made to use a hygrometer, but instead the time that tubers took to dry was initially determined by trial and error by doing a few test runs with tubers kept in the apparatus for various times at the different temperatures. Subsequent batches were then kept in the apparatus for the length of time necessary to complete drying.

The temperature and range of drying times are shown in Table 40.

Plate 14. General view of hot air drying machine after modifications before the 1967-68 trials.

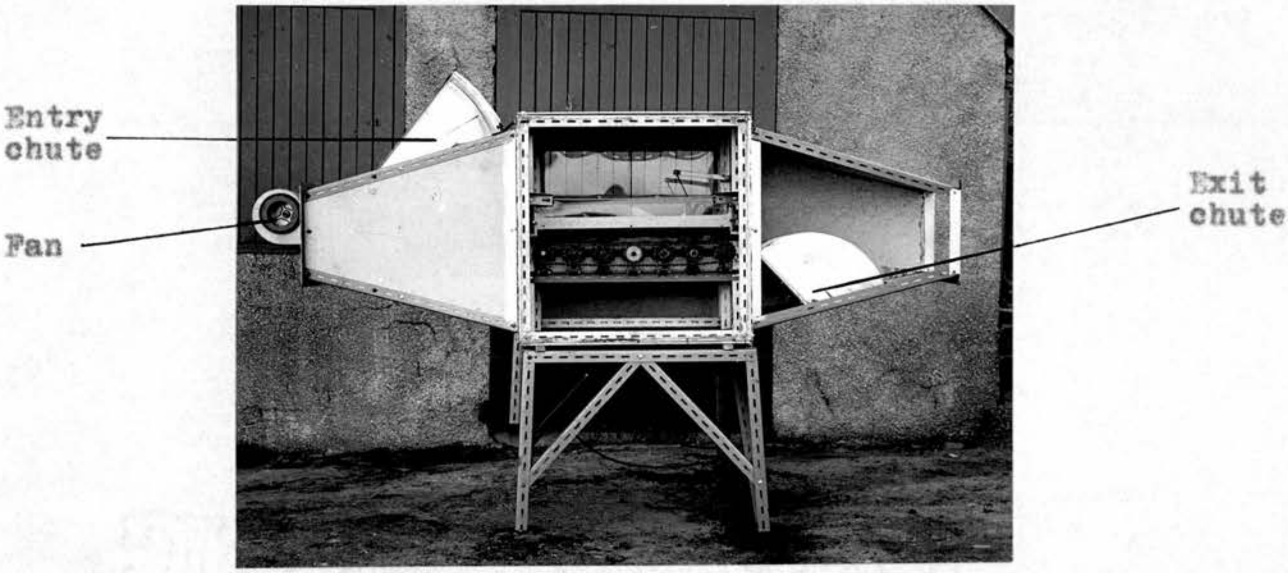



Plate 15. Detail of cowled roller bed in cube frame.

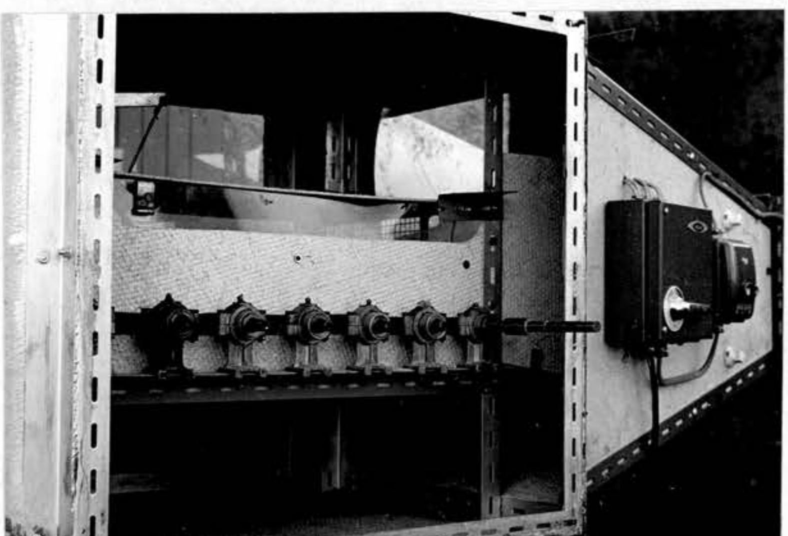


Table 40

The temperatures and range of drying times of tubers in the hot air drying apparatus.

| | King Edward | | Pentland Dell | | |
|---|---|---|---|---|---|
| | Temp. ($^{o}F$) | Drying time (sec.) Washed | Temp. ($^{o}F$) | Drying time (sec.) Washed | Unwashed |
| $H_1$ | 122 | 45-55 | 122 | 45-55 | 75-80 |
| $H_2$ | 167 | 35-45 | 167 | 35-45 | 60-65 |
| $H_3$ | 212 | 30-40 | 199 | 30-40 | 50-55 |

**The ambient temperature at the treatment dates was 52$^{o}$F for King Edward and 38$^{o}$F for Pentland Dell.**

Tubers were subjected to the following treatments:

1. Spool graded, kept in seed trays — M
2. Spool graded, washed, dried in seed trays — MWT
3. Spool graded, washed, dried at 122$^{o}$F — $MWH_1$
4. Spool graded, washed, dried at 199/212$^{o}$F — $MWH_3$
5. Spool graded, washed, disinfected, dried in seed trays — MWDT
6. Spool graded, washed, disinfected, dried at 122$^{o}$F — $MWDH_1$
7. Spool graded, washed, disinfected, dried at 167$^{o}$F — $MWDH_2$
8. Spool graded, washed, disinfected, dried at 199/212$^{o}$F — $MWDH_3$

With Pentland Dell only:

9. Spool graded, disinfected, dried at 122$^{o}$F — $MDH_1$
10. Spool graded, disinfected, dried at 167$^{o}$F — $MDH_2$
11. Spool graded, disinfected, dried at 199$^{o}$F — $MDH_3$

During drying of disinfected seed at each temperature an assessment of the concentration of elemental mercury in the exhaust gas of the drying machine was made but insufficient was detected in each test to be able to record a scale reading.

An assessment of the mercury residues on the Pentland Dell tubers was made on 15 December 1967, to determine whether drying at various temperatures affected the concentration of mercury. Analysis was carried out on a sample comprising one quarter from each of four tubers for each disinfected treatment.

All treatments were kept in seed trays after treatment and stored at a minimum of 35°F. Sprout counts and disease assessments were made before planting, on 8 May with King Edward and 13 May with Pentland Dell. Tubers were planted in randomised blocks, each plot having 5 drills of 10 tubers at 15 in. spacing in the rows. Plots were replicated 6 times. Only two of the unwashed, disinfected Pentland Dell treatments were planted.

During the growing season, counts of emergence, and with King Edward only counts of stem number, height and blackleg were made, and on 22 October plots were lifted and subsequently riddled and tubers of the various sizes counted and weighed.

4.3.3. Results

There was no visible effect of drying on any of the treatments and no apparent increase in the temperature of the dried tubers. The washed, and washed and disinfected Pentland Dell tubers lost excessive moisture during storage and became very wrinkled. There were other unfortunate features about this trial; at planting, the Pentland Dell tubers remained uncovered overnight since a sudden weather change and the aspect of the field made it impossible for machines to be used. Later on, some of the young plants were trampled and grazed by sheep when only a few inches high.

a) Mercury residues in Pentland Dell tubers

The results in Table 41 show that there was no significant loss of EEMC from the tubers.

Table 41

Effect of drying temperature on the mercury residue (ppm) on Pentland Dell tubers - 15 December 1967.

| Treatment | Mercury residue (ppm) Sample 1 | Sample 2 |
|---|---|---|
| MWDT | 2.0 | 2.8 |
| $MWDH_1$ | 2.9 | 2.6 |
| $MWDH_2$ | 2.5 | 2.1 |
| $MWDH_3$ | 1.9 | 2.2 |

b) Sprouting

Most disinfected treatments of both varieties initially tended to produce more sprouts than other treatments but by the March count this effect had disappeared in the Pentland Dell tubers. Washed only tubers also showed some sprout stimulation.

There was no marked effect of drying temperatures on the number of sprouts per tuber (Table 42).

There was a gradual increase in the length of sprouts in all the treatments during the storage period and at planting sprouts were of the order of $\frac{1}{8}$ - $\frac{1}{4}$ in. in length. The number of sprouts of various lengths are shown in Appendix 23.

Table 42

Mean number of sprouting eyes per tuber in relation to seed treatment - 1968.

| Treatment | Pentland Dell | | King Edward | |
|---|---|---|---|---|
| | 23 Jan. | 10 Mar. | 25 Jan. | 4 Mar. |
| Graded | | | | |
| M | 5.8 | 8.0 | 7.7 | 8.0 |
| Washed | | | | |
| MWT | 4.1 | 9.0 | 8.2 | 8.3 |
| $MWH_1$ | 4.0 | 9.1 | 7.6 | 8.0 |
| $MWH_3$ | 6.1 | 9.2 | 7.4 | 7.8 |
| Disinfected | | | | |
| MWDT | 5.2 | 8.8 | 8.0 | 8.9 |
| $MWDH_1$ | 5.3 | 8.2 | 8.5 | 9.0 |
| $MWDH_2$ | 6.0 | 8.1 | 8.5 | 9.4 |
| $MWDH_3$ | 7.6 | 8.5 | 8.3 | 8.9 |
| $MDH_1$ | 7.6 | 7.6 | - | - |
| $MDH_2$ | 7.1 | 8.2 | - | - |
| $MDH_3$ | 6.6 | 8.3 | - | - |
| S.E. $\pm$ | 0.66 | 0.43 | 0.46 | 0.26 |

c) Skin spot

Table 43

Effect of seed treatment on the incidence of skin spot - 1968.

| Treatment | Percentage tubers with infection at some eyes | Surface infection index | Percentage tubers free from obvious infection |
|---|---|---|---|
| Pentland Dell | | | |
| Graded | | | |
| M | 28 | 3.6 | 36 |
| Washed | | | |
| MWT | 12 | 1.8 | 52 |
| $MWH_1$ | 14 | 1.8 | 55 |
| $MWH_3$ | 11 | 1.6 | 56 |
| Disinfected | | | |
| MWDT | 0 | 0.0 | 100 |
| $MWDH_1$ | 2 | 0.1 | 96 |
| $MWDH_2$ | 0 | 0.0 | 100 |
| $MWDH_3$ | 0 | 0.1 | 94 |
| $MDH_1$ | 4 | 0.3 | 80 |
| $MDH_2$ | 4 | 0.2 | 88 |
| $MDH_3$ | 0 | 0.2 | 90 |
| King Edward | | | |
| Graded | | | |
| M | 26 | 2.9 | 28 |
| Washed | | | |
| MWT | 22 | 3.4 | 26 |
| $MWH_1$ | 16 | 3.6 | 24 |
| $MWH_3$ | 24 | 3.3 | 16 |
| Disinfected | | | |
| MWDT | 0 | 0.5 | 72 |
| $MWDH_1$ | 0 | 0.1 | 92 |
| $MWDH_2$ | 0 | 0.0 | 98 |
| $MWDH_3$ | 0 | 0.1 | 96 |

All disinfected treatments gave a reduction in the incidence of the disease. Washing alone decreased the disease in Pentland Dell but not in King Edward treatments. There appeared to be no definite effect of the different temperatures of drying on the incidence of skin spot (Table 43).

d) Tuber rots

All disinfected treatments in both varieties gave a satisfactory control of all diseases present, but in this case washing alone increased their incidence above that of other treatments. The disinfected treatments showed no apparent effect of the different drying temperatures. The washed only treatments of both varieties showed a similar trend in the levels of gangrene with the lowest level of the disease being in the treatment dried at 122$^{\circ}$F (Table 44).

Table 44

The effect of the various treatments on the incidence of tuber rots - 1968.

| Treatment | Total No. of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Hard rot per cent | Other rots per cent | Total rots per cent |
|---|---|---|---|---|---|---|---|
| Pentland Dell | | | | | | | |
| Graded | | | | | | | |
| M | 554 | 5.2 | 2.0 | 0.0 | 0.0 | 0.2 | 7.4 |
| Washed | | | | | | | |
| MWT | 712 | 14.0 | 3.0 | 0.0 | 0.3 | 1.5 | 18.8 |
| $MWH_1$ | 710 | 8.2 | 4.5 | 0.0 | 0.0 | 1.8 | 14.5 |
| $MWH_3$ | 615 | 12.2 | 5.0 | 0.0 | 0.0 | 0.7 | 17.9 |
| Disinfected | | | | | | | |
| MWDT | 507 | 0.4 | 0.2 | 0.0 | 0.0 | 0.2 | 0.8 |
| $MWDH_1$ | 548 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| $MWDH_2$ | 466 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.9 |
| $MWDH_3$ | 434 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.5 |
| $MDH_1$ | 511 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| $MDH_2$ | 421 | 0.2 | 0.5 | 0.0 | 0.0 | 0.0 | 0.7 |
| $MDH_3$ | 236 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| King Edward | | | | | | | |
| Graded | | | | | | | |
| M | 970 | 10.8 | 1.4 | 0.0 | 0.0 | 0.3 | 12.5 |
| Washed | | | | | | | |
| MWT | 635 | 17.1 | 4.1 | 0.3 | 0.3 | 1.1 | 22.9 |
| $MWH_1$ | 1008 | 11.6 | 3.6 | 0.0 | 0.4 | 1.3 | 16.9 |
| $MWH_3$ | 904 | 14.6 | 4.0 | 0.2 | 0.2 | 0.4 | 19.4 |
| Disinfected | | | | | | | |
| MWDT | 563 | 0.4 | 0.4 | 0.2 | 0.0 | 0.0 | 1.0 |
| $MWDH_1$ | 670 | 0.6 | 0.0 | 0.0 | 0.0 | 0.2 | 0.8 |
| $MWDH_2$ | 827 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 0.9 |
| $MWDH_3$ | 702 | 0.7 | 0.6 | 0.1 | 0.0 | 0.0 | 1.4 |

e) Emergence

Plants from disinfected Pentland Dell tubers emerged more quickly than those from the other treatments while with both varieties emergence was slower in the washed only treatments than in the riddled only, and washed and disinfected treatments. There were no marked differences between the rates of emergence associated with different drying temperatures (Table 45, Appendix 24).

Blanking was very pronounced in all treatments in the Pentland Dell trial (Table 45), especially in the washed only, hot air dried treatments. In the King Edward trial there was significant blanking in the washed only, tray dried treatment (Table 45).

In view of the high level of blanking with Pentland Dell this trial was abandoned. It was considered that the fact that tubers were not covered until 24 hours after planting was the most important factor that caused blanking. Sprout retardation or death may have led to 'little potato' to which the variety is very susceptible.

Table 45

The average number of days for emergence and the percentage blanking.

| Treatment | Pentland Dell Rate of emergence (days) | Pentland Dell Blanking (per cent) | King Edward Rate of emergence (days) | King Edward Blanking (per cent) |
|---|---|---|---|---|
| Graded | | | | |
| M | 35.8 | 19 | 34.5 | 1 |
| Washed | | | | |
| MWT | 36.6 | 16 | 36.7 | 6 |
| $MWH_1$ | 37.4 | 31 | 35.8 | 4 |
| $MWH_3$ | 35.9 | 23 | 35.8 | 4 |
| Disinfected | | | | |
| MWDT | 33.4 | 9 | 33.6 | 1 |
| $MWDH_1$ | 34.1 | 14 | 34.6 | 1 |
| $MWDH_2$ | 34.5 | 18 | 34.5 | 0 |
| $MWDH_3$ | 33.3 | 10 | 35.1 | 3 |
| $MDH_1$ | 32.9 | 11 | - | - |
| $MDH_3$ | 33.1 | 12 | - | - |

f) Number of stems

There were no differences in the number of stems of the different treatments in the King Edward trial (Table 46).

Table 46

The effect of seed treatment on the mean number of stems per plant - 1968.

| Treatment | Mean number of stems per tuber |
|---|---|
| King Edward | |
| Graded | |
| M | 6.1 |
| Washed | |
| MWT | 5.3 |
| $MWH_1$ | 6.0 |
| $MWH_3$ | 5.0 |
| Disinfected | |
| MWDT | 6.2 |
| $MWDH_1$ | 6.1 |
| $MWDH_2$ | 5.6 |
| $MWDH_3$ | 6.3 |
| S.E. ± | 0.33 |

g) Blackleg

Both washed, and washed and disinfected treatments tended to increase blackleg above the level in the riddled only treatment, although not always significantly. The washed and disinfected, tray dried tubers produced significantly more blackleg in the July and September counts than the washed only, tray dried tubers although both washed, and washed and disinfected tubers dried at similar temperatures gave the same level of the disease (Table 47, Appendix 26). All hot air dried treatments showed a tendency for a decrease in blackleg level corresponding to an increase in the temperature of drying and there were significant differences in the July count with washed only tubers and the August count with washed, and washed and disinfected tubers. However, a significant increase in the disease in tubers that had been washed only and dried at 50°C compared to washed only, tray dried tubers was found and a similar increase was also seen in the washed and disinfected tubers but in the August count only (Table 47, Appendix 26).

Table 47

The incidence of blackleg (per cent) in relation to seed treatment - 1968.

| Treatment | Date of Count<br>1 July | <br>1 August | <br>3 September |
|---|---|---|---|
| King Edward | | | |
| Graded | | | |
| M | 2.0 | 8.0 | 27.7 |
| Washed | | | |
| MWT | 6.0 | 12.3 | 28.0 |
| $MWH_1$ | 12.0 | 23.7 | 39.3 |
| $MWH_3$ | 5.7 | 13.7 | 28.7 |
| Disinfected | | | |
| MWDT | 10.7 | 14.3 | 43.3 |
| $MWDH_1$ | 11.0 | 19.3 | 40.0 |
| $MWDH_2$ | 9.7 | 14.3 | 39.0 |
| $MWDH_3$ | 7.3 | 11.7 | 36.0 |

h) Yield

There were no significant differences in total yield between any of the disinfected treatments or between disinfected treatments and graded only tubers. However, washed only, tray dried and dried at 167°F produced a significantly lower yield than graded only treatments. Washed only treatments produced a significantly lower total number of tubers compared to some of the other treatments (Table 48).

The weight and numbers of ware, seed and chats were approximately the same in the disinfected and graded only treatments. Washed only tubers produced significantly more ware, less seed and chats than some of the disinfected or graded only treatments (Table 48, Appendix 27).

Table 48

The yield (ton/acre) and number of tubers (thousand/acre) in relation to seed treatment - 1968.

| Treatment | Ware weight | Seed weight | Chats | Total weight | Total number |
|---|---|---|---|---|---|
| King Edward | | | | | |
| Graded | | | | | |
| M | 1.3 | 10.2 | 0.9 | 12.4 | 196.6 |
| Washed | | | | | |
| MWT | 1.9 | 7.9 | 0.8 | 10.6 | 152.6 |
| $MWH_1$ | 1.2 | 7.9 | 0.8 | 9.9 | 154.6 |
| $MWH_3$ | 2.0 | 8.8 | 0.8 | 11.6 | 168.8 |
| Disinfected | | | | | |
| MWDT | 0.9 | 10.4 | 1.0 | 12.3 | 209.5 |
| $MWDH_1$ | 0.6 | 9.7 | 0.9 | 11.2 | 179.9 |
| $MWDH_2$ | 0.7 | 9.2 | 0.9 | 10.8 | 183.7 |
| $MWDH_3$ | 1.0 | 9.4 | 0.9 | 11.3 | 178.6 |
| S.E. ± | 0.21 | 0.50 | 0.05 | 0.56 | 9.83 |

4.3.3. Discussion and conclusions

As in 1967, hot air drying of tubers did not produce any marked effect on the growth characteristics of disinfected seed. Disinfected treatments of both varieties showed sprout stimulation, which was also found to some extent in the washed only treatments, and there was earlier emergence in Pentland Dell. There was a significantly lower yield with some of the washed treatments.

Storage rots were effectively controlled by disinfection whether tubers were subsequently tray dried, or hot air dried within the temperature range 122-199/212$^{o}$F. Hard rot was again present to a very small extent in washed only treatments as in 1966-67, and is again attributed to the pintle rollers in the washing machine.

Although disinfection treatments had a higher incidence of blackleg than washed only treatments, there was no evidence that the incidence of the disease was influenced by hot air drying. The higher incidence of the disease may have been associated with the delay between lifting and treatment.

The results of the two years' trials showed that it was possible to dry tubers without necessarily causing any marked increase in their temperature. This is considered to be due to the cooling effect of evaporation of water from the tuber surface, cancelling out the heating effect of the hot air. This has previously been indicated by Ruehle (1940).

It may be concluded from the results that tubers of the varieties Majestic, King Edward and Pentland Dell can be satisfactorily dried with hot air within the range 72-212$^{o}$F when this is done without increasing the temperature of the flesh of the tuber.

# 5. EXPERIMENTS WITH A PROTOTYPE, CONTINUOUS DISINFECTION TANK

## 5.1. Introduction

In commercial practice, seed tuber disinfection is carried out mainly at large static plants where consignments are brought for treatment from the surrounding area. The grower who wishes to treat his own seed can only disinfect tubers in trays which involves an excessive amount of labour or use improvised equipment, as there appears to be no seed potato disinfection machinery available on the British market that fills the need of the individual seed potato grower. In the light of this, a small machine has been developed by the National Institute of Agricultural Engineering (Scottish Station) in conjunction with the Plant Pathology Department of the Edinburgh School of Agriculture and a commercial agricultural machinery firm, to provide a simple means of continuous disinfection.

The procedure for using the machine involves riddling, disinfection by immersion in a tank and drying the tubers, but omits washing. The period of immersion needs to be short so that the process can be continuous and the machine compact. The method is based on submerging tubers for ½ - ¾ minute in a solution of 150 ppm EEMC solution followed by drying in trays. Many workers have shown that a reduction of the main latent diseases can be achieved in this way, i.e. late blight (Greeves, 1937), skin spot (Greeves and Muskett, 1939; Foister, 1943; Edie and Boyd, 1966; McGee, 1967), dry rot (Foister, 1940; Foister and Wilson, 1943; Small, 1945; Logan, 1967b) and gangrene (Logan, 1967b).

One possible disadvantage of the omission of washing is that the presence of soil may lead to a progressive loss of the organo-mercurial from solution (Foister and Wilson, 1943; Logan, 1969) with a consequent decrease in the efficiency of disinfection with time. Moreover, the presence of a layer of soil at the tuber surface may act as a physical barrier to penetration of the EEMC solution or lead to a local loss of EEMC from solution at the surface. In this respect, it is of interest to note that Foister and Wilson (1943) found that the level of dry rot was never lower than 4-5 per cent in disinfected treatments, but they attributed this to infection established before disinfection.

Tubers that are disinfected after mechanical washing have a higher incidence of blackleg than those that are untreated or riddled only (Graham and Volcani, 1961; Graham, 1963; Jennings _et al_., 1964; Logan, 1964, 1969; Gray and Malcolmson, 1967). Logan (1969) was the first to describe the effect of disinfection of seed tubers without washing on the incidence of blackleg in the subsequent crop. The level of the disease in tubers treated in this way was the same as the untreated controls in one stock and only slightly higher in the other. It was, therefore, anticipated that the elimination of the problem of blackleg would be one of the main advantages of seed disinfection without washing compared with washing and disinfection.

An experiment, using the disinfection tank, was designed to examine the effects of the process on storage disease development, subsequent crop growth, incidence of blackleg and yield. A further aim of the investigation was to test for any decline in the efficiency of the disinfection process with time, associated with the presence of soil.

## 5.2. Materials and Methods

The trials were carried out in 1967-68 using commercial crops of the varieties Majestic, Redskin and King Edward, each grown at a different site in 1967. In the case of each crop, haulm destruction was carried out at least one month before lifting, which was by elevator digger. Following lifting, each stock was stored in bulk in a shed until riddling and the application of the experimental treatments on samples of the seed fraction of each crop. The samples of Redskin were stored in bags from the date of riddling until the time of treating the tubers. The source, date of lifting, date of riddling and method of riddling for the respective stocks are summarised in Table 49.

Table 49

Sources of experimental stocks - 1967.

| Variety | Source | Lifting date | Date of riddling | Method of riddling |
|---|---|---|---|---|
| Majestic | Westhaven, Carnoustie | 2 Oct. 1967 | 2 Nov. 1967 | Reciprocating riddle |
| Redskin | Flisk, Newburgh | 15 Oct. 1967 | 26 Oct. 1967 | Reciprocating riddle |
| King Edward | Logie, Newburgh | 27 Oct. 1967 | 2 Nov. 1967 | Spool grader |

On 2 November, the following treatments were applied using 6 seed chitting trays of tubers from each stock for each treatment:

1. Graded only (M)
2. Graded, disinfected (a) (MD (a))
3. Graded, disinfected (b) (MD (b))
4. Graded, disinfected twice (in the case of Majestic only) (MD (x 2))
5. Graded, washed and disinfected (MWD)

Disinfection was carried out in the prototype continuous disinfection machine (Plate 16). This consisted of a tank of about 80-100 gallons capacity, in which a wooden slatted conveyor belt ran at an angle of about $45^{o}$ (Plate 17). The belt was fitted with small paddles, spaced at 6 in. intervals, to elevate the tubers out of the tank and moved at a constant

Plate 16. General view of prototype continuous disinfection tank.


Plate 17. Detail of conveyor belt running from the base of the tank.

speed so that, with 80 gallons of solution, tubers were immersed for ½ - ¾ minute. A solution of 150 ppm EEMC and 200 ppm of a non-ionic wetting agent was used. In accordance with the manufacturer's recommendations, the solution of EEMC was not strengthened throughout the course of the disinfection.

Tubers were washed (treatment 5) by playing a power hose over trays containing a single layer of tubers to remove as much soil as possible but no attempt was made to simulate a high pressure washing machine.

In carrying out the treatments, Majestic tubers were disinfected first, followed by those of Redskin and then King Edward. For each variety, 6 trays of riddled tubers were disinfected (treatment MD (a)) followed by 6 trays of riddled and washed tubers (MWD), then 6 trays were disinfected by passing them through the tank twice (MD (x 2), Majestic only), and, finally, 6 trays of riddled tubers were disinfected (MD (b)). These various disinfection treatments were carried out with the object of assessing any variations due to the presence of soil on the tubers or possible loss of efficiency of the solution with time.

The trays of disinfected tubers were left to drain thoroughly then stacked in an open barn to complete drying. The following day the trays were transferred to an insulated shed where they were kept until planting.

During storage, sprout counts were taken on two dates and the incidence of tuber rots and skin spot determined. Sound tubers of each treatment were planted on 1 May with Majestic and 9 May with Redskin and King Edward. The Majestic were planted in a randomised block design with 6 replicates, and Redskin and King Edward in a split plot design with varieties as main plots and 4 replicates of each treatment. In each case, the plot size was of 5 rows of 10 tubers with 15 in. spacing in the rows.

Counts of emergence, height, stem number and blackleg were taken throughout the growing season and the yield, weight and number of tubers were recorded after lifting on 23 October.

## 5.3. Results

### a) Sprout growth in storage

The results of counts during the storage season (Table 50) indicate that the number of sprouts per tuber was significantly increased with all disinfected treatments compared with tubers which were riddled only, with the exception of the count in Redskin (Table 50).

The results for the mean number of sprouts in different size categories, for the two dates with each variety, indicate a progressive increase in growth during the storage season for all treatments. The longest sprouts were generally of the order of $\frac{1}{8}$ to $\frac{1}{4}$ in. by planting time for all treatments and varieties (Appendix 28).

Table 50

The mean number of sprouting eyes per tuber in relation to seed treatment - 1968.

| Treatment | Majestic 20 Mar. | Majestic 10 Apr. | Redskin 20 Apr. | King Edward 10 Feb. | King Edward 1 Apr. |
|---|---|---|---|---|---|
| M | 6.9 | 9.3 | 5.9 | 3.2 | 7.0 |
| MD (a) | 8.1 | 10.4 | 5.4 | 4.9 | 8.7 |
| MD (b) | 8.6 | 10.7 | 6.3 | 5.1 | 9.1 |
| MD (x 2) | 8.3 | 10.8 | - | - | - |
| MWD | 8.8 | 11.6 | 6.5 | 6.7 | 8.8 |
| S.E. ± | 0.25 | 0.24 | 0.40 | 0.50 | 0.40 |

b) Skin spot

The general level of surface infection was found to be higher in King Edward than in Majestic or Redskin, but in all three varieties, disinfection reduced disease incidence compared with that of riddled only tubers (Table 51). Washing and disinfection in all varieties, and disinfection (x 2) with Majestic gave the most effective level of control. In each variety, the disinfected treatment (a) tended to give a slightly better control of the disease than disinfected (b) (Table 51).

Table 51

The effect of different seed treatments on the incidence of skin spot - 1968.

| Treatment | Percentage tubers with infection at some eyes | Surface infection index | Percentage tubers free from obvious infection |
|---|---|---|---|
| **Majestic** | | | |
| M | 34 | 3.7 | 12 |
| MD (a) | 16 | 1.5 | 48 |
| MD (b) | 24 | 2.0 | 36 |
| MD (x 2) | 6 | 0.9 | 60 |
| MWD | 6 | 0.8 | 60 |
| **Redskin** | | | |
| M | 44 | 4.3 | 40 |
| MD (a) | 8 | 0.7 | 82 |
| MD (b) | 12 | 0.6 | 72 |
| MWD | 0 | 0.1 | 94 |
| **King Edward** | | | |
| M | 92 | 8.0 | 4 |
| MD (a) | 32 | 1.9 | 32 |
| MD (b) | 48 | 3.6 | 24 |
| MWD | 0 | 0.5 | 68 |

c) Tuber rots

The effects of the various seed treatments on the incidence of storage rots, recorded over the storage period until 3 May, are shown in Table 52.

In Majestic, gangrene developed to a marked extent and dry rot to a slight extent in the riddled only tubers and, compared with this, a considerable reduction was found in the incidence of both diseases with all the disinfected treatments.

In Redskin, a small amount of gangrene and a somewhat higher incidence of dry rot was found in the riddled only tubers. Again, there was a reduced disease incidence with all disinfected treatments, although the effects were much less marked than in Majestic.

A very low incidence of blight was found in Majestic and Redskin, the level being lower in disinfected tubers than in riddled only.

In both varieties the level of reduction in storage rots was less with disinfection treatment (MD (b)) compared with MD (a). Washing and disinfection tended to give the most effective control, but differences in all cases were only slight.

With King Edward the incidence of storage rots was negligible (Table 52).

Table 52

The effect of different seed treatments on the incidence of tuber rots - 3 May, 1968.

| Treatment | Total No. of tubers | Gangrene per cent | Dry rot per cent | Blight per cent | Other rots per cent | Total rots per cent |
|---|---|---|---|---|---|---|
| Majestic | | | | | | |
| M | 1173 | 24.7 | 4.9 | 0.6 | 0.9 | 31.0 |
| MD (a) | 1133 | 1.9 | 0.4 | 0.1 | 0.0 | 2.4 |
| MD (b) | 1617 | 4.0 | 0.6 | 0.1 | 0.0 | 4.6 |
| MD (x 2) | 1118 | 2.2 | 0.5 | 0.1 | 0.0 | 2.8 |
| MWD | 1150 | 1.4 | 0.4 | 0.1 | 0.0 | 1.8 |
| Redskin | | | | | | |
| M | 1950 | 5.6 | 9.1 | 0.6 | 0.7 | 15.8 |
| MD (a) | 1950 | 2.6 | 5.2 | 0.2 | 0.1 | 8.1 |
| MD (b) | 1950 | 2.9 | 6.8 | 0.3 | 0.3 | 10.1 |
| MWD | 1950 | 2.8 | 4.2 | 0.2 | 0.2 | 7.3 |
| King Edward | | | | | | |
| M | 979 | 0.4 | 0.2 | 0.0 | 0.2 | 0.8 |
| MD (a) | 911 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| MD (b) | 813 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MWD | 750 | 0.3 | 0.1 | 0.0 | 0.1 | 0.5 |

d) Emergence in the field

There was a slight tendency for plants from disinfected treatments of all varieties to emerge at a faster rate than the riddled only treatments but the effects were generally not statistically significant (Table 53, Appendix 29).

Blanking was negligible in the Majestic trial and occurred only very occasionally in the Redskin and King Edward plots, the highest incidence being found in the graded only King Edward (Table 53).

Table 53

The average number of days to emergence and the percentage blanking in relation to different seed treatments.

| | Majestic | | Redskin | | King Edward | |
|---|---|---|---|---|---|---|
| Treatment | Average number of days to emerge | Per cent blanking | Average number of days to emerge | Per cent blanking | Average number of days to emerge | Per cent blanking |
| M | 44.6 | 0 | 40.1 | 2 | 34.3 | 4 |
| MD (a) | 43.4 | 0 | 39.6 | 2 | 31.8 | 1 |
| MD (b) | 44.1 | 0 | 37.9 | 1 | 34.1 | 0 |
| MD (x 2) | 40.7 | 1 | - | - | - | - |
| MWD | 41.2 | 0 | 37.7 | 0 | 32.5 | 1 |

e) Number of stems

There were no statistical differences between the treatments in their effects on stem numbers in the Redskin or King Edward trials, although disinfected treatments always had a greater number than the riddled only treatment. With Majestic, all disinfected treatments had significantly more stems at soil level than the riddled only treatment (Table 54).

Table 54

The mean number of stems per plant in relation to different seed treatments - 1968.

| Treatment | Mean No. of stems/plant Majestic | Redskin | | King Edward |
|---|---|---|---|---|
| M | 5.0 | 3.7 | | 5.1 |
| MD (a) | 6.7 | 4.1 | | 5.5 |
| MD (b) | 6.5 | 4.5 | | 5.5 |
| MD (x 2) | 6.3 | - | | - |
| MWD | 6.6 | 4.1 | | 5.9 |
| S.E. | ± 0.26 | S.E. diff. 1 | 0.43 | |
| | | S.E. diff. 2)<br>S.E. diff. 3) | 0.32 | |

f) Blackleg

The percentage blackleg on different dates in relation to the different experimental treatments is shown in Table 55.

Both in Majestic and King Edward, all disinfected treatments tended to produce slightly less blackleg during the season than the riddled only, particularly in the last two dates of counts. However, the effects were only significant in Majestic.

In the latter variety, the washed treatment had a higher level of blackleg than other disinfected treatments and disinfected twice the lowest level, but the differences were not significant.

In the case of Redskin, disinfected treatments all had a higher level of blackleg than the riddled only but significant differences were only shown in the August count (Table 55).

Table 55

The incidence of blackleg (per cent) in relation to different seed treatments - 1968.

| Treatment | 1 July | 1 August | 1 September |
|---|---|---|---|
| Majestic | | | |
| M | 3.7 | 21.7 | 39.3 |
| MD (a) | 2.3 | 14.0 | 31.0 |
| MD (b) | 3.3 | 13.3 | 31.0 |
| MD (x 2) | 1.7 | 11.3 | 27.3 |
| MWD | 2.7 | 16.7 | 36.0 |
| Redskin | | | |
| M | 0.7 | 4.7 | 31.7 |
| MD (a) | 0.3 | 8.3 | 39.9 |
| MD (b) | 0.7 | 8.7 | 39.9 |
| MWD | 0.0 | 7.7 | 35.6 |
| King Edward | | | |
| M | 0.7 | 4.3 | 27.8 |
| MD (a) | 0.3 | 2.0 | 20.6 |
| MD (b) | 0.7 | 1.7 | 18.3 |
| MWD | 1.7 | 2.7 | 20.0 |

g) Yield

No significant differences were found between the different experimental treatments in their effect on total yield (Table 56). However, the total number of tubers produced per acre was generally significantly greater for all disinfected treatments than for riddled only treatments in all three varieties.

This increase in tuber number was associated with higher seed and chat yields for disinfected tubers compared with riddled only tubers, but the results were only significant for Majestic seed and chats and Redskin chats. Ware yield was significantly less from disinfected tubers than from riddled only tubers in Majestic (Table 56).

The results for the number of ware, seed and chats per acre for each variety are shown in Appendix 32.

With King Edward there was a significant negative correlation between yield and blackleg of individual plots of -0.52 while with Majestic and Redskin non-significant negative correlations were obtained of -0.15 and -0.11 respectively.

Table 56

Yield (ton/acre) and number of tubers (thousand/acre) in relation to treatment - 1968.

| Treatment | Ware (ton/ acre) | Seed (ton/ acre) | Chats (ton/ acre) | Total yield (ton/ acre) | Total tuber numbers (thousand/ acre) |
|---|---|---|---|---|---|
| **Majestic** | | | | | |
| M | 3.9 | 9.1 | 0.5 | 13.5 | 143.7 |
| MD (a) | 2.1 | 11.9 | 1.0 | 15.0 | 188.3 |
| MD (b) | 2.7 | 11.7 | 0.9 | 15.7 | 183.4 |
| MD (x 2) | 1.4 | 10.7 | 1.1 | 13.2 | 171.4 |
| MWD | 2.8 | 10.7 | 0.9 | 14.4 | 172.3 |
| S.E. ± | 0.39 | 0.41 | 0.06 | 0.64 | 7.27 |
| Redskin | | | | | |
| M | 1.9 | 5.6 | 0.5 | 8.0 | 112.7 |
| MD (a) | 1.7 | 6.4 | 0.7 | 8.7 | 128.5 |
| MD (b) | 2.4 | 6.7 | 0.7 | 9.8 | 139.1 |
| MWD | 1.3 | 8.3 | 0.8 | 10.4 | 157.6 |
| **King Edward** | | | | | |
| M | 3.1 | 9.5 | 0.9 | 13.5 | 169.9 |
| MD (a) | 2.9 | 10.5 | 0.9 | 14.3 | 200.3 |
| MD (b) | 2.0 | 10.9 | 0.9 | 13.8 | 207.7 |
| MWD | 1.5 | 11.6 | 1.1 | 14.1 | 224.2 |
| S.E. diff. 1 | 0.56 | 0.81 | 0.07 | 1.12 | 13.73 |
| S.E. diff. 2)<br>S.E. diff. 3) | 0.50 | 0.50 | 0.06 | 0.60 | 10.71 |

5.4. Discussion

The results from the experiments using the prototype disinfection machine indicate that, in general, all disinfection treatments gave the characteristic effects associated with washed and disinfected seed, although these were often slightly more marked where tubers were washed before disinfection and, in some cases, a lower response was obtained from later immersion using the same solution.

As in other experiments, the increase in the number of eyes showing active bud growth was shown by organo-mercury disinfection of tubers which also tended to give higher numbers of stems per plant and tubers per acre in the subsequent crop. Washing before disinfection gave slightly more effective control of skin spot, which would suggest that the presence of soil inhibited the activity of the fungicide. Effective control of gangrene and dry rot was also obtained from disinfection in Majestic, but the level of control of these diseases in Redskin was poor. The difference in response between the two varieties may have been due in part to the later immersion of Redskin in the disinfection solution and, also, to the delay in applying treatment after riddling. In both varieties, washing slightly improved the effectiveness of disinfection. From the storage disease results for Majestic, there was evidence of only a slight benefit from a longer disinfection time. The incidence of blackleg was generally high in all treatments, disinfection giving slightly lower levels in

Majestic and King Edward but higher levels in Redskin, compared with riddled only treatments.

The results must be viewed with some caution, as none of the varieties were disinfected within the recommended three days from lifting and the treatment itself was done comparatively late in the season when infection was more likely to have become established on the tubers (Foister and Wilson, 1943; Small, 1945; Boyd, 1960; Gray and Malcolmson, 1967). However, the disinfection effected a considerable control of storage diseases and it seems likely that an improved degree of control, particularly of tuber rots in Redskin and of skin spot with all varieties, would have resulted had the time of disinfection been closer to lifting.

While the results with the machine were generally satisfactory, there was evidence that the presence of soil slightly reduced the efficiency of the EEMC solution. In the experiments, the tubers were comparatively clean at the time of treatment. It is possible that the influence of soil on the efficiency of disinfection would be much greater with a crop lifted under wet or heavy soil conditions. This problem might be overcome by dry brushing tubers for disinfection (Logan, 1969), a higher solution strength or longer disinfection time, but further work is necessary on this aspect.

## 6. THE VARIATION IN BLACKLEG SYMPTOM EXPRESSION

It is known that there is a gradual increase in blackleg symptom expression during the growing season but there are little published data, particularly for the British Isles. This was implicit in the information given by Rosenbaum and Ramsey (1918) in Maine (U.S.) in the course of showing that obvious infection in the field was dependent on environmental conditions, particularly rainfall, rather than on the percentage blackleg in the previous crop. The association between blackleg and environment is also shown in Table 57, originally published by Graham and Harper (1967) showing the acreage rejected because of blackleg in the Scottish seed potato codification scheme. certification

Table 57

Data from the Scottish seed potato codification scheme of acreage rejected because of blackleg. certification

| Year | Percentage acreage rejected for blackleg |
|---|---|
| 1958 | 0.28 |
| 1959 | 0.21 |
| 1960 | 0.07 |
| 1961 | 0.18 |
| 1962 | 0.39 |
| 1963 | 1.70 |
| 1964 | 0.54 |
| 1965 | 1.05 |
| 1966 | 6.96 |

Although the tolerance for blackleg was reduced in 1963 from 3 to 2 per cent, it is clear that years in which blackleg is generally higher are often followed by a much lower incidence, as shown by a low percentage of acreage rejected. It is known that low acreage was rejected in 1967 after the very high level in 1966.

During the course of the work on seed tuber disinfection, periodic field observations were made throughout the season on the incidence of blackleg on seed treated in various ways.

Three phases of symptom expression were found during the growth of the plants:

1. A few plants showed symptoms within a day or two of emergence. These withered away leaving blanks.
2. A much larger number developed symptoms when plants were 15-20 in. high, when one or more stems died. It was not usual for the plant to be completely killed.
3. With the onset of senescence (late August and September) it was found that the number of infected plants usually doubled and premature death of all infected plants occurred.

Despite the various treatments applied to the tubers before planting, e.g. riddling, washing and disinfection, the same trends in the build up of the disease were found in all plots in the same season. The results of the 1967 and 1968 field trials showed that in 1968 the level of blackleg towards the end of the season tended to be much higher in all treatments than equivalent treatments in 1967. Table 58 shows the percentage blackleg which developed in plants from seed from several trials to which similar riddling treatments had been applied in 1967 and 1968. The arbitrary criterion of cumulative rainfall is also shown for the growing period.

Table 58

Blackleg development cumulative rainfall in experimental plots - 1967 and 1968.

| TABLE No. in Thesis Treatment | Percentage blackleg at different dates and cumulative rainfall | | | | |
|---|---|---|---|---|---|
| 1967 | 13-14 June | 24-25 June | 23-24 July | | 1-4 Sept. |
| 15. Maj. M | 3.6 | 7.5 | 8.2 | | 18.3 |
| 15. Maj. H Rid | 1.3 | 2.0 | 2.2 | | 3.8 |
| 37. Maj. M | 0.6 | 1.8 | 3.0 | | 4.6 |
| 15. K.E. H Rid | 0.0 | 0.0 | - | | 2.3 |
| 37. K.E. M | 0.0 | 0.0 | - | | 5.8 |
| Cumulative rainfall from May (in.) | 6.93 | 6.93 | 8.52 | | 11.83 |
| 1968 | 24 June | 1 July | 23 July | 1 Aug. | 4 Sept. |
| 23. Maj. M | 2.0 | 8.0 | 10.0 | 18.5 | 30.5 |
| 23. Maj. Recip Rid | 2.5 | 3.5 | 6.5 | 19.0 | 37.0 |
| 23. Maj. H Rid | 3.0 | 5.5 | 6.5 | 14.5 | 27.0 |
| 55. Maj. M | - | 3.7 | - | 21.7 | 39.3 |

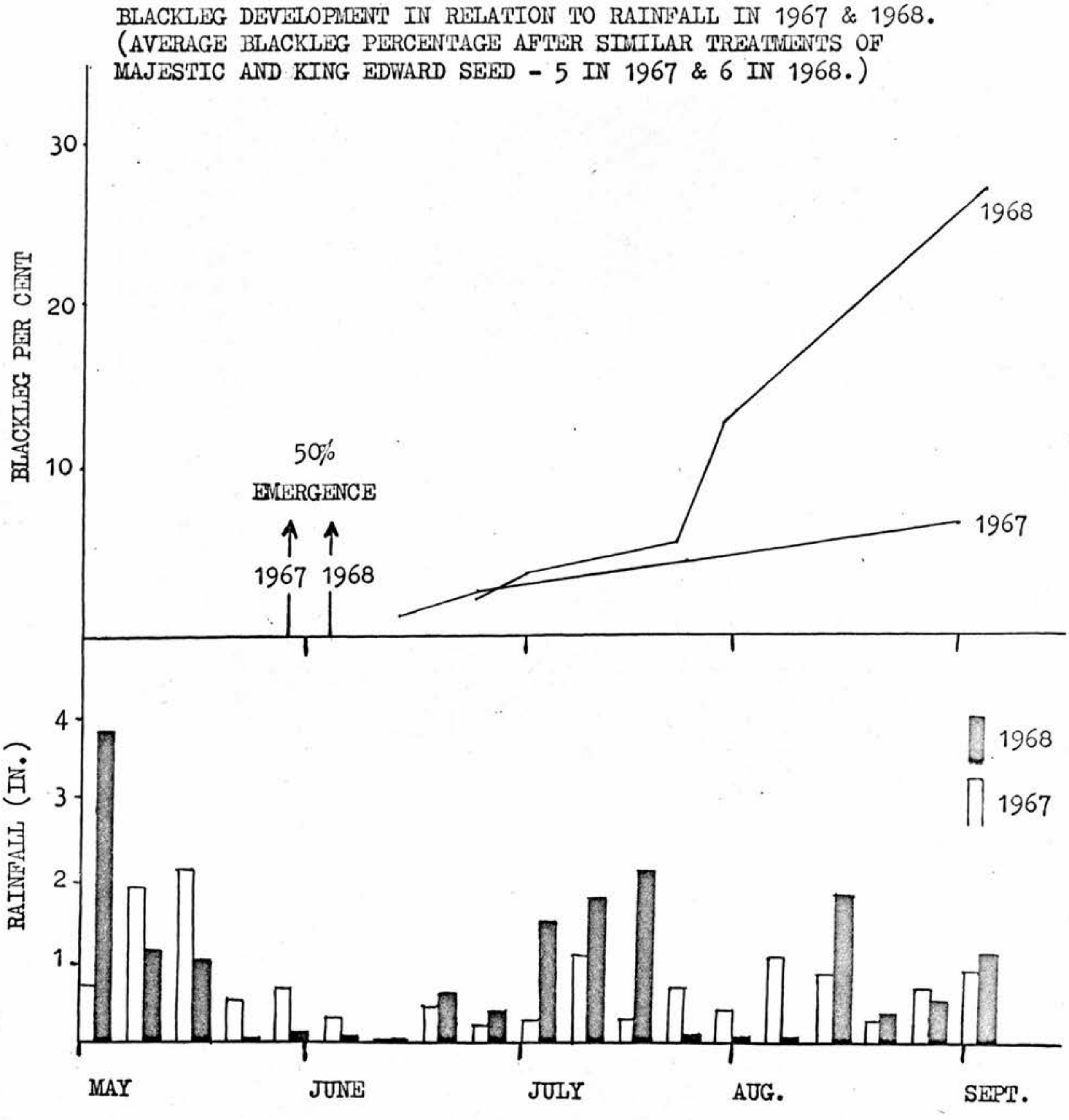
Table 58 (contd.)

| 1968 | 24 June | 1 July | 23 July | 1 Aug. | 4 Sept. |
|---|---|---|---|---|---|
| 23. K.E. M | 2.5 | 2.5 | 3.5 | 8.0 | 20.5 |
| 23. K.E. Recip Rid | 0.5 | 2.0 | 8.5 | 20.0 | 31.0 |
| 23. K.E. H Rid | 1.0 | 1.5 | 3.5 | 9.0 | 19.0 |
| 47. K.E. M | - | 2.0 | - | 8.0 | 27.7 |
| Cumulative rainfall from May (in.) | 6.27 | 7.28 | 12.63 | 12.80 | 14.98 |

The graph (Fig. 1) shows the average blackleg percent of similar riddled treatments (from Table 58) but excluding treatments that had been riddled on a bare wire reciprocating riddle, in the 1967 and 1968 field trials. The weekly total rainfall is also shown.

Although experiments were planted in different fields in the same area in the two years, it is suggested that the difference in blackleg incidence was the result of the rainfall pattern. It can be seen that the level of blackleg at the end of July is much higher in 1968 than in 1967 and the rapid increase in symptom expression may be associated with the very high rainfall during the first three weeks of July 1968. It may be that high rainfall in July 1968 resulted in the spread of bacteria under the very wet soil conditions or in a more rapid breakdown of the mother tuber.

Fig. 1



BLACKLEG DEVELOPMENT IN RELATION TO RAINFALL IN 1967 & 1968.
(AVERAGE BLACKLEG PERCENTAGE AFTER SIMILAR TREATMENTS OF MAJESTIC AND KING EDWARD SEED - 5 IN 1967 & 6 IN 1968.)
BLACKLEG PER CENT
30
20
10
50%
EMERGENCE
1967
1968
1968
1967
RAINFALL (IN.)
4
3
2
1
1968
1967
MAY
JUNE
JULY
AUG.
SEPT.

# 7. GENERAL DISCUSSION AND CONCLUSIONS

## 7.1. General Discussion

Disinfection of seed potatoes is now established as a commercial practice for the control of the main latent storage diseases following the development by Sir Thomas Wedderspoon of the plant for handling large quantities of seed tubers (Boyd, 1960). At present, three such plants are operated in Scotland, with an output of about 6500 tons of washed and disinfected seed each year. This output represents only about 0.25 per cent of the total seed produced and certified in Scotland.

In recent years there has been a decline in the Scottish seed potato trade. While this may be attributed in part to the more effective control of virus diseases in ware growing districts, the reputation of the trade has also suffered from problems arising from storage diseases. At the present time, the disinfection process represents the only effective way of controlling some of these diseases on a commercial scale. There are, however, possibilities of other methods of control being developed in the future, in cases where diseases are primarily seed-borne. The production of seed tuber stocks from stem cuttings may provide freedom from certain tuber-borne diseases, e.g. skin spot, and earlier harvesting of seed crops may reduce the losses caused by both skin spot and gangrene.

The process of washing and disinfection is far from a straightforward one and is beset with certain difficulties, the most important of which is concerned with the incidence of blackleg in crops grown from treated seed (Graham and Volcani, 1961; Graham, 1963; Jennings et al., 1964; Logan, 1964, 1969; Gray and Malcolmson, 1967). This is probably the main drawback to a more extensive use of washed and disinfected seed. The washing of tubers in machines with high pressure water jets before disinfection is generally considered to be the main factor responsible for the increase in blackleg incidence (Graham, 1963; Logan, 1964, 1969). Although the level of blackleg shown by planting washed tubers may be reduced by subsequent disinfection, the reduction is often only slight (Graham and Volcani, 1961; Graham, 1963; Jennings et al., 1964; Logan, 1964, 1969). The results from the present experiments showed that all treatments involving machine washed tubers were invariably associated with a high level of disease following riddling, especially on a bare wire riddle which gave a high degree of damage. Riddling may also be a means of spreading the organism in the presence of water. It was observed that grading on a moist riddle could increase the disease to the level found with washed tubers. In this case, it appeared that the two factors responsible for the high incidence of blackleg were damage and the presence of water. However, disinfection of unwashed tubers immediately after riddling led to a decrease in the incidence of the disease to the level given by tubers damaged only at lifting time, whereas, when disinfection followed washing, blackleg was not controlled by disinfection.

The results, therefore, would suggest that the washing process is more important than damage at lifting and riddling, in causing a rapid entry and establishment of the blackleg organism and thus in increasing the incidence of blackleg in washed and disinfected seed tubers. Attempts to decrease mechanical damage before washing and disinfection may thus be of little practical benefit for the control of blackleg. The washing process involving pressure jets of water must in some way assist the entry of the organism into the tuber byeond the reach of the disinfectant (Graham, 1963; Logan, 1964). It is likely that much of this occurs through lenticels whether these are damaged in the process or not. This is less likely to occur where mechanical damage by lifting or riddling machinery occurs with unwashed tubers. Smith and Ramsey (1947) suggested that further damage could be done to tubers during the washing process when proliferated lenticels were rubbed off. Until 1966, the commercial washing and disinfection process in Scotland included pintle rollers in the washing machines to help to remove soil from tubers. Graham (1967) suggested that these rollers were in part responsible for the spread of the blackleg organism, causing damage especially to lenticels (Hamilton and Ruthven, 1967). The substituting of pintle rollers by sponge rollers has been found to eliminate hard rot symptoms and reduce the severity of lenticel pitting, although the incidence of blackleg was not apparently significantly reduced.

Since pressure of water at the tuber surface may assist the entry of the bacteria into the tissues, attempts to reduce penetration by reducing the pressure have been made since the conclusion of this work, by delivering the water by sprays rather than by jets, thus reducing the pressure of water at the tuber surface to a few pounds per square inch.

Disinfection of unwashed tubers was generally found to reduce the incidence of blackleg to below the level of that given by tubers which had been graded only. This shows that in most tubers the blackleg organism is at the tuber surface where it is accessible to the organo-mercury solution (Graham and Volcani, 1961; Logan, 1964, 1969). With delay in applying the disinfection treatment after lifting, the effect of the solution was diminished and the incidence of the disease was increased (Gray and Malcolmson, 1967). In the few cases where disinfection did not reduce the disease it is possible that an experimental bias was introduced into the treatments by the removal of storage rots before planting. Tubers showing rot symptoms were generally more numerous in undisinfected treatments and it is possible that such tubers tended to carry more latent blackleg infection.

Some evidence was given to account for the generally higher incidence of blackleg in the trials in 1968 than in 1967. Although experiments were planted in different fields in the same area in the two years, it is suggested that the difference in blackleg incidence was the result of the rainfall pattern. This confirms work by Rosenbaum and Ramsey (1918) who stated that blackleg incidence was more dependent on rainfall and temperature than on the level of the disease in the crop from which the seed had been taken. Further study on this aspect of the work is in progress.

The experiments showed that disinfection of tubers in an organo-mercury solution generally reduced the incidence of skin spot, gangrene and dry rot to a satisfactory level in comparison with untreated tubers. There was also evidence that tuber blight could be reduced by disinfection. Where these diseases were not reduced to an acceptable level, this could be attributed to a delay of more than three days between lifting and treatment (Greeves and Muskett, 1939; Foister and Wilson, 1943; Boyd, 1960; Gray and Malcolmson, 1967). It is also possible that on one occasion there was a temporarily low concentration of EEMC in the disinfection tanks at the commercial plant.

Except when the level of storage diseases in a stock was very low, disinfection rarely provided eradication. This may have been due to prior infection in the field having become established in the case of gangrene or skin spot or the failure of the solution to penetrate into wounds which might have harboured the dry rot or gangrene organism (Foister and Wilson, 1943; Gray and Malcolmson, 1967; Todd, 1963).

The incidence of gangrene and dry rot were shown to be closely related to damage as has been previously shown by other workers (Foister, Wilson and Boyd, 1952; Kranz, 1958; Malcolmson, 1958; Harrison and Downie, 1960), and the effectiveness of the disinfection process is obviously influenced by the degree of previous damage sustained by the tubers. Logan (1967b) showed that disinfected tubers were less prone to infection by gangrene and dry rot if damaged after treatment. This is of importance in practice where transport from seed producer to the ware grower can cause considerable damage which could lead to higher incidence of gangrene and dry rot in untreated stocks, especially of susceptible varieties.

There is some evidence in this work to indicate that the disinfection of washed seed provided a slightly better control of storage diseases than disinfection alone using the same concentration of mercury for the same lengths of time. This suggests that soil has some effect in preventing EEMC from reaching the tuber surface, either by acting as a physical barrier, or possibly by absorption of EEMC from solution into the soil particles (Logan, 1969).

Washing tubers without disinfection had inconsistent effects on the incidence of skin spot, gangrene and dry rot. Sometimes there was an increase, sometimes a decrease and occasionally no apparent effect at all. Other workers have reported a decrease in the incidence of these diseases after washing (Boyd, 1957, 1960; Graham, 1964; Logan, 1967b).

The original purpose of washing seed tubers commercially was to remove soil which may have contained cysts of parasitic eelworms (Mabbott, 1960) and prevent their transmission. However, under the present regulations, since 1967, for the certification of all grades of seed crops in Scotland, the absence of potato cyst eelworm must have been shown by a pre-cropping soil test. There is, therefore, less necessity for washing tubers to remove soil. Washing is still incorporated in the process with the aim of reducing EEMC wastage (Logan, 1969).

In preliminary studies with a prototype disinfection tank, where disinfection was for $\frac{1}{2}$ - $\frac{3}{4}$ min. at a concentration of 150 ppm of EEMC, a reduction in the incidence of storage diseases was obtained despite a delay in applying the treatment but there was evidence that the presence of soil influenced the efficiency of disinfection. Foister and Wilson (1943), in assessing this method of disinfection, found that the solution was quickly inactivated by excessive soil which adhered to the tubers. It is necessary, therefore, to maintain the correct concentration of the EEMC solution during the disinfection process. If this method were to be used commercially, a means of removing excessive soil would undoubtedly be necessary. Logan (1969) has examined various methods of soil removal before disinfection but found that dry brushing, the most obvious method, slightly increased the incidence of blackleg compared with that given by untreated tubers. A higher concentration of EEMC or a longer disinfection period might be used as a possible means of improving the efficiency of this method of treatment.

The importance of effective drying after seed tuber disinfection has been emphasised by several workers (Foister and Wilson, 1943; Boyd, 1960; Jennings et al., 1964; Logan, 1964). It has been found that tubers will dry in seed chitting trays satisfactorily under most conditions (Boyd, 1960), but on a large scale this method of drying is found to be uneconomic because of the excessive labour involved. The method of commercial drying examined in this work, involving the ventilation of 10 cwt. boxes in stacks with forced air at ambient temperature, did not show any marked disadvantages compared with drying in trays. However, there was evidence that condensation moisture might form on tubers in the top boxes in some conditions in Autumn and favour the development of soft rot. The extensive losses due to soft rot experienced in more recent observations in 1968-69 emphasise the importance of defining the exact conditions under which condensation can take place. During one season an attempt was made to control this by the application of a straw layer on the top boxes on the stacks. The potatoes immediately underneath this straw remained dry while those in the unstrawed boxes were damp to a depth of at least 18 ins. This method, however, was not commercially acceptable. In practice, covering stacks with tarpaulins has been used but it is not known at present if this will be completely effective.

There was some indication that the planting of box dried tubers led to a higher incidence of blackleg in the crops in 1967 and 1968 than tray dried tubers. This increase may be connected with the slower rate of drying in the boxes. Logan (1964) has observed that, under conditions where drying is retarded, bacterial multiplication was encouraged.

It is possible that the difficulties entailed in drying tubers in 10 cwt. boxes could be avoided by the use of hot air to dry the tubers immediately after treatment and then to transfer them to bags for despatch to the grower. The results of the hot air drying experiments, using different varieties, indicated that tubers can be satisfactorily dried in a current of air, at temperatures up to 212$^{o}$F and periods of exposure up to 3½ minutes. No adverse side effects in relation to growth, yield or loss of control of storage diseases after disinfection were observed. It is thought to be important, however, that the tubers are removed from the hot air stream when they are dry but before the tubers themselves show a rise in temperature. The temperature of tubers did not rise in the force dried treatments, apparently because of the loss of heat from the surface by evaporation (Ruehle, 1940) and there was no evidence that the hot air caused a loss of EEMC from the tuber's surface. Further trials on hot air drying are in progress using a prototype commercial drying machine which has been installed at the disinfection plant at Eassie.

Although no mercury was detected in the exhaust gas from the experimental hot air drying apparatus and there was no apparent loss of EEMC from tuber surface as a result of drying, there are obvious dangers inherent in the commercial application of this process. Graham (1964) stated that organo-mercury vapour was given off by tubers immediately after treatment. Therefore it would be essential for commercial processes of hot air drying to be closely scrutinized for possible dangers to human health.

There were no marked or consistent differences in total crop yields between the various seed tuber treatments, with the exception of the yield decline often found with washed only treatments (Graham, 1964). This effect may have been due to the high incidence of blackleg in crops from washed seed, and there was evidence of a negative correlation between the incidence of blackleg and yield. However, washed and disinfected seed rarely gave a reduction in yield compared with riddled only seed, despite giving rise to comparatively high levels of blackleg. This may be attributed, in part, to the failure of field trials to show small differences, and to the compensating growth of healthy plants. Hirst (1967) has indicated that field experiments with potatoes will seldom detect yield differences smaller than about 5 per cent. They would not be expected to disinguish significantly between yields from full crops and from crops with fewer than 11 and

7 per cent of gaps at emergence and flowering respectively. He also recognised the ability of healthy plants to profit from lack of competition when they are adjacent to gaps and "sickly neighbours" and so to compensate for the potential losses. He further noted that the ability of diseased plants to compensate would be less. The general absence of yield reductions with disinfection after washing, despite a high number of blackleg infected plants, may, therefore, be due to the more vigorous condition of the remaining plants.

Disinfected seed tended to emerge earlier than untreated seed and the setts did not break down as rapidly in the soil. Moreover, disinfection probably checked the subsequent development of *Oospora pustulans* which can give rise to root and stolon damage (Salt, 1957). Some evidence that disinfection gave more vigorous crop growth is found in the results for disinfection without washing. This treatment gave a low incidence of blackleg and produced yields which compared favourably with graded only treatments, although the differences were not significant.

Although disinfection did not markedly influence total yield, the ratio of the numbers and weight of ware, seed and chats was affected by this treatment. Particularly in 1966-67, and to some extent in the other two years, there tended to be a greater weight and number of seed and chats and less ware. It seems likely that the increased proportion of seed and chats from disinfection treatments ~~and the resulting~~ are associated with increase in stem number and in the number of tubers per plant. Where blackleg was severe the yield reduction was mainly associated with the ware fraction. This may have been due to two factors. Firstly, in many cases, plants developed disease symptoms before tubers reached ware size. Secondly, a higher proportion of ware tubers showed obvious blackleg rotting at plant maturity and may therefore have been excluded at lifting.

Since the commencement of this work the Advisory Committee on Pesticides and other Toxic Chemicals has recommended that disinfection, using organo-mercurials, be only carried out in premises covered by the Factories Act. The individual farmer is therefore advised against using EEMC on the farm because of its high mammalian toxicity (Graham, 1964). Seed tuber disinfection with organo-mercurial compounds presents a health hazard not only in applying treatment but also in the disposal of the waste solution. Graham (1964) investigated some of the non-toxic organo-tin compounds but was unable to find a chemical giving a similar degree of control to that of the organo-mercurial compounds without phytotoxicity. In listing a range of fungicides for skin spot control, Lennard (1967) found that none of the compounds used was as effective as the organo-mercury compounds. There is an obvious need for the formulation of a satisfactory non-toxic alternative to mercury, particularly if disinfection by the individual farmer is to be carried out.

## 7.2. Conclusions

1. Experiments were carried out over three years to examine the commercial process of washing and disinfection in Scotland. An assessment was made of the effect of drying tubers after disinfection in ventilated stacks of 10 cwt. boxes compared with drying in seed chitting trays. In general, it was found that drying in 10 cwt. boxes was satisfactory and there was no marked effect on the control of latent storage diseases, crop growth or yield. However, there was a tendency for condensation moisture to form in the top boxes of the stacks and this was thought to have been associated with a slight increase in soft rot in 1965-66 and blackleg in 1966-67 and 1967-68. Covering boxes with a layer of straw apparently prevented the formation of condensation on the tubers but its use was not commercially acceptable.

2. Another factor studied in the series of experiments was the effect of washing and disinfection on the incidence of blackleg and possibilities for its control. The results showed that the incidence of the disease was higher in plants from tubers that had been washed compared, to those that were untreated. However, it was shown that riddling on a bare wire riddle or on a moist riddle could also give high levels of blackleg but disinfection without washing significantly reduced the disease. It was concluded that the washing process in some way assisted the entry of the bacteria into the tuber

beyond the reach of the disinfectant and therefore that attempts to reduce blackleg in crops from washed and disinfected seed by decreasing tuber damage before disinfection were probably of little benefit. The removal of pintle rollers from the washing machine reduced the severity of lenticel pitting and eliminated hard rot symptoms, but did not significantly affect the level of blackleg produced in crops.

3. Some evidence was given to account for the generally higher incidence of blackleg in the trials in 1968 than in 1967. Although experiments were planted in different fields in the same area in the two years, it is suggested that the difference in blackleg incidence was the result of the rainfall pattern.

4. Trials during 1966-67 and 1967-68, using the hot air drying apparatus, indicated that tubers can be satisfactorily dried with temperatures up to 212$^{o}$F when exposed to the hot air for up to 3½ mins. There were no adverse side effects in relation to growth, yield or loss of control of storage disease and there was no evidence that drying with hot air caused a loss of EEMC from the surface of tubers.

5. It is considered important that tubers are removed from the hot air stream when they are dry but before they show a rise in temperature. In the trials the temperature of the tubers had not increased when they were taken from the apparatus

just before complete dryness. It is probable that evaporation was responsible for this effect.

6. Disinfection of unwashed tubers in a prototype disinfection tank for $\frac{1}{2}$ - $\frac{3}{4}$ min. with an EEMC concentration of 150 ppm showed that this method of disinfection can produce a marked reduction in storage diseases despite a delay between lifting and treatment. However, there was evidence that the presence of soil at the tuber surface adversely affected the efficiency of disinfection.

Blackleg was controlled in two of the field trials and the increase observed with one stock was attributed to delay in treatment after lifting.

7. Disinfection usually reduced the incidence of the storage diseases - skin spot, dry rot and gangrene - to a satisfactory level. Where this was not the case, two factors were considered responsible: a) delay between lifting and treatment of more than 3 days and b) on one occasion it was possible that the level of EEMC in the commercial disinfection tanks was too low for effective control.

8. In general disinfection produced a greater number and length of sprouts than undisinfected tubers which was often reflected in earlier emergence, greater number of stems and an increase the number of tubers in the field. These

characteristics were more pronounced with washed and disinfected seed tubers than with unwashed, disinfected tubers.

9. The total yield given by washed and disinfected tubers was not significantly lower than that from untreated tubers despite the differences in the incidence of blackleg. Unwashed, disinfected tubers gave yields which compared favourably with untreated tubers. It is possible that earlier emergence, less rapid breakdown of the sett or check in the damage caused by Oospora pustulans to roots and stolons may result in more vigorous plants from disinfected seed tubers.

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Appendix 1

The mean number of sprouts over $\frac{1}{16}$ in. and the mean number of sprouts of various lengths, per tuber - 1966.

| Treatment | Mean No. of sprouts over 1/16" per tuber | Mean No. of sprouts of different lengths per tuber | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. | $\frac{1}{2}$ in. | $\frac{3}{4}$ in. | 1 in. and over |
| **Majestic** | | | | 10 January | | | |
| H Rid | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDT | 1.3 | 0.8 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| WMDB(a) | 0.8 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| WMDB(b) | 1.3 | 0.7 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 |
| WMDB(c) | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | 10 February | | | |
| H Rid | 2.1 | 1.7 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDT | 5.9 | 4.0 | 1.3 | 0.5 | 0.1 | 0.0 | 0.0 |
| WMDB(a) | 3.4 | 2.4 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 |
| WMDB(b) | 3.2 | 2.2 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 |
| WMDB(c) | 4.2 | 2.7 | 0.9 | 0.5 | 0.1 | 0.0 | 0.0 |
| **King Edward** | | | | | | | |
| | | | | 10 January | | | |
| H Rid | 4.7 | 2.6 | 1.8 | 0.3 | 0.0 | 0.0 | 0.0 |
| WMDT | 4.9 | 2.5 | 1.6 | 0.5 | 0.2 | 0.0 | 0.0 |
| WMDB(a) | 6.7 | 2.9 | 2.9 | 0.6 | 0.2 | 0.1 | 0.0 |
| WMDB(b) | 5.6 | 2.6 | 2.2 | 0.5 | 0.2 | 0.1 | 0.0 |
| WMDB(c) | 5.4 | 3.5 | 1.4 | 0.4 | 0.1 | 0.0 | 0.0 |
| | | | | 10 February | | | |
| H Rid | 5.9 | 3.6 | 0.9 | 0.6 | 0.8 | 0.0 | 0.0 |
| WMDT | 6.1 | 3.5 | 1.4 | 0.7 | 0.4 | 0.1 | 0.1 |
| WMDB(a) | 7.5 | 4.5 | 1.3 | 0.9 | 0.5 | 0.2 | 0.1 |
| WMDB(b) | 6.9 | 4.1 | 1.3 | 0.8 | 0.4 | 0.2 | 0.1 |
| WMDB(c) | 5.7 | 2.0 | 1.7 | 1.2 | 0.6 | 0.1 | 0.1 |

## Appendix 2

Percentage number of emerged plants at different dates in relation to seed treatment - 1966.

### Statistical analysis

Transformed data (Angles)

| Treatment | May 17 | 20 | 23 | 26 | 29 | June 1 | 4 | 7 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| **Majestic** | | | | | | | | | |
| H Rid | 0.11 | 0.13 | 0.24 | 0.39 | 0.69 | 1.16 | 1.33 | 1.50 | 1.50 |
| WMDT | 0.30 | 0.44 | 0.57 | 0.65 | 0.94 | 1.21 | 1.33 | 1.44 | 1.50 |
| WMDB(a) | 0.42 | 0.54 | 0.68 | 0.84 | 1.16 | 1.28 | 1.37 | 1.42 | 1.50 |
| WMDB(b) | 0.22 | 0.35 | 0.57 | 0.81 | 1.02 | 1.29 | 1.46 | 1.46 | 1.54 |
| WMDB(c) | 0.33 | 0.40 | 0.63 | 0.80 | 1.02 | 1.25 | 1.42 | 1.46 | 1.50 |
| S.E. ± | 0.07 | 0.07 | 0.06 | 0.06 | 0.05 | 0.08 | 0.07 | 0.05 | 0.04 |
| **King Edward** | | | | | | | | | |
| H Rid | 0.36 | 0.49 | 0.64 | 0.86 | 1.15 | 1.48 | 1.50 | 1.50 | - |
| WMDT | 0.58 | 0.71 | 0.90 | 1.03 | 1.36 | 1.50 | 1.50 | 1.50 | - |
| WMDB(a) | 0.37 | 0.52 | 0.65 | 0.88 | 1.12 | 1.39 | 1.47 | 1.47 | - |
| WMDB(b) | 0.41 | 0.62 | 0.81 | 0.98 | 1.15 | 1.32 | 1.42 | 1.46 | - |
| WMDB(c) | 0.43 | 0.48 | 0.70 | 0.88 | 1.13 | 1.35 | 1.50 | 1.54 | - |
| S.E. ± | 0.08 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.05 | 0.05 | - |

## Appendix 3

The effect of seed treatment on the average plant height - 1966.

| Treatment | Height (in.) Majestic 8 August | King Edward 8 August |
|---|---|---|
| H Rid | 25.6 | 31.0 |
| WMDT | 28.3 | 32.5 |
| WMDB (a) | 25.6 | 30.3 |
| WMDB (b) | 26.5 | 30.9 |
| WMDB (c) | 27.1 | 30.9 |
| S.E. ± | 0.96 | 0.92 |

## Appendix 4

The incidence of blackleg (per cent) in relation to seed treatment - 1966.

### Statistical analysis

Transformed data (Angles)

| Treatment | Majestic | King Edward |
|---|---|---|
| H Rid | 0.09 | 0.0 |
| WMDT | 0.47 | 0.17 |
| WMDB (a) | 0.39 | 0.11 |
| WMDB (b) | 0.40 | 0.19 |
| WMDB (c) | 0.32 | 0.13 |
| S.E. ± | 0.09 | 0.05 |

## Appendix 5

Yield (tons per acre) and number of tubers (thousands per acre) in relation to treatment - 1966.

| Treatment | Number of tubers (thousands per acre) Ware | Seed | Chats | Total |
|---|---|---|---|---|
| **Majestic** | | | | |
| H Rid | 27.4 | 185.0 | 70.2 | 282.6 |
| WMDT | 23.0 | 166.7 | 72.7 | 262.4 |
| WMDB (a) | 22.1 | 199.4 | 88.2 | 309.7 |
| WMDB (b) | 19.1 | 190.8 | 84.3 | 294.2 |
| WMDB (c) | 26.0 | 193.3 | 104.5 | 323.8 |
| S.E. ± | 3.71 | 12.29 | 8.15 | 16.54 |
| **King Edward** | | | | |
| H Rid | 10.2 | 269.3 | 138.3 | 417.7 |
| WMDT | 11.9 | 246.4 | 128.0 | 386.3 |
| WMDB (a) | 10.0 | 238.9 | 124.7 | 373.6 |
| WMDB (b) | 9.4 | 248.6 | 145.2 | 403.2 |
| WMDB (c) | 8.3 | 245.8 | 152.9 | 407.0 |
| S.E. ± | 2.80 | 16.54 | 14.10 | 21.87 |

Appendix 6

The mean number of sprouting eyes and the mean number of sprouts of various lengths per tuber - 1967.

| Treatment | Mean No. of sprouting eyes per tuber | Mean No. of sprouts of different lengths per tuber | | | | |
|---|---|---|---|---|---|---|
| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. | $\frac{1}{2}$ in. |
| Majestic | | 10 January | | | | |
| M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H Rid | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WM | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDT | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (a) | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (b) | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (c) | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (sa) | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (sb) | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| WMDB (sc) | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | 10 February | | | | |
| M | 3.6 | 3.5 | 0.1 | 0.0 | 0.0 | 0.0 |
| H Rid | 3.2 | 3.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| WM | 6.6 | 6.0 | 0.5 | 0.1 | 0.0 | 0.0 |
| WMDT | 9.7 | 7.9 | 1.6 | 0.2 | 0.0 | 0.0 |
| WMDB (a) | 9.2 | 8.3 | 0.7 | 0.2 | 0.0 | 0.0 |
| WMDB (b) | 9.5 | 8.2 | 1.2 | 0.1 | 0.0 | 0.0 |
| WMDB (c) | 9.4 | 8.3 | 1.0 | 0.1 | 0.0 | 0.0 |
| WMDB (sa) | 9.0 | 8.0 | 0.9 | 0.1 | 0.0 | 0.0 |
| WMDB (sb) | 9.5 | 8.2 | 1.3 | 0.0 | 0.0 | 0.0 |
| WMDB (sc) | 8.7 | 7.6 | 0.9 | 0.1 | 0.0 | 0.0 |

Appendix 6 (contd.)

| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. | $\frac{1}{2}$ in. |
|---|---|---|---|---|---|---|
| | | | 10 March | | | |
| M | 8.0 | 4.4 | 2.4 | 1.2 | 0.0 | 0.0 |
| H Rid | 9.4 | 5.5 | 3.0 | 0.9 | 0.0 | 0.0 |
| WM | 9.7 | 5.8 | 3.1 | 1.7 | 0.2 | 0.0 |
| WMDT | 10.8 | 4.7 | 3.3 | 2.6 | 0.2 | 0.0 |
| WMDB (a) | 11.4 | 5.6 | 3.3 | 2.4 | 0.1 | 0.0 |
| WMDB (b) | 11.1 | 5.2 | 3.2 | 2.5 | 0.1 | 0.0 |
| WMDB (c) | 10.8 | 5.4 | 3.1 | 2.2 | 0.2 | 0.0 |
| WMDB (sa) | 11.1 | 5.8 | 2.9 | 2.2 | 0.2 | 0.0 |
| WMDB (sb) | 10.3 | 2.7 | 5.1 | 2.1 | 0.4 | 0.0 |
| WMDB (sc) | 11.5 | 6.0 | 3.2 | 2.2 | 0.2 | 0.0 |
| King Edward | | | 10 January | | | |
| H Rid | 2.7 | 1.4 | 0.3 | 1.0 | 0.0 | 0.0 |
| WM | 3.5 | 3.2 | 0.2 | 0.1 | 0.0 | 0.0 |
| WMDT | 5.7 | 5.2 | 0.4 | 0.1 | 0.0 | 0.0 |
| WMDB (a) | 5.8 | 5.1 | 0.6 | 0.1 | 0.0 | 0.0 |
| WMDB (b) | 4.9 | 4.6 | 0.3 | 0.1 | 0.0 | 0.0 |
| WMDB (c) | 5.2 | 4.8 | 0.3 | 0.1 | 0.0 | 0.0 |
| WMDB (sa) | 5.7 | 4.8 | 0.7 | 0.2 | 0.0 | 0.0 |
| WMDB (sb) | 4.8 | 4.6 | 0.2 | 0.0 | 0.0 | 0.0 |
| WMDB (sc) | 6.5 | 5.4 | 0.8 | 0.3 | 0.0 | 0.0 |
| | | | 10 February | | | |
| H Rid | 6.8 | 3.4 | 1.7 | 1.4 | 0.3 | 0.0 |
| WM | 7.6 | 3.5 | 2.1 | 1.7 | 0.3 | 0.0 |
| WMDT | 8.8 | 3.9 | 2.9 | 1.8 | 0.1 | 0.0 |
| WMDB (a) | 8.9 | 4.3 | 2.8 | 1.7 | 0.1 | 0.0 |
| WMDB (b) | 8.4 | 3.9 | 3.0 | 1.4 | 0.1 | 0.0 |
| WMDB (c) | 9.0 | 4.3 | 2.8 | 1.8 | 0.1 | 0.0 |
| WMDB (sa) | 8.8 | 3.7 | 3.0 | 2.0 | 0.2 | 0.0 |
| WMDB (sb) | 9.1 | 3.4 | 3.6 | 2.0 | 0.1 | 0.0 |
| WMDB (sc) | 9.5 | 4.0 | 3.0 | 2.2 | 0.4 | 0.0 |

Appendix 6 (contd.)

| | | Up to 1/16 in. | 1/16 in. | 1/8 in. | 1/4 in. | 1/2 in. |
|---|---|---|---|---|---|---|
| | | | 10 March | | | |
| H Rid | 7.6 | 2.1 | 2.0 | 2.2 | 1.4 | 0.0 |
| WM | 7.6 | 2.0 | 2.2 | 2.1 | 1.2 | 0.1 |
| WMDT | 9.0 | 2.1 | 2.6 | 3.2 | 1.0 | 0.0 |
| WMDB (a) | 8.7 | 1.7 | 2.5 | 3.2 | 1.3 | 0.1 |
| WMDB (b) | 8.4 | 1.8 | 2.5 | 3.0 | 1.1 | 0.1 |
| WMDB (c) | 8.6 | 1.8 | 2.2 | 3.0 | 1.5 | 0.1 |
| WMDB (sa) | 8.9 | 1.7 | 2.3 | 3.1 | 1.7 | 0.0 |
| WMDB (sb) | 8.6 | 2.0 | 2.4 | 3.2 | 1.0 | 0.1 |
| WMDB (sc) | 8.8 | 2.1 | 2.5 | 3.0 | 1.1 | 0.1 |

## Appendix 7

The percentage number of emerged plants in relation to seed treatment - 1967.

### Statistical Analysis

Transformed data (Angles)

| Treatment | Date of Count May 17 | 24 | 29 | June 2 | 5 | 8 | 11 | 19 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| **Majestic** | | | | | | | | | |
| M | 0.07 | 0.28 | 0.66 | 1.12 | 1.31 | 1.34 | 1.40 | 1.46 | 1.48 |
| H | 0.22 | 0.45 | 0.81 | 1.20 | 1.37 | 1.40 | 1.47 | 1.56 | 1.56 |
| WM | 0.21 | 0.46 | 0.87 | 1.16 | 1.27 | 1.30 | 1.34 | 1.42 | 1.49 |
| WMDT | 0.29 | 0.56 | 1.00 | 1.34 | 1.48 | 1.52 | 1.55 | 1.56 | 1.56 |
| WMDB(a) | 0.43 | 0.73 | 1.13 | 1.45 | 1.55 | 1.55 | 1.56 | 1.56 | 1.56 |
| WMDB(b) | 0.36 | 0.67 | 1.09 | 1.41 | 1.50 | 1.53 | 1.53 | 1.55 | 1.55 |
| WMDB(c) | 0.39 | 0.67 | 1.01 | 1.43 | 1.54 | 1.54 | 1.54 | 1.54 | 1.54 |
| S.E. ± | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| **King Edward** | | | | | | | | | |
| H | 0.25 | 0.66 | 1.13 | 1.38 | 1.46 | 1.47 | 1.47 | 1.52 | - |
| WM | 0.20 | 0.54 | 1.07 | 1.32 | 1.37 | 1.39 | 1.45 | 1.54 | - |
| WMDT | 0.26 | 0.81 | 1.30 | 1.52 | 1.54 | 1.54 | 1.54 | 1.54 | - |
| WMDB(a) | 0.35 | 0.85 | 1.25 | 1.46 | 1.53 | 1.54 | 1.53 | 1.54 | - |
| WMDB(b) | 0.31 | 0.87 | 1.25 | 1.51 | 1.52 | 1.56 | 1.56 | 1.56 | - |
| WMDB(c) | 0.44 | 0.83 | 1.25 | 1.45 | 1.52 | 1.54 | 1.54 | 1.56 | - |
| S.E. ± | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | - |

# Appendix 8

The effect of seed treatment on the average plant height - 1967.

| Treatment | Height (in.) Majestic 14 June | Majestic 26 July | King Edward 14 June | King Edward 25 July |
|---|---|---|---|---|
| M | 3.8 | 22.5 | - | - |
| H Rid | 4.2 | 23.0 | 5.7 | 25.0 |
| WM | 4.1 | 23.4 | 5.4 | 24.0 |
| WMDT | 4.5 | 23.2 | 7.1 | 24.6 |
| WMDB (a) | 5.1 | 23.2 | 6.2 | 24.5 |
| WMDB (b) | 4.9 | 23.4 | 6.2 | 24.8 |
| WMDB (c) | 5.0 | 22.8 | 6.3 | 24.9 |
| S.E. ± | 0.14 | 0.28 | 0.27 | 0.37 |

## Appendix 9

The effect of seed treatment on the mother tuber - 1967.

### Statistical analysis

Transformed data (Angles)

| Treatment | Majestic | | King Edward | |
|---|---|---|---|---|
| | Healthy | Soft rotted | Healthy | Soft rotted |
| M | 0.62 | 0.56 | - | - |
| H | 0.88 | 0.36 | 0.74 | 0.33 |
| WM | 0.84 | 0.37 | 0.92 | 0.38 |
| WMDT | 0.99 | 0.18 | 1.01 | 0.06 |
| WMDB (a) | 0.94 | 0.23 | 0.96 | 0.21 |
| WMDB (b) | 1.12 | 0.05 | 1.08 | 0.17 |
| WMDB (c) | 0.97 | 0.23 | 1.13 | 0.09 |
| S.E. ± | 0.05 | 0.07 | 0.08 | 0.09 |

Appendix 10

The effect of the different seed treatments on the incidence of blackleg (per cent) in the field - 1967.

Statistical analysis

Transformed data (Angles)

| Treatment | Date of Count 14 June | 25 June | 24 July | 4 September |
|---|---|---|---|---|
| Majestic | | | | |
| M | 0.17 | 0.27 | 0.28 | 0.44 |
| H Rid | 0.09 | 0.12 | 0.13 | 0.19 |
| WM | 0.22 | 0.31 | 0.32 | 0.47 |
| WMDT | 0.15 | 0.19 | 0.20 | 0.35 |
| WMDB (a) | 0.21 | 0.26 | 0.27 | 0.40 |
| WMDB (b) | 0.20 | 0.24 | 0.25 | 0.46 |
| WMDB (c) | 0.19 | 0.29 | 0.29 | 0.43 |
| S.E. ± | 0.03 | 0.03 | 0.03 | 0.03 |
| King Edward | | | | |
| H Rid | 0.00 | 0.00 | - | 0.15 |
| WM | 0.13 | 0.21 | - | 0.47 |
| WMDT | 0.00 | 0.09 | - | 0.38 |
| WMDB (a) | 0.06 | 0.06 | - | 0.45 |
| WMDB (b) | 0.04 | 0.03 | - | 0.39 |
| WMDB (c) | 0.04 | 0.06 | - | 0.44 |
| S.E. ± | 0.03 | 0.02 | - | 0.02 |

Appendix 11

The yield (tons per acre) and number of tubers (thousands per acre) in relation to seed treatment - 1967.

| Treatment | Ware | Number of tubers (thousands per acre) Seed | Chats | Total |
|---|---|---|---|---|
| Majestic | | | | |
| M | 46.5 | 63.9 | 17.6 | 127.9 |
| H | 65.1 | 58.5 | 15.2 | 138.8 |
| WM | 47.8 | 65.3 | 16.5 | 129.5 |
| WMDT | 55.2 | 105.7 | 30.2 | 191.1 |
| WMDB (a) | 54.2 | 97.1 | 25.0 | 176.3 |
| WMDB (b) | 56.8 | 104.8 | 31.2 | 192.8 |
| WMDB (c) | 55.5 | 99.0 | 26.0 | 180.4 |
| S.E. ± | 2.40 | 3.11 | 1.82 | 6.17 |
| King Edward | | | | |
| H Rid | 72.1 | 95.0 | 18.6 | 185.7 |
| WM | 54.9 | 101.8 | 29.6 | 186.3 |
| WMDT | 59.3 | 124.2 | 30.3 | 214.8 |
| WMDB (a) | 53.1 | 133.4 | 36.9 | 223.4 |
| WMDB (b) | 61.1 | 122.3 | 25.4 | 208.8 |
| WMDB (c) | 56.7 | 130.0 | 31.7 | 208.4 |
| S.E. ± | 2.74 | 6.26 | 2.98 | 7.02 |

Appendix 12

The mean number of sprouting eyes and the mean number of sprouts of various lengths per tuber - 1968.

| Treatment | Mean No. of sprouting eyes per tuber | Mean No. of sprouts of different lengths per tuber | | | |
|---|---|---|---|---|---|
| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. |
| **Majestic** | | | 1 March | | |
| M | 2.0 | 2.0 | 0.0 | 0.0 | 0.0 |
| Recip Rid | 2.6 | 2.6 | 0.0 | 0.0 | 0.0 |
| H Rid | 4.3 | 4.3 | 0.0 | 0.0 | 0.0 |
| H Pick | 5.7 | 5.7 | 0.0 | 0.0 | 0.0 |
| WM | 6.7 | 6.7 | 0.0 | 0.0 | 0.0 |
| WH Pick | 7.2 | 7.2 | 0.0 | 0.0 | 0.0 |
| WMDT | 9.1 | 9.0 | 0.1 | 0.0 | 0.0 |
| WMDB | 8.5 | 8.4 | 0.1 | 0.0 | 0.0 |
| DM | 3.5 | 3.5 | 0.0 | 0.0 | 0.0 |
| DH Pick | 7.2 | 7.2 | 0.0 | 0.0 | 0.0 |
| | | | 1 April | | |
| M | 10.0 | 1.2 | 2.4 | 6.1 | 0.3 |
| Recip Rid | 10.6 | 1.6 | 2.3 | 6.6 | 0.2 |
| H Rid | 10.8 | 0.8 | 2.4 | 7.3 | 0.3 |
| H Pick | 10.9 | 1.3 | 2.3 | 6.8 | 0.5 |
| WM | 11.2 | 1.4 | 1.9 | 7.4 | 0.4 |
| WH Pick | 11.5 | 1.6 | 2.2 | 6.9 | 0.7 |
| WMDT | 11.9 | 1.2 | 2.0 | 8.0 | 0.8 |
| WMDB | 12.4 | 1.2 | 1.8 | 8.7 | 0.8 |
| DM | 12.1 | 1.3 | 2.7 | 7.8 | 0.3 |
| DH Pick | 10.8 | 1.3 | 2.1 | 7.0 | 0.4 |

| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. |
|---|---|---|---|---|---|
| King Edward | | | 15 February | | |
| M | 4.0 | 3.7 | 0.2 | 0.0 | 0.0 |
| Recip Rid | 5.1 | 4.7 | 0.3 | 0.1 | 0.0 |
| H Rid | 4.6 | 4.4 | 0.2 | 0.0 | 0.0 |
| H Pick | 5.0 | 4.7 | 0.3 | 0.0 | 0.0 |
| WM | 5.5 | 5.3 | 0.2 | 0.0 | 0.0 |
| WH Pick | 6.0 | 5.7 | 0.3 | 0.0 | 0.0 |
| WMDT | 7.3 | 7.1 | 0.2 | 0.0 | 0.0 |
| WMDB | 7.0 | 6.8 | 0.3 | 0.0 | 0.0 |
| DM | 7.9 | 5.7 | 0.2 | 0.0 | 0.0 |
| DH Pick | 7.0 | 6.7 | 0.3 | 0.0 | 0.0 |
| | | | 1 April | | |
| M | 6.6 | 2.0 | 2.4 | 2.2 | 0.1 |
| Recip Rid | 7.3 | 1.8 | 2.6 | 3.0 | 0.0 |
| H Rid | 7.3 | 1.9 | 2.2 | 3.1 | 0.1 |
| H Pick | 8.0 | 1.9 | 2.6 | 3.4 | 0.1 |
| WM | 8.1 | 2.2 | 2.5 | 3.3 | 0.1 |
| WH Pick | 7.5 | 2.0 | 2.0 | 3.4 | 0.1 |
| WMDT | 10.0 | 3.2 | 3.4 | 3.5 | 0.1 |
| WMDB | 9.6 | 2.7 | 3.4 | 3.5 | 0.1 |
| DM | 9.3 | 3.5 | 3.3 | 2.5 | 0.0 |
| DH Pick | 8.3 | 2.6 | 3.2 | 2.6 | 0.1 |

Appendix 13

The percentage number of emerged plants in relation to seed treatment - 1968.

Statistical Analysis

Transformed data (Angles)

| Treatment | Date of Count | | | | | |
|---|---|---|---|---|---|---|
| | May 26 | June 3 | June 10 | June 17 | June 24 | July 1 |
| Majestic | | | | | | |
| M | 0.00 | 0.38 | 1.05 | 1.44 | 1.45 | 1.47 |
| Recip Rid | 0.07 | 0.47 | 1.13 | 1.44 | 1.52 | 1.52 |
| H Rid | 0.07 | 0.45 | 1.11 | 1.56 | 1.56 | 1.56 |
| H Pick | 0.00 | 0.51 | 1.08 | 1.50 | 1.56 | 1.56 |
| WM | 0.12 | 0.50 | 1.19 | 1.41 | 1.52 | 1.52 |
| WH Pick | 0.21 | 0.56 | 1.17 | 1.44 | 1.45 | 1.45 |
| WMDT | 0.19 | 0.64 | 1.27 | 1.31 | 1.33 | 1.38 |
| WMDB | 0.09 | 0.59 | 1.23 | 1.50 | 1.52 | 1.52 |
| DM | 0.22 | 0.55 | 1.23 | 1.45 | 1.52 | 1.52 |
| DH Pick | 0.08 | 0.51 | 1.47 | 1.52 | 1.56 | 1.56 |
| King Edward | | | | | | |
| M | 0.07 | 0.27 | 1.23 | 1.33 | 1.33 | 1.38 |
| Recip Rid | 0.00 | 0.14 | 1.04 | 1.38 | 1.48 | 1.50 |
| H Rid | 0.00 | 0.28 | 1.20 | 1.37 | 1.47 | 1.47 |
| H Pick | 0.05 | 0.33 | 1.26 | 1.52 | 1.52 | 1.56 |
| WM | 0.05 | 0.16 | 0.96 | 1.30 | 1.37 | 1.41 |
| WH Pick | 0.00 | 0.33 | 1.12 | 1.38 | 1.44 | 1.44 |
| WMDT | 0.00 | 0.16 | 1.16 | 1.56 | 1.56 | 1.56 |
| WMDB | 0.00 | 0.37 | 1.35 | 1.56 | 1.56 | 1.56 |
| DM | 0.00 | 0.19 | 1.29 | 1.36 | 1.45 | 1.45 |
| DH Pick | 0.00 | 0.37 | 1.43 | 1.47 | 1.52 | 1.56 |
| SE diff. 1 | 0.09 | 0.11 | 0.08 | 0.07 | 0.07 | 0.07 |
| SE diff. 2)<br>SE diff. 3) | 0.04 | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 |

SE diff. 1. For comparison between treatments within the same varieties.

SE diff. 2. For comparison between varieties within the same treatments.

SE diff. 3. For comparison between treatments within different varieties.

## Appendix 14

The effect of seed treatment on the average plant height - 1968

| Treatment | Height (in.) Majestic 24 July | King Edward 24 July |
|---|---|---|
| M | 4.7 | 6.0 |
| Recip Rid | 4.4 | 7.0 |
| H Rid | 4.2 | 6.8 |
| H Pick | 4.6 | 6.3 |
| WM | 4.4 | 7.1 |
| WH Pick | 4.6 | 7.1 |
| WMDT | 5.0 | 7.0 |
| WMDB | 5.1 | 7.8 |
| DMT | 4.8 | 6.8 |
| DH Pick T | 5.6 | 8.1 |
| S.E. diff. 1 | 0.56 | |
| S.E. diff. 2) 3) | 0.26 | |

Appendix 15

The effect of different seed treatments on the incidence of blackleg (per cent) in the field - 1968.

Statistical Analysis

Transformed data (Angles)

| Treatment | June 24 | July 1 | July 23 | August 1 | September 4 |
|---|---|---|---|---|---|
| | | | Date of Count | | |
| **Majestic** | | | | | |
| M | 0.12 | 0.28 | 0.32 | 0.44 | 0.58 |
| Recip Rid | 0.16 | 0.18 | 0.26 | 0.44 | 0.59 |
| H Rid | 0.14 | 0.23 | 0.25 | 0.38 | 0.54 |
| H Pick | 0.11 | 0.15 | 0.17 | 0.26 | 0.43 |
| WM | 0.21 | 0.31 | 0.35 | 0.56 | 0.81 |
| WH Pick | 0.17 | 0.26 | 0.33 | 0.52 | 0.74 |
| WMDT | 0.10 | 0.15 | 0.23 | 0.40 | 0.70 |
| WMDB | 0.05 | 0.19 | 0.32 | 0.50 | 0.68 |
| DM | 0.04 | 0.11 | 0.12 | 0.18 | 0.42 |
| DH Pick | 0.04 | 0.12 | 0.12 | 0.17 | 0.36 |
| **King Edward** | | | | | |
| M | 0.11 | 0.10 | 0.16 | 0.28 | 0.47 |
| Recip Rid | 0.04 | 0.10 | 0.29 | 0.46 | 0.59 |
| H Rid | 0.05 | 0.06 | 0.10 | 0.29 | 0.45 |
| H Pick | 0.00 | 0.11 | 0.16 | 0.35 | 0.52 |
| WM | 0.00 | 0.12 | 0.18 | 0.41 | 0.62 |
| WH Pick | 0.07 | 0.14 | 0.20 | 0.43 | 0.64 |
| WMDT | 0.00 | 0.11 | 0.16 | 0.34 | 0.61 |
| WMDB | 0.07 | 0.12 | 0.14 | 0.37 | 0.67 |
| DM | 0.00 | 0.00 | 0.00 | 0.07 | 0.40 |
| DH Pick | 0.00 | 0.00 | 0.00 | 0.07 | 0.37 |
| SE diff. 1 | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 |
| SE diff. 2)<br>SE diff. 3) | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 |

Appendix 16

The yield (tons per acre) and number of tubers (thousands per acre) in relation to seed treatment - 1968.

| Treatment | Ware | Seed | Chats | Total |
|---|---|---|---|---|
| | | Majestic | | |
| M | 17.0 | 108.2 | 17.3 | 142.6 |
| Recip Rid | 13.9 | 117.1 | 24.6 | 155.7 |
| H Rid | 18.3 | 106.3 | 23.2 | 147.8 |
| H Pick | 17.2 | 102.6 | 16.8 | 136.5 |
| WM | 6.2 | 107.8 | 28.4 | 142.4 |
| WH Pick | 11.5 | 102.9 | 22.6 | 137.0 |
| WMDT | 9.7 | 107.3 | 29.2 | 146.2 |
| WMDB | 9.4 | 114.4 | 24.1 | 148.0 |
| DM | 11.0 | 133.3 | 21.5 | 165.8 |
| DH Pick | 13.3 | 145.9 | 19.6 | 178.8 |
| | | King Edward | | |
| M | 8.6 | 160.7 | 27.1 | 196.5 |
| Recip Rid | 4.0 | 119.5 | 30.6 | 154.0 |
| H Rid | 7.6 | 179.6 | 39.1 | 226.3 |
| H Pick | 10.2 | 171.7 | 29.4 | 211.3 |
| WM | 4.0 | 137.5 | 29.3 | 170.8 |
| WH Pick | 6.3 | 157.8 | 32.4 | 196.5 |
| WMDT | 3.4 | 146.0 | 42.3 | 191.7 |
| WMDB | 1.8 | 152.9 | 31.5 | 186.2 |
| DM | 2.3 | 181.6 | 33.8 | 217.8 |
| DH Pick | 3.2 | 158.0 | 34.4 | 195.7 |
| SE diff. 1 | 2.81 | 17.17 | 4.87 | 19.33 |
| SE diff. 2)<br>SE diff. 3) | 1.14 | 5.87 | 2.17 | 7.19 |

Appendix 17

The mean number of sprouting eyes and the mean number of sprouts of various lengths per tuber - 1967.

| Treatment | Mean No. of sprouting eyes per tuber | Mean number of sprouts of different lengths per tuber | | | | |
|---|---|---|---|---|---|---|
| | | $0 - \frac{1}{16}$" | $\frac{1}{16}$" | $\frac{1}{8}$" | $\frac{1}{4}$" | $\frac{1}{2}$" |
| Majestic | | | 10 January | | | |
| M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWT_0$ | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| $MWH_3$ | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_1$ | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_2$ | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_3$ | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | 10 February | | | |
| M | 4.3 | 3.8 | 0.4 | 0.1 | 0.0 | 0.0 |
| $MWT_0$ | 10.4 | 7.9 | 2.1 | 0.5 | 0.0 | 0.0 |
| $MWH_3$ | 6.1 | 4.0 | 2.0 | 0.2 | 0.0 | 0.0 |
| $MWDH_1$ | 8.9 | 6.6 | 1.9 | 0.4 | 0.0 | 0.0 |
| $MWDH_2$ | 9.3 | 6.1 | 1.8 | 1.4 | 0.0 | 0.0 |
| $MWDH_3$ | 9.1 | 7.2 | 1.6 | 0.3 | 0.0 | 0.0 |
| | | | 10 March | | | |
| M | 9.0 | 5.2 | 2.3 | 1.2 | 0.3 | 0.0 |
| $MWT_0$ | 10.3 | 4.9 | 2.5 | 2.2 | 0.6 | 0.1 |
| $MWH_3$ | 9.9 | 6.0 | 1.9 | 1.7 | 0.4 | 0.0 |
| $MWDH_1$ | 10.6 | 5.2 | 2.4 | 1.9 | 1.0 | 0.1 |
| $MWDH_2$ | 10.2 | 4.9 | 2.1 | 2.0 | 1.1 | 0.1 |
| $MWDH_3$ | 10.6 | 5.2 | 2.4 | 1.9 | 1.1 | 0.0 |

Appendix 17 (contd.)

| | | $0 - \frac{1}{16}$" | $\frac{1}{16}$" | $\frac{1}{8}$" | $\frac{1}{4}$" | $\frac{1}{2}$" |
|---|---|---|---|---|---|---|
| King Edward | | | 10 January | | | |
| M | 0.9 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 |
| MWT$_0$ | 2.3 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| MWH$_3$ | 2.6 | 2.5 | 0.1 | 0.0 | 0.0 | 0.0 |
| MWDH$_1$ | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| MWDH$_2$ | 2.7 | 2.6 | 0.1 | 0.0 | 0.0 | 0.0 |
| MWDH$_3$ | 2.4 | 2.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| | | | 10 February | | | |
| M | 7.8 | 5.0 | 1.9 | 0.9 | 0.0 | 0.0 |
| MWT$_0$ | 9.0 | 4.8 | 2.4 | 1.7 | 0.1 | 0.0 |
| MWH$_3$ | 8.7 | 4.5 | 2.8 | 1.3 | 0.1 | 0.0 |
| MWDH$_1$ | 9.3 | 5.9 | 2.4 | 0.7 | 0.3 | 0.0 |
| MWDH$_2$ | 9.8 | 6.1 | 2.6 | 1.0 | 0.2 | 0.0 |
| MWDH$_3$ | 9.7 | 5.7 | 2.9 | 1.0 | 0.1 | 0.0 |
| | | | 10 March | | | |
| M | 7.6 | 3.2 | 2.1 | 1.3 | 1.0 | 0.0 |
| MWT$_0$ | 8.5 | 3.4 | 2.1 | 1.6 | 1.3 | 0.0 |
| MWH$_3$ | 9.4 | 3.7 | 2.3 | 1.7 | 1.3 | 0.3 |
| MWDH$_1$ | 9.3 | 3.5 | 3.3 | 1.7 | 0.7 | 0.2 |
| MWDH$_2$ | 9.5 | 3.5 | 3.3 | 1.7 | 0.9 | 0.1 |
| MWDH$_3$ | 9.1 | 3.5 | 3.0 | 1.8 | 0.8 | 0.1 |

## Appendix 18

The percentage number of emerged plants in relation to seed treatment - 1967.

### Statistical Analysis

Transformed data (Angles)

| Treatment | Date of Count | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | May 11 | 14 | 18 | 24 | 29 | June 1 | 4 | 7 | 11 | 30 |
| **Majestic** | | | | | | | | | | |
| M | 0.07 | 0.32 | 0.43 | 0.68 | 1.06 | 1.29 | 1.41 | 1.46 | 1.46 | 1.49 |
| MWT | 0.31 | 0.57 | 0.62 | 0.98 | 1.22 | 1.38 | 1.43 | 1.47 | 1.49 | 1.51 |
| $MWH_3$ | 0.30 | 0.51 | 0.55 | 0.86 | 1.20 | 1.35 | 1.42 | 1.47 | 1.49 | 1.51 |
| $MWDH_1$ | 0.25 | 0.48 | 0.55 | 0.87 | 1.17 | 1.28 | 1.36 | 1.47 | 1.68 | 1.49 |
| $MWDH_2$ | 0.22 | 0.41 | 0.48 | 0.80 | 1.04 | 1.29 | 1.42 | 1.48 | 1.49 | 1.51 |
| $MWDH_3$ | 0.35 | 0.58 | 0.64 | 0.93 | 1.16 | 1.32 | 1.43 | 1.46 | 1.46 | 1.49 |
| S.E. ± | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 |
| **King Edward** | | | | | | | | | | |
| M | 0.20 | 0.35 | 0.41 | 0.79 | 1.15 | 1.33 | 1.39 | 1.42 | 1.44 | 1.47 |
| MWT | 0.28 | 0.48 | 0.55 | 0.91 | 1.28 | 1.40 | 1.40 | 1.45 | 1.46 | 1.49 |
| $MWH_3$ | 0.20 | 0.40 | 0.46 | 0.95 | 1.33 | 1.42 | 1.48 | 1.51 | 1.51 | 1.51 |
| $MWDH_1$ | 0.24 | 0.41 | 0.48 | 0.90 | 1.25 | 1.36 | 1.46 | 1.46 | 1.48 | 1.51 |
| $MWDH_2$ | 0.16 | 0.33 | 0.45 | 0.92 | 1.27 | 1.37 | 1.45 | 1.46 | 1.47 | 1.49 |
| $MWDH_3$ | 0.28 | 0.44 | 0.53 | 0.95 | 1.22 | 1.33 | 1.42 | 1.44 | 1.45 | 1.49 |
| S.E. ± | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 |

## Appendix 19

The effect of seed treatment on the average plant height - 1967.

| Treatment | Height (in.) Majestic 13 June | Majestic 22 July | King Edward 13 June | King Edward 22 July |
|---|---|---|---|---|
| M | 4.4 | 22.1 | 5.7 | 23.1 |
| WMT | 5.6 | 21.3 | 6.4 | 22.9 |
| $MWH_3$ | 5.0 | 21.9 | 7.1 | 22.6 |
| $MWDH_1$ | 5.3 | 21.7 | 6.9 | 23.2 |
| $MWDH_2$ | 4.9 | 20.5 | 6.9 | 24.0 |
| $MWDH_3$ | 5.2 | 21.3 | 7.1 | 24.6 |
| S.E. ± | 0.28 | 0.52 | 0.41 | 0.53 |

## Appendix 20

The effect of seed treatment on the mother tuber - 1967.

### Statistical Analysis

Transformed data (Angles)

| Treatment | Majestic Healthy | Majestic Soft rot | King Edward Healthy | King Edward Soft rot |
|---|---|---|---|---|
| M | 0.79 | 0.37 | 0.68 | 0.65 |
| $MWT_0$ | 0.86 | 0.35 | 0.54 | 0.78 |
| $MWH_3$ | 0.81 | 0.37 | 0.66 | 0.67 |
| $MWDH_1$ | 1.06 | 0.30 | 1.10 | 0.21 |
| $MWDH_2$ | 0.88 | 0.22 | 0.96 | 0.24 |
| $MWDH_3$ | 0.96 | 0.26 | 0.96 | 0.29 |
| S.E. ± | 0.06 | 0.07 | 0.06 | 0.05 |

## Appendix 21

The effect of the different seed treatments on the incidence of blackleg (per cent) in the field - 1967.

### Statistical Analysis

Transformed data (Angles)

| Treatment | Date of Count 13 June | 24 June | 24 July | 25 August and 1 September |
|---|---|---|---|---|
| | **Majestic** | | | |
| M | 0.04 | 0.12 | 0.16 | 0.20 |
| $MWT_0$ | 0.20 | 0.28 | 0.28 | 0.39 |
| $MWH_3$ | 0.17 | 0.20 | 0.22 | 0.36 |
| $MWDH_1$ | 0.19 | 0.24 | 0.23 | 0.37 |
| $MWDH_2$ | 0.19 | 0.23 | 0.25 | 0.35 |
| $MWDH_3$ | 0.24 | 0.26 | 0.26 | 0.33 |
| S.E. ± | 0.03 | 0.02 | 0.02 | 0.02 |
| | **King Edward** | | | |
| M | 0.00 | 0.00 | - | 0.26 |
| $MWT_0$ | 0.03 | 0.03 | - | 0.47 |
| $MWH_3$ | 0.03 | 0.06 | - | 0.41 |
| $MWDH_1$ | 0.00 | 0.02 | - | 0.32 |
| $MWDH_2$ | 0.00 | 0.02 | - | 0.29 |
| $MWDH_3$ | 0.00 | 0.00 | - | 0.35 |
| S.E. ± | 0.01 | 0.01 | - | 0.03 |

Appendix 22

Yield (tons per acre) and number of tubers (thousands per acre) in relation to seed treatment - 1967.

| Treatment | Ware | Number of tubers (thousands per acre) Seed | Chats | Total |
|---|---|---|---|---|
| Majestic | | | | |
| M | 58.4 | 62.4 | 13.9 | 134.7 |
| MWT | 53.3 | 81.1 | 20.6 | 155.1 |
| $MWH_3$ | 48.7 | 66.1 | 17.1 | 131.9 |
| $MWDH_1$ | 50.3 | 85.1 | 23.6 | 159.0 |
| $MWDH_2$ | 53.4 | 90.2 | 22.6 | 166.2 |
| $MWDH_3$ | 51.9 | 81.2 | 19.5 | 152.6 |
| S.E. ± | 2.78 | 3.75 | 2.11 | 5.74 |
| King Edward | | | | |
| M | 62.9 | 105.2 | 22.7 | 190.8 |
| MWT | 49.2 | 117.6 | 31.2 | 198.0 |
| $MWH_3$ | 55.1 | 124.4 | 27.8 | 207.3 |
| $MWDH_1$ | 50.5 | 150.0 | 30.6 | 231.1 |
| $MWDH_2$ | 58.4 | 134.0 | 29.0 | 221.4 |
| $MWDH_3$ | 56.3 | 133.6 | 31.9 | 221.8 |
| S.E. ± | 3.00 | 4.26 | 2.47 | 6.48 |

Appendix 23

The mean number of sprouting eyes per tuber and the mean number of sprouts of various lengths per tuber - 1968.

| Treatment | Mean No. of sprouting eyes per tuber | Mean No. of sprouts of different lengths per tuber | | | | | |
|---|---|---|---|---|---|---|---|
| | | Up to $\frac{1}{16}$" | $\frac{1}{16}$" | $\frac{1}{8}$" | $\frac{1}{4}$" | $\frac{1}{2}$" | $\frac{3}{4}$" |
| Pentland Dell | | | | 25 January | | | |
| M | 5.8 | 4.4 | 1.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| MWT | 4.1 | 3.1 | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 |
| $MWH_1$ | 4.0 | 2.9 | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 |
| $MWH_3$ | 6.1 | 4.9 | 0.9 | 0.2 | 0.0 | 0.0 | 0.0 |
| MWDT | 5.2 | 5.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_1$ | 5.5 | 5.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_2$ | 6.0 | 5.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MWDH_3$ | 7.6 | 7.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MDH_1$ | 7.6 | 7.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MDH_2$ | 7.1 | 7.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| $MDH_3$ | 6.6 | 6.1 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| | | | | 10 March | | | |
| M | 8.0 | 3.1 | 2.0 | 1.8 | 0.9 | 0.2 | 0.0 |
| MWT | 9.0 | 3.8 | 2.5 | 1.8 | 0.8 | 0.1 | 0.0 |
| $MWH_1$ | 9.1 | 3.3 | 2.3 | 2.3 | 1.0 | 0.1 | 0.0 |
| $MWH_3$ | 9.2 | 4.1 | 2.2 | 2.1 | 0.8 | 0.0 | 0.0 |
| MWDT | 8.8 | 5.2 | 2.3 | 1.2 | 0.1 | 0.0 | 0.0 |
| $MWDH_1$ | 8.2 | 3.6 | 2.3 | 1.9 | 0.4 | 0.0 | 0.0 |
| $MWDH_2$ | 8.1 | 4.1 | 2.2 | 1.3 | 0.5 | 0.0 | 0.0 |
| $MWDH_3$ | 8.5 | 4.4 | 2.4 | 1.4 | 0.3 | 0.0 | 0.0 |
| $MDH_1$ | 7.6 | 4.1 | 2.1 | 1.4 | 0.0 | 0.0 | 0.0 |
| $MDH_2$ | 8.2 | 4.4 | 1.9 | 1.3 | 0.2 | 0.0 | 0.0 |
| $MDH_3$ | 8.3 | 3.3 | 2.4 | 2.0 | 0.5 | 0.1 | 0.0 |

| | | Up to $\frac{1}{16}$" | $\frac{1}{16}$" | $\frac{1}{8}$" | $\frac{1}{4}$" | $\frac{1}{2}$" | $\frac{3}{4}$" |
|---|---|---|---|---|---|---|---|
| **King Edward** | | | | 25 January | | | |
| M | 7.7 | 5.8 | 1.2 | 0.6 | 0.1 | 0.0 | 0.0 |
| MWT | 8.2 | 5.8 | 1.3 | 0.8 | 0.2 | 0.0 | 0.0 |
| $MWH_1$ | 7.6 | 5.4 | 1.3 | 0.7 | 0.2 | 0.0 | 0.0 |
| $MWH_3$ | 7.4 | 5.1 | 1.0 | 0.9 | 0.3 | 0.0 | 0.0 |
| MWDT | 8.0 | 7.3 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 |
| $MWDH_1$ | 8.5 | 7.0 | 1.0 | 0.4 | 0.1 | 0.0 | 0.0 |
| $MWDH_2$ | 8.5 | 7.1 | 0.9 | 0.4 | 0.1 | 0.2 | 0.0 |
| $MWDH_3$ | 8.3 | 7.0 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 |
| | | | | 4 March | | | |
| M | 7.0 | 2.6 | 1.8 | 1.3 | 1.2 | 0.1 | 0.0 |
| MWT | 8.3 | 3.0 | 2.3 | 1.6 | 1.1 | 0.1 | 0.1 |
| $MWH_1$ | 8.0 | 2.6 | 2.3 | 1.8 | 1.2 | 0.1 | 0.0 |
| $MWH_3$ | 7.8 | 2.5 | 1.9 | 1.9 | 1.2 | 0.3 | 0.1 |
| MWDT | 8.9 | 3.3 | 3.1 | 1.9 | 0.5 | 0.1 | 0.0 |
| $MWDH_1$ | 9.0 | 2.9 | 3.0 | 2.3 | 0.8 | 0.1 | 0.0 |
| $MWDH_2$ | 9.4 | 3.1 | 3.1 | 2.4 | 0.7 | 0.1 | 0.0 |
| $MWDH_3$ | 8.9 | 2.8 | 2.9 | 2.6 | 0.5 | 0.1 | 0.0 |

# Appendix 24

**The percentage number of emerged plants at different dates in relation to seed treatment - 1968.**

## Statistical Analysis

Transformed data (Angles)

| Treatment | June 10 | 17 | 24 | July 1 | 8 | 16 |
|---|---|---|---|---|---|---|
| Pentland Dell | | | | | | |
| M | 0.42 | 0.86 | 1.01 | 1.05 | 1.12 | 1.12 |
| MWT | 0.51 | 0.90 | 1.07 | 1.11 | 1.15 | 1.17 |
| $MWH_1$ | 0.37 | 0.81 | 1.03 | 0.94 | 0.97 | 1.00 |
| $MWH_3$ | 0.49 | 0.85 | 0.97 | 0.98 | 1.02 | 1.11 |
| MWDT | 0.60 | 1.08 | 1.17 | 1.22 | 1.29 | 1.29 |
| $MWDH_1$ | 0.53 | 1.02 | 1.15 | 1.16 | 1.19 | 1.19 |
| $MWDH_2$ | 0.49 | 0.96 | 1.05 | 1.08 | 1.11 | 1.14 |
| $MWDH_3$ | 0.59 | 1.07 | 1.21 | 1.23 | 1.25 | 1.27 |
| $MDH_1$ | 0.60 | 1.03 | 1.22 | 1.23 | 1.24 | 1.24 |
| $MDH_3$ | 0.63 | 1.05 | 1.23 | 1.20 | 1.20 | 1.27 |
| S.E. | 0.05 | 0.04 | 0.06 | 0.05 | 0.05 | 0.04 |
| King Edward | June 3 | 10 | 17 | 24 | July 1 | 8 |
| M | 0.17 | 1.01 | 1.46 | 1.51 | 1.51 | 1.51 |
| MWT | 0.03 | 0.84 | 1.27 | 1.30 | 1.34 | 1.34 |
| $MWH_1$ | 0.15 | 0.89 | 1.33 | 1.35 | 1.40 | 1.40 |
| $MWH_3$ | 0.07 | 0.88 | 1.25 | 1.32 | 1.35 | 1.39 |
| MWDT | 0.19 | 1.22 | 1.40 | 1.51 | 1.51 | 1.51 |
| $MWDH_1$ | 0.06 | 1.09 | 1.50 | 1.50 | 1.51 | 1.51 |
| $MWDH_2$ | 0.16 | 1.13 | 1.42 | 1.51 | 1.54 | 1.54 |
| $MWDH_3$ | 0.03 | 1.07 | 1.39 | 1.42 | 1.43 | 1.45 |
| S.E. | 0.05 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 |

Appendix 25

The effect of seed treatment on the average plant height - 1968.

| Treatment | Height (in.) King Edward |
|---|---|
| M | 20.7 |
| MWT | 20.2 |
| $MWH_1$ | 20.7 |
| $MWH_3$ | 21.0 |
| MWDT | 20.7 |
| $MWDH_1$ | 20.7 |
| $MWDH_2$ | 20.5 |
| $MWDH_3$ | 20.6 |
| S.E. ± | 0.41 |

Appendix 26

The effect of different seed treatments on the incidence of blackleg (per cent) in the field - 1968.

Statistical Analysis

Transformed data (Angles)

| Treatment | Date of Count<br>1 July | <br>1 August | <br>3 September |
|---|---|---|---|
| King Edward | | | |
| M | 0.10 | 0.28 | 0.55 |
| MWT | 0.24 | 0.35 | 0.56 |
| $MWH_1$ | 0.34 | 0.50 | 0.68 |
| $MWH_3$ | 0.22 | 0.37 | 0.61 |
| MWDT | 0.32 | 0.38 | 0.71 |
| $MWDH_1$ | 0.33 | 0.45 | 0.66 |
| $MWDH_2$ | 0.31 | 0.39 | 0.65 |
| $MWDH_3$ | 0.27 | 0.35 | 0.62 |
| S.E. ± | 0.03 | 0.03 | 0.03 |

Appendix 27

Yield (tons per acre) and number of tubers (thousands per acre) in relation to seed treatment - 1968.

| Treatment | Ware | Seed | Chats | Total |
|---|---|---|---|---|
| | Number of tubers (thousands per acre) | | | |
| King Edward | | | | |
| M | 7.0 | 146.3 | 43.3 | 196.6 |
| MWT | 6.5 | 112.0 | 34.1 | 152.6 |
| $MWH_1$ | 6.4 | 113.6 | 34.6 | 154.6 |
| $MWH_3$ | 12.3 | 127.3 | 29.2 | 168.8 |
| MWDT | 4.8 | 164.4 | 40.3 | 209.5 |
| $MWDH_1$ | 3.2 | 137.3 | 39.4 | 179.9 |
| $MWDH_2$ | 3.9 | 139.2 | 40.6 | 183.7 |
| $MWDH_3$ | 5.1 | 137.8 | 35.7 | 178.6 |
| S.E. ± | 1.16 | 9.93 | 3.08 | 9.83 |

<u>Appendix 28</u>

The mean number of sprouting eyes per tuber and the mean number of sprouts of various lengths per tuber - 1968.

| Treatment | Mean No. of sprouting eyes per tuber | Mean No. of sprouts of different lengths | | | |
|---|---|---|---|---|---|
| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. |
| **Majestic** | | | 20 March | | |
| M | 6.9 | 6.6 | 0.3 | 0.0 | 0.0 |
| MD (a) | 8.1 | 7.7 | 0.4 | 0.0 | 0.0 |
| MD (b) | 8.6 | 8.0 | 0.6 | 0.0 | 0.0 |
| MD (x2) | 8.3 | 7.9 | 0.4 | 0.0 | 0.0 |
| MWD | 8.8 | 8.6 | 0.3 | 0.0 | 0.0 |
| | | | 10 April | | |
| M | 9.3 | 2.1 | 2.6 | 4.3 | 0.3 |
| MD (a) | 10.4 | 2.2 | 3.0 | 5.2 | 0.0 |
| MD (b) | 10.7 | 3.1 | 2.5 | 4.8 | 0.3 |
| MD (x2) | 10.8 | 2.4 | 2.8 | 5.5 | 0.1 |
| MWD | 11.6 | 3.0 | 3.2 | 5.4 | 0.1 |
| **Redskin** | | | 20 April | | |
| M | 5.7 | 5.5 | 0.1 | 0.0 | 0.0 |
| MD (a) | 5.4 | 5.5 | 0.2 | 0.0 | 0.0 |
| MD (b) | 6.3 | 6.0 | 0.3 | 0.0 | 0.0 |
| MWD | 6.5 | 6.3 | 0.2 | 0.0 | 0.0 |

## Appendix 28 (contd.)

| | | Up to $\frac{1}{16}$ in. | $\frac{1}{16}$ in. | $\frac{1}{8}$ in. | $\frac{1}{4}$ in. |
|---|---|---|---|---|---|
| **King Edward** | | | **10 February** | | |
| M | 3.2 | 2.8 | 0.3 | 0.1 | 0.0 |
| MD (a) | 4.9 | 4.4 | 0.4 | 0.1 | 0.0 |
| MD (b) | 5.1 | 4.8 | 0.3 | 0.0 | 0.0 |
| MWD | 6.7 | 6.1 | 0.5 | 0.0 | 0.0 |
| | | | **1 April** | | |
| M | 7.0 | 2.5 | 2.3 | 1.8 | 0.4 |
| MD (a) | 8.7 | 2.5 | 2.8 | 3.1 | 0.3 |
| MD (b) | 9.1 | 2.9 | 2.7 | 3.4 | 0.1 |
| MWD | 8.8 | 2.7 | 3.0 | 2.9 | 0.1 |

Appendix 29

The percentage number of emerged plants at different dates in relation to seed treatment - 1968.

Statistical Analysis

Transformed data (Angles)

| Treatment | June 3 | 10 | 17 | 24 | July 1 | 8 |
|---|---|---|---|---|---|---|
| | | | **Majestic** | | | |
| M | 0.21 | 0.91 | 1.40 | 1.47 | 1.54 | 1.56 |
| MD (A) | 0.27 | 1.08 | 1.51 | 1.54 | 1.54 | 1.56 |
| MWD | 0.38 | 1.19 | 1.49 | 1.54 | 1.54 | 1.56 |
| MD (B) | 0.17 | 0.90 | 1.44 | 1.54 | 1.54 | 1.56 |
| MD (x 2) | 0.43 | 1.17 | 1.49 | 1.49 | 1.49 | 1.51 |
| S.E. ± | 0.06 | 0.06 | 0.04 | 0.03 | 0.01 | 0.01 |
| | | | **Redskin** | | | |
| M | 0.00 | 0.47 | 0.98 | 1.30 | 1.49 | 1.49 |
| MD (A) | 0.14 | 0.51 | 1.23 | 1.42 | 1.48 | 1.48 |
| MWD | 0.11 | 0.56 | 1.26 | 1.50 | 1.56 | 1.56 |
| MD (B) | 0.10 | 0.53 | 1.26 | 1.44 | 1.47 | 1.53 |
| | | | **King Edward** | | | |
| M | 0.29 | 0.94 | 1.30 | 1.32 | 1.37 | 1.43 |
| MD (A) | 0.37 | 1.15 | 1.50 | 1.53 | 1.53 | 1.53 |
| MWD | 0.29 | 1.17 | 1.53 | 1.53 | 1.53 | 1.53 |
| MD (B) | 0.20 | 0.97 | 1.39 | 1.53 | 1.56 | 1.56 |
| S.E. Diff. 1 | 0.08 | 0.08 | 0.10 | 0.07 | 0.05 | 0.05 |
| S.E. Diff. 2)<br>S.E. Diff. 3) | 0.05 | 0.08 | 0.06 | 0.05 | 0.04 | 0.04 |

Appendix 30

The effect of seed treatment on the average plant height - 1968.

| Treatment | Majestic | Height (in.) Redskin | King Edward |
|---|---|---|---|
| M | - | 15.8 | 21.8 |
| MD (a) | - | 16.1 | 22.2 |
| MD (b) | - | 16.1 | 21.2 |
| MWD | - | 15.9 | 22.3 |
| | S.E. diff. 1 | 0.56 | |
| | 2) 3) | 0.41 | |

Appendix 31

The effect of different seed treatments on the incidence of blackleg (per cent) in the field - 1968.

Statistical Analysis

Transformed data (Angles)

| Treatments | 1 July | Date of Count<br>1 August | 1 September |
|---|---|---|---|
| | | Majestic | |
| M | 0.17 | 0.48 | 0.68 |
| MD (A) | 0.12 | 0.38 | 0.59 |
| MWD | 0.15 | 0.42 | 0.64 |
| MD (B) | 0.16 | 0.37 | 0.58 |
| MD (x 2) | 0.09 | 0.34 | 0.55 |
| S.E. ± | 0.04 | 0.03 | 0.03 |
| | | Redskin | |
| | 10 July | 1 August | 4 September |
| M | 0.05 | 0.17 | 0.60 |
| MD (A) | 0.02 | 0.29 | 0.67 |
| MWD | 0.00 | 0.27 | 0.64 |
| MD (B) | 0.05 | 0.30 | 0.67 |
| | | King Edward | |
| M | 0.03 | 0.20 | 0.55 |
| MD (A) | 0.02 | 0.13 | 0.47 |
| MWD | 0.09 | 0.13 | 0.45 |
| MD (B) | 0.05 | 0.09 | 0.44 |
| S.E. Diff. 1 | 0.04 | 0.05 | 0.05 |
| S.E. Diff. 2)<br>S.E. Diff. 3) | 0.03 | 0.03 | 0.04 |

Appendix 32

Yield (tons per acre) and number of tubers (thousands per acre) - 1968.

| Treatment | Number of tubers (thousands per acre) Ware | Seed | Chats | Total |
|---|---|---|---|---|
| | | Majestic | | |
| M | 17.1 | 102.0 | 24.6 | 118.6 |
| MD (A) | 9.6 | 138.3 | 40.2 | 139.3 |
| MWD | 12.9 | 120.7 | 38.6 | 133.6 |
| MD (B) | 12.7 | 131.7 | 39.0 | 144.0 |
| MD (x 2) | 7.0 | 124.3 | 40.2 | 131.2 |
| S.E. ± | 1.54 | 3.95 | 2.25 | 5.87 |
| | | Redskin | | |
| M | 10.5 | 86.8 | 15.5 | 112.8 |
| MD (A) | 9.1 | 97.3 | 21.7 | 128.1 |
| MWD | 7.7 | 125.9 | 23.9 | 157.6 |
| MD (B) | 14.2 | 107.5 | 19.2 | 140.9 |
| | | King Edward | | |
| M | 14.6 | 128.8 | 26.4 | 169.9 |
| MD (A) | 15.0 | 155.0 | 30.4 | 200.3 |
| MWD | 8.0 | 176.6 | 39.6 | 224.1 |
| MD (B) | 10.7 | 162.1 | 33.2 | 206.0 |
| S.E. diff. 1 | 2.81 | 12.18 | 3.18 | 13.73 |
| S. E.diff. 2)<br>S. E.diff. 3) | 2.54 | 9.66 | 2.82 | 10.71 |

## Appendix 33

## Meteorological Data, Bush, Midlothian

A) 1966

| Month | Weekly Mean Temp. (°F) Max. | Min. | Weekly Mean Rainfall (in.) | |
|---|---|---|---|---|
| April | 45.1 | 33.1 | | 0.78 |
| | 41.1 | 31.6 | | 0.46 |
| | 37.6 | 31.9 | | 0.79 |
| | 44.0 | 30.7 | | 0.54 |
| | 55.3 | 42.7 | | 0.15 |
| Monthly mean | 45.0 | 34.5 | Total | 1.94 |
| May | 58.2 | 39.9 | | 0.25 |
| | 55.3 | 38.7 | | 0.73 |
| | 57.1 | 41.0 | | 0.35 |
| | 57.0 | 43.6 | | 0.55 |
| Monthly mean | 57.9 | 40.4 | Total | 1.88 |
| June | 64.3 | 42.7 | | 0.07 |
| | 57.9 | 48.7 | | 0.65 |
| | 62.9 | 50.4 | | 1.72 |
| | 60.4 | 47.9 | | 1.72 |
| Monthly mean | 61.0 | 48.7 | Total | 4.66 |
| July | 63.7 | 47.9 | | 0.50 |
| | 63.1 | 50.6 | | 0.18 |
| | 60.7 | 50.1 | | 0.81 |
| | 65.9 | 43.7 | | 0.00 |
| | 61.7 | 48.0 | | 0.71 |
| Monthly mean | 62.7 | 48.0 | Total | 2.16 |
| August | 57.7 | 44.7 | | 3.05 |
| | 62.4 | 49.4 | | 1.39 |
| | 64.1 | 48.6 | | 2.37 |
| | 58.4 | 43.0 | | 1.34 |
| Monthly mean | 60.5 | 46.7 | Total | 7.79 |
| September | 60.0 | 48.9 | | 0.47 |
| | 61.1 | 51.1 | | 0.71 |
| | 60.3 | 48.4 | | 1.07 |
| | 62.3 | 48.1 | | 0.00 |
| | 55.7 | 47.4 | | 0.23 |
| Monthly mean | 60.1 | 48.8 | Total | 2.38 |

Appendix 33 (contd.)

B) 1967

| Month | Weekly Mean Temp. (°F) Max. | Min. | | Weekly Mean Rainfall (in.) |
|---|---|---|---|---|
| April | 43.6 | 32.4 | | 0.27 |
| | 47.3 | 35.0 | | 0.49 |
| | 48.7 | 36.9 | | 0.06 |
| | 52.7 | 36.7 | | 0.11 |
| | 56.4 | 39.1 | | 0.09 |
| Monthly mean | 51.1 | 37.0 | Total | 0.81 |
| May | 49.7 | 37.1 | | 0.67 |
| | 53.2 | 42.3 | | 1.92 |
| | 47.6 | 39.0 | | 2.16 |
| | 55.1 | 41.0 | | 0.54 |
| Monthly mean | 52.2 | 39.8 | Total | 5.89 |
| June | 59.6 | 43.4 | | 0.71 |
| | 58.3 | 44.7 | | 0.33 |
| | 65.6 | 43.1 | | 0.00 |
| | 62.3 | 47.0 | | 0.47 |
| Monthly mean | 61.7 | 46.1 | Total | 1.10 |
| July | 61.3 | 49.4 | | 0.24 |
| | 62.6 | 47.7 | | 0.27 |
| | 60.7 | 49.6 | | 1.02 |
| | 63.8 | 50.4 | | 0.29 |
| | 63.1 | 49.6 | | 0.50 |
| Monthly mean | 63.0 | 49.5 | Total | 2.41 |
| August | 63.6 | 48.1 | | 0.41 |
| | 63.4 | 50.0 | | 1.05 |
| | 58.4 | 48.1 | | 0.84 |
| | 68.4 | 51.7 | | 0.26 |
| Monthly mean | 62.9 | 49.4 | Total | 2.43 |
| September | 61.7 | 49.1 | | 0.73 |
| | 58.7 | 45.4 | | 0.85 |
| | 59.1 | 45.1 | | 0.19 |
| | 57.1 | 43.6 | | 0.17 |
| | 61.4 | 46.0 | | 1.00 |
| Monthly mean | 59.2 | 45.3 | Total | 2.79 |

Appendix 33 (contd.)

C) 1968

| Month | Weekly Mean Temp. (°F) Max. | Min. | | Weekly Mean Rainfall (in.) |
|---|---|---|---|---|
| April | 39.5 | 27.0 | | 0.87 |
| | 47.4 | 29.1 | | 0.00 |
| | 55.2 | 40.5 | | 1.11 |
| | 58.7 | 41.5 | | 0.13 |
| Monthly mean | 50.4 | 34.9 | Total | 2.14 |
| May | 47.7 | 38.4 | | 3.80 |
| | 47.6 | 33.4 | | 1.13 |
| | 50.7 | 37.1 | | 1.00 |
| | 52.6 | 39.3 | | 0.07 |
| Monthly mean | 51.3 | 38.0 | Total | 6.02 |
| June | 60.0 | 45.0 | | 0.16 |
| | 58.7 | 43.7 | | 0.11 |
| | 67.0 | 46.1 | | 0.00 |
| | 60.8 | 46.1 | | 0.61 |
| | 62.5 | 46.0 | | 0.40 |
| Monthly mean | 62.0 | 45.7 | Total | 1.23 |
| July | 59.3 | 48.1 | | 1.50 |
| | 55.3 | 46.1 | | 1.75 |
| | 60.9 | 48.9 | | 2.10 |
| | 63.7 | 50.1 | | 0.17 |
| Monthly mean | 60.1 | 48.2 | Total | 5.53 |
| August | 63.6 | 47.3 | | 0.03 |
| | 64.1 | 50.0 | | 0.01 |
| | 60.9 | 45.7 | | 1.80 |
| | 63.9 | 52.6 | | 0.34 |
| Monthly mean | 62.1 | 48.8 | Total | 2.44 |
| September | 58.4 | 48.0 | | 0.50 |
| | 61.9 | 44.1 | | 1.14 |
| | 59.4 | 50.6 | | 1.37 |
| | 57.1 | 42.8 | | 0.36 |
| | 56.6 | 45.1 | | 1.34 |
| Monthly mean | 58.8 | 45.6 | Total | 4.78 |