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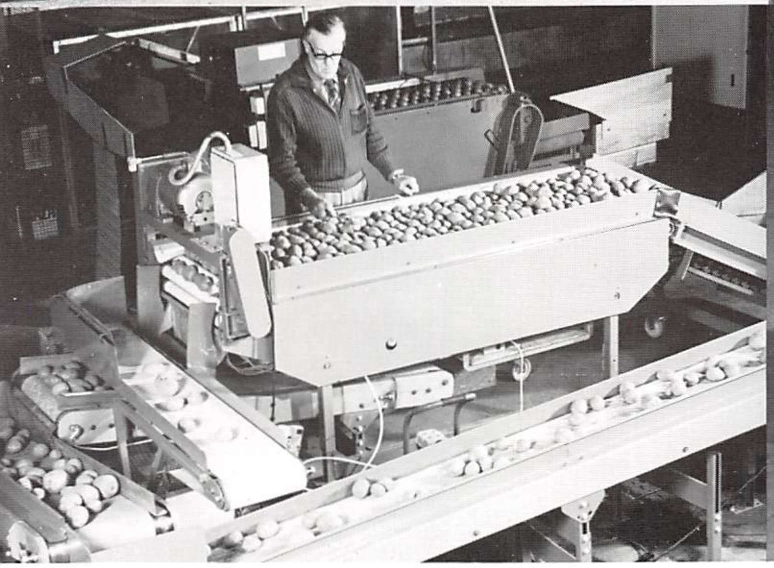

# *Seed potato production*

*Proceedings of the Spring National Conference*

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*Three categories of paper appear in the Journal:-*
- *a) Papers submitted to the Honorary Editor and subsequently refereed.*
- *b) Conference papers not generally refereed but which may be if the authors so request and if the refereeing process can be completed before the Conference Report is due to be published.*
- *c) Mechanisation and review articles not normally appropriate for refereeing.*

*Front cover: Developments in potato crop mechanisation:*
*Top left - bulk handling system for chitted seed*
*Top right - double disc shore*
*Bottom left - 'magic wand' inspection aid*
*Bottom right - low damage retail carton for ware potatoes*

[SIAE 'photos]

# Editorial
# Seed potato production
## A Langley

FOR the first time in the history of the IAgrE, England was relieved of the venue for a National Conference. The Secretariat travelled northwards across the Border to arrange the 1983 Spring National Conference in Scotland in association with the Scottish Branch of the Institution. The Conference was held at Dundee and, being at the heart of the Scottish seed potato industry, it was fitting that the Conference theme was based on seed potato production. It was also appropriate to hold the Conference in Scotland in as much as the Institution President, Hamish Shiach, hails from this area of the country.

From a mechanisation and engineering viewpoint, the potato crop holds many challenges. Many improvements to all aspects of crop production have been achieved but avoidance of damage, better storage techniques and faster and more satisfactory planting and harvesting are areas where advances still can be made. However, technical improvements can only be considered in the light of economic constraints. For example, the large industrial conurbation of Dundee with its high unemployment, unfortunately can provide a large pool of casual labour for harvesting. Hand-picking obviously plays a retrograde part in the development of machines suitable for harvesting the seed crop.

This conference could not hope to cover all engineering and mechanisation aspects of seed production but had to confine itself to a few important topics. As with most other crops, the seed potato producer finds that he must run to keep still in terms of crop returns. How can the producer aim at maximising returns? Three basic points spring to mind. Firstly, yield per unit area can be increased. For the seed producer, the quantity and uniformity of tubers is important and therefore accuracy of planting has much to commend it in order to achieve regular set spacing within the row. Irrigation and chitting are further methods of increasing yield. Chitting effectively increases the growing season with a resultant yield response but if one has gone to the trouble of artificially initiating growth, the planting method must be capable of handling seed gently and ensuring that the chitting potential is not lost. The development of the all British microprocessor controlled planter being marketed by Smallfords may prove to have all the necessary requirements — speed, gentleness and accuracy.

Chitting also gives the advantage of earlier crop maturity which allows crops to be lifted earlier with potential benefits in disease reduction and easier harvesting. However, damage at harvest time may be greater due to the drier conditions, and storage methods and requirements may need to be reassessed if harvesting in warmer weather occurs. Early harvesting also makes life more pleasant for the hand picking squads or harvester operators especially if harvesting takes place in early September rather than late September!

In addition to increasing yields, loss levels both during harvesting and in store must be minimised if maximum returns are to be achieved. Time prevented discussion of cultivations and stone windrowing techniques as methods of reducing harvesting losses, but a thorough analysis of the potato harvester identified problem areas and suggested possible solutions to avoiding losses and preventing potato damage — a problem that was again highlighted in the recent Potato Marketing Board National Damage Survey. Harvester developments at the Scottish Institute of Agricultural Engineering include investigations into alternative web agitation methods and effects of varying the area of the primary web — both topics aim at achieving maximum soil tuber separation with minimum tuber damage.

Much of the seed potato crop is stored in boxes which although expensive, have many advantages in terms of ease of handling. This is especially the case when small lots of different varieties have to be stored under one roof. Ease of access for inspection during storage and removal for grading are advantages of the system. However, this type of storage method is not without its problems, especially in terms of adequately controlling the environment around the tubers. Access lanes between boxes are the preferred air flow routes and careful planning and attention to detail are important if a successful environmental control system is to be achieved. Condensation both in box and bulk stores can create problems and reduce the saleable crop. Adequate insulation, ensuring no thermal bridges exist, and ventilation are two approaches to combating this problem.

With increased competition both at home and from abroad, a third method, a maximising return is introduced. Giving the ware grower what he requires in terms of tuber quality and size will be an increasingly important factor in the future. With large potential export markets available, it is imperative that the quality of the product offered is in keeping with the customers' standards if reputations are to be maintained and increased trading is to flourish. The Dutch are the recognised experts of the potato export trade and one must look to them to discover if any of the mechanisation aspects of our production systems are lacking.

The Conference was split into morning and afternoon sessions, with Mr John Fotheringham acted as Chairman for each session. Mr Fotheringham is currently Chairman of the Scottish Seed Potato Development Council whose objectives are to improve and promote the seed potato industry both at home and abroad. The morning session consisted of papers dealing with in field production. Dr Robert Lang of the East of Scotland College of Agriculture discussed the implications of early lifting with chitting, planting, harvesting and storage all being mentioned.

Bill Maunder of the Agricultural Development and Advisory Service looked at planters and planting methods and discussed various options of successfully handling seed from the store to the planter. Douglas McRae of the Scottish Institute of Agricultural Engineering took us on a journey from the intake end of the harvester to the unloading elevator discussing en route what improvements could be made.

The afternoon session was opened by Oliver Statham of the Potato Marketing Board who discussed alternative box storage systems and methods of dealing with condensation. Pieter de Haan from Institute for Storage and Processing of Agricultural Produce, Netherlands, discussed factors which affect grading accuracy and throughput and also mentioned the methods of grading and handling potatoes in Holland.

Finally, Ken Smith of the Forfar Potato Company gave a grower/merchant's view of seed potato production and discussed some of the problems particular to the merchant who rented land for potato production.

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# Implications of early lifting

**R W Lang**


## Abstract

TO maintain existing markets and ensure an increasing share of exports, Scottish seed growers must produce seed of the highest quality. Two factors are particularly important in this respect: minimisation of damage, and early lifting.

Early haulm destruction and early lifting prevent disease development, minimise the damage associated with cold and wet lifting conditions, and maximise the yield of high value seed. Against these advantages must be set loss of total crop yield. This loss of yield can be offset by chitting the seed in trays under lights to advance crop growth. Haulm can then be destroyed about twenty days earlier without yield loss. A reduction in wastage of around five per cent is all that is required to cover the cost of chitting, estimated at £40 per tonne.

Chitting the seed has implications for the husbandry of the crop but any difficulties which arise as a result of chitting should not deter growers from changing to this method of seed storage.


## Introduction

TO all of us involved in potato production, particularly in the growing of seed, it must be apparent that the quality of the final product is becoming increasingly important. Consumption is falling in Europe if not in the UK, there are surpluses, particularly of seed, and there is the increasing threat of imports of seed and ware into England. In this economic climate, Scottish seed growers consistently have to produce seed of only the highest quality, not only to retain existing markets but to make a significant impact on the export trade.

Of the factors involved in producing quality seed, two are of paramount importance. The first is minimisation of damage and the second is early haulm removal and early lifting. There are few farms where even a cursory examination of the handling system would not lead to a useful reduction in damage. The means are there but full advantage is not taken of available knowledge. Many new ideas, aimed at minimising damage are coming forward, particularly from the Scottish Institute of Agricultural Engineering and we must capitalise on these.

## Advantages of early lifting

The subject of early haulm removal and early lifting is an emotive one and the implications for the seed grower are numerous and far-reaching. There has been a tendency to talk much more of early haulm removal than early lifting.

Although the second cannot be achieved without the first, and early haulm destruction is important in itself, the real advantages come from early lifting. There is not too much to be gained by removing haulm early and then leaving the crop in the ground for seven or eight weeks. This is a particularly difficult problem for the small or relatively small grower who cannot tackle the cereal and potato harvest at the same time. For him there is no easy solution.

The advantages to be gained from early haulm removal and early lifting are numerous. Not least is the effect on disease development. Experiments at Edinburgh have shown that the severity and incidence of gangrene (*Phoma exigua*) and skinspot (*Oospora pustulans*) increase the longer the crop remains in the ground (Lang 1980). The situation is similar with blackleg: the earlier crops can be lifted before mother tubers or systemically infected tubers break down, the less will be the spread of infection through the ridge. These diseases are spread most readily in wet conditions so the earlier crops are lifted before the weather deteriorates, the better the quality of the seed will be. Black scurf (*Rhizoctonia solani*) is yet another problem. This disease is of increasing concern not only to seed growers in Scotland but to ware growers in the South trying to meet premium grade standards and growing for the pre-pack market. Although sclerotia formation on new tubers is initiated at any time depending on soil conditions, greatest development occurs between the death of the haulm and lifting. Early lifting is, therefore, of considerable advantage in preventing the build-up of black scurf.

Lastly, there is the question of disease spread by aphid borne viruses. Although virus disease is at an all time low in Scottish seed stocks, the possibility of late virus must not be forgotten. It is well established that virus spread early in the season is the main danger but late spread in certain seasons cannot be ruled out. The early and thorough desiccation of haulm is very important in this context.

In addition to the disease control associated with early lifting, there are advantages in terms of reduced damage. Early desiccated crops required two to three weeks after haulm death for tuber skins to mature before lifting. No further reduction of damage is likely to be achieved by further delay. On the contrary, it is likely that damage levels will rise as lifting is carried out in progressively wetter conditions, predisposing the crop to splitting. There is, in addition, the ever present danger of early frosts such as occurred in both 1980 and 1981. These factors can combine to give slower throughput and may necessitate double handling which, in turn, produces more damage.

It is important to keep in mind that damage not only increases wastage and reduces quality in its own right but is the predisposing factor to disease. Gangrene and blackleg are highly dependent on damage and, for dry rot, damage is essential.

An advantage of early haulm removal, as opposed to early lifting, is the production of the maximum yield of high value seed. As the crop bulks through the month of August, tubers in the seed category begin to move more rapidly into the large ware fraction and, as a result, seed yield declines. In addition, the average tuber size in the seed category increases, that is, there is a decrease in the number of tubers in the 50 kg bag. Although at the present time there is no premium for small seed, the time must shortly come when the higher value of small seed will be recognised and will receive a just return.

## Yield loss from early lifting

Against these very considerable advantages inherent in early haulm removal and early lifting must be set the main disadvantage, namely, the loss of

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yield. And this can be substantial. During the period of mid August to mid September the crop, depending on variety and season, can bulk at a rate of around five tonnes per hectare per week. Because of the traditionally inadequate premium for seed over ware, it is not surprising that the seed grower is often tempted to allow his crop to bulk in an attempt to maximise returns. Until such times as growers receive a just return for the additional cost, expertise and risk involved in quality seed production, the question we have to ask is: "Is it possible to manipulate the growth of the crop in such a way that the best of both worlds can be achieved, that is, can growth be advanced so that the crop can be burned down and lifted two or three weeks earlier without a loss of yield?" The only way this can be achieved is by chitting seed in trays under artificial light. This procedure should not be confused with mini-chitting in half tonne boxes which does not advance crop growth to this extent. The requirements and cost of mini-chitting have been discussed by Lang (1980).

## Chitting in trays

Since there is greatest need to advance the lifting date of maincrop varieties only these are discussed. Figure 1 illustrates diagrammatically the effect of chitting on bulking rate. Relative to chitted seed, unchitted seed is slower to emerge and produce tubers. The crop bulks faster however. It tends to catch up with that from chitted seed, and may have the potential to do so completely; but in Scottish conditions, with a short growing season, it rarely, if ever, does so. Table 1 gives the yields from chitted and unchitted seed, meaned for the varieties King Edward and Pentland Crown in experiments in Edinburgh over the period 1976-78. The yield from chitted seed at 15th August was not reached by the unchitted seed until 4th September. The advance in crop bulking achieved varied among years but averaged twenty days.

**Table 1 The effect of planting chitted seed, 1976-78 (cv Pentland Crown and King Edward)**

| | *Total yield, t/ha* | | |
|---|---|---|---|
| Haulm destruction date | 15 Aug | 30 Aug | 15 Sep |
| Unchitted | 31.1 | 38.5 | 43.3 |
| Chitted in trays | 39.8 | 46.3 | 49.9 |
| Advantage with chitted seed | 8.7 | 7.8 | 5.6 |
| SE | ±0.93 | ±1.20 | ±0.87 |

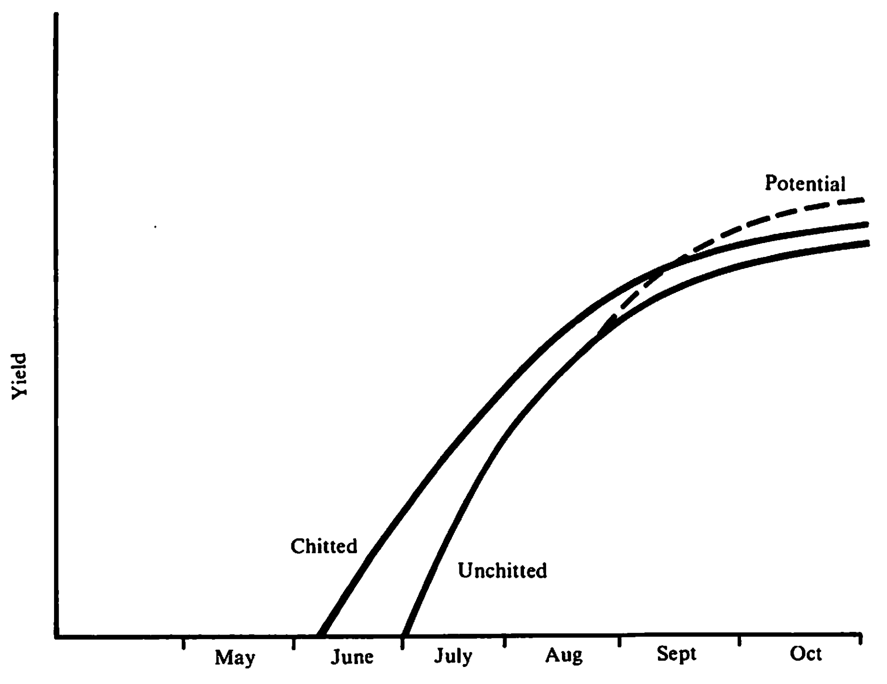
The advantage of being able to burn down and lift twenty days earlier and the subsequent improvement in crop quality has to be set against chitting costs which have been estimated at a maximum of £40/tonne (Lang 1980), assuming that a suitable building is available but requiring some additional insulation, and that trays and lights are purchased new. Table 2 examines the economics of chitting, firstly for the seed grower and secondly for the ware grower. In seed production, a reduction in wastage of less than two tonnes per hectare by burning down and lifting early is sufficient to pay for the cost of chitting.

**Table 2 Economics of chitting (maincrop varieties)**

*For the seed grower*
Burn off 20 days earlier without yield loss
Cost of chitting@£40/tonne = £160/ha
At a return of £95/tonne (£65 ware; £105 seed)
— a reduction of $1\frac{3}{4}$ tonne wastage will pay the cost of chitting.

*For the ware grower*
Burn off end of August/beginning September
Increase of 6 t/ha@£65/tonne = £390/ha
Cost of chitting @£40/tonne = £120/ha
Increased return = £270/ha
— a yield increase of only 2 t/ha will pay for chitting.

*Fig 1 Tuber bulking with chitted and unchitted seed – maincrop varieties*




For the ware grower, an increased return of abut £270 per hectare is possible depending on the date of haulm removal, but he would be well advised to take much of the advantage of chitting, like the seed grower, in terms of less wastage and better quality.

## Husbandry implications of planting chitted seed

The chitting of all or a portion of the seed has some important husbandry implications. There are, firstly, problems associated with the handling and planting of chitted seed. This is discussed by W F Maunder (1983). Some recent results at Edinburgh are of interest here. In an experiment designed to study the effect of chitting and sprout damage on disease development in the growing crop, chitted seed with varying lengths of sprout growth was tipped from one tray into another four times from a height of one metre. Wounding of sprouts, but not sprout removal, was extensive. The results are given in table 3. Damaging the sprouts delayed emergence and early growth but at maturity, yield was not significantly different from the crop grown from undamaged seed. The number of tubers was increased by 50% and this was reflected in a marked increase in seed yield. These increases are associated with an increase in mainstem numbers but the effect on tuber number was much greater than the effect on mainstems. It is not suggested on the basis of this experiment that sprouts should be damaged deliberately to increase seed yield. It should, however, give food for the thought that the importance of damage to sprouts should be investigated thoroughly before expensive means of preventing it are sought. It stresses also the need to produce strong sprouts which, though wounded, are not easily knocked off.

Secondly, there is the question of weed control. Because the time between planting and emergence is so short, weed germination and growth are not sufficiently advanced to use a contact herbicide. A more expensive residual or post emergence herbicide must be used.

Thirdly, the effect of early drought must be considered. Since the crop from chitted seed is two or three weeks more advanced in growth than that from unchitted seed, it may suffer most if a period of drought occurs early. The reverse of course may happen when dry conditions occur later but it seems to be the early drought which is the greater danger. With irrigation, there is no problem but, without irrigation, growers must assess the frequency and likely seriousness of the problem in their particular situation.

Lastly, there is the possible influence of chitting on disease development in the growing crop. It is often said that disease, such as blackleg, shows up more readily in the more mature crop grown from chitted seed and, unless early inspection is forthcoming, these crops are more likely to fail classification. The question which arises from this observation is: "Is there more blackleg in chitted crops or does it only appear so because the crop matures

**Table 3 Effect of damaging sprouts at planting (c v Pentland Javelin, 1982)**

| | *Days to 95% emergence* | *Total yield, t/ha* | *No tubers, '000/ha* | *Seed yield, t/ha* | *No mainstems per plant* |
|---|---|---|---|---|---|
| Sprouts damaged at planting | 42 | 41.3 | 335 | 34.5 | 6.0 |
| Sprouts undamaged | 36 | 43.3 | 219 | 27.9 | 5.2 |
| SE | ±0.6 | ±1.3 | ±9.4 | ±1.18 | ±0.23 |

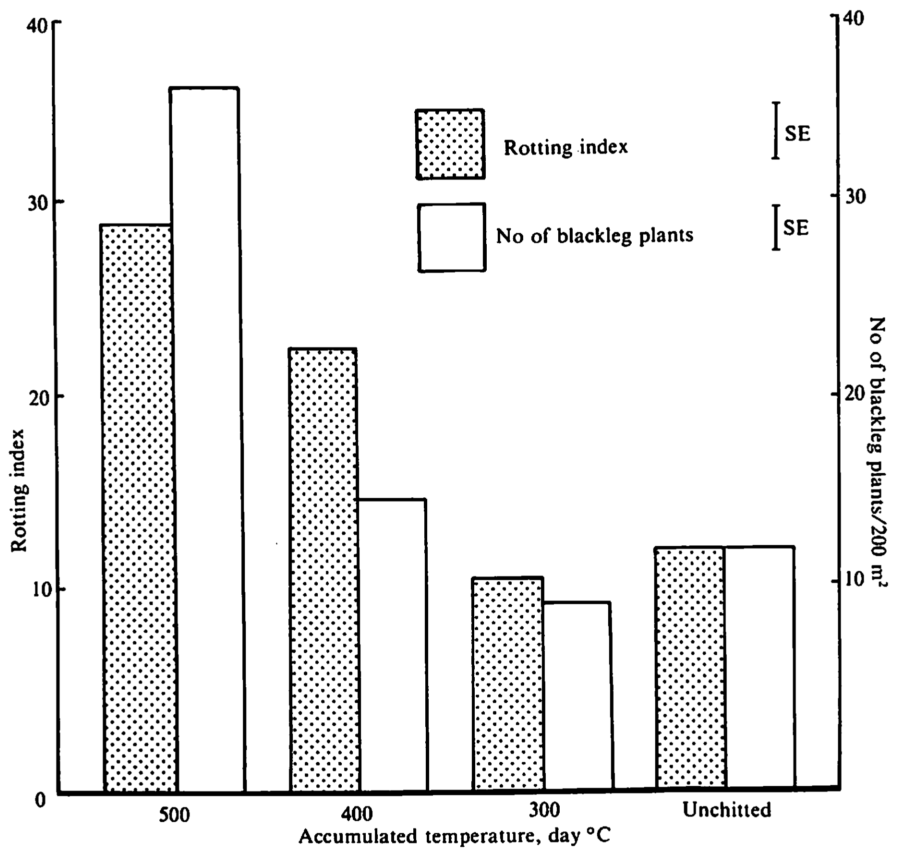
more quickly?". Observations at Edinburgh in two experiments with Pentland Javelin and Maris Piper (1980 and 1981) comparing tray chitting and mini-chitting with an unchitted control showed a marked increase in blackleg in the tray chitted seed which had been given about 500 day °C (>4°C). The mini-chitted and unchitted seed showed similar low levels of blackleg.

In 1982, a further experiment was carried out with Pentland Javelin in an attempt to explain this effect. Three levels of heat input during storage were compared with an unchitted control. Half of the seed from each treatment was damaged as described previously; the remaining half was undamaged as far as possible. Samples were dug at intervals to examine the mother tubers for the extent of break-down and the plots were scored for blackleg incidence. The effect of heat treatment on the rate of break-down of the mother tubers and the incidence of blackleg at the beginning of August are shown in fig 2. As accumulated temperatures rose above 300 day °C (>4°C), the rate of break-down of the mother tubers increased. This was associated with an increase in the incidence of blackleg. The 400 day °C treatment was not significantly greater than the control but 500 day °C more than doubled the number of blackleg plants. It is clear that, whatever the requirement for accumulated temperature might appear to be from the physiological point of view, it would be inadvisable for seed production to exceed a heat input of around 300 day °C from dormancy break. This does not conflict with our current recommendations for seed production. Where chitting is started at the beginning of February at 8°C and the crop planted in mid April, an accumulated temperature of 200 - 230 day °C (>4°C) from dormancy break will be given. There would appear to be little danger of increasing blackleg incidence at this level of heat input.

Returning to the problem of stem canker, there is every indication that the increase in incidence and severity of this disease is associated with the length of time the crop takes to emerge. In the days of inter-row cultivation when crops emerged in two weeks, plants were able to grow away quickly from attack. Our current weed control practice coupled with stone separation, means that crops receive their final covering at planting and take four or five weeks to emergence. Planting chitted seed would redress this balance and be an effective measure against canker.

The final implication is the problem which may arise from lifting crops early in dry warm weather particularly on lighter soils. Early lifting in these conditions gives rise to high damage levels through insufficient cushion on the harvester web. High ambient temperatures make it difficult to cool the crop efficiently. Damaged, it will be respiring at a high rate, particularly if it tends to be immature as is not infrequently the case with crops lifted early. There are two ways of tackling this problem. The first is to find a way of minimising the damage and the Scottish Institute of Agricultural Engineering may have the answer in their "variable area web harvester" which is discussed by D McRae (1983). The second is by judicious handling and storage. With efficient forced ventilation it should be possible to prevent temperatures rising even if, because of high ambient temperatures, the desired holding temperature cannot be achieved. Without forced ventilation, temporary stacking in an open barn has to be considered. With many of these crops it is wiser to omit the curing period and aim to keep the crop cool, particularly if there is no forced ventilation. Refrigeration would be a useful, though not essential, tool in this sort of early lifting situation. It is not suggested that refrigeration should be installed specifically for this purpose but on farms where seed, or a proportion of it, is being mini chitted in half tonne boxes the refrigeration facility which is essential to do this job properly could, in the autumn, be used to keep early lifted 'problem' stocks cool.

*Fig 2 Rotting of mother tubers and blackleg incidence in relation to accumulated temperature (cv – Pentland Javelin), 1982*




## A seed management system

A system of management which might be considered is that half to one third of the crop, depending on what varieties were grown, would be chitted in trays in an adapted building. The main store, with a forced ventilation system, would have an area sectioned off as a cold store to mini-chit the remaining half or two thirds of the seed. This area could be used for temporary storage of the earliest lifted crops, especially in years when ambient temperatures were high.

The way ahead in seed production lies in providing customers with a product which is reliably second to none. Early lifting is a means to this end and can best be achieved by chitting the seed. The advantages of chitting and the subsequent early lifting, in terms of disease and damage reduction and of overall quality, far outweigh any difficulties which might arise from changing to this method of husbandry.

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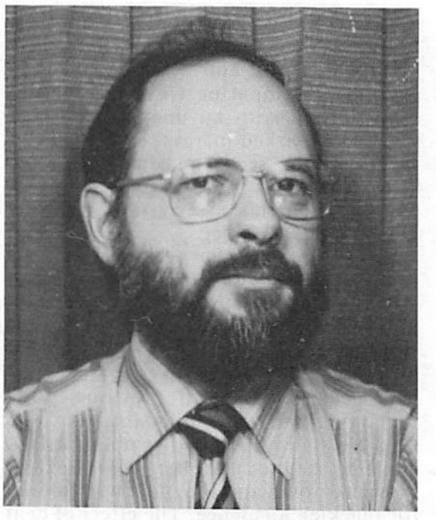
# Planting and mechanical handling of seed

**W F Maunder**

**Abstract**

THE selection of planters and the methods of handling the seed tubers are influenced considerably by the agronomic requirements of the potato crop. The paper highlights some of these factors and relates them to planter type and handling system. The recent developments in planter design and seed handling systems are discussed and an assessment of their possible merits made.

The importance in terms of planting rate of adopting an efficient, high speed handling system for seed tubers is emphasised.



## Introduction

IT is perhaps essential, before discussing planter types and systems of planting, to examine some of the agronomic factors that influence planter design and a farmer's choice of planter. Briefly, the planting system must sow seed tubers at the desired population, at a set even spacing, at the required depth and at a rate of work which will enable the whole crop to be planted before there is a significant yield penalty. Also, where the seed has been pre-sprouted the damage to the sprouts is kept to the minimum.

## Agronomic Aspects

### Seed Rate

The seed rate or population is determined by four factors — variety, seed size, intended use (ware/seed) and the relationship between the seed cost and the likely ware/seed monetary return. Table 1 illustrates the seed rates for a number of varieties based on seed size and weight, the seed cost ratio and variety requirements (MAFF 1982).

**Table 1 Influence of variety, seed size and seed cost on seed rate/ha**

| *Seed size, sets/50 kg* | *Seed rate (2:1 cost ratio for seed:ware), sets/ha* | *t/ha* |
|---|---|---|
| Varieties — Pentland Crown, Desiree, Pentland Ivory | | |
| 500 | 36,900 | 3.7 |
| 1000 | 55,900 | 2.9 |
| Varieties — Record, Pentland Dell | | |
| 500 | 32,000 | 3.2 |
| 1000 | 44,900 | 2.2 |

The typical seed rate for seed production is 60,000 sets/ha (2.5 - 4.5 t/ha) but the range may be as wide as 30,000 - 85,000 sets/ha. For ware production, the typical rate is 40,000 sets/ha (2.5 t/ha) with the possible range being 30,000 - 70,000 sets/ha (1.5 - 6 t/ha).

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In terms of planter choice, it is important to check that the planter mechanism can cope with the high populations at a reasonable rate of work or can accept the larger seed experienced with lower populations. This, of course, will depend on individual farm requirements. Most planters can achieve accurately the desired population when correctly calibrated, but evenness of spacing is more variable certainly with the less positive planter mechanisms.

### Seed spacing

Seed spacing is dependent on the population and row width. Table 2 illustrates the range of populations, row widths and corresponding spacings likely to be required (MAFF 1982).

mechanisms vary as to their ability to produce even spacing. The typical co-efficient in variation for the various planter mechanisms is given in table 3. (Bishop and Maunder 1981). The higher the percentage co-efficient, the more inaccuracy in spacing.

**Table 2 Seed spacing, cm, for different plant populations and row widths**

| *Population, sets/ha* | *Row width, cm* 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|
| 20,000 | 71.4 | 66.6 | 62.5 | 58.8 | 55.5 |
| 40,000 | 35.7 | 33.3 | 31.3 | 29.4 | 27.8 |
| 60,000 | 23.8 | 22.2 | 20.8 | 19.6 | 18.5 |
| 85,000 | 16.8 | 15.7 | 14.7 | 13.8 | 13.1 |

The factors which are relevant to the farmer are: is the planter suitable for the desired row width spacing and can it meet the anticipated range of spacings within the row required? Even spacing within the row is considered to be of more importance now than was the case a few years ago. The optimum space within the row has been selected on the basis of variety, seed size and cost. If spacing is irregular, some compensation from the extra room between tubers would result but a marked irregularity can reduce yields by as much as 2 t/ha (MAFF 1972). This can also lead to more outgrades and a reduced marketable yield. Planter

**Table 3 Evenness of tuber spacing — planter types**

| *Planter type* | *Co-efficient variation, mean %* |
|---|---|
| Twin cup fed | 27 |
| Moulded belt fed | 30 |
| Finger fed | 37 |
| Multi-belt fed | 40 |
| Flat belt fed | 57 |

With all types, closer grading of the seed tubers will improve the accuracy of spacing. This is particularly the case with the belt-type planter mechanisms. Split grading the seed into grades with a 10 mm range is essential and even closer grading is considered worthwhile with some planters.

Tuber shape will also affect the regularity of spacing. The likelihood of misses and doubles is more prevalent with varieties producing long oval or long shaped tubers. It is important that the planter mechanism is able to cope with the various shaped tubers and that the farmer is aware of the limitations that might be imposed by any particular mechanism. Various manufacturers will supply inserts for cup-fed planters to suit various seed sizes and shape.

### Correct depth

The depth of the seed tuber influences greening, damage and, indirectly, the degree of clod at harvest. Irregular depth control is quite often a problem with wide planters which have fixed planting mechanisms. Planters of this type should always be fitted with floating coulter furrow openers and it is essential that a level seed bed cultivated to an even depth is achieved prior to planting.

**Rate of work**
Work rate is dependent on many factors; the planter, its mechanism, row width and number, seed spacing, handling system and labour available and the method of pre-planting cultivations. Stone windrowing which is a cultivation method, may delay planting as it requires soil conditions drier than that for conventional cultivations. The work rate of stone windrowers is in the region of 0.4 — 0.7 ha/h. However, the benefits of stone windrowing when required, outweigh this disadvantage. The important of planting rate is emphasised by the effect of delayed planting on yield. Normally, if a farmer can get all the farm area planted within ten working days, then there will be little noticeable effect on total yield. In Eastern England, the 13th April is a reasonable date after which to expect a drop in yield from delayed planting amounting to some 0.35 t/ha per day until about mid-May (MAFF 1971); in reality this drop in yield will be lower at the beginning of the period than at the end. It is essential, therefore, to establish the potential work rate for a particular planting and handling system before committing yourself to purchasing any equipment.

This information must relate to the likely seed rates, spacings and seed size. The higher the seed rate, the slower many seed planting mechanisms have to operate. Organisation of planting, as will be shown later, can influence dramatically the work rate of planters.

**Planting sprouted seed**
The primary objective of sowing sprouted 'seed' is to achieve earlier growth and faster initial bulking up of earlies and main crop, with the intention of producing an earlier marketable yield for earlies and earlier maturity for main crop varieties. Much of this advantage is lost if the sprouts are damaged and removed during handling and planting. A typical reduction in yield due to damage of healthy sprouts is 1.8 t/ha. If these are soft white sprouts, the loss is increased further. Short green sprouts tend to suffer less damage during planting and handling than soft white sprouts of the same length (MAFF 1972).

It is very often the condition of the seed, the method of sprouting and the degree of split grading which can have an overriding effect on the yield reduction brought about by different planting mechanisms. Closer grading can reduce yield loss from damaged sprouts in most automatic planters. This allows planter selection mechanisms to be presented with a shallow depth of seed and more accurate setting of control shutters, etc.

It has been shown over many years that the bulk sprouting of seed and bulk handling had lead to a reduction in yield over conventional sprouting in trays manually handled. Recent trials at Terrington Experimental Husbandry Farm with the variety, Pentland Crown, have shown very favourable results with 500 kg wooden boxes, the mesh crate and three tier shelved box in comparison with tray sprouting. Emphasis, however, is placed on the level of management, the choice of variety and environment of the buildings used for sprouting.

## Automatic planters

**Planter types**
It is not possible in this paper to examine fully the various types of planter. Briefly, therefore, they can be divided in five types according to their metering mechanism.

Positive mechanisms — Cup fed
Moulded belt fed
Finger fed
Non positive mechanisms — Flat belt fed
Multi-belt fed

The following table indicates comparative work rates for these various planter types working on a ten day period and operating for about eight hours per day. It must be realised that the overall rate of work is determind by a number of factors — organisation at planting, seed handling system, gentleness to seed, etc, so these figures must be interpreted on this basis.

**Table 4 Planter performance**

| *Planter type* | *Overall rate of work, ha/row/10 days* |
|---|---|
| Cup fed (twin) | 17 |
| Moulded belt fed | 12 |
| Flat belt fed | 20 |
| Multi-belt fed | 20 |
| Finger fed | 17 |

Moulded belt, flat belt and multi-belt are generally more gentle to chitted seed — but that does not mean that the other planter mechanisms cannot be operated in a gentle manner.

**Planter developments**
Recently, a new fully automatic planter has been introduced — the Smallford Setronic potato planter. The basic principle was developed by the Scottish Institute of Agricultural Engineering (Carruthers 1983) with the electronics developed specially by the National Engineering Laboratory. The planter comprises a full width hopper mounted above two feed belts which discharge into two planting belts running at right angles to the feed belt and in-line with the potato furrows.

The feed belts collect rows of six tubers in individual moulded cups which convey them up and out of the hopper with a regular intermittent action into the planting belt, six at a time. The planting belt is divided longitudinally and has flights spaced alternately across its length forming compartments into which the tubers are transferred.

Each compartment is twice the width of the feed belt cup and, by diverting alternative tubers to back and front of the belt, positive transfer from feed belt cup to planting belt compartment is achieved. As the planting belt drops to the ground level for planting, the seed rolls or slides down the slope until it reaches the compartment dividing flight thus ensuring accuracy at the release point.

Detectors located above one row of the feed belt cup, before the discharging point, detect missing tubers. Two independently powered make-up belts on the down stream end of each feed belt collect tubers from the hopper and fill spaces on the planting belt caused by missing tubers on the feed belt. Infra-red detectors placed above the make-up duct ensure they index-on until they have a tuber available to fill the next space in the planting belt.

Tuber spacing on the planter is push button selected and is achieved by the micro-processor controlling the speed on the hydraulic motor in relation to the land wheel transducer and the spacing selected. A hydraulic motor drives the planting belt.

A proximity switch operated by a metal insert located on every sixth flight of the planting belt, causes a solenoid operated spring clutch to drive the feed belt from a constant speed shaft by means of a chain and sprocket. Timing of the discharge is adjustable by moving the proximity switch to ensure that accurate transfer will take place at all planting speeds. A push button priming facility is fitted to the planter. This device can also be used as a means of testing the function of the planter. Tuber spacing is from 10 cm to 50 cm in 1 cm increments and is push button selected. The machine will plant 30-55 mm graded seed without split grading. The planter is capable of planting up to 500 tubers per minute per row (eight tubers per second per row) which gives a forward speed of 10 km/h at 30 cm tuber spacing.

At this stage, there is no test data available for this machine but it is understood from the designers and manufacturer that tests will be carried out this spring. If the planter performs as the designers and manufacturer hope, then it should provide a high speed fully automatic planter which is suitable for sprouted seed. It should provide accurate spacing of seed as well as coping with a range of seed sizes. The electronic control of the machine offers the facility of finger tip selection of seed spacing, which may lead to greater precision in the whole area of seed rate, spacing and tuber population.

## Handling seed potatoes

The choice of system for handling seed potatoes must depend on a number of factors:

- labour available
- area to be planted
- whether seed is sprouted or not.

Controlled sprouting will involve handling the tubers into the store whether this is a glasshouse or a controlled environment building, removing it from store in the spring, and transporting to the field and planter. This takes time and a great deal of labour, certainly when conventional chitting trays are used.

The introduction of high-speed automatic planters in recent years has highlighted the inefficiency of traditional handling methods. Hand fed planters travel at about 1.6 km/h, so the time spent filling the planter is not significant overall. With high-speed automatic planters which can travel at speeds up to 10 km/h, filling time by traditional methods can account for up to 50% of planting time. To make full use of their planting potential, bulk seed handling is essential.

Table 5 clearly indicates the benefits of improved seed handling with high speed planters.

Cut filling time by half with a high speed planter and the benefit is a 22% increase in work rate but, with a slow planter, it is only five per cent.

**Seed handling systems**
There are four basic systems of potato seed handling using various types of container and systems of operation. Figure 1 illustrates the various systems (Bishop and Maunder 1981).

1 Tray systems
  — trays by hand (A)
  — trays on pallets (B)
  — trays to bucket (C)
  — trays into bulk box (D)
2 Sacks on pallets (E)
3 Bulk container
  — mesh crate (F)
  — shelved and pallet box (G)
4 On floor to trailer (H)

**Tray systems**

*Trays by hand*
Handling trays by hand has the greatest labour/time involvement. Filling the planter by hand can take from 10-20 man minutes per tonne.

*Trays on pallets*
This is the next stage in improving seed handling. Special skeleton two-way entry pallets are available whose base area of 1500 × 900 mm suits four trays. Stacking 7 to 10 high is possible, particularly if the central four posts of the top layer of boxes are wire-tied for transit to give increased stability.

These next two systems speed handling into the planter but do involve double handling of the seed tuber and can lead to increased sprout damage.

*Trays to loader bucket*
The technique relies on the trays being tipped into the forklift or fore-end loader bucket in the field while the planter is still planting. The bucket can then be tipped into the planter at the headland at a rate of 4–5 man minutes per tonne. One man can keep a 4-row high-speed planter moving. It is, of course, useful to be able to vary the amount of tubers into the planter hopper as row lengths vary.

A bucket with a controlled hydraulic tipping action is an advantage, allowing careful transfer of seed to the planter hopper.

*Trays to bulk box*
In the chitting house or in the field, seed is transferred from the trays into a bulk box. The box should not be too deep, be wide enough to suit the planter hopper, and have a bottom gate for tuber discharge. Planter filling time is short but extra labour is required in the store for box filling. The efficiency of transporting the tubers to the field is improved as the trailer will carry an increased capacity. The Scottish Institute of Agricultural Engineering hinged box could be used to advantage with this type of system.

**Table 5 Effect of reducing filling time on planting rate**

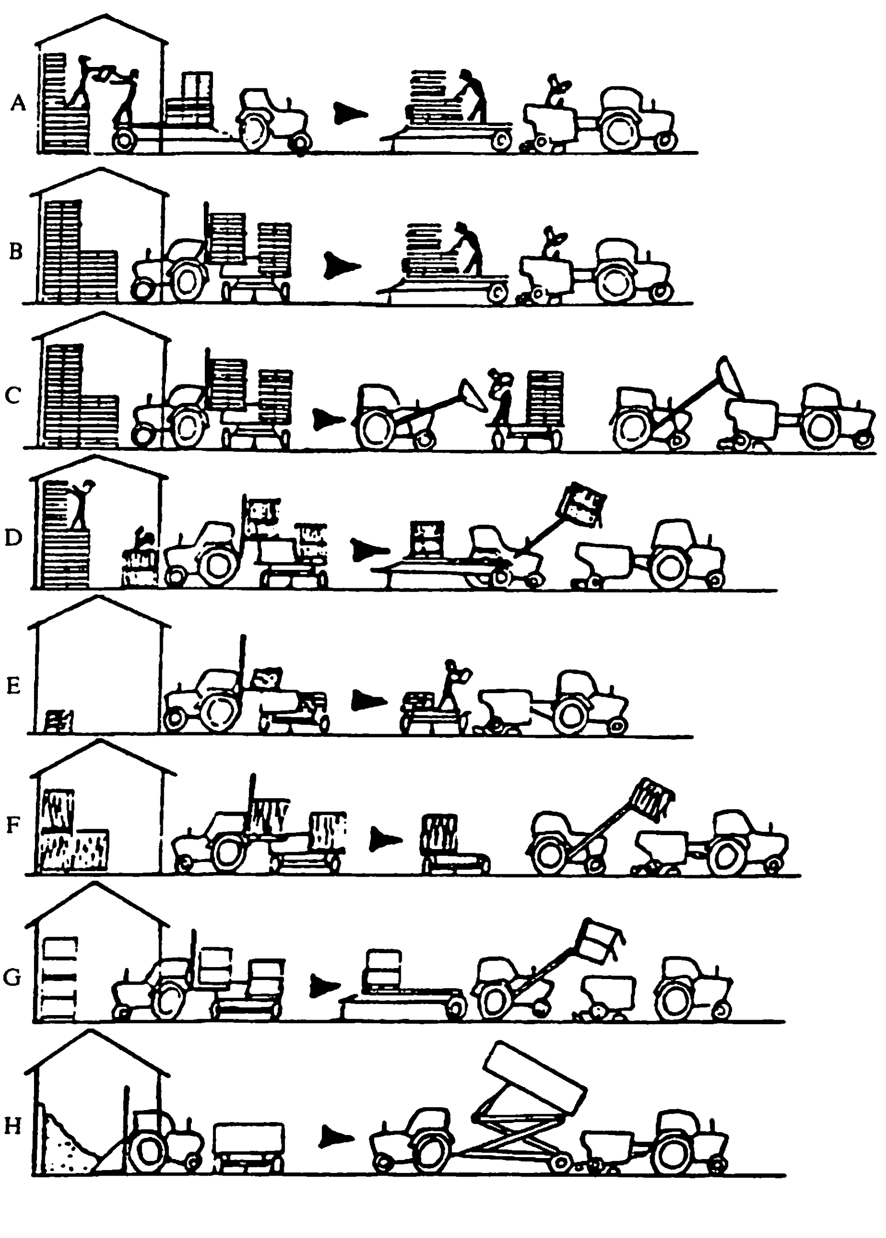
| *Speed, km/h* | *Planting time, min* | *Filling time, min* | *Turning time, min* | *Work rate, ha/h* |
|---|---|---|---|---|
| 1.6 | 33 | 5 | 3.3 | 0.21 |
| 1.6 | 33 | 2.5 | 3.3 | 0.23 |
| 10 | 5.5 | 5 | 3.3 | 0.64 |
| 10 | 5.5 | 2.5 | 3.3 | 0.78 |

**Sacks on pallets**
Keeping the seed in sacks or nets means that either the seed must be delivered late, or it must be stored and possibly sprouted in bags — this is often difficult to do successfully without forced ventilation and refrigeration.

Filling the planter using sacks is quicker than using trays, but not as speedy as bulk systems. Filling times of up to ten man minutes per tonne have been recorded.

**Bulk containers**
Handling seed in bulk reduces the labour requirement and speeds handling at all stages. The main advantages over trays can be outlined as follows:—
— planter filling time reduced to 3–5 man minutes per tonne compared with 10–20 man minutes per tonne for trays;
— filling the containers and putting into store takes less time (40 man minutes per tonne compared to 120 man minutes per tonne);
— bulk containers can take less room within the store;
— trailers can be used more efficiently,

*Fig 1 Potato seed handling systems*



enabling larger loads;
- handling with forklifts avoids manual work;
- cost of containers can be less than trays.

There are disadvantages:—
- with some containers sprout control can be difficult, requiring refrigeration and forced ventilation;
- inspection for diseased tubers is difficult;
- bulk systems of chitting do not always offer the yield advantages of tray chitting.

*Mesh crate*
The mesh crate is a commercial bulk chitting container developed from the crate originating at the Terrington Experimental Husbandry Farm and manufactured by Coningsby Metals Limited. The crate with dimensions of 1500 mm long, 910 mm wide and 940 mm high will hold approximately 525 kg of seed. It is made with an angle-iron outer frame with weld-mesh sides and has a removable liner of mesh which forms vertical pockets into which the tubers are placed. Light and ventilation can enter through the vertical gaps between the pockets.

Crates with side-opening gates are available as well as units suitable for inversion tipping.

The containers can be used in conventional chitting stores and provide a complete mechanical handling system from store to planter. It is essential, however, to maintain good control over the store environment; long sprouts will result in chit damage and difficulties with emptying the crate can be experienced.

*Shelved pallet box*
This slatted wood container is fitted with two side opening gates, one above the other. The box is divided into two sections with a central shelf which can be removed to allow the bottom layer to be filled. To avoid uneven chitting, the container should not be overfilled, but an adequate gap left for ventilation. Because the layers of tubers are deeper than those of trays, illumination to some tubers is poor; good ventilation and temperature control is essential.

The container has dimensions of 1485 × 935 × 882 mm and will hold about 500 kg of seed. When handling into the planter the forklift must have adequate tilt for the tubers to flow out of the gates or a forward tippler must be used. A three-tier box is also available giving an increased capacity.

*Pallet boxes*
Pallet boxes can be used for handling into the planter and are suitable for mini-chitting seed if air can be forced through the box to give even temperatures; refrigeration is almost always necessary. A number of systems have been developed in recent years to give through ventilation to standard half-tonne or tonne slatted boxes.

**On floor to trailer**
With the advent of the large full-width hoppers on planters, it is possible to tip tubers into the planter using a high tip trailer. Where seed is unchitted or the tuber eyes are just open, the system may be possible but a reduction in yield over traditional sprouting is to be expected. A controlled environment store would be necessary.

Planter filling time is short at 2.4–3 man minutes per tonne.

**Recent handling developments**
Recently, two new 'seed' handling containers have been introduced, both products of the Scottish Institute of Agricultural Engineering (Carruthers 1983). The two containers are a bulk box and a chitting tray container. Each is split vertically and hinged at the top. These half tonne containers are placed by the forklift onto two pivoting 'goal post' type frames fitted over the hopper of a two row planter. The frames are opened and closed hydraulically, splitting and emptying the container into the planter hopper. The possible major advantages of these containers over existing handling systems are that they are carried on the planter and can be emptied on the move as the planter hopper empties — reducing tuber drop to the minimum and giving an increased capacity to the hopper. Turn round at filling should be fast as the box is not emptied completely at this stage.

There are many other ideas for improving the handling of seed. One manufacturer offers a trailer frame and bed which can accommodate a two row planter. Additional trays or sacks can be loaded on to this trailer, giving a larger holding capacity and increasing the potential row length.

One farmer operates two planters working alternately with the same planting team operating each planter. One man fills each planter while the other is planting. This is another way of looking at it and could be useful where fertiliser is applied at the same time as planting, but careful setting of the planters would be essential.

**Cost comparison**
Table 6 gives container costs based on the requirement to equip a 60 tonne store quoted January 1983 ex works less VAT.

**Table 6 Container cost**

| *Container* | *Approximate capacity* | *Cost each, £* | *Cost per tonne capacity £/t* |
|---|---|---|---|
| Wooden tray | 3 per 50 kg | 1.40 | 84.00 |
| Plastic tray | 3 per 50 kg | 2.50 | 150.00 |
| Wooden pallet | 28 trays | 5.50 | 11.79 |
| Half-tonne box | 500 kg | 18.00 | 36.00 |
| Shelved bulk box | 525 kg | 34.00 | 68.00 |
| Mesh crate | 500 kg | 77.47 | 154.94 |
| Hinged box | 500 kg | 65.00 | 130.00 |
| Hinged chitting container | 500 kg | 115.50 | 231.00 |

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# Better harvester design

**D C McRae**


### Summary

THERE have been few radical changes in potato harvester design in recent years, though many of the components have been improved. The major problem of separating stones and clods from potatoes has been successfully tackled by the X-ray separator and the introduction of stone windrowing techniques. Yet harvesters can still cause considerable tuber damage and throughput could be further increased.

Since the 1970s, efforts have been made to improve shares and developments, such as powered disc shares with driven scrapers which cause less damage and have much lower draught, have taken place. Less damaging web rods have been produced in prototype form. Research in North America and the UK has shown that potato damage is lower, if web speed and web/forward speed ratio are reduced. Some harvesters now have manual web speed control and, in the USA, a prototype automatic control has been successfully tested. In the UK, a web/ forward speed ratio meter has been shown to help in reducing potato damage.

The advantage of horizontal rather than vertical web agitation was established by the Scottish Institute of Agricultural Engineering work and now a harvester with a horizontally agitated web has been built. Another harvester with a variable area web is also undergoing tests.

Future developments are likely to include electronic control of all the principal harvester components and, on some self propelled harvesters, onboard potato damage monitoring may become feasible.


### Introduction

WHILST over the years, since the first potato harvesters appeared, there have been many attempts to depart from the basic configuration which is so familiar throughout Europe and North America, few of the variants have become well established. Basic components, such as the share, sieving and transporting web, haulm remover, elevating conveyor or drum, picking table (which is omitted on the increasingly popular unmanned harvesters) and delivery conveyor or self-emptying bunker, though they have undergone design improvements, have changed little in function.

Improvements have been made to many details of component parts. More extensive use of rubber cushioning beyond the primary web, automatic share depth control and simple mechanical agitation adjustment on some machines have helped to reduce damage. Variable speed drives to the webs and other conveyors and the provision of automatic height control where a delivery conveyor is fitted are further advances.

The major problem of separating potatoes from stones and clods at harvest time has been tackled in two ways. The X-ray separator on the harvester has dealt with the problem directly, though its potential for two-row machines has yet to be exploited. Other types of electronic separators are now being introduced, though as yet they have not become established in the UK.

The second approach has been to carry out stone treatments, the most successful of which has been the stone windrowing technique to remove stone and clod from the ridges prior to or during planting.

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Unmanned harvesters have become increasingly popular as the area of de-stoned land has been extended. Their spread has been furthered by the back-up of static X-ray stone/clod separators at the potato store. Further developments to utilise stone treatment machines at harvest time by removing beater bars and adding harvesting components are showing promise.

With all these improvements, one might ask: are there any problems? There is evidence that modern potato harvesters still cause too much damage and that a higher output would be desirable. The 1981 National Potato Damage Campaign showed that a typical 2-row unmanned harvester can cause around 8% severe damage to potatoes and over 39% internal bruising. Little detailed information is available on their throughput. In the 1978 harvest, two different makes of harvester used in an East of Scotland College of Agriculture trial (Witney 1980) harvested 0.33 and 0.55 ha/h, respectively (spot rate of work). It can be estimated from these figures that the seasonal work rates would be approximately 0.15 and 0.25 ha/h. In a typical season of 21 harvesting days, the faster harvester might lift up to 39 hectares of severely damage over 100 tonnes of potatoes in a 36 t/ha crop. Clearly from the above results, it can be concluded that there is scope for reducing tuber damage on the harvester and, in certain conditions, for raising throughput as well.

### Harvester components

In the mid 1970s, it was decided at the Scottish Institute of Agricultural Engineering to make a critical examination of the major components of a potato harvester and to assess any promising alternatives. Overriding considerations were, and still are, the need to minimise damage, whilst improving throughput and reliability.

**Shares**

Whilst fixed shares have advantages of simplicity and cheapness over alternatives such as powered disc or vibrating shares, they do have drawbacks which include high draught and susceptibility to blockage in weedy conditions, in sticky soils, or when digging downhill in dry conditions. When properly set, damage attributable to flat shares can be low, nevertheless, it may occur both at the leading edge and at transfer from the trailing edge to the front of the web where potatoes in the lower part of the ridge may encounter web rods travelling vertically at over 2 m/s.

Improvement in share performance can be achieved by using power driven disc shares (Hutchison and Fleming 1980). Table 1 summarises the typical performance of a power driven two-row

**Table 1 Comparison of the performance of a two-row powered double disc share with a conventional flat share fitted to identical diggers on heavy clay loam soil.**

| *Type of share* | *Damage index*[1] | *Draught, kg* | *Leavings, kg/ha* | *Soil uptake,*[2] *kg/ha* | *Clod uptake,*[3] *over 35 mm* |
|---|---|---|---|---|---|
| Disc | 120 | 136 | 271 | 195 | 25 |
| Flat | 193 | 639 | 349 | 116 | 50 |

[1] *For share and short web.*
[2] *Weight of clod and any remaining loose material passing over the web.*
[3] *% by weight of all the clod or remaining loose material passing over the web.*

disc share developed at the Scottish Institute of Agricultural Engineering. It can be seen that there are worthwhile reductions in draught, damage and clod uptake. The reduced damage is mainly attributable to the transfer of soil from the scraper disc to a point well rearwards of the front of the web (fig 1). The very much lower draught confirms other research work with disc shares, for example, that of Siepman and van der Weerd (1971) in Holland.

A disadvantage of the disc share is increased soil uptake, compared with the flat share, but provided that the disc diameter does not exceed 0.9 to 1.0 m, this problem can be minimised. Another drawback of the powered disc share is the higher cost, particularly where a hydraulic drive is used. A mechanically driven disc share is being developed at the Scottish Institute of Agricultural Engineering with the object of reducing the cost substantially.

**Depth control**

The enormous quantity of soil lifted per hectare when harvesting in typical potato land points to the need for accurate share depth control. Useful developments of automatic depth controls have been made by UK firms. There are problems in positioning the control sensors, because of the tendency of the ridge to bulge or even to be bulldozed ahead of the leading edge of the share. Disc shares cause scarcely any bulging and, therefore, errors in response to depth sensor signals are likely to be reduced with this type of share.

**The Web**

Until recently little attention has been paid to web rod design. Probit analysis of drop tests carried out at the Scottish Institute of Agricultural Engineering (McRae *et al* 1975) showed that, for several leading maincrop potato varieties, H50 — the drop height estimated to produce severe damage in 50% of the potatoes — was under 150 mm. More recent tests (Carruthers 1982) show the advantage of a curved but substantially flat web rod, 22 mm wide and 16 mm radius of curvature, compared to a standard 5 mm radius

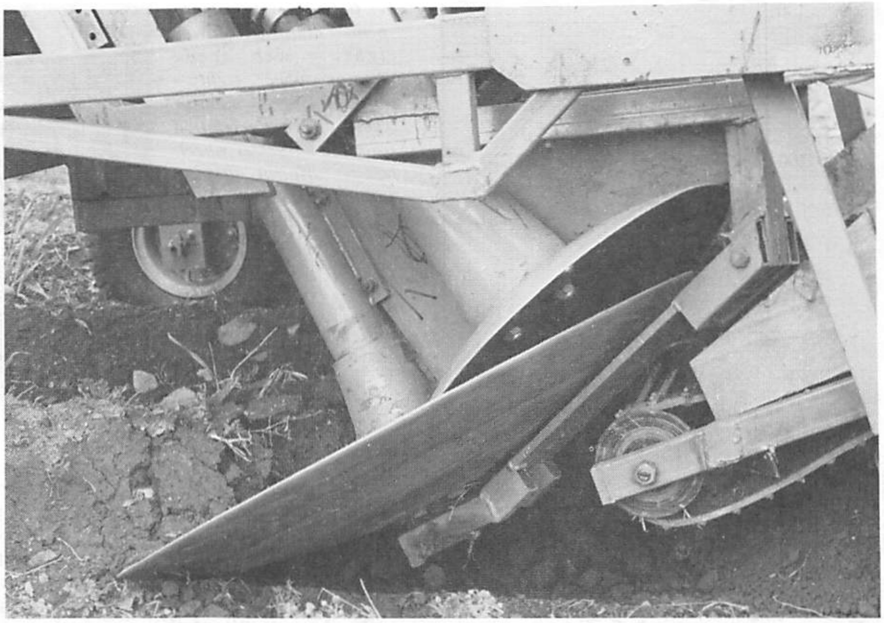


*Fig 1 The SIAE double disc share, showing transfer from digging and scraper discs to a point rearwards of the front of the web*

round section rod. Figure 2 shows the severe damage (deeper than 3 mm) and bruising incurred when potatoes are dropped from a range of heights on to the curved rod and fig 3 shows the damage sustained on a round bar. A potential drawback of the curved rod is the reduction in effective sieving area. This could be more than offset by improved methods of agitation.

In the mid 1970s, the relationships between web speed, forward speed and damage were explored at Washington State University (Thornton *et al* 1973) and in the UK by the Agricultural Development and Advisory Service research staff (1975) and Butson and Hamilton at the Scottish Institute of Agricultural Engineering (1978). The work cited shows conclusively that damage increases with web speed and with web/forward speed ratio. More recent work of Hamilton and Sharp (1978) gives added support to these findings (fig 4 and fig 5).

A practical outcome of this research has been the provision by some manufacturers of manual control of web speed. This is done for example on the Ransomes Sovereign harvester by means of a variable vee pulley drive to the web. On the Standen self-propelled harvester, a variable delivery hydraulic pump can be manually adjusted to control the speed of a motor driving the web.

Variations in the web speed alter the web loading, ie the quantity of soil passing over any specific point on the web. An interesting development in the USA at Washington State University (Hyde *et al* 1980) is a web load control system. The main components in this system are pairs of support rollers over which the web runs. These are connected to a strain gauged lever arm. The signals from the strain gauge are amplified and conditioned to control a linear actuator responsible for altering the speed of a hydraulic motor driving the web. It is understood that this system performs

*Fig 2 Histogram showing percentage of tubers severely damaged and bruised at each height when dropped on a curved bar (16 mm radius)*

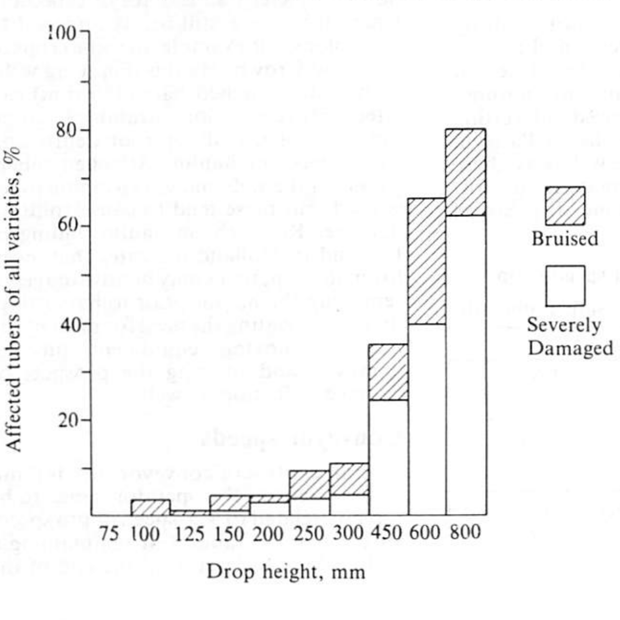
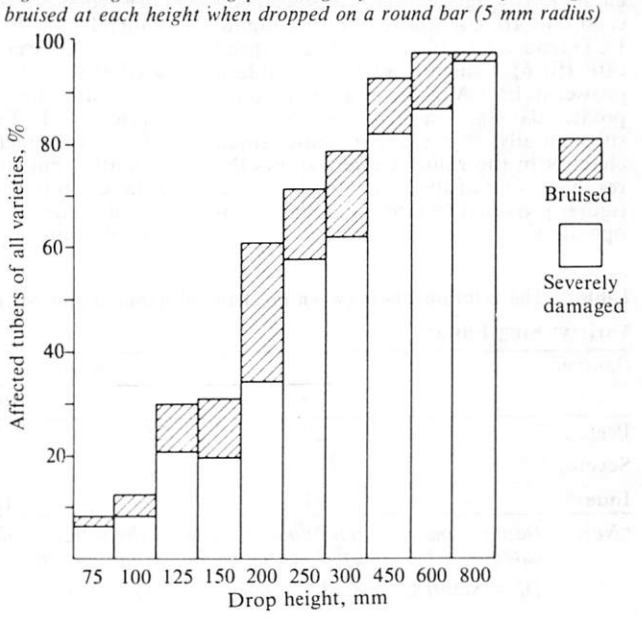



*Fig 3 Histogram showing percentage of tubers severely damaged and bruised at each height when dropped on a round bar (5 mm radius)*



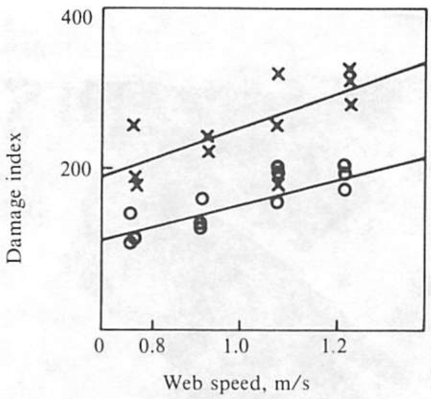



*Fig 4 Damage index as a function of web speed for Pentland Crown (x) and Maris Piper (o), 1977*

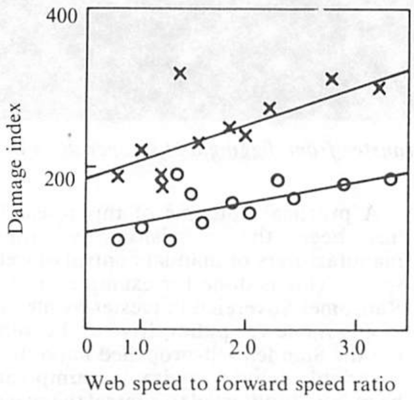
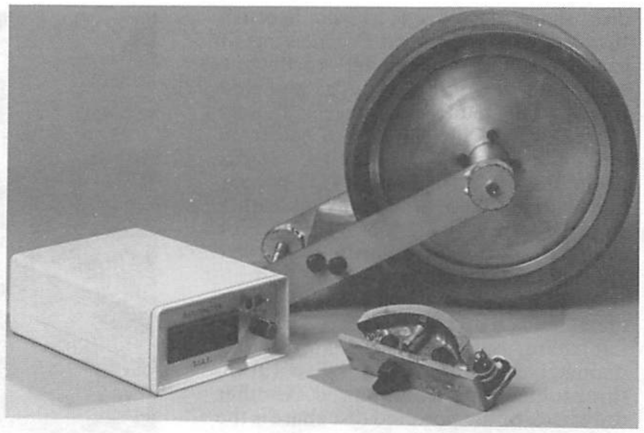



*Fig 5 Damage index as a function of speed ratio for Pentland Crown (x) and Maris Piper (o), 1977*

effectively over a range of working speeds.

The importance of controlling web speed in relation to forward speed has underlined the advantage of providing the harvester operator with a monitor. The idea of a web/forward speed ratio meter has been developed at the Scottish Institute of Agricultural Engineering (Carlow 1980) from a fixed unit, tailored specifically to one type of harvester, to a portable unit comprising a friction driven harvester wheel monitor and a web rod counter. The signals from transducers on each unit are combined to give a digital LCD read-out of the web/forward speed ratio (fig 6). Using the meter as a guide, a grower in East Anglia was able to reduce potato damage on his harvester very substantially, by making quite small changes in the ratio. Table 2 shows the results of one of the test runs, from test figures provided by Holbeach Marsh Co-operative.

*Fig 6 SIAE web forward speed monitor: lower right - web speed monitor; upper right - forward speed monitor wheel driven by friction from the harvester wheel; left - digital display ratiometer*



## Web agitation

Recent work (McGechan 1977) has underlined the need to review the agitation method used universally on harvester webs. These findings indicate that horizontal agitation is superior to vertical agitation for both sandy and clay soils. As a result of the experiments on agitation, the motion parameters were quantified. Horizontal oscillation frequencies of 3 - 5 Hz depending on conditions, with an amplitude of 25 mm are suggested. These should give a sieving time for 90% of the material on the web in a sandy loam of 1.1 - 1.6 s, whilst in clays, about 70% of the soil will pass through the sieve in 3.2 - 3.7 s. These figures can be applied where the web/forward speed ratio is 1:1. Using them, the ratio of web length needed for a clay soil, to that for a sandy soil is about 2.3: 1 over the speed range 1.6 - 10 km/h.

At the latter speed, the web would have to be some 10 m long, to give time for the soil to fall through. A change to a web/forward speed ratio of 2:1 alters the picture in complex ways. The soil depth on the web will be approximately halved, but some additional sieving will occur as the ridge is accelerated to the web speed from the forward speed. At a ratio of 2:1 the sieving time available is halved. With the high forward speed of 10 km/h, the transfer speed to the next conveyor or a cross conveyor would be from 10-20 km/h, this could cause serious tuber damage. The practical upper limit for the forward speed of a harvester is probably under 10 km/h.

A harvester with a horizontally oscillated web underwent preliminary tests at the Scottish Institute of Agricultural Engineering in autumn 1981. The machine showed interesting potential, but since the webs oscillated in a direction normal to the web rods, there was a tendency for the material to drift downhill on sloping ground. It is hoped that this problem will be overcome by mounting the oscillating webs at right angles to the direction of travel and oscillating them in a direction parallel to the web rods.

The problem of the wide difference in sieving area requirements between sandy soil and clay soil is being investigated in a second harvester at the Scottish Institute of Agricultural Engineering which has a variable area web. A carriage mounted on the harvester chassis moves an overlapping fold in the web, up or down the chassis (fig 7). This changes the discharge point from the front (agitated portion of the web) according to the conditions. When sieving is impaired by heavy soil or sticky conditions, the carriage is moved towards the cross transfer conveyor end of the web. Agitation will be either by conventional eccentric agitators, which impart vertical agitation, or by means of two hydraulically driven industrial shakers, with which it is hoped to impart horizontal agitation to that portion of the web between the front web cones and the carriage.

The overall advantage of the system could be that without any increase in web speed, or change in severity of agitation, it should be possible to handle varying soil conditions with a more flexible choice of settings.

## Haulm removal

The present provisions on harvesters for removing haulm and root material are not completely satisfactory, especially where tubers are still firmly attached to the stolons, for example, in some crops of Pentland Crown. Haulm removing webs with widely pitched bars (150 mm) can effectively remove long strands of haulm, but are not useful for root debris and short pieces of haulm. Attached tubers pass over the web unless a stripping roller is used, but these tend to cause splitting damage. Research on haulm pulling in UK and in Holland indicates that, even for maincrop, there may be advantages in removing the haulm prior to harvesting, thereby obviating the need for most of the haulm removing equipment on the harvester and offering the prospect of damage reduction as well.

## Conveyor speeds

Overall control of conveyor speeds if not in the hands of the operator, tends to be directly related to web speed or pto speed. In the UK desirability of maintaining a soil cushion at least until the end of the

**Table 2 The relationship between mechanical damage and web/forward speed ratio**

**Variety: King Edward** **Soil: Light Silt**

| *Damage* | *Ratio* | | | |
|---|---|---|---|---|
| | 1:1 | 1.2:1 | 1.4:1 | 1.6:1 |
| Peeler, % | 20 | 25 | 30 | 36 |
| Severe, % | 3 | 2 | 7 | 13 |
| Index* | 81 | 89 | 139 | 199 |

**Note:* *Damage index is determined by adding the weighted damage percentage in each category (the "scuffed" category has been omitted in the table) as follows:*

*DI = Scuffed, % + (3 × Peeler, %) + (7 × Severe, %)*

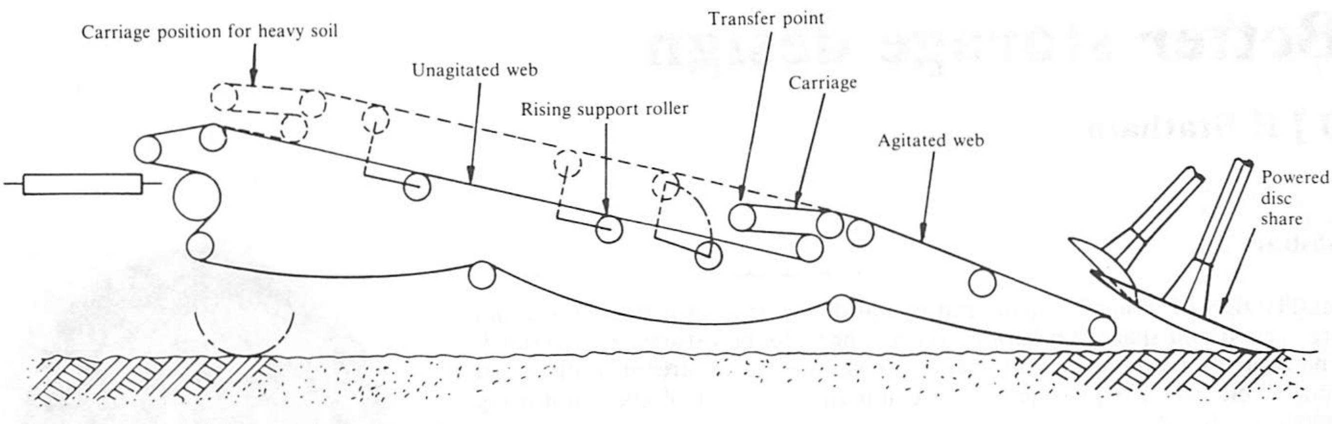



*Fig 7 Diagram of variable area web digger test rig*

primary web and sometimes further is accepted by many. In the USA, Thornton *et al* (1973) and, in Canada, Townsend *et al* (1976) have investigated control of other conveyor speeds as well as the web. They have found it effective to reduce the conveyor speeds progressively to ensure complete fill of the conveying area with potatoes, which provide mutual cushioning. Townsend derives formulae for conveyor speed control according to conditions.

Delivery conveyors have altered little over the years. Generally, they are heavy and vulnerable to collision damage in spite of the relatively simple engineering design required to fit break-back arrangements. Height control systems are now available (McRae 1974) and one UK importer is fitting an electro-hydraulic height control using mercury switch sensors.

With improved throughputs of harvesters, increased delivery conveyor speeds are required if over-wide conveyors are to be avoided. This presents problems at the discharge end of flighted conveyors, due to the high angular velocity imparted to the flights as the conveyor negotiates small diameter head rollers or sprockets. Sometimes potatoes are thrown from the conveyor quite violently. Another feature of flighted belts is the often excessive drop for the potatoes at the feed-on point. One manufacturer has introduced an interesting folding flight arrangement (fig 8) which substantially reduces the drop from the cross transfer conveyor to the delivery conveyor.

## Future developments

The application of some of the developments in share, web and conveyor design mentioned, could achieve improved throughput with less mechanical damage. If the present single- and two-row intake harvesters are to remain dominant types then increased forward speeds to achieve greater throughput may raise some problems at transfer points on the machines, though these are by no means insuperable.

Further improvements to basic components are to be expected. Changes in web rod configuration may be beneficial. The use of polyurethane and other plastics for rollers is improving the life of these components on abrasive soils in the USA by a factor which more than offsets the increased costs.

Electronic controls on high capacity harvesters and monitoring equipment, such as the web/forward speed ratio meter, will help the operator to achieve optimum settings of all the major parts. This facility could be particularly effective where the harvester is self propelled and the operator has a good all-round view of the machine. The present situation of delayed response to damage as it occurs during harvesting is likely to become even more of a problem as the throughput rises. On the largest self-propelled harvesters, there could be a case for on-board damage monitoring equipment used by a specially trained operator, in addition to the driver. Ideally such a system would have to include a very rapid internal bruise identifying system and this has yet to be developed.

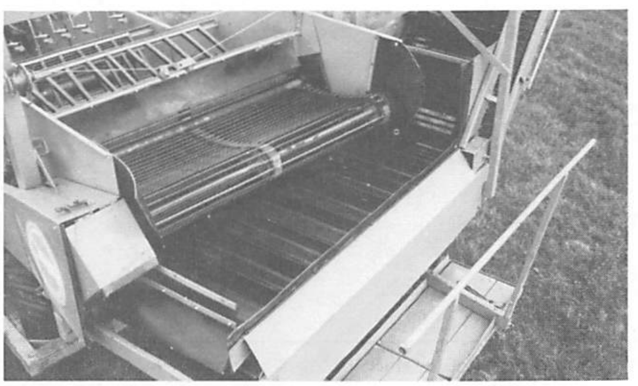


*Fig 8 The KeyAg two row harvester with folding flight delivery conveyor*

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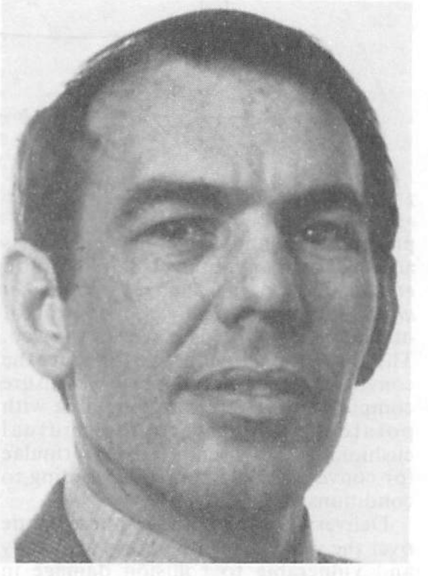
# Better storage design


## O J H Statham


### Abstract

METHODS of designing main and lateral duct systems for bulk stores and pressurised and space ventilation systems for pallet box stores are described. The control of vapour pressure deficits in ventilating air streams is discussed and the elemental requirements of a comprehensive control and monitoring system are listed.


## Introduction

A BETTER potato store house must be able to create the optimum storage environment at an economical cost. To achieve these objectives due attention must be given to the ventilation rates provided and to the degree of efficiency with which the air can be distributed within the store and how it may be made to directly influence the crop environment.

Optimum ventilation rates in the UK have traditionally been stated at 0.02 $m^3$ $s^{-1}$ $t^{-1}$ for potatoes in bulk, whilst for crops stored in pallet boxes the ventilation rate is sometimes increased to 0.025 - 0.03 $m^3$ $s^{-1}$ $t^{-1}$.

The spiralling costs of energy, fans and ductwork now require serious consideration to be given to reduced air volumes and it becomes more important that the air which is applied to the store should be used efficiently. Efficient utilisation will depend upon properly programmed controls, accurate selectivity and temperature measurements and, rather more fundamentally, uniform air distribution systems within store.

In most new storage installations, there is invariably scope to improve the efficiency of air distribution by adopting appropriate design measures. There is also considerable scope for improved control systems and some elementary air conditioning.

## Bulk stores ducted systems

Ideal air distribution can be obtained in a ventilated floor store where the distance between gaps is extremely limited, often described as "drive over" floors.

Where air is distributed through separate underfloor ducts, their spacing should be limited to L = 0.8H between centres, where L is the centre to centre distance between ducts and H is the stack height. For above floor ducts, spacing should be to the formula L = H. Providing these centre to centre dimensions are not exceeded, the air velocity through the potatoes mid-way between the ducts will be about 80% of that directly above the duct.

Air should also be uniformly distributed over the entire length of the duct whether it be a main air duct or a lateral. However, if the duct has a constant cross-sectional area, the volume of air moved by the duct will continuously decline owing to discharge through the duct outlets, this will result in the total velocity pressure at the duct outlet being converted to static pressure at the end of the duct. This increase in static pressure which reaches its highest value at the end of the duct will lead to very uneven air distribution, because it is static pressure which determines the air velocity through the discharge openings.

The effect can be negated by the use of equal pressure ducts (fig 1) where the characteristic variation of the cross-sectional area of an equal pressure duct is represented by the full line. Air distribution through an equal pressure duct having equal size discharge openings is independent of air velocity and, as a result, the duct size and the static gauge pressure inside the duct can be kept small. However, since high air velocities necessitate a considerable increase in fan power consumption, it is preferable to limit the air velocity at the duct inlet to 6 m/s.

An equal pressure duct, as illustrated in fig 1, is too complicated to build and, therefore for practical reasons, a tapered configuration is adopted as indicated by the dashed line. Table 1 sets out the recommended ratios between inlet and end cross sections of distribution ducts of differing lengths.

The static pressure in this kind of duct changes only to a limited extent. To achieve even air distribution, the velocity should be maintained at or above 4 m/s at the discharge point and this value corresponds to a maximum effective cross section at the discharge opening of 0.25$m^2$ per $m^3$/s of air blown through the duct. However, since anything between two-thirds and three-quarters of the discharge openings will be blocked by potatoes when stored in bulk heaps, the area must be increased to between 0.75 and 1$m^2$ per $m^3$/s of discharge air.

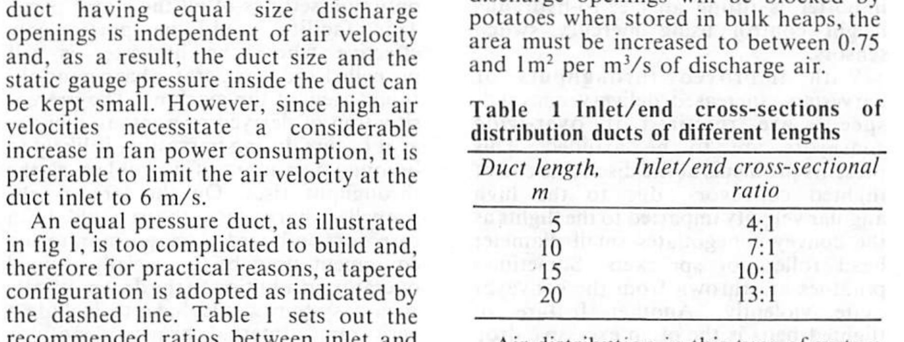
**Table 1 Inlet/end cross-sections of distribution ducts of different lengths**

| *Duct length, m* | *Inlet/end cross-sectional ratio* |
|---|---|
| 5 | 4:1 |
| 10 | 7:1 |
| 15 | 10:1 |
| 20 | 13:1 |

Air distribution in this type of system can best be tested when the store is empty. Providing any irregularities found are small, air distribution should prove more uniform once the store is filled.

Alternatively, where ducts of equal cross section throughout are to be employed, say in the case of a main air duct, it is recommended that the effective

*Fig 1 Cross sectional area of an equal pressure duct and of a more practical form of tapered duct*





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area of the discharge opening should be kept equal to or smaller (0.75) than the cross section of the duct. In general, the air distribution through a duct of equal cross section will become more uniform the higher the pressure losses in the system; thus air distribution will become more uniform the higher the heap of the potatoes and the greater the air flow per tonne of stored crop. If the equal section duct is a lateral, bear in mind that some 65% to 75% of the discharge area will be blocked by potatoes and the duct will need to have a total area of discharge openings between three and four times its cross section.

## Air distribution in box stores

The ventilation of box stores presents a greater range of alternatives. Bear in mind that air will never pass through the contents of a box (unless it is a pressurised system) until such time as the resistance imposed by the velocity of air passing around the boxes equals the resistance engendered by the contents of the box itself. Of the two positive ventilation systems which may be employed, the letterbox layout is the easier to understand. However, the more recently introduced differential pressure system has the theoretical advantage of allowing a greater run of boxes to be ventilated. In any pressure ventilation arrangement, the boxes in a given row must be stacked to a close tolerance to minimise air losses since the 'distribution duct' formed by the fork entry openings has an equal cross section. Both this cross section and that of the discharge openings being determined by the construction and the number of boxes, the number of boxes per discharge opening in the main duct must be limited if uniform air distribution is to be obtained.

The number of boxes in a row is determined by the requirement that the total discharge area of all box bases in a row must be equal to or smaller than three to four times the cross section of the pallet fork opening. Since the distribution duct is not absolutely air tight, high pressure cannot be built up in it. For this reason the air velocity through the discharge openings of the filled boxes must be limited to 3 to 4 m/s. For this reason, the velocity on admission to the pallet of the first box must not exceed 4 m/s.

Assuming no air loss, the number of boxes, N, in a row can be determined as follows:

$$N = 4 \times \frac{\text{Cross-sectional area of pallet duct (m}^2\text{)}}{\text{Volume air flow through each box (m}^3\text{/s)}}$$

In practice even with good stacking, air losses will be a minimum of 20% and could easily be double, in which case N = 3.3 or N = 2.

The total area of the gaps in the bottom of the box is given by the equation:

$$\text{Area} = 3 \times \frac{\text{Cross sectional area of pallet duct}}{\text{Number of boxes}}$$

The main duct of letterbox ventilation systems will usually have an equal cross section throughout its length. For good air distribution through all the distribution ducts connected, the cross section of the main duct must be equal to or larger than the cross section of all the connections. However, there would be no limitations on cross section of equal pressure main ducts.

There are four distinct ventilation systems which may be employed in a non-positive ventilated box store.

(i) Air may be distributed through an arrangement of underfloor ducts. Whilst this system can be designed to give an initial even air distribution over the floor area of the store it is infrequently specified because of the high capital costs involved.

(ii) Space ventilation relies upon air being introduced to the box store either by free discharge or, to achieve better initial distribution, by the use of a primary spreader duct. Passage ways are appropriately located between blocks and columns of boxes in order to give direction and achieve a crude measure of distribution. Although positive ventilation of the contents of individual boxes is not achieved, providing sufficient volumes of air are used (perhaps 0.025/0.03 $m^3\ s^{-1}\ t^{-1}$), reasonable results can be obtained, relying on convection and conduction to dissipate the products of respiration produced by the potatoes within each box.

(iii) A simpler and yet in many ways more effective ventilation system utilises the empty head space above the boxes as a vast plenum chamber into which the ventilating air is thrown. Providing it is given sufficient velocity and direction, it may be made to achieve reasonably even distribution. The ventilating air being colder and consequently denser then falls between the box interstices before being exhausted or recirculated from the store at low level. If the system is to work satisfactorily, it is important that convectively induced stack temperature gradients are prevented from occurring and, to this end, the regular use of recirculation is important to the success of the system.

(iv) Finally, a ventilation system based upon cross flow top ventilation may be employed. Inlet and exhaust points usually in opposed gable ends of the building are used to induce a cross flow of ventilating air, the temperature of the store being at all times dependent upon the head space temperatures being maintained. Forced ventilation can be used for this system but more typically natural ventilation of the store is encouraged. The Scottish Farm Buildings Investigation Unit has recently developed an automatically controlled natural ventilation system for potato stores. The system consists of a controller linked to mechanically actuated flaps in the gables of the store and the controller attempts to hold the crop at a pre-set temperature by opening the ventilation flaps whenever the store temperature rises above a set value and when ambient conditions are suitable. A refinement of the system is the use of a number of small recirculation fans with polythene distribution socks hung from the roof. These fans are run continuously and recirculate the warm air from the top of the boxes to reduce the temperature gradient within the store.

## Air conditioning

Air is the medium used to control the environment in a potato store and temperature must always be the dominant management factor. Any ambient ventilation system is clearly constrained by the availability of air at a suitable temperature and fig 2 indicates the general extent to which any given store temperature can be maintained in the south east of Scotland where there is no recourse to refrigeration equipment (Lang 1982). It is generally accepted that the ambient air temperature, at any given point during the storage period, must be below the desired holding temperature for at least 25 - 30% of the time. Where temperatures lower than that indicated by the curve are required, mechanical refrigeration must be installed. Generally speaking, refrigeration is limited to seed storage or where table or processing potatoes are to be stored long term say until May or June.

Considerable refinement to an ambient air system may be provided by an ability to recirculate the air and, more particularly, to provide proportional air mixing.

Recirculation of the store's environment can be used for the control of structural and interstitial pile condensation; it can be used to control stack temperature gradients during periods of non-ventilation; it may be used to induce more even curing temperatures and, during periods of very severe weather, can be used as an anti-frost measure by re-distributing the reservoir of warmth contained within the store, thus minimising the risk to potatoes on the periphery of the pile.

If a proportion of this warmer recirculated air can be mixed with incoming ambient air, precise control of ventilating air temperatures can be achieved and ventilation may take place no matter how low the ambient air temperature is. Precise control of ventilating air temperatures has now become an important consideration in many processing stores where thermal shock and sugaring of the crop has to be avoided at all costs.

Combinations of forced ventilation, recirculation and air mixing can ensure, in a well designed system, that store temperatures do not fluctuate by more

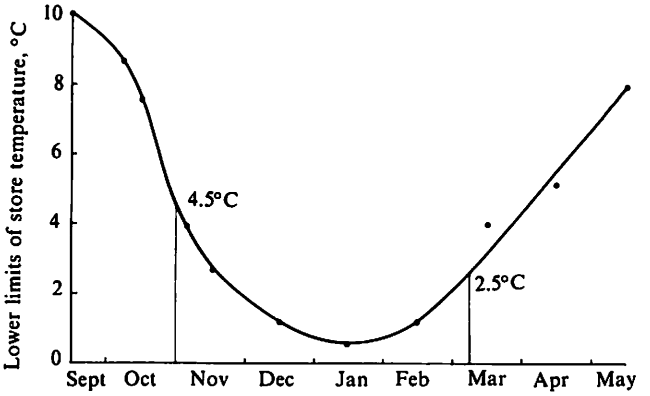


*Fig 2 The lower limit of store temperature likely to be achieved, based on the average of the 20 year period 1959-78 (ambient temperature > store temperature for 30% of time)*

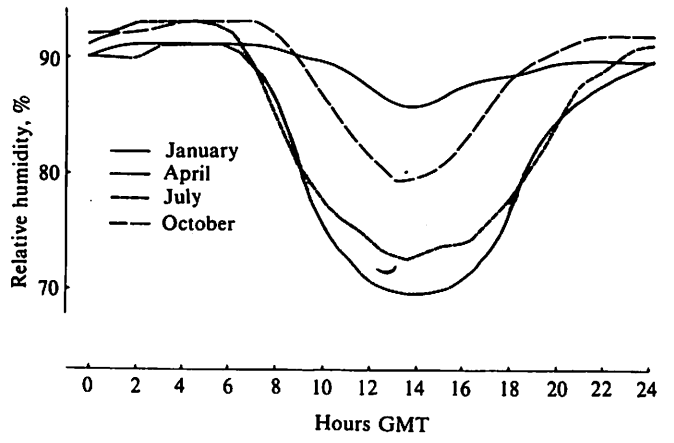


*Fig 3 Relative humidity – Eskdalemuir (average diurnal variation 1957–1970)*

than 2°C overall. However, not only is the control of temperature important if losses are to be minimised in a store, but humidity and the extent of any vapour pressure difference between the crop and the ventilating air are important. Under systems of forced ventilation, evaporative weight loss from the crop is proportional not to the ventilation rate but to the exposure time and to the relative humidity of the air stream. It is advantageous to ventilate potatoes with very humid air, the aim being to achieve a relative humidity of 95% or higher. If ambient relative humidity is lower than this, water can be evaporated into the air and there will be a secondary beneficial effect in so much as the latent heat of evaporation will be drawn from the air reducing its temperature and thus increasing its cooling capacity. To accelerate the evaporation process, air must come into contact with a large area of water, for the degree of evaporation is directly proportional to the area of water over which evaporation occurs. The area of a given quantity of water can be increased in two ways, viz:

(a) atomising the water in fine drops;
(b) dividing the water into thin layers.

The first principle is used in water atomisers and the second in air washers. Particularly with the former, it is essential to be aware of the dangers of wetting the potatoes during ventilation; small droplets can be entrained in the air stream and carried in to the potato pile with the obvious danger of inducing serious rotting. The problem is compounded by the difficulty in satisfactorily measuring high humidities which is necessary to achieve any form of close control. Whilst water atomisers of the spinning disc or ultrasonic nozzle type are relatively simple and efficient devices, control in relation to need is poor. Over humidification can be prevented by the use of air washers which, if properly designed, can usually achieve an RH of approximately 98%. However, air washers are more expensive than water atomisers and they have not been used so far in the United Kingdom where the economic benefits of humidification have yet to be proved. The benefits of humidification are currently being extensively explored by the Potato Marketing Board at its Sutton Bridge Experimental Station. In a maritime climate, relative humidities are in any case comparatively high and it can be seen from fig 3 that during the calendar months of the year when ventilation normally takes place, providing ventilation periods are restricted, average natural humidities can be as high as 90%. A simple time clock which would prevent ventilation occurring during, say, the period 9.00 a.m. till 3.00 p.m. could effectively ensure that humidities were sufficiently high as to avoid the need for artificial humidification.

## Control systems

The extent to which any ventilation and form of air conditioning system can be effective will greatly depend upon the efficacy of the control system, particularly at the beginning and end of the storage season when ambient conditions suitable for ventilation are restricted. An effective control system must first and foremost depend upon the accurate multi-point sensing of temperatures within the potato pile. Temperature control equipment must be so positioned as to indicate temperature distribution on a three dimensional basis and there should be sufficient sensing points to equate to one per 50–100 tonnes of potatoes in store. Control equipment must also be capable of accurately determining the ambient air temperature, the temperature of the air down stream of the ventilation fan and the temperature of the air at selected points in the head space above the crop.

Given the ability to determine these temperatures, a fixed logic control system can be provided which will:

1. initiate ventilation whenever any one of the crop temperature sensors exceeds a pre-set value;
2. allow the introduction of ambient ventilating air, providing a sufficient temperature differential exists between the crop sensor and the ambient to achieve cooling — never less than 2°C;
3. ensure that any ventilating air does not fall below a pre-set value by governing the mix of recirculated and ambient air;
4. initiate recirculation whenever the stack temperature gradient exceeds a pre-set value — usually 2°C;
5. recirculate the air whenever the peak pile temperature exceeds the head space temperature by a pre-set value — often 2°C (an anti-condensation measure).

The opening and closing of inlet and exhaust louvre dampers and the relative positions of recirculation and ambient dampers to achieve the desired air mix are all by-products of such a control system. Whilst these control functions would be seen to be simple and elemental, very few of the proprietary systems offered to growers are able to satisfactorily provide a full spectrum of control priority and proportional weighting. Work sponsored by the Potato Marketing Board is now aimed at the development of micro-processor controlled systems which would readily permit a series of operating programmes to be provided and which would additionally take account of such factors as off-peak electrical usage, crop and ambient temperature differentials in relation to time of year and the time temperature relationship involved in curing periods.

This paper has deliberately dwelt on just some of the problems involved in the design of any efficient environmental control system. The influence of the building is very much a secondary factor in the design of effective potato stores, for the structure is no more or less than the package which is put around the crop and its associated environmental control equipment, to separate a hopefully stable internal condition from a fluctuating external one. The degree to which the structure can be successful in this respect depends upon the insulating properties of the building and the extent to which it can limit unwanted air changes by leakage.

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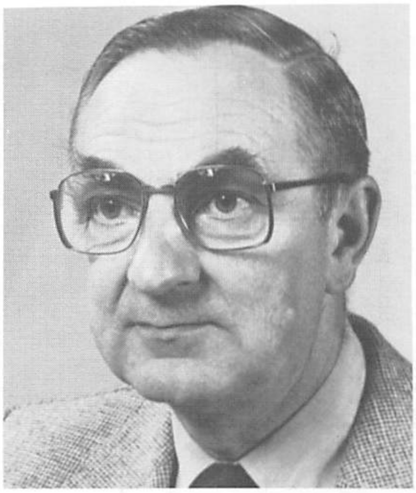
# Dutch grading and packaging systems

## Ing P H de Haan




### Abstract

Prevention of damage is an important aspect of grading and handling potatoes.

The extent of damage is determined by the susceptibility of the tubers on the one hand and to the way of grading and handling on the other hand.

It is recommended that measures should be taken to decrease the susceptibility of the tuber to damage as well as to reduce cause of damage in the grading line. Accuracy and uniformity of square-mesh grading depend largely on tuber shape.

In respect of the throughput of inspection lines, diminishing the percentage of defective tubers is important, as are the method of inspection and the construction of roller tables.

The method of packaging potatoes depends on several factors, such as requirements of clients and official authorities, destination, means of transport, etc.

There is a wide choice of different packaging materials and machinery.


## Introduction

When designing and constructing potato grading and packing plants, several aspects should be taken into account.

Minimisation of damage and minimisation of unit costs are important aspects.

It will often be necessary to compromise, so as to meet the nearly always conflicting requirements as effectively as possible.

The seriousness of damage is determined by the susceptibility of the potatoes on the one hand and by the method of grading and handling on the other.

## Damaging aspects

Classifying according to the nature of damage (Heesen and Kroesbergen 1959), the first distinction can be made between external and internal damage. External damage such as cuts, scuffing, flesh wounds and cracks occurs usually and relatively more often during and immediately after harvest. After storage, during grading and handling, common types of damage are: internal bruising (black spot) and cracks. The potato skin forms a barrier to penetration of micro-organisms as well as to evaporation of water. Tubers with a damaged skin are therefore more susceptible to infection (diseases) and higher weight losses can be expected.

**Factors influencing the degree of damage**

In the framework of grading and packing, special attention will be paid to internal bruising (black spot) and cracking.

The susceptibility to black spot is influenced by several factors, such as: varietal characteristics (eg dry matter content), growing conditions (eg supply of potassium, weather conditions), storage conditions (eg weight losses) and the temperature of the tubers during grading and handling — heating the tubers before handling and grading (Rastovski *et al* 1981). The way of handling and grading determines the degree of damage to a great extent.

Given a specified susceptibility of the tubers, the severity of damage is mainly determined by the amount of energy absorbed by the tuber and the hit area of the skin.

Therefore the following points are important (de Haan 1973):

- the dropping height (reduce as much as possible);
- the speed of a conveyor belt (determines the speed of tubers leaving the belt);
- the weight (mass) of the tuber;
- the nature of the surface on which the tuber is falling (padding material absorbs energy, diameter of rods, etc);
- the number of times the tubers fall (complicated or simple lay-out of a handling and grading line);
- the dwell time on shaking or jumping mechanisms (precleaner, graders).

The influence of different factors on the severity of damage is illustrated in fig 1, 2 and 3.

## Grading

Grading is carried out according to the square mesh system in the Netherlands.

Some important aspects of grading are: uniformity within a grade size, accuracy, damage and throughput.

**Uniformity of the tubers**

The aim of grading is to obtain a greater uniformity in a particular grade size than in a lot as a whole. Measurements have been carried out at the IBVL dividing the tubers of a particular grade according to different characteristics, ie length and weight. Some summarised results are shown in table 1 and table 2 (de Haan 1968).

The figures show clearly that there are remarkable differences between the varieties as well as between the tubers in the same size grade of one variety.

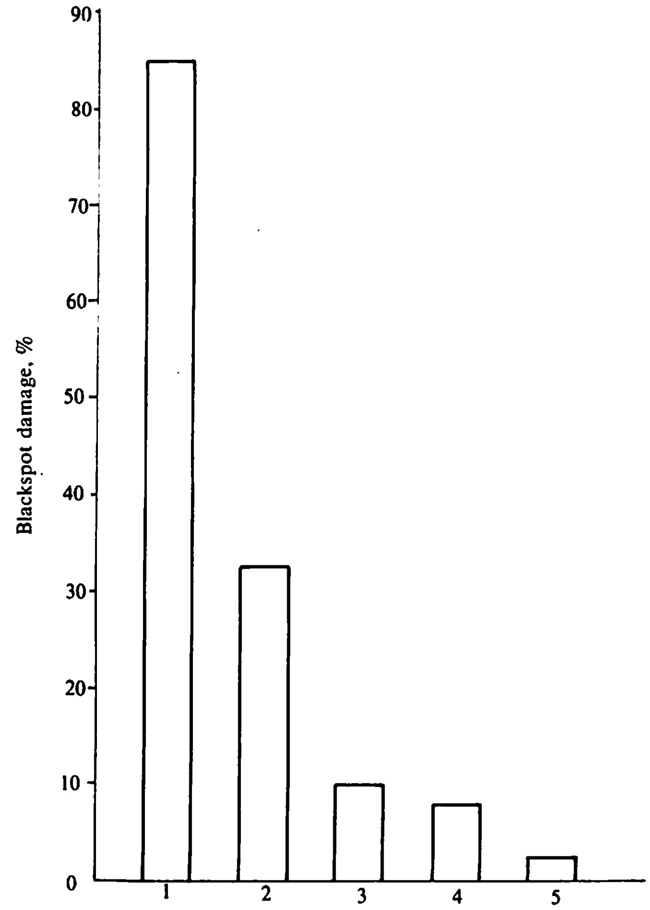
**Table 1 Distribution of the number of tubers in the square mesh size grade 44/55 mm in weight and length classes for three varieties varying in tuber shape (R = round, O = oval, E = elongated)**

| *Weight classes g* | *Tuber shape* R | O | E | *Length classes mm* | *Tuber shape* R | O | E |
|---|---|---|---|---|---|---|---|
| 40–120 | 90 | 52 | 33 | 40–80 | 97 | 50 | 13 |
| 120–200 | 10 | 46 | 62 | 80–120 | 3 | 50 | 75 |
| 200–280 | | 2 | 5 | 120–160 | | | 12 |

**Table 2 Greatest difference (in round figures) between the smallest and biggest tubers in the size grades 35/45, 45/55 and 55/65 mm between three varieties, varying in tuber shape (R = round, 0 = oval, E = elongated)**

| *Size, mm* | *Greatest difference in weight, g* R | O | E | *Greatest difference in length, mm* R | O | E |
|---|---|---|---|---|---|---|
| 35/45 | 70 | 100 | 180 | 50 | 60 | 100 |
| 45/55 | 90 | 130 | 200 | 50 | 70 | 90 |
| 55/65 | 180 | 160 | 200 | 60 | 80 | 90 |

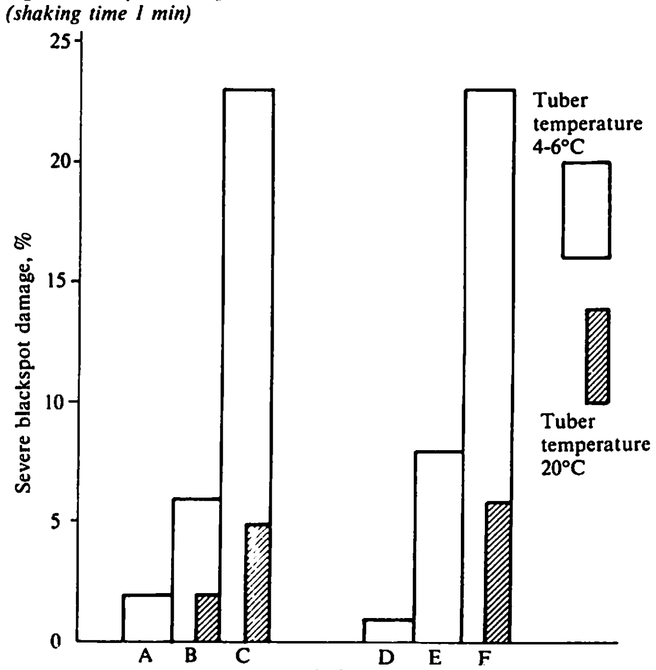
*Pieter de Haan is a research scientist at the Institute for Storage and Processing of Agricultural Produce (IBVL), Wageningen, Netherlands.*




| No | Variety | Size, mm | Temperature, °C | Surface |
|---|---|---|---|---|
| 1 | Woudster | 55/65 | 4–6 | hard wood |
| 2 | Bintje | 55/65 | 4–6 | " |
| 3 | " | 34/45 | 4–6 | " |
| 4 | " | 55/65 | 18–20 | " |
| 5 | " | 55/65 | 4–6 | covered with 3 cm foam |

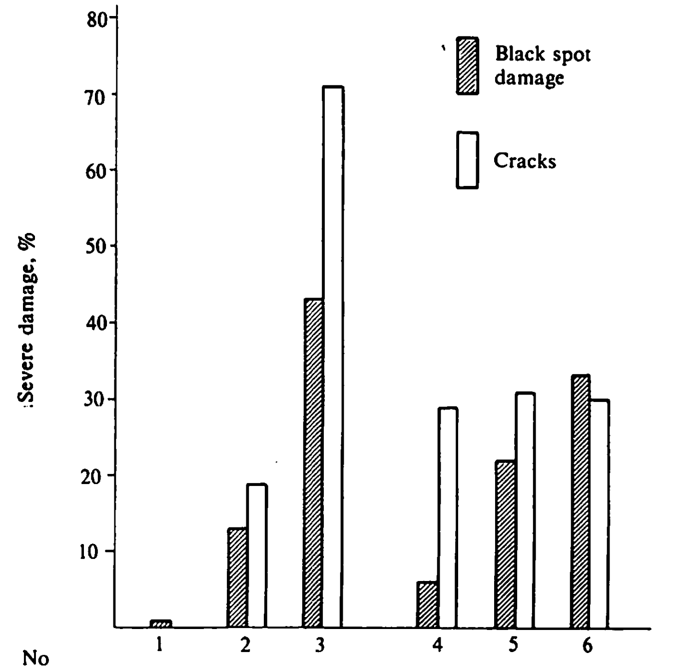
*Fig 1 Some results of dropping tests (drop 1.5 m)*

*Fig 3 Blackspot damage due to treatment on a shaking mechanism (shaking time 1 min)*




Potatoes: from one lot (variety Bintje)

| | | | |
|---|---|---|---|
| A = tuber weight | 40– 60 g | } | same specific gravity (1.07 < 1.12) |
| B = " " | 60– 80 g | | |
| C = " " | 80–160 g | | |
| D = specific gravity | 1.07 < 1.09 | } | same weight of the tubers (40–180 g) |
| E = " " | 1.09 | | |
| F = " " | 1.10 < 1.12 | | |




| No | | | | |
|---|---|---|---|---|
| 1 | Dropping height | 0.5 m | } | At same specific gravity |
| 2 | " " | 1.5 m | | |
| 3 | " " | 2.5 m | | |
| 4 | Specific gravity | 1.07< 1.09 | } | At same dropping height |
| 5 | " " | 1.09< 1.10 | | |
| 6 | " " | 1.10< 1.12 | | |

*Fig 2 Some results of dropping tests at a tuber temperature of 4–6°C (variety: Bintje)*

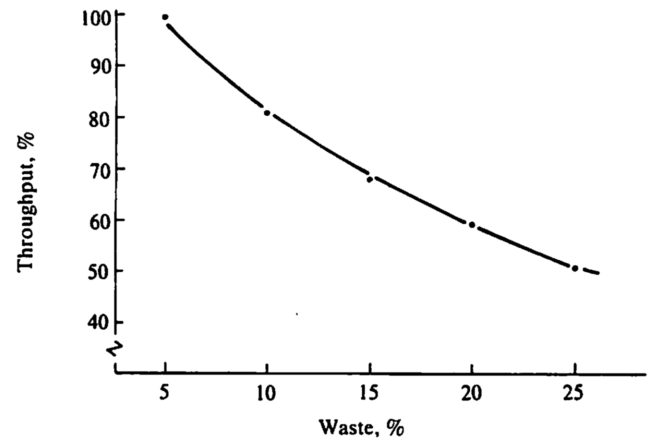
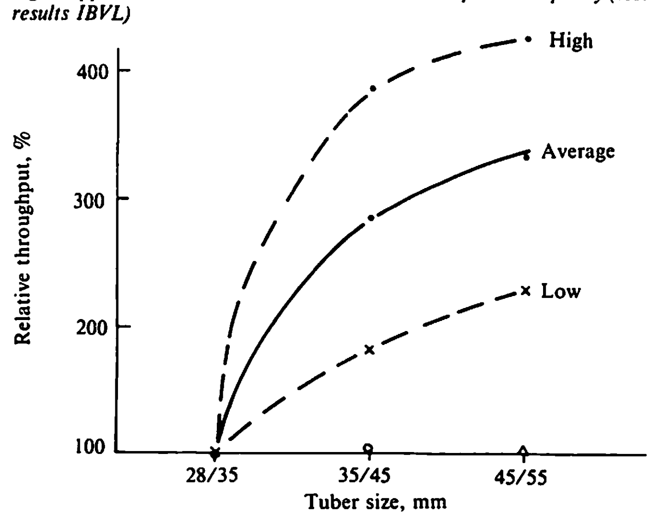



*Fig 4 Approximate ratio between waste percentage and inspection capacity (test results IBVL)*

*Fig 5 Approximate ratio between tuber size and inspection capacity (test results IBVL)*



#### Grading accuracy
Measuring the grading results of widely used grader types showed that grading accuracy depends mainly on tuber shape. This means that the accuracy of round tubers is very high. Accuracy decreases according to the elongation of the tubers. A low accuracy can be expected when grading the big sized tubers of a pronounced elongated variety. It can run to 60%. Measurements were carried out under normal practical conditions: an acceptable throughput, avoiding damage as much as possible and correct adjustment of the grader.

#### Damage
In relation to graders, the following remarks can be made (de Haan 1978). The screens should be well filled (eg 80% covered area). Potatoes blocking the holes of a screen can be damaged seriously. Improvements are possible by applying special mechanisms ('ejectors') and/or specific motions of the screens (variable lengths of the motion).

Padding material on plates, screen, etc is recommended. Although damage on graders deserves attention, the role of the grader must not be overestimated. Measurements showed that, in the whole line on central grading plants, the grader normally causes a minor part of the total damage. It is very important to pay continuous attention to other factors such as: dropping height, belt speed, padding material, limitation of numbers of falls, transfer from one belt to another, etc. With respect to black spot damage, warming the potatoes is a first requirement before grading and handling.

#### Throughput
Determinant factors in view of throughput are: width of the screens (rather than the length), the size of the tubers and the number of size grades. Grades are available with throughputs up to about 60 t/h per machine. For practical reasons, owners of central grading plants often prefer two machines of 30 t/h instead of one with a throughput of 60 t/h (flexibility).

#### Grading systems
In the Netherlands, predominantly screen graders are used with a shaking or jumping motion of the screens (other systems used are roller graders and graders with rotating screens).

Stacked screen graders nearly always have shaking motions of the screens, whereas graders having the screens behind each other are mainly equipped with a jumping system.

## Inspection of potatoes
Up to now, inspection of unpeeled potatoes is usually carried out by hand, nearly always on roller tables. The finished product has to meet certain requirements (quality standards). Except for the official regulations, the requirements are mainly determined by the utilisation of the sample (seed potatoes, ware potatoes, potatoes for the processing industry etc). In addition, the client can impose special demands.

Materials like clods, stones, stem pieces, etc, can, for the greater part, be removed mechanically.

Defective tubers (tubers with rot, damage, greening, diseases, etc) must be eliminated. An efficient method is required in order to keep the costs at a low level.

The capacity per operator (kg/h) depends greatly on the following: the waste percentage (defective tubers), tuber size, and inspection system (including the construction of the roller table). Some results of tests of the influence of waste percentage and tuber size are given in figures 4 and 5 (van Zwol 1970).

Because the waste percentage has a great influence on the capacity, a reduction in inspection costs can only be achieved by careful management of the growth and harvesting of the crop as well as of the storage conditions.

According to inspection tests at the IBVL, the following recommendations can be given:
- one man at one roller table or two men opposite each other,
- inspection of one grade size at one time;
- the tuber must rotate about one and a half times in the inspection field;
- the density of the tubers on the roller table should be sufficient (covering about 80% of the area);
- the diameter of the rollers should be adapted to the size (diameter) of the tubers;
- transport rate of the rollers should be variable from 2 to 8 m/s;
- the width of the roller table should not exceed 60 cm with one inspector per roller table or 80 cm with two inspectors, one on each side;
- lighting of the inspection field and positioning of the inspector should meet ergonomic requirements.

## Grading and inspection systems
A distinction has to be made between central grading plants and grading equipment of farms.

#### Central grading plants
A widely used system is inspection of one grade size. To achieve that aim, grading takes place before inspection.

Several systems are used such as:
- receiving field crop, grading, storage of separate sizes in bulk hoppers, inspection size by size;
- receiving field crop in bulk hoppers, grading, storage of the different sizes in bulk hoppers, inspection size by size;
- supply of field crop potatoes by trailers, grading, inspection of two 'main' sizes, storage of other sizes in bulk hoppers or pallet boxes.

To distribute the potatoes over the different roller tables, a so called 'dividing belt' is used. On this belt, a size grade is divided into a number of equal parts corresponding to the number of roller tables.

In many cases, ware potatoes or potatoes for the processing industry are delivered in bulk.

For loading lorries, special loading installations are frequently used, minimising damage and saving labour. In some cases, pallet boxes with a content of one tonne or five tonnes are used.

#### Grading on farms
As a rule, the set up of grading lines on farms is quite different from grading lines on central plants due to the different circumstances. Firstly, the quantity of potatoes is relatively small, the number of people are very restricted (1-3) and the available space is limited.

One can distinguish two main grading systems.

(a) *A system with compact mobile grading equipment*
Because of the lack of labour, it is not possible to use a number of roller tables. Therefore, the potatoes are inspected on one roller table before grading. As a rule, pregrading takes place to remove small tubers and clods. In order to limit the length of the grader, the roller table is on top of the grader. The grading screens (frequently jump grading systems with the screens behind each other) are situated underneath the roller table. Alongside the machine bags can be attached.
Unloading the bin and supply of potatoes to the grading equipment can be done with the aid of an underfloor conveyor, shovel equipment or a bucket on a tractor, sometimes in combination with a bulk hopper.

(b) *A system for a stationary grading installation*
The grader is situated on top of a few bulk hoppers (one hopper per grade size). From the bulk hoppers, the potatoes are supplied to roller tables, with separate inspection and bagging up for each size.
Sometimes, a few farmers may work together, in order to extend their mechanisation possibilities.

## Packing of potatoes
The form and size of the various packages depend on a number of factors, such as: customer's requirement, destination (ware, seed, in the country, abroad), method of transport (road, rail, sea) etc. Besides, there can be requirements imposed by the official authorities.

Depending on the duration of transport, elimination of respiration products and supply of fresh air should be possible, at the same time avoiding greening of the tubers.

Apart from the points already mentioned, it is essential to minimise the amount of work (mechanisation) without damaging the tubers. For practical reasons, from a wide choice of packs (in terms of types, size and shape) only a limited number is used.

#### Forms of packaging
Jute sacks are often used for seed potatoes and (sometimes also for ware potatoes) for export from the Netherlands.

Plastics sacks of knitted material are also used. Paper sacks of multiply, moisture proofed material are mainly used as packing material for retail packs. Wooden crates are used on a limited scale for export of feed potatoes. Advantages of crates are the protection of potatoes against damage and a good ventilation. Because of the rather high costs, they are used in special cases. Cartons made of solid or corrugated board are also used to a very limited extent.

**Packing machinery and equipment**

Several types of weighing machines are available, ranging from simple to complicated constructions, varying also in throughput and labour saving. Large sacks (25–50 kg) are usually stitch-sealed, although other possibilities exist. When packing seed potatoes a double thread chain-stitch is stipulated. Fully automatic packing lines with a high throughout are in use. The entire process of supplying sacks, suspending, filling, weighing, sealing (if labelling is needed) and transporting is mechanised. When using jute sacks, suspension of the sacks must be carried out by hand.

The major part of table potatoes is sold in small packs (2½ and 5 kg units). Fully automatic packing machines are usual. The packing material consists of perforated plastics film or woven plastics (net sacks). Small packs are put in crates, (roll) containers and paper sacks.

## New developments

Efforts have been made to replace the square mesh grading, in order to improve the uniformity in a size grade and if possible to reduce damage. Grading according to the weight or the 'shadow' of the tuber is possible. The problem is still to develop a machine that can compete with the square mesh system in respect of throughput and costs.

Very important in view of labour savings is the mechanisation of inspection.

Electronic sorters are used for washed and peeled potatoes. In fact, it is a colour measurement (defects on the outside of the tubers). The use of transmitted light gives the opportunity to detect internal defects (differences in thickness of the tubers). A combination of electronic sorting (colour measurement) and transmitted light is under investigation at the IBVL (Rastovski *et al* 1981).

Indication of defective tubers by hand followed by mechanical removal can be considered as a kind of semi-electronic sorting. Such a system appears to raise the throughput per inspector only if the percentage of defective tubers exceeds about ten per cent.

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# Edited summary of the discussion
# Seed potato production

## Questions following paper 1, (R W Lang — Implications of early lifting)

**Dr P D Waister (Scottish Crop Research Institute)**

Q. In seed production, how early is an 'early burn down' of haulm? Is there any guide for different sites and cultivars?

A. *It is not possible to give precise dates for burn down and lifting because of variations between seasons, varieties and geographic areas. Generally, the longer the crop is left in the ground, the greater the risk of disease. Without a large premium for seed potatoes, growers often allow crops to grow on, increasing ware yield but also increasing disease risk. Earlier lifted seed with a lower disease incidence should demand, in time, higher premiums.*

**Mr R Watson (Farmer, Dundee)**

Q. What is the recommended method of haulm removal?

A. *I do not recommend flailing the haulm as this can spread blackleg. The preferred technique is to use acid to burn down. With earlier lifting, two applications of acid may be needed as penetration of the foliage is more difficult. 'Defta' should only be used for crops grown on as this has a much slower action than acid.*

**Mr F J Pirie (F J Pirie and Co Ltd)**

Q. Is there any advantage in phasing the heat treatment and chitting of seed to optimise the harvesting date?

A. *Whilst there are recommendations for chitting to provide 240 degree days for planting in mid April, these cannot be precise because of variations in variety and season. Although there is a target date, in practice, planting may be two weeks early or late. Only a small proportion of growers in Scotland chit seed and few of these have good control of the environment, so general recommendations seem more appropriate.*

**Mr C Murray (Clarence Murray (Potato Growers and Farmers) Ltd)**

Q. One of the implications of early harvesting on light land is additional damage. What can one do about it?

A. *Higher soil moisture content at harvest will help reduce damage on light soils and a delay in harvest may be beneficial. Gentle handling is clearly important. Developments underway at the Scottish Institute of Agricultural Engineering may help in the future.*

**Mr C Murray (Clarence Murray (Potato Growers and Farmers) Ltd)**

Q. Should growers take care of sprouts as your results suggest an advantage in damaging them?

A. *I am not advocating producing flesh damage to sprouts. The tubers damaged in the investigation were well chitted and the rough handling was intended to illustrate the value of good chitting procedures.*

## Questions following Paper 2, (W F Maunder — Planting and mechanical handling of seed)

**Dr B D Witney (East of Scotland College of Agriculture)**

Q. Is the speaker proposing to monitor the performance of the new Smallford planter this year?

A. *The Agricultural Development and Advisory Service is hoping to monitor planter performance at Terrington Experimental Husbandry Farm to provide factual information on planters. The Smallford planter will probably be included in this assessment.*

**Mr J Fotheringham (Scottish Seed Potato Development Council)**

Q. Are figures available showing the cost benefits of the different systems for handling chitted seed as it is important to know the cost/benefit ratio when advising a charge?

A. *It is difficult to precisely define the advantage of one system over another as rarely is one starting from scratch. Systems must be developed to match the farm in question. The use of the front end loader for filling the planter appears to show a great advantage over other systems.*

**Mr R R Morrison (East of Scotland College of Agriculture)**

Q. Could the speaker describe the process of packaging and handling chitting trays from store to field?

A. *Trays are stacked on a small pallet in layers of 4 trays. Each pallet may load to 7 or 8 layers high before the centre posts of the trays are wired together to provide a stable package. In the chitting house, these can be stacked up to 3 packages high and the packages then loaded onto trailers to be taken to the field – still in a stable unit.*

**Mr E Cumming (Farmer)**

Q. Which planters are suitable for planting Pentland Dell?

A. *This variety is a problem for cup fed planters. The new Smallford planter should be able to handle this satisfactorily. Generally, planters require a large throat through which the tuber is conveyed to prevent it becoming wedged. Some planters use different shaped cup inserts to accommodate different varieties.*

→ *page 59*

# A Grower/Merchant's view — maximising returns and minimising costs

**G K Smith**

## Sales potential and markets

### Seed quality and presentation

In an earlier paper, delivered in 1970, on a similar theme, an extract reads: "Let us retain our naturally high health standards which have previously helped sell the crop, and super-impose on the present scheme another more sophisticated, but nearer the customers requirements. The new super Scotch seed would specify and guarantee that crops were burned down before the end of August, and harvested before the first week in October, the maximum size to be $2\frac{1}{8}$ in (or 55 mm) (Smith 1970).

We have not progressed very far on this proposal of super seed, only the size specification dropping from 57 to 55mm, and this only by the accident of metrication. Progress now dictates a move towards earlier harvesting, to eliminate tuber defects, and *the offering of various sizes, coupled with precise tuber counts per bag.* This is what our customer wants, this is what his advisers suggest he should have and as our main competitor, the Dutch, are half way along this trail, we must try to catch up. The re-equipment and reinvestment from the cash flow of 1976 and 1977 into destoners and boxes, graders and purpose built stores, has certainly helped in the quality presentation of the tubers. However, we still shield ourselves by allowing only a ten day guarantee of quality after delivery. We must ask ourselves if this is fair and reasonable to our customers. Perhaps we ought in the first instance to consider doubling the complaint period to 21 days after delivery. If we are to be professional seed growers, we must supply '*goods fit for the purpose*', ie goods which will survive after grading out, for up to six months, compared to the average of six days for table potatoes. I hope that the Scottish Seed Potato Development Council will be able to advise the Department of Agriculture and Fisheries for Scotland to have earlier burning down targets, to allow for and commit the crop to be harvested by, say, 7th October. This dead-line could be variable and based on soil temperature. In the firt instance, FS grades should automatically drop to AA if harvested after that date, and an export certificate should only be given to seed harvested prior to the dead-line. Gangrene, soft rots, and frost in consignments would instantly disappear, after all, the Dutch do it with even earlier targets than these, albeit for a different reason. Looking back on the advance of the past fifty years in the Scottish seed crop, my opinion is that progress has been brought about much more rapidly by legislation, than a system based on the phrase 'putting one's own house in order'. This general scheme would not only improve tuber presentation and health, but would also make Scottish seed, on average, about ten days 'physiologically older' or 'naturalised'. This would allow us to challenge, explore, and capture a small part of the UK ware growers 'once grown' seed usage — at the momment more than half of the total.

*Ken Smith is Managing Director of The Forfar Potato Co Ltd and farms 480 ha in Angus.*

### GEMS

This month my company is bringing to the market place a package of super seed, called or branded GEMS, based on the phrase Guaranteed Earlier Matured Seed.

The buyer will have *any* desired size to the nearest 10 mm, burning and harvesting dates will be guaranteed as discussed above, and a guarantee of *tuber viability* on and after delivery until the following March. The buyer will be able to purchase at cost plus, a product that he apparently so wishes to have, by ordering mainly before planting, but finally and no later than the end of July ie after roguing and certification. The quid pro quo of what you might think is an extreme gamble, is that the buyer helps in this way to reduce our financial risk, and stabilise seed growing returns. He will obviously benefit from a more specialist and desirable product.

### Goods fit for the purpose/eelworm

It is all too easy to consider that our liability ceases at the farm gate but we should not hide behind a paper certificate saying that eelworm cysts are *not* present in a random and miniscule *field* test. As producers and sellers to supply 'goods fit for the purpose', we must deliver tubers *absolutely* free of eelworm. Therefore we should participate in further tests along the line, especially in the soil adhering to the tubers at harvest time. It is also probable that September-harvested seed has a much less chance of carrying soil cysts. If each grower was concerned that the whole cost of a returned export cargo might be charged to him, because of *his* consignment *only* being rejected, the eelworm risk would substantially diminish.

### World markets

Table 1 is an interesting list of world seed markets (1980). Not only is the total enormous compared to our own production, but many more markets open up, such as that of South America, (100,000 tons), if seed potatoes are ready for despatch in October. With application, more suitable varieties, and control of costs, we must explore further this enormous market. I hope the Scottish Seed Potato Development Council will be able to help, and improve on the good track record of the past ten years.

## Lower production costs

### Split sizing seed for seed production

In the 1970 paper, mention was made of '*split sizing the seed,* chitting the small seed to get more economic use of trays, and planting the big seed separately, and earlier'. This system still applies because, with destoning, the seed is not planted at an ideal depth for seed production (less tubers are produced from a deeper mother tuber). The big tubers, planted separately once destoning starts, have vigour to push up through the earth above; then the small chitted tubers, being planted later and in better conditions, have a strong start from their chitted vigour. I am sure it is right to do this, and also right to plant the various sizes separately at precise spacings.

### Another method of chitting?

On this subject, I wonder if, some day, we will be able to prepack seed into standard sized 'jiffy' type pots made up of say peat and straw mixed, and with added hormones, antibiotics, micro nutrients and fertiliser. By doing so we might then eliminate costly chitting trays, put 500 day degrees of heat in to the tubers without the risk of the sprouts being knocked off at planting, allow precision spacing because of their uniformity, and ensnare in some way the bacteria from the mother tuber breakdown. Then, although perhaps far fetched, we might get a few problems and requirements of Scottish seed resolved at a stroke.

### Destoning

To quote from 1970: 'Stone shedding during Spring cultivations can't be said to have become a popular technique. This season I am to use the front end of a harvester suitably modified as a destoner. The reasonably stone and clod free mould in which the seed is planted will, in my opinion, enhance growth and hasten the harvest of unblemished tubers' (Smith 1970).

Destoning has come a long way in the last decade, and shows how rapidly farmers adapt and improve new techniques. There are now an array of successful machines on the market, and I can claim to have been the progenitor of one of them. My first prototype destoner/planter placed the stones in *each* row bottom, thereby reducing the quantity and volume as compared to two row machines of today. I cannot admit to seeing a better finished job since that experiment. With today's destoner/ planters, stones go over the top of or by-

Table 1 Seed potato markets overseas (1980 ex Potato Marketing Board)

| *Country* | *Seed import requirements, tonnes per annum (approx)* | *Time of shipping* |
|---|---|---|
| Belgium | 32,000 | November/January |
| Denmark | 100 | January/February |
| France | 118,000 | November/January |
| Italy | 85,000 | *October/December/January/March |
| West Germany | 32,000 | November/January |
| Austria | 4,000 | January/February |
| Canary Islands | 15,000 | *Late September/October/November/January |
| Cyprus | 8,200 | November/December |
| Finland | 1,000 | March/April |
| Greece | 15,000 | November/December/January/February |
| Hungary | 10,000 | November or February |
| Madeira & Azores | 1,200 & 100 | November/January |
| Malta | 3,000 | November/January |
| Norway | 100 | February/March |
| Portugal | 45,000 | December/January |
| Spain & Balearics | 25,000 | *October/November/December |
| Sweden | 100 | March |
| Yugoslavia | 2,000 | November/December |
| **Europe** | **400,000 (approx)** | |
| Argentina | 16,000 | *October |
| Brazil | 16,500 | *First week October |
| Cuba | 19,000 | *October/November |
| Uruguay | 13,000 | November/February |
| Venezuela | 26,000 | *October |
| West Indies | 3,500 | *October/November |
| **S America** | **100,000 (approx)** | |
| Algeria | 70,000 | *October/November (earlies)<br>November/December (maincrop) |
| Angola | 7,700 | March |
| Egypt | 32,000 | *October/November/December |
| Ghana | 100 | December |
| Kenya | 100 | December |
| Libya | 3,700 | November/December<br>December/January |
| Morocco | 22,000 | November/January |
| Senegal | 1,300 | November/December |
| South Africa | 500 | *October/November |
| Tunisia | 11,000 | November/December<br>December/January |
| Zambia | 1,500 | December |
| Bangladesh | 2,000 | *End September/October |
| Iraq | 15,000 | November |
| Israel | 7,000 | *October/November |
| Lebanon | 25,000 | November/January |
| Pakistan | 1,400 | *First week October |
| Sri Lanka | 4,000 | *Early October |
| Syria | 6,900 | December/January |
| **Med. Basin Middle East & Africa** | **200,000 (approx)** | |
| TOTAL | 702,000 | |

**October shipping total 322,900 tonnes*

pass the planter, and all normally into each alternate drill, where often space is limited.

A suggestion that may be useful is for the rear cross web to have say a 50mm gap, all stones above this going across into the valley bottom to be run over next time round, (as is normal practice), and small stones and clods going through the cross web into each valley bottom behind the planter ridging bodies (fig 1).

At the moment, I hold a patent on a combined machine, a stone separator/planter/harvester. This has already been taken up by one major manufacturer, and I wish them success, for it has always struck me that the manufacturers claim that destoners and harvesters were not the same basic machine was a nonsense. The industry can easily do without a duplication of machinery costing £15,000/unit or more.

Destoning is still a very expensive and a relatively slow operation often delaying planting and reducing potential yields by 2.5 t/ha per week (Maunder 1983). Diesel consumption is dramatic in the tasks of prior cultivations, of gouging out enormous drill bottoms to take stones and clods, and then also lifting vertically up to half a metre in height the soil of the whole field.

Designers must try to resolve this massive consumption of energy. It is known that vibrating and oscillating shares reduce draught, and perhaps this coupled to a long rotary drum running behind would cut the cost of manufacture, incorporate tilth-making and allow faster forward speed and less consumption of energy.

**Harvesters**

To quote from 1970, having '*criticised potato harvesters*, I pursued the gamble this past season of having one built to my design, two drills flowing straight through the machine without a change in direction. Figure 2, which was handed out at the time, shows a remarkable similarity to today's market leader' (Smith 1970).

However, I am very suspicious of the large two row harvesters for seed production as compared to ware production. Not only are the webs tighter, and therefore more stones and clods are carried through with the smaller seed crop, but also they are very difficult to set up in destoned land in this seed growing area, where there are very few fields free from varying slopes. There can often be one side of the harvester in too deep, collecting stones, and the other side too shallow, and damaging or not harvesting potatoes. It is nearly impossible hour after hour on slopes and through wet hollows to carry out a proper job.

And so for my business at least, hand squads are still competitive, the extra cost balancing the apparent extra revenue and the reduction in harvesting risks. Ideally, for my business, I require a single row harvester working at higher forward speed, of lighter weight and with some picking space. This machine working at two thirds of the speed of a two row harvester would be much more usable and less risky. A faster single row machine allows the coulters to be set properly, the tractor wheels to be kept away from the ridge, specially important on destoned land, and with a throughput commensurate with picking space on the table.

Although this may look a backward step, it is the way in which I would like to proceed.

Using Scottish Institute of Agricultural Engineering harvester designs, fig 3 incorporates the points that the seed grower requires, fast forward speed, minimum damage, rough sizing of seed and ware, minimum tuber damage and recovery from the haulm extractor, and the ability to tackle varying slopes.

One plea for progress — harvesters are much cheaper at harvesting the crop, the problem still lies in the probable cash out turn from the crop. Harvesting after destoning might save the seed grower around £150 per hectare, or about 5% of total costs, a major consideration. Like the Potato Marketing Board harvester demonstration for ware producers, could we not organise in this local seed area a seed harvester demonstration, with research staff checking the product through to the following planted crop and especially with selected risky varieties, such as Bard, Estima, Wilja and Desiree etc (as compared to the Potato Marketing Board demonstration of ware potatoes going to the table instantly)?

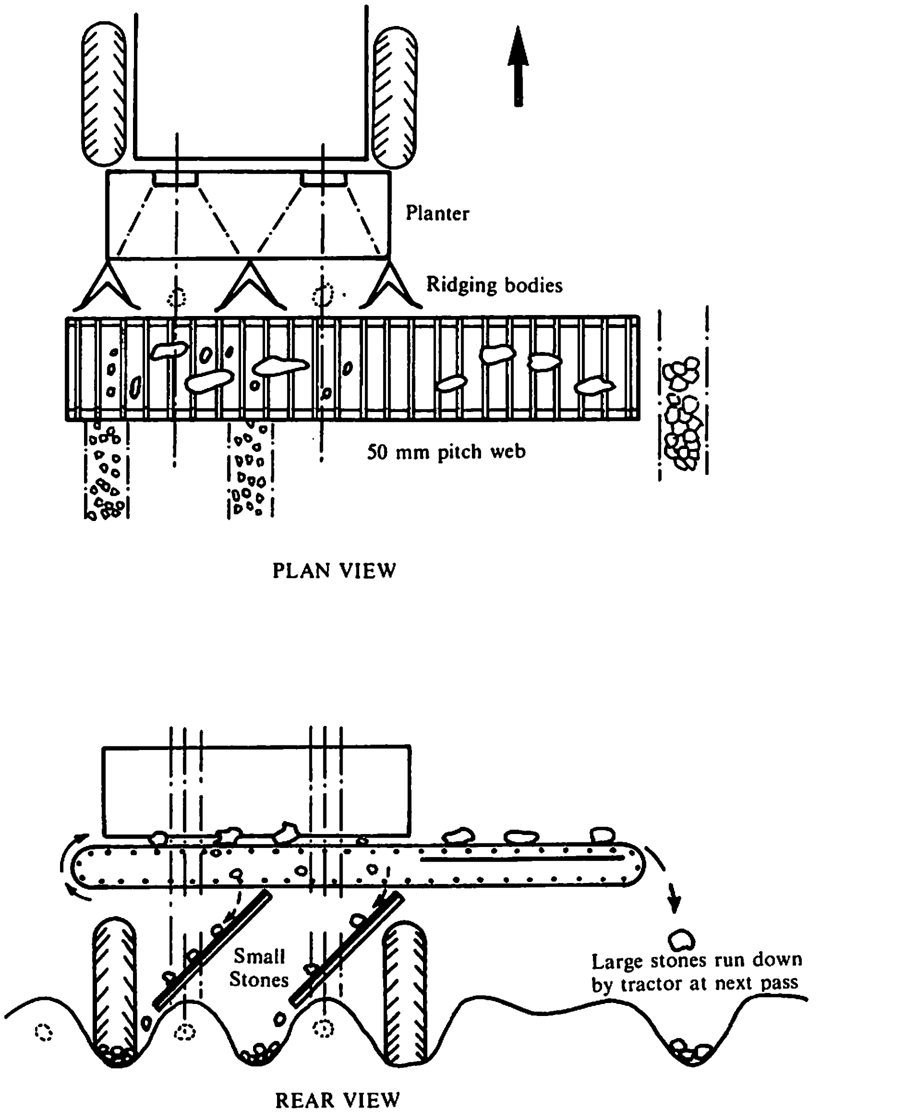



*Fig 1 The design of a two row stone separator for splitting the stone flow and equalising the quantity into each valley bottom*

**Seed growing costs**

From appendices 1 and 2, the pertinent results are:

| | |
|---|---|
| Costs before profit margin | £2718 per hectare |
| Extra costs of seed where total field yield for seed crop is $3\frac{3}{4}$ t/ha less than ware crop | £27 per tonne |
| or | 43% |
| Overhead & Quango costs | £5.50 per tonne |
| Specialist seed crop costs | £12.20 per tonne |
| Balance yield factor | £9.30 per tonne |
| | £27.00 per tonne |

How can we reduce them?

(a) Ask the Department of Agriculture and Fisheries for Scotland to investigate a thorough review of costs, and demand an agreement of no charges in a year of income lower than costs.

(b) Demand that the 'home' trade does not pay a penny more in total than the total of all export variety royalties, ie penalise the plant breeders for abusing in the past their monopoly power.

(c) Three quarters of all roguing is a nonsense. Have the first inspection before roguing to check the intrinsic quality of the seed crop and insist that the Department of Agriculture and Fisheries for Scotland provide proof that blackleg roguing is beneficial.

(d) Adopt controlled chitting, irrigation, earlier harvesting, etc to produce larger and more saleable yields.

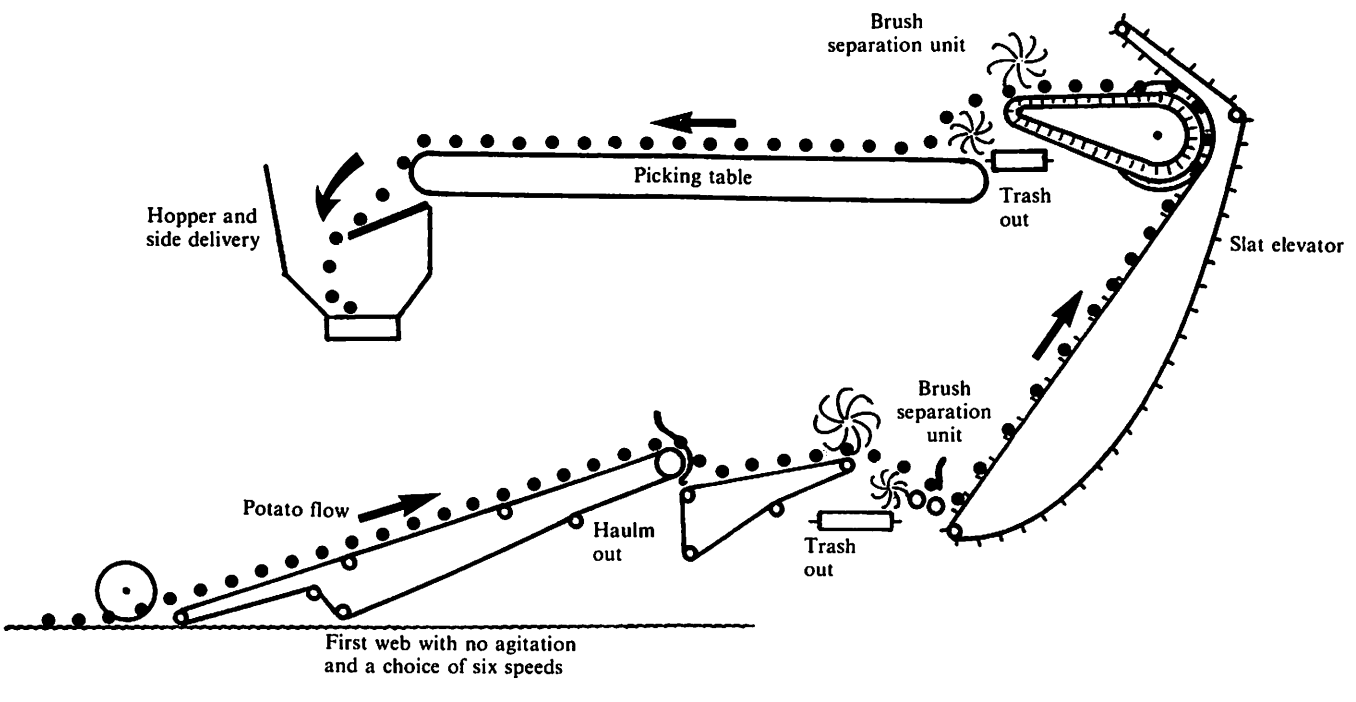
(e) Use of suitable harvesters to save at least £125 per hectare on my cost schedule.

(f) Flexibags — boxes have twice the life — £100 per hectare saved.

(g) Exchangeable pallets — £25 per hectare saved.

(h) Replace the Scottish Seed Potato Development Council levy with part of the Potato Marketing Board levy.

*Fig 2 A two row harvester design for straight through flow of potatoes*



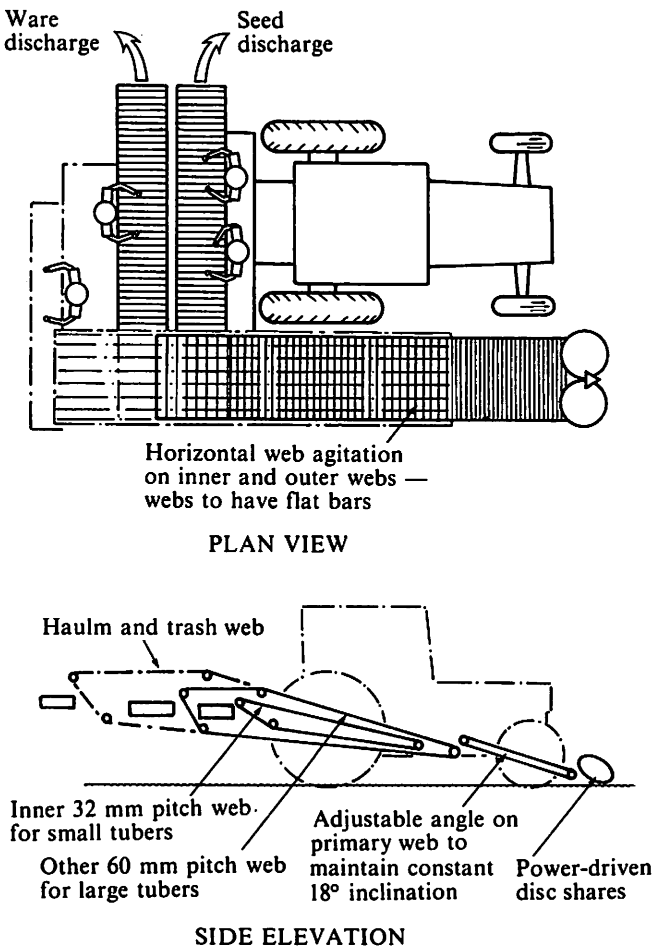



*Fig 3 A single row, side mounted harvester incorporating the features that a seed grower requires*

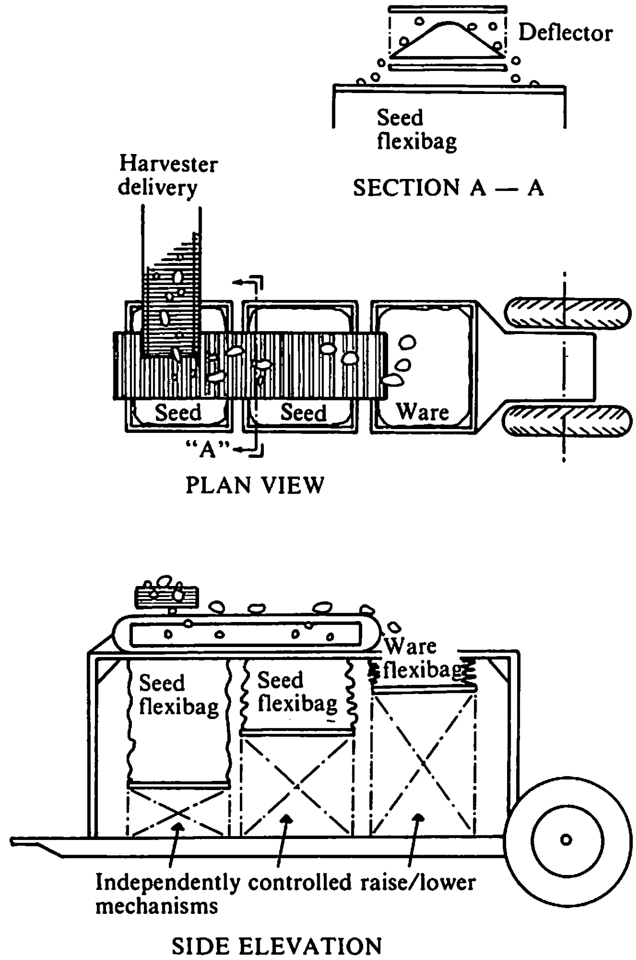



*Fig 4 Flexibag transporter system*

The above might save us at least £250 per hectare about 10% of our costs or £10 per tonne.

## Higher saleable yields

**Growing crop**

Our total yield potential is less in the East of Scotland than in other areas because of our cooler environment, but this should not concern the seed grower as much as the ware grower.

If all inputs are to be as near ideal as possible, seed quality and size chitting, spacing, fertilizing, destoning and harvesting, we still run into problems caused by lack of rainfall. The one input missing is that of control of soil moisture.

It is known that Common Scab can be minimised by adequate soil moisture at tuberisation, and also that tuber numbers may increase giving seedier crops. Shortage of moisture with a chitted crop can reduce yields.

We should be asking the National Institute of Agricultural Engineering and machinery manufacturers for a cheaper and more easily used system of irrigation to cover us for this particular and short time of the year.

**Flexi - bags**

Harvesters are often seen to be dropping potatoes into trailers through a much greater distance than advised and, with unmanned machines, stones also. Hand picking squads can also be negligent in this area. I would like to suggest that this could be avoided by using flexi-bags with either a harvester or hand squad, as shown in fig 4. Bags on a transporter with a scissor type floor under each bag would allow the harvester or a hand squad to feed at a consistent level with a precise and constant damage-free drop in to the filling flexi-bag. The transport tractor driver, using hydraulics, with ample time on hand, would lower the filling bag to keep this constant discharge height. The filled flexi-bag, on arrival at store, could then be emptied in to a hopper or in to boxes, with no further damage at this transition point, thus avoiding the horrifying methods of trailer emptying, box tippling and box filling which we still have in our systems. An indirect gain would be the ability to add on a small device to rough size seed and ware in the field. A simple flat bar type web, such as in diagram, could be incorporated above the flexi-bags and, as bags are not the storage but the transit medium, they could be used to precisely fill the seed and ware boxes back at the store without any or further damage. I, for one, wish to know to within a few percent what seed I have in store for future sale. The ware could then be stored separately, with its own chemical and temperature environment and, if need be, allowing it to be stored until the highest price time of the year, April/May, or used for a buyer wishing a regular supply of a repeat product.

An indirect gain, or cost cutting benefit, is the probability of the storage boxes lasting twice as long, thereby saving £100 per hectare per annum (3½% of costs).

**Grading lines**

Grading lines are still antiquated, troublesome and damaging to tubers. This is one area where legislation is unrewarding for the square hole is the only legal method of measurement and is to be continued in revised seed legislation. It is extremely difficult to size potatoes through a square hole without causing damage. Parallel bar sizing would be cheaper, simpler and less damaging. This, coupled to a tuber counter would give us the product that the customer desires. The more progressive ware grower would apparently like to take delivery of a precise number of tubers per bag in a common range of size, the tuber count being more important than a precise size. This allows the professional grower to plant a precise area at a precise distance between sets with a tuber reasonably uniform in weight, size and performance.

I have designed a machine able to count precise numbers of tubers in to a 50 kg bag. It should not be too difficult to put together using modern counters, weighers and a small home-type computer. One on the market now at £14,000 is surely for central stores only. We need one for the farm. If my design was confirmed as being viable by engineers and at a budgeted cost, I wonder if the new Scottish Seed Potato Development Council would give a grant help build the first prototype?

**Weighing and bagging**

Graders universally throw potatoes off the end of the picking tables into bagging machines, of which the hopper base can be up to one metre below. The bagging machines then rumble them around and throw them into bags, falling a similar distance, at a speed of about 32 km/h. The proof is in looking at some of the clear and white skin varieties, such as Maris Peer, where literally tens of small half moon marks can be seen on inspection after bagging. These are all caused by tubers hitting each other at speed. Whether it be at the tippling stage, or the sizing stage, or the bagging stage, it is for the engineer to tell us, and then to resolve. All that I can say is that these marks, proof of damage, are present with modern seed grading equipment costing £40,000 or more.

In fig 5, I suggest a design for a hinged type bagging belt which would mostly run in a horizontal plane, but drop down when the belt is stationary and a weight of potatoes accumulates. Similarly, I cannot see how it would be too difficult to place each bag on an inclined slope and likewise hinge and swing it into the vertical as it fills.

**Exchangeable pallets**

Damage is still caused by undue movements. Firstly, filled bags are placed on to pallets, then on to lorry platforms and, thirdly, on to something else at the receiving point.

All ware is now moved on 4 × 4 exchange pallets. It is quite possible to pack 50 kg seed jute bags onto this type of pallet and still load a full twenty-tonne lorry. (18 pallets × 24 bags each = 21.6 tonnes). The reductions in tuber damage, as with ware, would be immense, hauliers would save on time and perhaps charge less and the English buyer would be satisfied.

Perhaps standardisation procedures could be looked at by the Scottish Seed Potato Development Council. The savings in costs and damage to a similar value of, say, £1 per tonne, might save the industry over £400,000 per annum, or 1% of our delivered values.

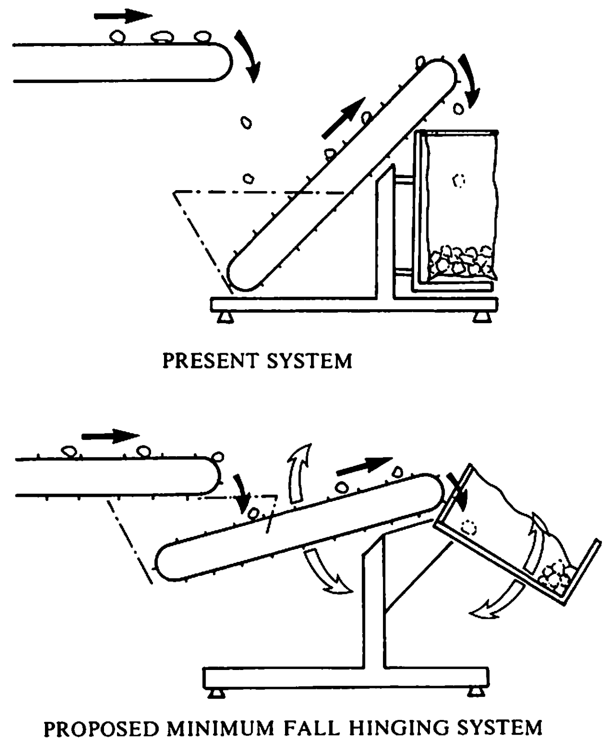



*Fig 5 A design for a hinged type of bagging device for minimising drop height*

## Supply/demand control

**Compulsory, legislative, and other bodies**
**The Futures Market**

The Futures Market has increased the risks of potato trading, because we will never know which far-away market ware trader or country seed merchant, who for fun or excitement or to resolve a problem, gambles away his financial backing, and our security. It is a superb gambling arena, because the levy is only 1%. Excluding speculators, it is also very one-sided because there are many producer/sellers who could use the market as a hedge, but there are hardly any real purchasers, whether from the processing or retailing sector, who wish o hedge in comparable amounts. The over reactions, if one looks at the graphs, are a speculators' and manipulators' paradise, making it very difficult for the producer to hedge in a sane and logical way. By being forced to pay up "losses" day by day, a producer hedging all his crop might have to take his bank manager along with him, and they, in their ignorance, at the present moment cannot see the wood for the trees.

The potato futures market started in America about 100 years ago, as a type of forward contracts market, whereby merchants and processors entered into contracts with growers at cost plus, and by so doing allowed the growers to borrow on their growing costs, and stabilising the market. We have a long way to go with bankers, merchants and processors before this happens in our futures market.

**The Plant Royalties Bureau**

The Plant Royalties Bureau has been criticised heavily by seed growers. However, we should now respect that breeders of new varieties hold patents and, as with machinery, inventors should be able to ask and charge as much as the market will bear. We are not obliged in any way to plant a registered variety. That being the case, our only criticism should be on the method of calculation, ie it ought to be related to value, like VAT, and on a tonnage basis as with cereals. This method would be much more equitable. Some of the criticism of the Bureau seems to me to be associated with the fact that nearly all recent new varieties have been State bred. I look forward to the day when we can all use the pool of genetic material held by the State but not available to private individuals. After all, if Bintje and King Edward 70 or 80 years ago were 'flashes in the pan' rather than being scientifically bred, then perhaps as in Holland the smaller breeder could again come up with the winners that we in Britain so obviously require.

And if we look further ahead to the day that commercial organisations hold the varietal rights, will it not be that seed areas will be more controlled and the market thereby not allowed to be over produced and collapse? Piper, Desiree, Wilja, Estima, Record all under breeders control would produce a different scenario, giving us a much more stable market-place.

**Potato Marketing Board seed and ware licences**

The Potato Marketing Board and its officials are again heavily criticised, especially in Scotland, in a year in which ware values are below the cost of production. The Potato Marketing Board Balance Sheet of production and consumption, imports and exports, and seed usage etc is a new explanatory venture using the figures put forward by farmers on the production side, and those of merchants on the retail and consumption side. The Potato Marketing Board is not trying to massage or distort information, it is trying to present in a logical way the information collected. Therefore, at the end of the season, if the present figures are wrong we will more than likely have to look to ourselves, either the growers for not admitting to larger stocks, or the merchants for not filling-in trading returns properly.

The weakness of the Potato Marketing Board is exposed in a year like this. The Government fall-back price of £43 per tonne is a joke, and the Price Insurance Scheme is only effective at about £55 per tonne, about £10 to £15 per tonne below costs. The Potato Marketing Board has the *impossible* task of defending a UK structure when a massive surplus, lurking in the wings, is ready to flow in behind its back. In a year where we have grown the area demanded by the Government and where the stock situation is in apparent balance, market confidence has been eroded because of exposure to actual imports of chips at below cost of production and the threat of imported table potatoes also at below cost, before the season ends.

Even after the disgrace of 1980, the National Farmers' Union and the Potato Marketing Board agreed this system with the Government. Who do you think won the war?

How can cereals, dairy products, beef, etc, have a cost plus system and maincrop and seed potatoes, perhaps the most capital investment of all, be thrown to free, but Ministry of Agriculture, Fisheries and Food distorted market forces? The sooner we know which side of the fence we are on, the better.

**Ministry of Agriculture, Fisheries and Food**

If criticism has to be levied, because of a fall in value in a supposed balanced crop year, it must be towards the Ministry of Agriculture, Fisheries and Food. Abusing the Quota system carried forward from that prior to European Economic Community days, and knowing that farmers will always grow the Quota, (as it may be a long-term asset, and there is a penalty for not growing), we have been persuaded and seduced to grow 100% of the Nation's requirements for this year. Knowing that there is now no import barrier, and knowing that there is always a surplus in Northern Europe, surely Ministry of Agriculture, Fisheries and Food behaviour is wrong, unjust and immoral in calling 100% of the Nation's requirements with a fall back price of only 60% of the cost of production. Either we have 100% strategic production and a guarantee of the cost of production, or we should demand through the National Farmer' Union and the Potato Marketing Board that the Minister for Agriculture should be persuaded to use a lower target area of say 90%, with a derisory £40 fall-back price and import the rest, or we should have a free marekt. As an example of how we are being misled, given historical yields over the past 15 years, an average annual increase of 2½% per year, the Ministry of Agriculture, Fisheries and Food is only allowing for a ¾% increase in production in 1983 in the Quota area calculation. With the obvious improvements in technology, better seed, destoning, more efficient harvesters and storage, new varieties, irrigation, management, this is a nonsense. There is apparently, at the moment, no challenge to this device for keeping consumers' prices down in an Election year and, indeed, no reduction of about ¾% on Quota has been announced to take account of the 50,000 tonnes carry-over to next year by way of the Potato Marketing Board frozen chips.

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**Appendix 1 Seed potato growing costs, 1983 (at contractor rates)**

| | | *Production costs, £/acre* | *£/ha* |
|---|---|---|---|
| Seed | 1.75 ton/acre × £120 | 210 | 519 |
| Fertilizer | 0.45 ton/acre × £140 | 65 | 161 |
| Chitting | (£ 60/acre) say 1/3 | 20 | 49 |
| Plough | | 9 | 22 |
| Rotovate | | 9 | 22 |
| Destone | | 20 | 49 |
| Plant and fertilizer | | 20 | 49 |
| Control of weeds, chemical | | 12 | 30 |
| Control of blight and aphids | | 12 | 30 |
| Rogue labour at cost | | 14+ | 34+ |
| Plant Royalty Bureau | £20 to £50 /acre say | 23 | 57 |
| Department of Agriculture inspection fees | | 12 | 30 |
| Department of Agriculture labels | | 11+ | 27+ |
| Potato Marketing Board levy | | 15 | 37 |
| Scottish Seed Potato Development Council costs | | 4 | 10 |
| Pulverise and acid burn | | 22 | 54 |
| Hand pick squad and bus | £110/acre; harvester £60/acre say | 90 | 223 |
| Harvester field tractor, digger, transporters, forklift, trailers and labour | | 65 | 161 |
| Haulage to store | 14 ton/acre × £2 | 28+ | 69+ |
| Dressing labour | 14 ton/acre × £6 | 84 | 208 |
| Other storage costs, ventilation, insurance, etc | | 15 | 37 |
| Management | | 35 | 86 |
| | | 795 | 1964 |
| Store rental | 70 | | |
| Boxes rental | 80 | | |
| Store forklift £1.50/ton | 20 | | |
| Grader rental | 20 | 190 | 470 |
| | | 985 | 2434 |
| Rents (farmers fixed costs incorporated in above contractors costs) | | 75 | 185 |
| Interest 8 months 8% on £500 | | 40 | 99 |
| Total | | 1100 | 2718 |

**Appendix 2 Extra costs of seed production over ware production**

| | | | *Extra costs for seed £/acre* | *£/ha* |
|---|---|---|---|---|
| Department of Agriculture inspection fees | | 12 | | |
| labels | | 11 | 23 | 57.50 |
| Total including eelworm testing, inspectors and export certificates. | | | | |
| Plant Royalty Bureau | Up to £50 per acre say | | 23 | 57.50 |
| Scottish Seed Potato Development Council | | | 4 | 10.00 |
| | (at 9 ton per acre = £5.50 per ton) | | 50 | 125.00 |
| Field roguing | 10 | | | |
| Extra seed -½ ton @ £120 | 60 | | | |
| Premium for box storage ½ ton × £80 | 40 (at 9 ton per acre = £12 per ton) | | 110 | 275.00 |
| | (at 9 ton per acre = £18 per ton) | | £160 | £400.00 |

Costs ex Potato Marketing Board for ware £2300 per hectare (£940 per acre)

Add £400 for seed above

£2700 per hectare

about £1100 per acre as on Cost Analysis Schedule

Ware at £940 per acre, 15 ton/acre crop = £63 average cost per ton.

Seed £1100 per acre, 13½ ton/acre crop — £90 per tonne

| | | |
|---|---|---|
| say 4½ ton | ware @ £63 | 283 |
| 9 ton | seed @ £90 | 810 |
| 13½ | about | £1100 |

Equal to an extra cost, seed over ware = £27 per tonne

= 43%

OR £1100 per acre, 15 ton/acre crop — £80 per tonne

| | | |
|---|---|---|
| say 5 ton | ware @£63 | 315 |
| 10 ton | Seed @£79 | 790 |
| 15 | about | £1100 |

Equal to an extra cost, seed over ware = £16 per tonne

= 25%

# Edited summary of the discussion
# Seed potato production

←page 52

## Questions following Paper 3, (D C McRae — Better harvester design)

**Dr B D Witney (East of Scotland College of Agriculture)**

Q. By reducing the area of agitated web in the variable web design, another drop is introduced. Does this not tend to counteract any advantage in reducing the area of agitated web?

A. *This is a valid comment but care has been taken to ensure that the drop is only a few inches by the use of small rollers. The advantage of the drop is that it gets rid of loose soil but only a small drop is required. Usually, cascade rollers are of large diameter, generating large drops which cause damage. This device has yet to be evaluated.*

**Mr J Bethell (Scottish Seed Potato Development Council)**

Q. Soil removal seems to be a major problem in potato lifting: ceramic to metal bonding systems have been developed for use in internal combustion engines. Have these ceramics any application in reducing the adhesion of soil to metal on the harvester?

A. *Some work has been done on this but mainly for inhibiting wear rather than adhesion. The store is a suitable place for this application. Electro-osmosis has been tried to develop water lubrication of the surfaces but this is not necessarily advantageous.*

## Questions following Paper 4, (O J H Statham — Better storage design)

**Mr R Pringle (North of Scotland College of Agriculture)**

Q. Has any work been done to indicate how ventilation fans should be sited to obtain optimum environmental control within a store?

A. *There has not been any specific work on this subject. The first priority in any store is to have forced ventilation, after which a recirculation unit may be considered. These can be controlled by a timer to operate for 1–2 hours a day, which is useful for balancing out temperature variations in a bulk store. Small fans distributed around the roof space can be used to provide continuous recirculation, while also reducing the incidence of condensation.*

**Mr C Bates (North of Scotland College of Agriculture)**

Q. Can the speaker quantify the weight loss expected by maintaining the relative humidity inside the store at a given level, eg 85%?

A. *Evaporative weight loss is determined to greater extent by the ventilation period rather than ventilation rate, so that it may be minimised by using large volumes of air over a short period. The typical equilibrium relative humidity, at which no evaporation will occur, is about 98%. Normally, after 6–8 months storage a weight loss of about 5% may be expected. Control of the store temperature is much more important than control of humidity.*

**Mr J Fotheringham (Scottish Seed Potato Development Council)**

Q. Little attempt seems to be made to control environmental conditions on board ships used for exporting seed. Do you have any recommendations for ventilating ships' holds?

A. *Modifying the tubers' environment depends on intimate contact between tubers and the ventilating air. Once the potatoes are packed into sacks or polythene bags for shipping, our ability to modify storage conditions is severely restricted. There is little point in ventilating the sacks.*

## Questions following Paper 5 (P H de Haan — Dutch Grading and packaging systems)

Mr D C McRae (Scottish Institute of Agricultural Engineering)

Q. Could the speaker define the damage assessment used in the Netherlands, as it is evidently different to that used in Britain?

A. *The type of damage which gives most concern in the grading and packaging context is internal bruising (or 'blackspot'). The acceptability of blackspot in the large Dutch processing market is minimal and this must be borne in mind when installing a grading/packaging system. Damage occurring in the system is assessed by measuring internal bruising levels before and after potatoes pass through the system.*

# Energy conservation and dehumidification in greenhouses


## S N Saluja and S Simpson



### Abstract

THE incidence of high humidity in greenhouses is detailed and the conditions and mechanisms which influence humidity levels are outlined. The effect of energy conservation on internal humidity is examined. Possible reduction in condensation heat loss which results from controlling the humidity is shown and an indication of the amounts of latent heat energy available for short term storage is given. It is suggested that the provision of humidity control as an option would be worthwhile if heat pumps are to be used for greenhouse heating.


*Som Saluja*

*Stan Simpson*

### Introduction

ACTIVE climate control using dehumidification in greenhouses was first proposed and investigated as an aid to carbon dioxide enrichment. By providing sensible cooling and dehumidification in place of the normal temperature control of ventilation, artificially high concentrations of carbon dioxide can be maintained and hence an increase in crop yield. Wolfe (1970), came to the conclusion that the cost of providing the evaporative cooling required for the British climate outweighed the returns expected for tomatoes. Silverston *et al* (1980), studied condensation heat losses for the Canadian climate, where temperatures drop well below freezing, using a quasi steady-state heat balance. Results showed significant heat loss by condensation especially for plastics houses when it could be up to 20% of the total. Again mechanical dehumidification was found to be uneconomic on the basis of energy saving alone.

Heat pumps have been shown to be economic for glasshouse heating (Nisbet and Chee 1977) and their use in an integrated system incorporating heating and refrigerative dehumidification has been described (Morgan 1981). As part of an integrated system, the economics of providing dehumidification looks promising. The savings which accrue from reduced heat losses are only offset by a small extra capital outlay. In this paper, it is proposed to examine the extent of these reduced heat losses together with other benefits that such a system can provide.

### Excessive humidities

Traditional greenhouses do not suffer, to any great extent, from high humidity problems. When the plants are ejecting large amounts of water vapour through evapotranspiration, the solar radiation level is high. In these conditions, there is sufficient solar heat gain available to allow venting without supplementary heating. Although this is primarily used to keep the greenhouse air temperature down, it has the additional effect of removing the water vapour laden air and replacing it with air of lower enthalpy value and thus controlling the humidity. When it is prohibitive in energy terms to use venting to control humidity, other mechanisms provide the control. Infiltration and condensation on the glazing surfaces normally provide excellent humidity control although they are wasteful and costly. In some instances, high humidities do occur and are a problem or have the potential to become a problem should the greenhouse design be changed. It is useful to look at these cases more closely.

The change from day to night temperature regimes has potential for causing high humidities. Consulting the psychometric chart, it can be seen that for a fall in temperature of 5°C the relative humidity will be substantially increased. A drop from 20°C to 15°C will cause saturation (100% R H) of air originally at 70% R H.

At sunrise when the solar input and change in temperature regime would suggest a reduction in humidity problems, condensation may occur on the foliage and fruit. This is caused by two factors. One, the leaf and fruit temperatures are low due to radiation losses to the night sky or the glazing surfaces.

And two, the onset of solar radiation causes a sudden increase in evapotranspiration. The resultant wet foliage and fruit is a nuisance to the operatives, and can be detrimental to fruit quality if it is picked under these conditions.

The use of plastics as a glazing material has led to a reduction of passing climate control inherent in the traditional designs. The sealed nature of plastic houses make them susceptible to excessive humidities and the attendant problems of drip damage, reduced light transmission (due to condensation on the glazing surfaces), problems with pollination, plant elongation and increased risk of disease propagation.

Double glazed plastic greenhouses, the type which will become the next generation of greenhouse stock, have even less passive humidity control. The inner surface of the glazing is at a high temperature than the single glazed structure, due to the increased thermal resistance of the air gap between the glazing. This reduces the condensation potential and hence allows the humidity of the greenhouse atmosphere to rise to high levels before condensation occurs.

This type of greenhouse design is desirable due to its low energy requirements, although active climate control to limit the humidity levels which occur may well be essential.

### Sacrificial humidity control

Savings can be made by introducing refrigerative dehumidification as an option when using a heat pump for all or part of the heating load. Water vapour is removed from the greenhouse atmosphere by condensing on the evaporator coil.

The latent heat release by the water vapour is returned to the greenhouse as sensible heat via the normal operation of the heat pump. Reducing the humidity reduces the condensation heat losses. The amount of heat returned to the greenhouse is equal to the extra heat which would have been lost due to higher humidity levels. Condensation heat loss is sacrificed in favour of sensible heat gain. Obviously, the twofold effect of reduced losses and released latent heat can only be sustained whilst the humidity is maintained. In practice, the humidity levels are reduced and the savings finite and calculable during the night-time period. During daylight, they are less easy to assess.


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*His colleague, Stan Simpson is Senior Research Assistant and is applying mathematical modelling techniques to predict the thermal performance of greenhouses.*

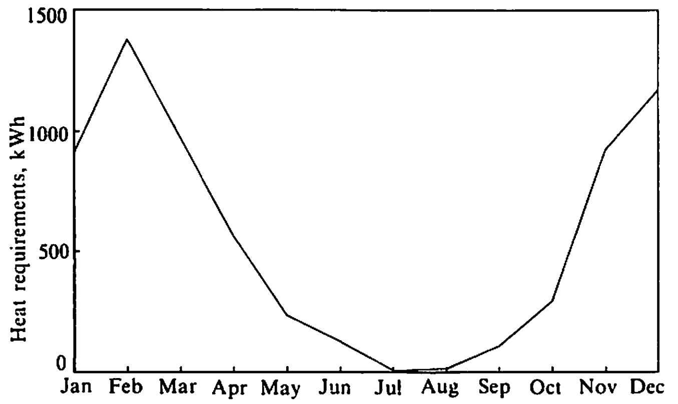


*Fig 1 Night heat requirements of a 0.1 hectare greenhouse. Based on a U-value of 6.2 W $m^{-1}$ °$C^{-1}$* and an internal temperature of 150°C. From hourly external temperatures (Kew 1969)

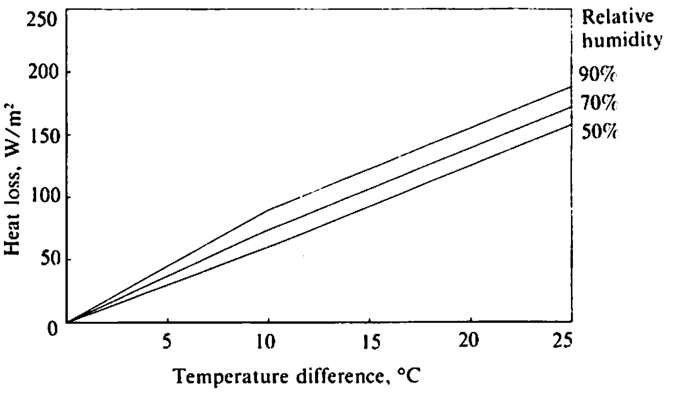


*Fig 2 The effect of internal humidity on heat loss*

## Savings due to dehumidification

One method of estimating the magnitude of the savings in heat energy is to view the greenhouse atmosphere as a 'change of phase' heat store. The solar energy input during the day causes the humidity levels to be near saturation at sunset. If we assume that evapotranspiration ceases at sunset, a not unreasonable assumption for this purpose (Morris *et al* 1957) then the difference between the enthalpy value of the air at sunset and the minimum value that it falls to during the night is equal to the heat loss via infiltration and condensation. This is the potential for saving.

As an illustration, the stored enthalpy in a 0.1 hectare greenhouse can be simply calculated. By assuming a constant temperature, and a drop in relative humidity from 100% at sunset to 70% some time later, we have:

heat energy stored = volume x density x change in enthalpy KJ.

If the solar input is high and the daytime temperature is allowed to rise to 25°C with solar gain and again the night maintained temperature is 15°C, then for a 0.1 hectare greenhouse:

$$\text{heat energy stored} = \frac{3000 \times 1.2 \times 42.48}{1000 \times 3.6} = 42.48 \text{ kWh}$$

To put this in perspective, the night-time heat required by a 0.1 hectare greenhouse, calculated using a method similar to that of Bailey (1977), is shown in fig 1. As can be seen, the possible contribution to the total demand is small but worthwhile when viewed against the small extra capital investment.

During daylight, the process of evapotranspiration replenishes the water vapour removed from the atmosphere via condensation and infiltration. This is also true at night, although the rate of evapotranspiration is lower.

The heating requirements may be reduced by depressing the relative humidity inside the greenhouse and hence reducing condensation heat loss and infiltration heat loss (exiting air of lower humidity will have a lower thermal energy content). A simple energy balance model may be used to illustrate this point and has been developed by the authors to give an indication of the values involved. The method is not reproduced here in full but involves the following steps.

1) An energy balance is performed using convection, radiation, condensation and infiltration heat loss at the glazing.
2) The energy balance is solved using an iterative procedure to obtain the glazing temperature and hence the heat loss.
3) This procedure is repeated for a wide range of internal and external conditions.

The above method was used to produce the graph shown in fig 2. This shows the effect on the effective heat loss through the glazing of changes of the internal relative humidity. A reduction in relative humidity from 90 to 70% reduces the total losses by between 9% when the temperature difference between inside/outside is 20°C and 15% reduction in total heat losses when the temperature difference inside/outside is 10°C. For temperature differences below 10°C the effect remains constant at 15% reduction.

## Short term solar storage

During a large portion of the heating season the solar input during the daylight hours is greater than the heat requirements over the 24 hour period. This excess heat energy is lost by ventilation in order to maintain temperatures.

This heat energy can be extracted and stored by using sensible cooling. Even when the sensible heat gain of the greenhouse does not provide a high enough temperature lift so that sensible heat recovery can be performed, there can still be large amounts of energy available for storage.

Approximately 80% of the solar radiation which is transmitted into the greenhouse goes to either sensible heat gain or to drive the process of evapotranspiration. The exact proportion which goes to each depends on the season and varies between 38% and 62% of the transmitted solar energy used in the evapotranspiration would be lost via condensation or infiltration. A heat pump working as a dehumidifier under these conditions can recover the latent heat energy locked up in the water vapour. Particularly important is the fact that the heat pump will perform at a very high coefficient of performance since the temperature lift can be kept small.

It is useful to look at the amounts of energy available for recovery. Looking at the median value of solar radiation on a horizontal surface (Kew 1952–1971) for February, a typical day would yield 997 Wh/m². If we assume that 62% of this incident energy is transmitted and, of this, 38% is used by the plants for evapotranspiration, then:

$$997 \times \frac{62}{100} \times \frac{38}{100} \times \frac{1000}{1000} = 235 \text{ kWh/day for a 0.1 hectare greenhouse.}$$

This large amount of heat energy (235 kWh) will provide a high grade source for the heat pump and enable the effective Coefficient of Performance to be raised above that which would normally be achieved when using ambient air as the source.

## Conclusions

If heat pumps are to be used for greenhouse heating, then the option of using the installation for active climate control would seem to offer many benefits. In addition to the extra climate control needed by the new greenhouse designs, which can in themselves reduce the energy requirements by up to 50%, the depression of the humidity levels can reduce the heat losses and there is scope for increasing the efficiency of the heat pumps by using solar storage. Apart from the solar storage, the other benefits can be provided for the small extra cost of ducting and controllers.

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