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Haulm killing and damaging potatoes

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Preface

Specialists from ten countries attended the Meeting of Section Engineering of the European Association for Potato Research, held in Wieringerwerf, The Netherlands in September 1992.
The subjects of the meeting were 'Haulm Killing' and 'Damaging Potatoes'. The presented papers of this meeting are brought together in these Proceedings.

The haulms of a seed potato crop have to be killed to preclude virus infection of the crop. Other reasons are to stop the growth to obtain the desired sizes and to have an easier harvest.
Haulm killing can be done by chemical, thermical or mechanical methods. In consideration to the environment the use of chemicals has to be minimised and some chemicals are forbidden.
Therfore mechanical systems as haulm pulling and green crop harvesting are developed.

The quality of potatoes is assessed largely by damages, which can be internal and external damages. They are arise mostly from mechnical influences as bumping, pressing and cutting. The amount of damage depends on falling height, the transport speed, the maturity and the structure and the weight of the tuber and the pressure on the tuber. The research is working on all this areas.

Manufactures and importers of machinery and equipment for planting, ridging and haulm killing, they have given us the possibilities for organizing the demonstration. Besides that the manufacturers of sieving webs and storage equipment have invited the participants for the excursions.
Members of the organizing committee and employees of the IMAG-DLO have also contibuted to the success of the meeting.

A.A. Jongebreur
Director of the Institute of Agricultural Engineering

Contents

Introduction

The meeting of the Section Engineering of the European Association for Potato Research was attented by 37 specialists from 10 countries. The meeting was held in Wieringerwerf (The Netherlands) in September 1992.

Prof.Dr.Ir. P.C. Struik opened the meeting with a survey of the potato cultivation and haulm destruction in the Netherlands.

Haulm Killing and Damaging Potatoes were the main subjects of the meeting.

In various countries there is a tendency towards minimizing the use of chemicals for haulm killing in consideration of the environment. A system to achieve such minimization is a combination of spraying with pulverizing the haulms. The quantity of chemicals can be reduced to 50%.
Instead of using chemicals, flaming can be used in combination with pulverizing. At present LPG gas is used instead of diesel oil. The costs of fuel for the burners, the production of carbon dioxyde and the distribution of LPG gas are problems of this system.
Besides the chemical and thermical treatments of potato haulms there are the mechanical treatments of pulverizing, haulm pulling and green crop lifting. These treatments can be combined.
In the proceedings, attention has been paid to all these systems, and the results of the killing are discussed. Besides the results of haulm killing, the effect of the various systems on the spread of diseases and the sensitivity to peeling are reported.
The different systems of haulm killing were demonstrated on the experimental farm 'Oostwaardhoeve' of IMAG-DLO in Slootdorp. There was also an exhibition of a complete line of potato mechanization.

The quality of potatoes is assessed on the basis of damaging, greening, presence of diseases, etc. The subjects of the proceedings dealing with the mechanical damage are the measurements of the sensitivity of peeling, a method of rapidly developing latent bruising in potatoes, the use of electronic tubers to locate bruise spots in a harvester, the damaging of potatoes in a commercial storage installation, and a comparison between two types of pendulems.
A factory of sieving webs and a factory of storage equipment were visited. In both, the production was shown with special attention being paid to mechanical damage. Covering of the rods, the use of covering materials in the implements, drop heights, and so on, were discussed and shown.

At the business meeting the following four items were discussed:
- In the future the quality of potatoes will become more important for both table potatoes and potatoes for processing. To gain an insight into the sources of damage in the whole chain of potato handling to be able to remedy the problems, an inventory has to be made. Besides, the direction for research can be indicated.
- The classification of the different types of mechanical damage and also the rate of damage in the different classes. At the meeting it was decided to make a proposal for

a discussion at the next meeting in 1993.

- It is important that next to a system for rapid development of bruises in potato tubers there is a system for an objective, fast and uniform classification.
- There is much misunderstanding with regard to terminology in mechanization and especially in haulm killing. In the section, representives of Britain, Germany and France will draft a list of the most usual terms. This is coordinated by the chairman.

Aries Bouman
Chairman of the Section Engineering of the EAPR

Potato cultivation and haulm destruction in the Netherlands

P.C. Struik

Agricultural University, Wageningen, The Netherlands

Summary

In the Netherlands, potato is widely grown for ware, seed and starch potato production. Large concentrations of potato production are found in the south-west and centre of the country (ware potato), along the northern coast and in Flevoland (seed potato) and in and around the peat colonies (starch potato). Yields increased steadily over the years, although trends are different for ware, seed and starch potato. The input of fertilizer and pesticides also strongly increased. Stimulated by consumers' awareness for quality and environment and by government policy, the crop husbandry changes, including the haulm destruction methods.

Haulm destruction is carried out to control spread of diseases, to manipulate tuber-size distribution, and to advance skin set and ease harvesting. In seed potato production, the timing of the haulm killing is crucial for the economic return. The haulm can be destroyed by flaming, pulling, chopping, chemical treatment or by a combination of methods. The choice depends on crop characteristics (type, maturity), occurrence of pests, costs and convenience, weather and concern for the environment. Mechanical haulm destruction increases the number of growing days, is environment friendly and may reduce infestation of the produce and of the soil.

1 Outline

In this short opening paper, some information will be provided on the potato cultivation in the Netherlands and on the trends in yields, use, production and research of the crop. The main theme of this contribution, however, will be the goals, methods and effects of haulm destruction.

2 Potato cultivation in The Netherlands

In the Netherlands, potato is mainly grown to produce ware, seed or starch potatoes. Potato is hardly grown for animal feed, although a large portion of the condemned lots is used as such. Table 1 summarizes some statistical data of the year 1991. Recent changes in area are not large. The potato industry is very export-oriented for all production purposes. In the Netherlands, the per capita consumption has decreased over the last decades, but it still is about 80 kg per year. At the same time, the consumption shifted from consuming table potato to the consumption of processed potato.

Table 1 Acreage, yield and production for ware, seed and starch potatoes in the Netherlands in 1991 (Data from Annual report of the Dutch Commodity Board for Potatoes, 1992).

Crop	Area × 1000 ha	Fresh yield (Mg/ha)	Total production × 1000 Mg
Ware potato	79.7	45.5	3626
Seed potato	37.2	34.0	1265
Starch potato	62.7	33.5	2106

Potato is widely grown in the Netherlands, but the seed potato production is concentrated in the Noordoostpolder, Drenthe and along the northern coast, the ware potato production is mainly found in the south-west, Flevoland and Noord-Holland, whereas the starch potato production is concentrated in and around the peat colonies.
The yield per hectare has strongly increased in time, especially during the last 35 years (Fig. 1), but the trends were not similar for ware, seed or starch crops. These increases are large, considering the limited progress in yield through breeding, as compared to other field crops. At the same time, the amount of pesticides and fertilizers applied strongly increased. Per hectare, the different potato crops rank very high in use of biocides, mainly due to the large amounts of fungicides applied (Table 2; chemicals applied for soil sterilization are not included; soil sterilization, however, is mainly carried out to allow more frequent potato production in the same field). Over 50% of the total amount of chemicals used in arable farming is applied in potato crops. These facts attracted attention from organizations of consumers and environmentalists. Together with the recently adopted government policy to reduce the use of and dependence on biocides in agriculture, and the increase in popularity of bio-organic farming, this consumers' awareness for the environment will have a great impact on the crop husbandry and hybrid choice of potato.

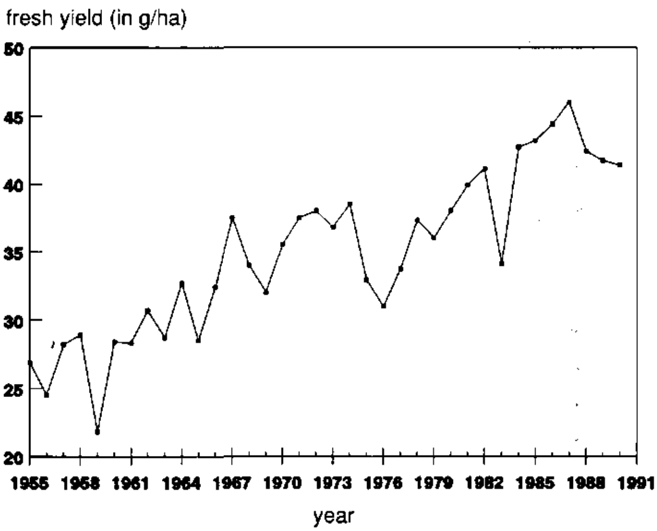

Fig. 1 Changes in time in yield of (ware and seed) potato in The Netherlands. Source: Landbouwcijfers, LEI, The Hague.

Table 2 Amounts of active ingredient used in arable crops in the Netherlands in 1987 (after Berends, 1988).

Crop	Amount	
	kg/ha • year	Mg/year
Onion	20.0	310
Potato	13.1	2200
Ware	17.0	1300
Seed	13.0	450
Starch	7.8	450
Sugar beet	4.9	630
Winter wheat	3.1	320
Maize	1.7	340
Spring barley	1.5	63
Total (all arable crops)	5.5	4200

Moreover, there is an increase in the consumers' awareness for internal (residues of nitrate, pesticides) and external quality, a possible preference for environment friendly products, more diversification in the consumers' price and a stronger preference for certain cultivars (depending on the use of the potato). All these developments strongly influence both fundamental and practice-oriented research in the Netherlands.

3 Haulm destruction

Haulm destruction is a drastic method of crop protection or crop manipulation. Killing the haulm is a dramatic event in the life of a potato tuber, especially in the case of seed potatoes where the treatment is carried out when the haulm is still very active and tuber bulking is still rapid. Haulm destruction completely changes the physiological behaviour of the tuber, as is illustrated by the effects of temperature on dormancy (Fig. 2; note that the comparison is not perfect, because data are from different experiments and tubers are not of the same age). The haulm has a controlling influence on the dormancy of tubers, although the variation in behaviour of tubers from the same stem is still extremely large.

The main objectives for haulm killing are:

- for seed potatoes: control of spread of virus, manipulation of tuber-size distribution, stimulating skin set, and advancing and easing harvest.
- for ware potatoes: control of spread of *Phytophthora* to the tubers, stimulating skin set, and advancing and easing harvest.

In starch potatoes haulm killing is not common.

Control of tuber-size distribution is crucial in seed potatoes. When the harvest is delayed, the physical yield still increases but the financial yield can decrease by up to DFl. 400/ha•day.

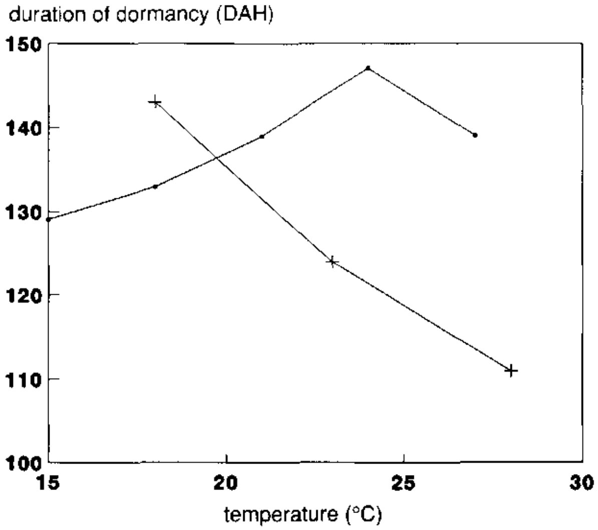

Fig. 2 Effect of temperature during the last 4 weeks before haulm destruction (HD) or during storage on the duration of dormancy (in days after harvest, DAH) for cv. Désirée. Based on Van Ittersum, 1992.

Methods of haulm destruction include flaming, chopping, pulling, chemical treatment, or a combination of treatments. The choice of method depends on the crop (type, maturity), the occurrence of weeds, pests and diseases, aphids, other insects and bacteria, costs and convenience, weather conditions, and the concern for the environment. Because the use of chemicals should be decreased and dinoseb is banned in the Netherlands, mechanical methods are becoming more popular. Table 3 gives an overview of advantages and disadvantages of mechanical haulm destruction.

Table 3 Comparison of mechanical vs chemical haulm destruction.

Yield	+
Quality of result	–
Weed control	–
Independent of weather	–
Cost effective	–
Environment friendly	+
Disease protection in product	var
Effect on soil infestation	var

\+ means that mechanical destruction has an advantage;
– means that mechanical destruction has an disadvantage;
var means that the effect depends on the organism.

Especially for seed potatoes, the 'green-crop harvesting system' is promising. In this system the haulm is mechanically destructed, tubers are lifted and stored in a hill to harden, sometimes after application of antagonists of fungal diseases. This system

strongly reduces problems with *Rhizoctonia solani* and *Phoma*. For ware potatoes, two-stage harvesting techniques are developed which also may reduce diseases and storage losses.
The method of haulm killing influences the occurrence of diseases on the harvested products, but may also affect the level of soil infestation. This will be demonstrated by some unpublished results of research at the Department of Agronomy, Wageningen.
In 1991, seed tubers of cv. Santé were planted, which were heavily infested with Rhizoctonia solani. In some treatments, Monceren (a.i. pencycuron) was applied in April in 50 or 100% of the advocated amounts. At the end of the growing season black scurf was recorded. In the same field plots, healthy tubers (disinfected with Solacol, a.i. validamycine) of the cv. Element were planted in 1992 to test the stem infection by Rhizoctonia after the treatments of the previous growing season. Black scurf was reduced by green-crop-harvesting and to some extent by Monceren, but increased by chemical haulm killing (Table 4). The stem infection in the next year was reduced by mixing the haulm with the upper soil after green-crop harvesting, probably because of heavy competition with other microorganisms and (to some extent) by a Monceren treatment in the previous year.

Table 4 Effects of haulm destruction methods on *Rhizoctonia solani*. Unpublished data of M. Lootsma.

Treatment in 1991	Black scurf index 1991	Stem infection index 1992
·Green-crop harvesting·		
haulm removed	6 a	26 bc
haulm on soil	7 a	28 bc
haulm in soil	6 a	17 a
Haulm pulling	35 c	39 d
Chemical haulm killing	44 d	33 cd
Chem. haulm killing + 50% Monceren	27 b	27 bc
Chem. haulm killing + 100% Monceren	26 b	23 ab
Natural maturing	31 c	30 bc

Also in the case of *Verticillium dahliae* (an important soil-borne fungus with a wide host range, causing early dying), the method of haulm destruction is relevant. Microsclerotia (survival structures, which are stimulated to germinate by root exudates) are formed on senescing plant material or plant debris, mainly stem parts, but also on other plant organs. The amounts of microsclerotia are much larger when the crop is harvested late and when a sensitive cultivar is grown. Haulm destruction methods have a considerable effect on the number of microsclerotia on the haulm. At a seed potato harvest, chemical haulm killing and flaming resulted in more microsclerotia per amount of dry haulm material than haulm pulling or chopping (Fig. 3). Mixing with the upper soil did not result in a significant effect.

These and other results suggest that mechanical destruction may reduce the occurrence of some diseases in the harvested product, but may also reduce the level of soil infesta-

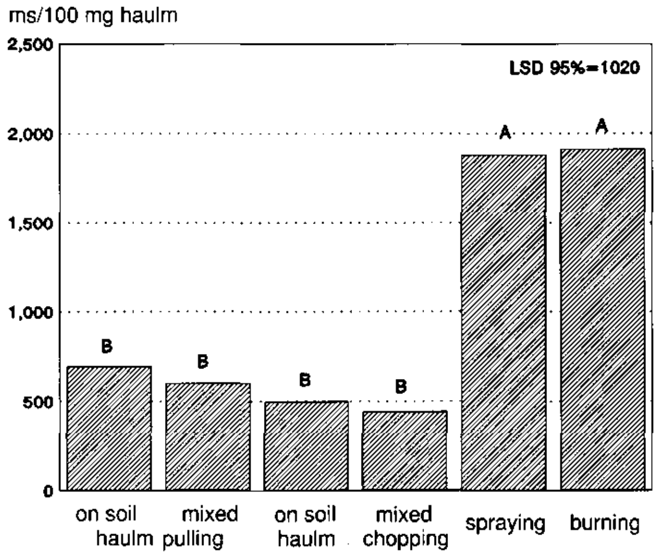

Fig. 3 The number of microsclerotia of *Verticillium dahliae* per 100 mg of dry haulm four weeks after haulm killing by pulling or chopping (cutting) with or without mixing with the upper soil layer or by spraying a chemical or burning. Unpublished data of L. Mol.

tion. On the other hand, it may stimulate some other pests and diseases. More research into the possibilities to control soil-borne diseases with haulm treatments and other cultivation techniques (e.g. green manure) is necessary.

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Haulm killing

A review of the research work into the different haulm killing methods in The Netherlands

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Summary

Haulm killing has a history of more than fifty years. There has been an evolution from fully manual operations towards full mechanization by chemical, thermical and mechanical methods.
The different systems are reviewed with respect to the effect of haulm killing on the susceptibillity to peeling, the incidence of black scurf, late blight and gangrene, the influence of weather and field conditions, the capacity and the costs.
The most effective systems of haulm killing are green-crop lifting and haulm pulling. These two systems, including flaming, need less or no chemicals.
Most of the haulm killing systems have a small working width, and therefore they can have problems under wet weather and field conditions.

Introduction

The haulm of a seed potato crop has to be killed or removed for a number of reasons. These are to preclude virus infections of the crop, to stop growth in order to get the desired grades of the tubers, and to have an easier harvest.
Virus infection takes place by virus-transmitting aphids. The time of killing depends on the likehood of flights of these aphids and the variety and classification of the seed potatoes.
The grower wishes the highest yield of tubers in the grades between 35 and 55 mm. When the haulm has been removed it is easier to separate haulms and tubers without loss and damage. For that reason, the haulm of the crops of ware potatoes and starch potatoes also need to be killed.
Immature tubers have a high susceptibility to peeling and should therefore not be harvested. Peeled areas open the way for further infection by disease organisms. Susceptiblity to peeling decreases, when haulms are expiring. This process can be chosen at an earlier time by haulm killing or removing.
In earlier times the crop was dug by hand. The capacity was low and this system required many workers. The next step was the introduction of haulm pulling by hand. Though the capacity was twice as much, but the system still required 20 to 25 manhours per ha. This work was also very hard for the backs and wrists of the workers.
Therefore, in 1947 the first experiments were carried out with mechanical haulm pulling. The development of chemicals for haulm killing pushed the method of haulm pulling

aside. The capacity of the full-width spraying machines was much higher and the job was easier. After chemical haulm killing, however infection with black scurf increased more than after pulling. The use of machines for haulm pulling gained interest, but decreased again with the development of fungicides to control black scurf, such as Solacol and Monceren.
In the near future the use of some chemicals will be forbidden. The use of Dinoseb is no longer allowed already. Besides, there is also a general attitude to minimize the application of chemicals. The interest in alternatives is growing.
Researchers have done much work in developing and testing of the different haulm killing sytems.
The systems are chemical (full-width spraying and strip spraying in combination with pulverizing), flaming in combination with pulverizing and mechanical methods such as haulm pulling, root cutting and green-crop lifting.
There are several factors, which influence the grower's choice of system for killing the haulm. The susceptibility to peeling and the incidence of black scurf (*Rhizoctonia solani*) are two of them. These factors depend on potato variety and type of soil. With the application of a fungicide, such as Monceren at planting time, black scurf can be controlled (Mulder and Roosjen, 1984).
Besides these two factors, the capacity of spreading diseases, such as late blight (*Phytophthora infestans*) and bacteria (*Erwinia*), dependence on weather and field conditions, and the costs of the systems, are important for making a decision.
All these factors are affected by the system of haulm killing or removing.

Materials and methods

The different methods of haulm killing or removal were investigated with particular attention to the following items: efficiency of haulm killing, susceptibility to peeling, black scurf (*R. solani*), late blight (*P.infestans*), gangrene (*Phoma exigua var. foveata*), dependence on weather and field conditions, capacity and costs.
The extent of peeling is presented as a peeling index, and the incidence of black scurf as a *Rhizoctonia solani* index (Bouman et al., 1983). The maximum index figure, which is allowed for the two indices, is 20.
The results of the following systems are discussed:
- the combination of pulverizing and strip spraying with a working width of 300 cm (four rows),
- the combination of pulverizing and vine burning with a working width of 300 cm (four rows),
- haulm pulling with the two systems with pulling belts and pulling balls, respectively. The working width was 150 cm (two rows),
- root cutting. The working width was 300 cm (four rows). The machine had been developed for reseach purposes. With this machine the roots of every row were cut by two knives.
- green-crop lifting was done with a two-row pulverizer as well as with a two-row haulm puller mounted to the front of the tractor, and a two-row lifter with two discs mounted to the back of the tractor. With the discs the tubers were covered over (Bouman et al., 1990).

  The pulverizer, as well as the haulm puller, is capable of transporting the haulm and the stalks sideways out of the undug rows. This ensures, that haulm and stalks are not present in the new ridge formed after haulm pulling.

In the tables the methods of haulm killing are described with abbreviations, which are presented in Table 1.

Table 1 The abbreviations of the haulm killing methods.

Method	Abbreviation
Full-width spraying	FWS
Strip spraying and pulverizing	SSP
Flaming and pulverizing	FP
Haulm pulling	HP
Root cutting	RC
Green-crop lifting	GCL
GCL and pulverizing	P/GCL
P/GCL and haulm transportation	PT/GCL
GCL, HP and haulm transportation	HPT/GCL

The results of the last ten years are summarized.

Results and discussion

The results, which are discussed, are related to seed potatoes.

Haulm killing

After a chemical treatment haulm dies back slowly. The variety has a great influence on the effect of chemical killing. The quantity of haulm mass (40 or more tonnes/ha) and the weather and crop conditions (wet) necessitate the treatment sometimes to be repeated more than once. The quantity of chemicals can be reduced by over 50% with strip spraying in combination with pulverizing (Breemhaar, 1992).
The amount of haulm killed by flaming is often inadequate. The treatment has to be repeated once or more times.
The killing effect of haulm pulling is mostly sufficient when the shape of the ridge is uniform and the stalks are on the top of the ridge. Over the years the percentage of pulled stalks varied from 96 to 100% (Bouman and Bouma, 1982). The variety also has a great influence on the results. In practise sometimes a treatment with a low concentration of a herbicide is used.
The effect of root cutting is insufficient and has to be combined with spraying or flaming. Under dry weather and field conditions the results of this combination tended to be better.
With green-crop lifting there is no regrowth, when the haulms are pulled or pulverised to short stalks and the tubers covered sufficiently. The depth of soil covering the tubers has to be at least 10 cm.

Susceptibility to peeling

The susceptibility to peeling decreases in time after haulm killing or removing and mostly the crop can be harvested 10 to 17 days after the treatment. The length of the period depends on the variety and on the maturity of the crop.
The decrease in susceptibility is the same whatever the method is of killing and removing. The susceptibility to peeling averages from peeling index 51 to peeling index 7 in 9 to 17 days after haulm killing.
The system of green-crop lifting gave a peeling index of 7 to 15 over the years (Peeling index, see Bouman et al., 1983).

Black scurf

After spraying, the incidence of black scurf has increased strongly in case of naturally infected soils and infected seed potatoes. Flaming has the same effect on the development of black scurf as spraying.
Mostly after ten days the incidence is over 20 (index). Therefore, after spraying the potatoes have to be dug with peeling or with black scurf, because the peeling index is above 20.
Table 2 shows average results of the incidence of black scurf after spraying and pulling in five varieties.

Table 2 Incidence of black scurf (*Rhyzoctonia index*) after spraying and haulm pulling of five varieties on a peat soil*.

Harvest dat (days) **	Spraying (*R.index*)	Haulm pulling (*R.index*)
0	4	4
7	19	12
14	49	26
21	59	34

* Bouman et al., 1983.
** Days after haulm pulling treatment.

The incidence of black scurf 14 days after pulling is just more than 20. In this case the grower has only 4 days to dig his potatoes without peeling and black scurf.
Root cutting has resulted only in decreasing black scurf in a dry growing time, because the roots were growing deep and cutting could be effective (Dijst, 1989).
The results of the development of black scurf after green-crop lifting are presented in Table 3.

Table 3 Effect of green-crop lifting after haulm pulverizing and haulm pulling with an application of Monceren and Verticillium biguttatum on the development of Rhizoctonia solani after 20 days.

Method	Black scurf index		
	No application	Monceren	*V. biguttatum*
SSP	60	–	–
P/GCL	45	15	21
PT/GCL	49	10	23
HPT/GCL	11	2	3

Green-crop lifting in combination with haulm pulling with the transportation of the haulms and stalks to the side the incidence of black scurf can be limited to below the index 20.
Green-crop lifting gives the oppertunity for chemicals or antagonists to be applied to the tubers before they are covered again. With an application of the fungicide Monceren (pencycuron) or the antagonist *Verticillium biguttatum* in combination with removing the haulm and stalks by pulling, the incidence of black scurf can be greatly limited. Haulm in the new ridge influences the incidence of black scurf; the more haulm, the more the incidence of black scurf (Molema et al., 1992).

Late blight

The plots were artificially inoculated with *P. infestans*. Two weeks later the haulm was killed by the different methods. The results are presented in Table 4.
After spraying there is a small increase in late blight (0.2 and 0.5%). Burning can have the same effect, because for a period of two seconds the stalks are exposed to a temperature of 1000 °C, and in this time the spores are killed.

Table 4 Increase of late blight in infected crops* on a sandy clay and a clay soil after four treatments (% infected tubers)**.

Method	Clay soil	Sandy clay soil
SSP	0.2	0.5
HP	0.2	1.9
P/GCL	3.1	4.1
P/GCL and chloratonil	0.7	0.6

* The infection on vine killing date was 2%.

** Turkesteen et al., 1990.

Haulm pulling gives an increase in infected tubers of 0.2 and 1.9%. A possible explanation of the difference is, that on clay soil the haulm was pulled by hand and on the sandy clay soil by machine. With manual pulling the haulm was not pulverized and directly taken out of the plots. On the sandy clay soil the haulm was pulled mechanically. In this case the pulverized haulm and the pulled stalks were laid on the ridges and after that sampled by hand, with a greater chance of infection. In 1991 a system of haulm pulling and direct transport of all haulm and stalks out of the undug fields was developed. Green-crop lifting with short pulverized stalks on the ridges showed an increase in late blight by 3.1 and 4.1%. When a fungicide Daconil (chloratonil) was applied, the increase of infected tubers was 0.6 and 0.7%.

Gangrene

The plots were artificially infected with gangrene (*P. exigua var. foveta*) and situated on sandy clay soils (Turkesteen et al., 1990). The results are presented in Table 5.
Spraying shows an increase of gangrene in the infected tubers by 4.5% in 1988 and 2.2% in 1989.
Green-crop lifting reduced the infection (lesions/tuber after standard wounding) in 1988 by 84% and in 1989 by 70% in comparison with spraying. With an application of the fungicides Thiabendazol and Daconil or the antagonist *Trichoderma harzianum* during green-crop lifting, the infection was reduced by 95.0 % and 99.6% in comparison with spraying. Green-crop lifting appears to be a promising system to control gangrene (Turkesteen et al., 1990).

Table 5 Infection of tubers (in lesions/tuber) with gangrene after chemical haulm killing and green-crop lifting in combination with the addition of fungicides or antagonists*.

Method	1988	1989
SSP	4.5	2.2
PT/GCL	0.8	0.6
PT/GCL and Trichoderma harzianum	0.3	0.1
PT/GCL and chloratonil	0.1	0.1

* Turkesteen et al., 1990.

Weather and field conditions

Most systems have a small working width of two or four rows and therefore all the ridges are near the wheels of the tractor.
In wet field conditions the wheels will slip, and deep tracks will be formed. This causes clods to be formed and the ridges and tubers are damaged.
A solution is, to fit tyres of not wider than 9 inches when the row width is 75 cm.
At this moment the main problem of all systems referred to, is moving over the fields. The problems of pulverizing, pulling and digging in wet field conditions, especially on sandy clay and clay soils, have not yet been researched. In wet circumstances the chance of spreading diseases settled in the haulm is high, specially when the haulm is pulverized and spread over the ridges.
After a rainy period the moisture content in the new ridges after green-crop lifting is the same as in undug ridges, when green-crop lifting was done under dry conditions. The ridges dry out to the same extent as undug ridges. At harvest, there are no difficulties in

sieving out the soil, and clods are not present.
Under wet weather and crop conditions mostly spraying and burning have to be repeated once or more times. After haulm pulling a treatment with a low rate of a chemical may sometimes be necessary.

Capacity

The capacity of the different methods is presented in Table 6. The gross capacity is the working width multiplied by the working speed. The net capacity (ha/h) is 75% of the gross capacity.

Table 6 Working width (m), working speed (km/h) and net capacity (km/h) of the different methods of haulm killing.

Method	Working width m	Working speed km/h	Net capacity ha/h
Full-width spraying	24	5	9.1
Pulverizing/spraying	3	4.7	1.0
Flaming	3	1.8	0.4
Haulm pulling two rows	1.5	4.7	0.5
Green-crop lifting	1.5	4.0	0.4

The net capacity in this table is the capacity for one treatment. Mostly spraying and burning have to be repeated one or more times.
After haulm pulling sometimes a chemical treatment is necessary.
Green-crop lifting does not need an extra treatment for killing.

Costs

The costs of the different methods have been calculated with the IMAG-DLO Data Service. For the calculations the following factors are used: capacity, required tractor power, area to be treated per year (hectares), new price, interest, depreciation, final value, costs of repair, etc.
The interest, the depreciation, the final value and the costs of repair are admitted, and therefore the costs are presented as proportional numbers. The costs of strip spraying in combination with pulverizing is set at 100.
The results are presented in Table 7. In the costs of burning and spraying, account is taken of the fact, that the treatments have to be done twice.

Table 7 Costs (index) of the different haulm killing methods, the area and the equipment will be used (ha/year). The costs of strip spraying are fixed at 100.

Method	Number of ha/year	Costs/ha index
SSP (four rows)	100	100
FP (four rows)	50	201
HP (two rows)	100	87
PT/GCL (two rows)	100	89

The results show, that there is hardly any difference in the costs of strip spraying in combination with pulverizing, haulm pulling and green-crop lifting in combination with pulverizing. The costs of burning in combination with pulverizing are twice as much due to the low capacity, the double treatment and the LPGgas price.

Discussion and conclusions

The percentage of killed haulm and stalks with all systems of green-crop lifting is 100% and after haulm pulling it varies from 95 to 100%. After spraying and burning the effect is insufficient.
The infection of tubers with black scurf can be very much reduced with green-crop lifting combined with an application of a fungicide or the antagonist *Verticillium biguttatum* in combination with haulm pulling, when the haulm is delivered to the side. After green-crop lifting in combination with haulm pulling and side delivery of the haulm, the black scurf index will stay below a maximum admissible index 20.
With spraying, haulm pulling and green-crop lifting (in combination with pulverizing) there is a low increase in late blight infection.
Green-crop lifting, whether or not with an application of a fungicide, keeps gangrene infection down.
In general it can be assumed, that the quantity of haulm is important in the spread of diseases in the new ridge formed after green-crop lifting. For that reason, the quantity of haulm has to be minimized. Haulm pulling with side delivery of the haulm will be a solution. In the case of black scurf, late blight and gangrene, antagonists and fungicides need not be applied.
The systems mentioned have a small working width of 150 and 300 cm. Under wet conditions there are problems in moving on the fields. There is no reliable information about the influence of wet conditions on the operations of haulm pulling and green-crop lifting.

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Minimizing the use of chemicals for haulm destruction of potatoes by combining haulm pulverizing with row spraying

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Summary

Haulm destruction of potatoes is needed to keep the tubers healthy, to avoid tuber outgrades and facilitate the lifting of the potatoes.
Nowadays chemical haulm destruction is one of the most important methods. Because of environmental considerations the use of chemicals in agriculture needs to be restricted.
An important reduction of chemicals can be reached by combining haulm pulverizing with row spraying.
The destruction results strongly depends on the cultivars which are used (maturity, haulm mass).
Single and double flat fan nozzles were applied, but no significant differences were found.

Introduction

Haulm of potatoes has to be destroyed for several reasons:

- to avoid virus infections of tubers by restricting the movement of sap from the haulm to the tubers (in particular seed potatoes);
- to stop tuber growth to avoid tuber outgrades;
- to release haulm from the tubers to give the opportunity for the skin to harden;
- to avoid blockages when the potatoes are lifted;
- to avoid reducing separation capacity.

Haulm of potatoes can be destroyed mechanically, with burning techniques or chemically. Because of environmental considerations the use of chemicals in agriculture shall to be restricted.
IMAG-DLO has investigated the possibility of reducing the amount of chemicals by simple technical methods. Haulm pulverizing in combination with row spraying could be a suitable method. The amount of chemicals could possibly be halved because haulm pulverizing halves the spraying area.
By preference the haulm has to be pulverized in front of the tractor, to avoid running over the haulm with the tractor wheels. As regards spraying minimize the influence of aerosols caused by the haulm pulverizer, it is better to spray at the rear of the tractor.

The sprayer can also be fixed at the rear of the haulm pulverizer if there is a good shield between pulverizer and sprayer.

Materials and methods

The location of a trial in 1991 was the IMAG-DLO experimental farm 'Oostwaardhoeve' in Slootdorp. The trial was carried out in two cultivars (Bintje and Alpha), using four concentrations of chemicals and three replicates. If the results of haulm destruction were not sufficient after the first treatment, the crop was sprayed a second, or even a third time.
The chemicals used were DNOC and Reglone in the following concentrations: DNOC: 25.00, 12.50, 6.25, 3.13 l/ha and Reglone: 5.00, 2.50, 1.25, 0.63 l/ha (concentrations were halved every time). A total amount of 400 l liquid was sprayed per ha.
Flat fan nozzles (single and double) were used because they spray more effectively than for example, cone nozzles. It was to be expected that the stems would be better covered with the chemicals using double flat fan nozzles because they receive spray from two sides. The following flat fan nozzles were used: nozzle A: T-jet 8002E (single) and nozzle B: T-jet 60-6503 (double).
Spraying took place on a moist potato crop. After spraying the warm and dry weather conditions were ideal to achieve good results.
Is was established that Alpha produced more haulm mass than Bintje. Alpha had fewer stems per plant, but they were rather bigger than the stems of Bintje.
The treatments with DNOC 25.00 l and Reglone 5.00 l were the controls in the trial (usually used concentrations in practice for whole-field spraying in full haulm). The controls were only sprayed with nozzle A because nozzle B often caused blockages due to of the very narrow gaps.
In vigorous crops with bulky haulm and/or under moist conditions, spraying has to be repeated several times to achieve a sufficient haulm destruction result. 'Sufficient' in this case is at least 95% of the stems dead, and no growth of new leaves. The trial was repeated ten days after the first spraying, because desiccation of none of the haulm was sufficient.
To establish the haulm destruction results, the haulm was examined twice, ten days after each spraying.
Ten days after the second spraying the number of stems per plant and stems with new growth were counted. The percentage of haulm destruction was calculated from these figures. The results are shown in Table 1.

Results and discussion

At the start of the trial the cultivar Bintje was physiologically more mature than the cultivar Alpha. Is was established that Alpha produced more haulm mass than Bintje. Alpha had fewer stems per plant, but they were rather bigger than the stems of Bintje. Alpha had also much more haulm to be destroyed than Bintje.
After the first spraying, the destruction results of Bintje were better than those of Alpha. DNOC showed a better result than Reglone.
The table shows that the percentage destruction depends very strongly on the cultivar

used. The already somewhat mature cultivar Bintje was destroyed with less chemicals than Alpha.
In comparison with a whole-field spraying there is an important reduction, even when sprayed twice, for both cultivars.
Both types of nozzles worked well and no significant difference in the results of destruction was found.
It was supposed, that Reglone could only be sprayed with good results in a full haulm crop. This trial has shown that Reglone can give a good result in pulverized haulm as well.
The haulm should not be pulverized too short, otherwise the stems have insufficient contact area for absorbing the chemical.
An important condition for using haulm pulverizing in combination with row spraying is that the crop has to be fully free from *Phytophthora infestans*. Otherwise the spores of this fungus could be spread by the haulm pulverizer.
After spraying, the haulm dies slowly. Therefore spraying has to be done in good time before lifting the potatoes.
A limited nitrogen application, so that the mineral nitrogen has been used at the moment of haulm destruction, might have a positive effect on the haulm destruction results. However, it is rather difficult to adjust the nitrogen application to a date of lifting.
A disadvantage of pulverizing and spraying is the smaller working width in comparison to whole-field spraying.

Table 1 Average percentage of haulm destroyed after haulm pulverizing followed by spraying twice for Bintje and Alpha.

Chemical	Amount (l/ha) 2x	% haulm destruction flat fan *nozzle A* (single)		% haulm destruction flat fan *nozzle B* (double)	
		Bintje	Alpha	Bintje	Alpha
DNOC*	25.00	100	90	–	–
DNOC	12.50	100	82	100	77
DNOC	6.25	100	58	100	62
DNOC	3.13	99	20	98	54
Reglone*	5.00	100	88	–	–
Reglone	2.50	99	72	99	78
Reglone	1.25	98	61	97	60
Reglone	0.63	95	48	98	40

* = full haulm treatment

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Testing for tuber skin maturity subsequent to vine killing

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Summary

After a development period, a device has been used to conduct trials to determine potato tuber skin strength. Factors which cause variation in strength values have also been examined. Measurements were done with a torsional device and have only been applied to the Russet Burbank variety so far. Some factors which affect strength values are: elapsed time after vine killing, moisture on skin, location of test on tuber, characteristics of tester tip, and operator skill.

Introduction

Producers traditionally determine when potato tubers are mature by applying thumb pressure and lateral force to the skin of freshly dug tubers. Variance of such measurements is so great as to preclude accurate quantification by which production practices could be improved.

Skin damage during harvest and handling lowers the fresh market value as well as increasing storage loss from dehydration and microbial decomposition. Producers in south eastern Idaho are currently allowing approximately three weeks between vine killing and beginning of harvest. A shorter maturation period would be quite advantageous if tuber maturity can be maintained or improved relative to current levels. Trails of various types of vine killing have not yet shown any method which provides superior or more rapid tuber maturity. To improve the sensitivity and repeatability of tuber maturity measurement, a study was undertaken which led to the present device. Other researchers have also been examining procedures and equipment for determination of tuber skin maturity.

The torsional test device (Fig. 1) has a tip diameter of 1.27 cm with the best performing tip composed of neoprene. A force of 71 N has proven to be suitable for use as a normal force for tip contact with the skin. Torsional resistance forces of a range of 288 to 4600 g-cm have been observed. During development, factors such as tip material, tip hardness, tip area, tip normal force and ease of operation have been examined and optimized. However, the device provides better performance with a trained operator.

Testing methods and results

Several trials have been conducted over a period of several years. Only a brief description will be noted herein for each trial. Vine killing trials were conducted to examine their effect on the rate of change and amount of tuber skin strength. Vine killing treatments were all applied the same day to vines with less than 10% senescence. Treatments were; sulfuric acid, Diquat, flail, puller (Drost) and the untreated control. Skin strength was measured, over a period of three weeks, from freshly dug tubers. No difference could be detected in skin strength due to vine killing treatments except for the control.
Several types of tester tip materials were studied by examining data variance from skin strength tests of freshly dug tubers for three weeks after vine killing with a flail. Best results were obtained with a neoprene tip of 67 hardness on the Durometer "O" scale. The tip needs to be sufficiently resilient to conform to the curvature of tubers but sufficiently stiff to not deform at the contact area while under thrust and torsional forces. Usage causes wear and rounding of the tip periphery. Tips were replaced when wear approximated a decrease in diameter of 4 mm, or a change of 10% in tip area.
To determine the effect of test location differences on the tuber, tests were conducted every Monday, Wednesday, and Friday for seven times after vine killing with a flail. Freshly dug tubers were allowed to air dry for 15 minutes before testing. Tubers ranged in weight from 170-200 g to permit sufficient test area. The length of the tuber was visually divided into thirds, with 16 tubers having four tests with the No. 3 tip in each of the three areas. Results show that the stem-end skin has greatest strength, followed by the center and then the bud end (Fig. 2). The stem-end values are 250 g-cm higher than the center and 600 g-cm higher than the bud-end.
To determine the effect on skin strength of air drying time between digging and testing, time periods of 0, 15, 30 and 45 minutes were established. Four tubers were used for tests for each time period with four skin strength measurements per tuber with each of three different tips (No. 2, 3 and 4). Results primarily show that tester tip No. 3 provided the most consistent response of all tips but performed better at 45 minutes after digging than for shorter times (Fig. 3). There was interaction between drying time and tester tips.

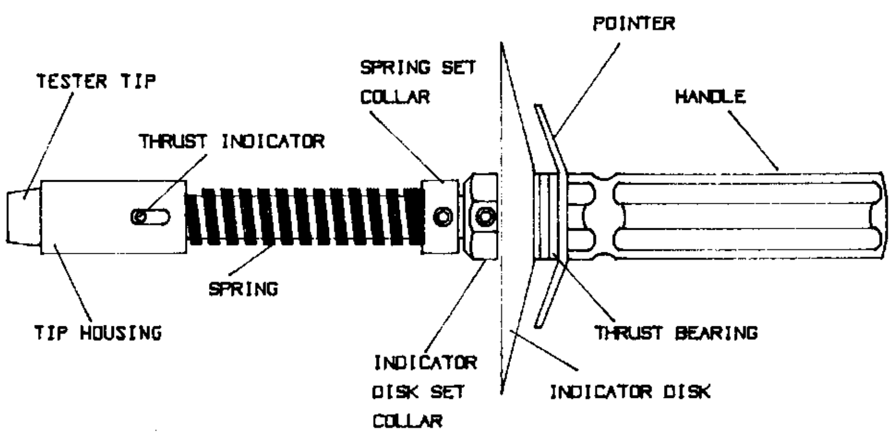

Fig. 1 A field tester for determining tuber skin resistance to scuffing. The tester tip has an area of 1.3 sq cm and the normal force was 71 N. A torsion bar connects the handle end to the tip end. The pointer can rotate in either direction relative to zero on the disk.

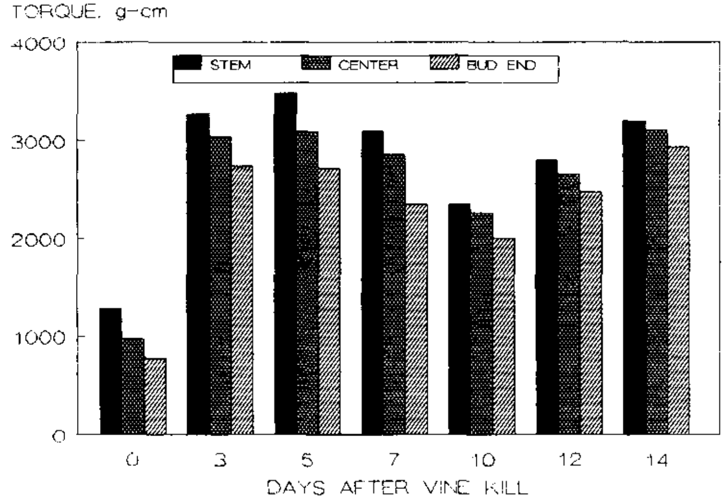

Fig. 2 Change of tuber skin strength over time due to differing test locations on the Russet Burbank tuber. All values are significantly different within each day at P = 0.05.

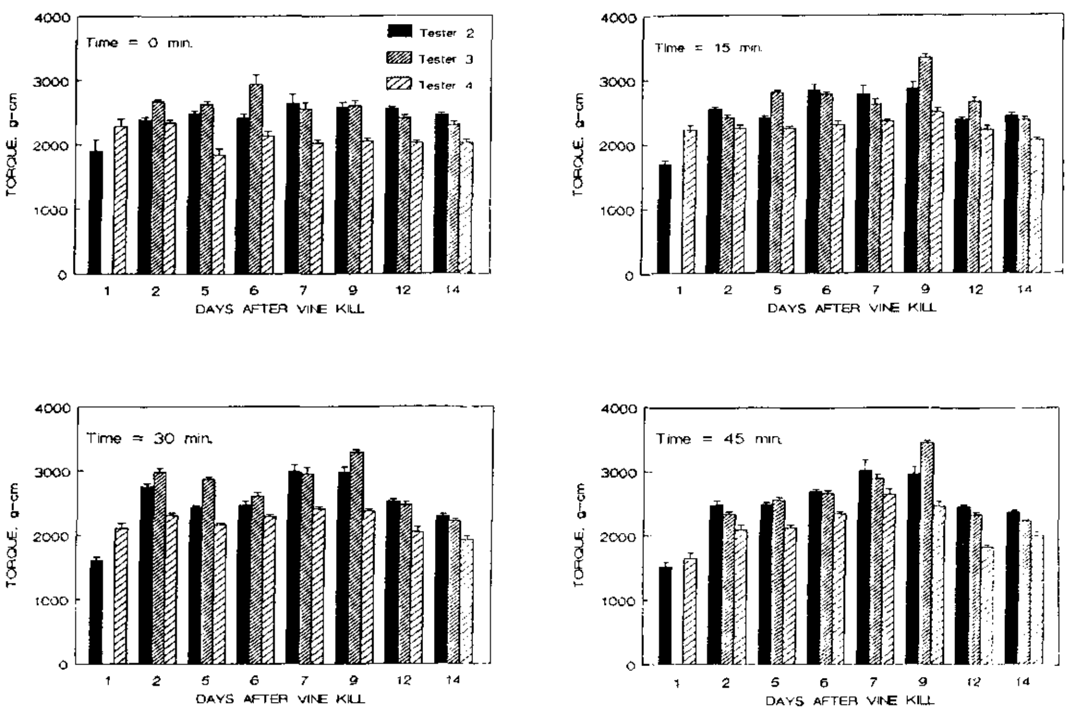

Fig. 3 Response of three different tester tips, in field testers, to tuber exposure time after digging. The error bars represent standard error of means. Tip No. 3 in tester 3 is the most sensitive to skin strength change. The longest elapsed time provided the best results as evidenced by a significantly greater peak in results.

Potato haulm killing by flaming

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1 Introduction

Treatment and removal of haulm before harvest is an important part of potatogrowing. At present, chemical spraying is the usual method. However, the use of chemicals in potatoes is becoming increasingly questioned, particularly in late stages of the growing season. For the growers, the handling is risky, the effect of the spraying is not always satisfactory, and the consumers are concerned that chemical residues may be present in the potatoes. Thus, the development should be towards limitation of chemical inputs and their future replacement by other methods.

2 JTI's project

The methods being studied by JTI are mechanical, mechanical-chemical and mechanical-thermal. The studies started in 1986 and continued in an increasing scale to 1990. The methods have been tested on 12 different potato varieties grown under various conditions from the south to the north of Sweden.

A break-through for the flaming technique was made in 1988 following the development of a burner with high capacity, efficiency and safety. The flamer was developed in co-operation with a commercial firm, Svenska Primus AB.

In the following only the thermal technique will be discussed.

3 Pulverization + flaming

3.1 Technique

Before flaming the haulm is pulverized to a height of about 10-15 cm with a flail or chain pulverizer. By using this method the heat energy can be reduced, the killing effect increased and the risk of infection on the potatoes due to diseased haulm is avoided. In addition, the harvesting is facilitated at the same time as the losses and the mechanical damages to the potatoes are reduced. The pulverization can be done simultaneously with the flaming or separately.

The flamer can be a 2-row or a 4-row machine, attached to the 3-point hitch on the tractor (Fig. 1).

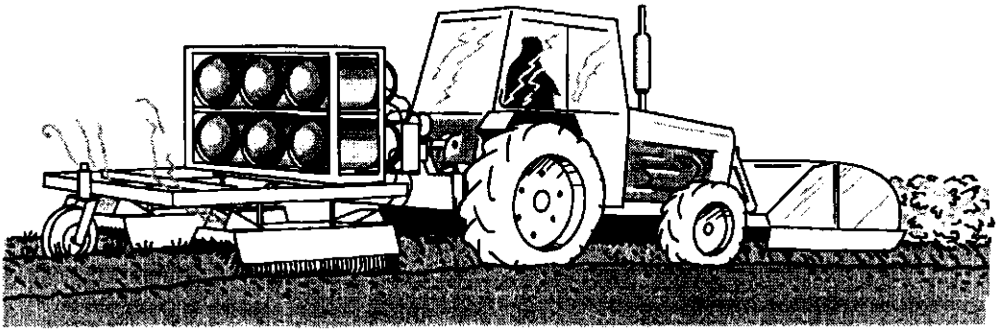

Fig. 1 JTI-flamer with frontmounted pulverizer.

LPG is vaporized in a vaporizer with a capacity of 100 kg LPG/h. The vapourization heat is taken from the tractor's cooling system (Fig. 2). Two gas-phase burners per row, each with a capacity of 8 kg/h at 2 bar, are placed under an entire shield or adjustable shields for separate rows. The working pressure is adjustable within 1-4 bar. The temperature around the haulm stumps is about 800 °C at normal driving speed. An electronic system monitors and controls the function of main gas valve, auto ignition, burners, vaporizer, gas and electrical power supplies. If a hazardous situation arises the gas supply is automatically shut down. The system is monitored from a remote-control box in the tractor cab. The gas is supplied from 16 kg LPG cylinders or from a tank, 200-400 kg LPG.

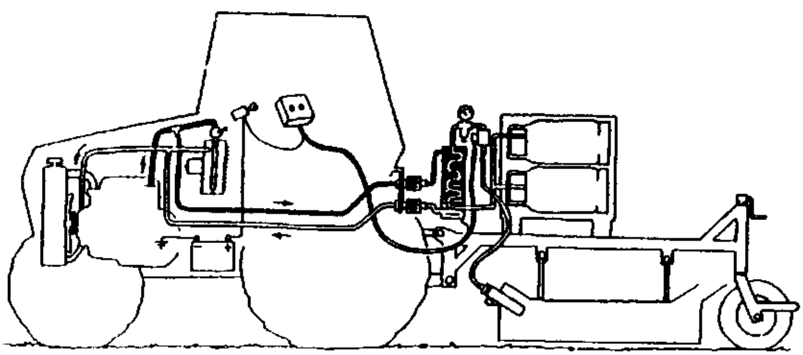

Fig. 2 Vaporization heat is taken from the tractor's cooling system.

3.2 Treating results

Thermal treatment effectively kills the haulm, relatively independent of weather and field conditions. However, an exception is certain organic soils which may easily become ignited. A normal dose of LPG is for common table potato varieties 60 kg/ha but the dose can be reduced to 40-50 kg/ha during favourable conditions. Haulm killing in an early stage of development will require high dose and/or repeated treatment, e.g. seed production and potatoes grown further north in Sweden. Some late potato varieties for processing will need repeated treatments.

The time required for haulm desiccation and for the skin of the potato to mature amounts to about 14 days. The desiccation goes faster than when Reglone is sprayed on whole haulm (Fig. 3 and 4). After 14 days the pulverized haulm in the furrow has more or less wilted away. Harvesting is facilitated to a large extent and simple harvesters can be used.

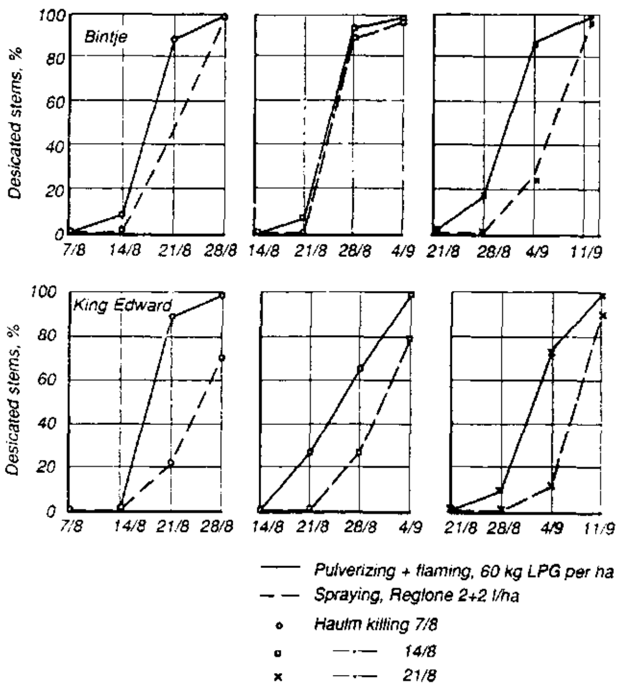

Fig. 3 Haulm desiccation rate by flaming and spraying.

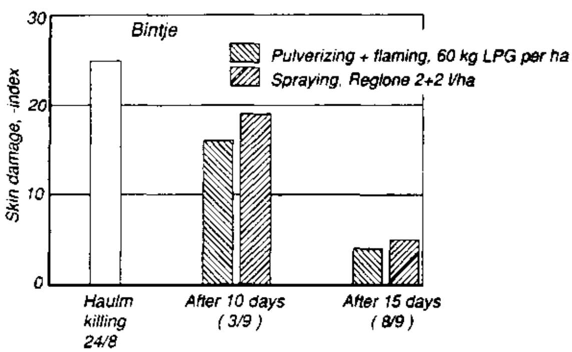

Fig. 4 Skin damage to the tubers. JTI-tester.

The pulverizing/flaming technique implies an increased driving in the field, which may cause soil compaction problems and damages to the potatoes from the tractor wheels. By using 4-row machines, row-cropping wheels and wide row spacing the problems are reduced. Another negative consequence of burning LPG is emissions of nitrous oxides and carbon dioxide. However, in relation to the emission from burning fossil fuels in total, the addition from flaming potatoes is marginal.

3.3 Capacity, costs

The driving speed for pulverizing, pulling and flaming is normally 5-7 km/h, i.e. a capacity of 0.5-0.7 ha/h for a 2-row machine and 1.0-1.3 ha/h for a 4-row machine.

The costs for alternative haulm-killing methodes are showed in Fig. 5. Pulverizing combined with flaming is more expensive than pulverizing combined with pulling or spraying. The difference, compared to pulling, is about 200 SEK/ha or 0.005 SEK/kg potatoes (40 ton/ha).

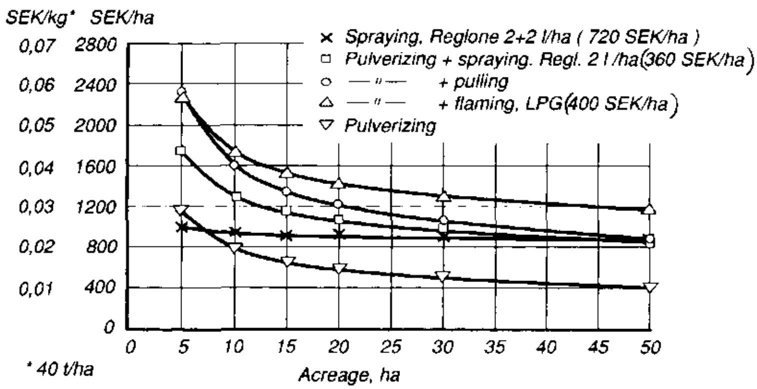

Fig. 5 Costs for different haulm killing methods.

Pulverizing + spraying is about 400 SEK/ha (0.01 SEK/kg potatoes) cheaper than pulverizing + flaming. Noticeable is that on large areas the cost for pulverizing + spraying is about the same as for spraying whole haulm with Reglone according to lower chemical costs. Even if the costs for the new methods are 50%-80% higher compared to the traditional methods, the benefits concerning environment, efficiency and potato quality are well worth the price.

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The effect of green-crop lifting in combination with Monceren or *Verticillium biguttatum* on the development of *Rhizoctonia solani* on seed potatoes

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Summary

Green-crop lifting was developed especially as an alternative to haulm killing, which also could reduce the development of *Rhizoctonia solani* on the tubers. Green-crop lifting offers prospects to treat tubers against diseases before they are again covered with soil. IMAG-DLO investigated four haulm killing techniques in regard to the development of *R. solani* and compared them mutually. Also the effect of a natural antagonist and a fungicide on the development of *R. solani* has been studied.
Both the techniques in which the haulm was pulverized to short stalks caused no difference in the development of *R. solani*. Haulm pulverizing to short stalks followed by green-crop lifting without the use of a fungicide or antagonist was not effective. When selecting this treatment and using a fungicide or antagonist, the results could be acceptable.
The technique of haulm pulling (whether or not using a fungicide or antagonist) offers a very good prospect for decreasing the infection with *R. solani*.
Both Monceren and *Verticillium biguttatum* reduced the incidence of of black scurf considerably. Haulm pulverizing combined with row spraying is used as a reference.

Introduction

In the Netherlands haulm killing of seed potatoes is necessary to avoid virus infections of the tubers (transmitted by aphids). Another reason for haulm killing is to avoid excessive tuber grades.
Problems with the fungus *Rhizoctonia solani* (causing black scurf) after spraying the haulm, and the prohibition of the herbicide Dinoseb have led to the development of alternatives. Green-crop lifting (GCL) is such an alternative, next to haulm pulling (HP), haulm flaming and spraying the haulm with permitted herbicides. Green-crop lifting was developed especially as an alternative to haulm killing (Bouman, 1990), which also could reduce the development of *R. solani* on the tubers.
Green-crop lifting is based on results of research to the development of *R. solani* after different methods of haulm killing. From this research it appeared that black scurf development will be countered by:

- bringing air into the ridge;
- severing grow contacts between tubers and soil, uptake contacts between roots and soil and transport contacts between tubers and plant;
- minimizing the quantity of green parts of plants into the ridges (Dijst,1989).

The situation meant can be reached by removing the haulms (foliage) followed by separating potatoes, roots and stolons from the soil by windrowing. Removing the haulm can be done with a haulm pulverizer or with a pulverizer followed by a haulm puller. After windrowing the potatoes are covered with soil; a new ridge is built. Peeling of tubers is reduced by preventing them from rolling back on the sieving webs and by minimizing the height of fall on to the soil (into wind-row).
Another aspect that is in contrast with the usual method of harvesting, is that not all the soil has to be sieved.
Green-crop lifting offers prospects to treat tubers against diseases before they are covered with soil. With seed potatoes this is very important because the tubers are very sensitive to infections during the period between haulm killing and harvest. When they are falling from the sieving web to the soil, antagonists or fungicides can be applied to the tubers. Another advantage is that the covered tubers are held in conditions akin to those of a potato store so the tubers can be harvested at the most suitable point in time.
IMAG-DLO has investigated four haulm killing techniques in regard to the development of *R. solani* and compared them mutually. Also the effect of a natural antagonist and a fungicide on the development of *R. solani* has been studied.

Materials and methods

The experiments were carried out at the IMAG-DLO experimental farm 'Oostwaardhoeve' at Slootdorp in 1991 and 1992. In both years seed potatoes of the cultivar Bintje (35-45 mm) were used. In 1991 the seed potatoes had a natural infection with *R. solani*. Before planting the tubers were treated with Solacol. In 1992 a natural infection and an artificial infection of *R. solani* were present. For the artificial infection seed potatoes with a slight infection of *R. solani* were used.
The experiments were planned as a completely randomized block design with three and four replicates in the years 1991 and 1992 respectively. In both years the crops were grown on sandy clay soils. The planting distances in the ridge were 30 cm. The potatoes were planted in April, and the different treatments were carried out in July.
In principle four main techniques were compared:

- haulm pulverizing combined with row spraying (HPRS);
- haulm pulverizing to short stalks on the ridge without removing the haulms followed by green-crop lifting (HP-GCL);
- haulm pulverizing to short stalks on the ridge removing the haulms followed by green-crop lifting (HPR-GCL);
- haulm pulling removing the haulms followed by green-crop lifting (PULR-GCL).

Haulm pulverizing combined with row spraying is used as a reference. The response of the other three objects to the use of a fungicide and a natural antagonist during the process of green-crop lifting was also investigated. The fungicide Monceren (10 l/ha in

400 l water/ha) and the natural antagonist *Verticillium biguttatum* (2.000.000 spores/ml in 400 l water/ha)(Jager and Velvis, 1985) were used.
From the time of GCL and HPRS every ten days (in total four times) samples of tubers were taken to follow the development of *R. solani* on the tubers in the ridge exactly. The susceptibility to peeling of the tubers was followed every three days after treatment (in total five times) also by sampling. The susceptibility to peeling will not be discussed in detail in this paper.
The sample size for assessing the infection with *R. solani* numbered in both years 100 tubers (>30 mm) per experimental unit (plot). In 1991, 100 tubers were taken from one sampling point. However, in 1992 a divided sampling method was chosen. Per experimental unit four samples of 25 tubers were taken spread over the plot.
After washing the tubers they were assessed individually as to the rate of black scurf infection and classified as slightly, moderately and heavily infected by *R.solani*. The degree of infection is finally expressed as an index number (black scurf index) which is calculated as follows:

$$\text{Black scurf index} = \frac{\%\ \text{light} \times 1 + \%\ \text{moderate} \times 2 + \%\ \text{heavy} \times 3}{3}$$

(Bouman et al., 1983)

The black scurf index can vary between 0 and 100. The norm of the General Netherlands Inspection Service for agricultural seeds and seed potatoews (NAK) for black scurf incidence in seed potatoes is 'slight' when the index number amounts to 20 or less.
The soil-temperature as well as the soil moisture surrounding the tubers were measured during the experiments.
After transformation of the indices the results were analysed statistically by means of a variation analysis. Both soil temperature and the soil humidity were taken in the analysis as a co-variable.

Results and conclusions

Successively the results of 1991 and 1992 will be discussed. From the experimental year 1992 only the experiment where an artificial infection was assumed, will be discussed. The development of *R. solani* was followed in both years. As sampling dates were held 0, 10, 20, and 30 days after HPRS and GCL. Only the situation after 10 and 20 days will be discussed in detail because in general this appears the most important period.
The four main techniques (methods) in 1991 are compared in Table 1. At the time of treatment the mean black scurf index of all the experimental units was two. Ten days after treatment (Table 1) there was no significant difference yet. After 20 days, haulm pulling followed by green-crop lifting showed in relation to the *R.solani* assessment a clearly better result in comparison with haulm pulverizing followed by row spraying.

Table 1 Mean black scurf indices of four methods at two times in 1991.

Method	Black-scurf index	
	after 10 days	after 20 days
HPRS	7	40
HPGCL	7	30
HPR-GCL	22	45
PULR-GCL	12	15

Subsequently the additional effect of the fungicide Monceren (pencycuron) and the natural antagonist *V.biguttatum* were studied after 10 (Table 2) and 20 days (Table 3).

Table 2 The effect of Monceren and *V. biguttatum* on the development of *R. solani* after 10 days.

Method	Black scurf index (after 10 days)		
	X[1]	Monceren	*V. biguttatum*
HPRS	7	–	–
HP-GCL	7	4	3
HPR-GCL	22	2	7
PULR-GCL	12	2	5

[1] Without additive

Table 3 The effect of Monceren and *V. biguttatum* on the development of *R. solani* after 20 days

Method	Black scurf index (after 20 days)		
	X[1]	Monceren	*V. biguttatum*
HPRS	40	–	–
HP-GCL	30	6	17
HPR-GCL	45	13	8
PULR-GCL	15	3	13

[1] Without additive

From Tables 2 and 3 it appears that haulm pulverizing to short stalks followed by green-crop lifting does not cause an improvement over the results in relation to haulm pulverizing combined with row spraying. However, application of Monceren or *V. biguttatum* shows a much better result. Green-crop lifting combined with haulm pulling always gives a satisfactory result. In this experimental year the tubers were hardened sufficiently after 10 days.

In 1992 the same four main methods were compared mutually. The results are shown in Table 4.

Table 4 Mean black scurf indices of four methods at two times in 1992.

Method	Black-scurf index	
	After 10 days	After 20 days
HPRS	16	60
HP-GCL	31	45
HPR-GCL	24	49
PULR-GCL	9	11

The mean black scurf index of all the experimental units on the day of treatment was two. After 10 days the combination of haulm pulling and green-crop lifting showed the best result. After 20 days haulm pulverizing followed by row spraying showed the worst result. Haulm pulverizing to short stalks also showed a poor result in both cases. The results of haulm pulling followed by green-crop lifting were good. Even after 30 days the index number hardly increased.
The additional effect of Monceren and *V. biguttatum* is shown in Tables 5 and 6. In 1992 the tubers were hardened enough after 10 days.

Table 5 The effect of Monceren and *V. biguttatum* on the development of *R. solani* after 10 days.

Method	Black-scurf index (after 10 days)		
	X[1]	Monceren	*V. biguttatum*
HPRS	16	–	–
HP-GCL	31	7	22
HPR-GCL	24	6	9
PULR-GCL	9	4	4

[1] Without additive

Table 6 The effect of Monceren and *V. biguttatum* on the development of *R. solani* after 20 days.

Method	Black scurf index (after 20 days)		
	X[1]	Monceren	*V. biguttatum*
HPRS	60	–	–
HP-GCL	45	15	21
HPR-GCL	49	10	23
PULR-GCL	11	2	3

[1] Without additive

Both Monceren and *V. biguttatum* reduced the incidence of black scurf considerably. In this year Monceren showed a slightly better result than *V. biguttatum*. By addition of a fungicide or antagonist, haulm pulling in combination with green-crop-lifting reduced

the development of *R. solani* considerably. Even after 30 days the black scurf index hardly increased.
If haulm pulling combined with GCL (removing the haulms) is adopted, harvest can take place at the most favourable moment. It is unlikely that an *R. solani* explosion will occur whether or not a fungicide or antagonist is used.
Haulm pulverizing to short stalks followed by GCL without the use of a fungicide or antagonist was not effective. When selecting this treatment and using a fungicide or antagonist, the results could be acceptable.

Discussion

Both techniques in which the haulm was pulverized to short stalks (HP-GCL and HPR-GCL) caused no difference in development of *R. solani*. However, this was an unexpected result. Removing the pulverized haulm hardly improved the result because there were still rather many green-plant parts (short stalks) which came into the new ridge. Pulverizing to short stalks and GCL combined with a fungicide or an antagonist offers a perspective with regard to haulm pulverizing combined with row spraying. However pulverizing to short stalks is not practical because of the large areas causing a heavy wear of the haulm pulverizer.
In 1992 the results of haulm pulling were much better than those of 1991. In 1991 the newly formed ridge contained more green plant parts. The results in relation to the development of *R. solani* did not show any important differences between the two years. The technique of haulm pulling even when the result is not perfect, offers a very good prospect for decreasing the infection with *R. solani*.

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Alternative Krautminderungsmethoden auf leichten Böden

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Zusammenfassung

Die begrenzte Zulassungsdauer chemischer Sikkative und die immer stärkere Gewichtung von Umweltfaktoren zwingen zur Erarbeitung umfassender Erkenntnisse über alternative Krautminderungsverfahren. In Verbindung mit dem mechanischen Krautschlagen wurden das Rupfen und das thermische Mindern des Krautes sowie das dreigeteilte Ernteverfahren mit der chemischen Krautminderung verglichen.

Die Funktions- und Einsatzfähigkeit der für die alternativen Krautminderungsverfahren erforderlichen Maschinen ist auch auf leichten Böden weitgehend gewährleistet. Ihr Einsatz ist mit einer geringen Flächenleistung und höheren Verfahrenskosten als bei der mechanisch-chemischen Krautminderung verbunden. Die Schalenfestigkeit der Kartoffeln erreicht nach einer Wartezeit von 14 bis 21 Tagen mit der chemischen Krautminderung vergleichbare Werte. Das Krautschlagen reicht als alleinige Maßnahme nicht aus. Zudem tritt dabei ein deutlich stärkerer Wiederaustrieb auf. Beim Rhizoctonia-Sklerotien-Besatz lag die mechanisch-chemische Krautminderung mehr im oberen Bereich, während die alternativen Verfahren eine verhaltenere Entwicklung widerspiegeln. Das Krautrupfen wies im Mittel geringere Befallswerte als das Abbrennen auf. Bei der dreigeteilten Ernte bietet der krautfreie Schwad und eine Abtrocknungsphase zwischen Schwaden und Zudecken die günstigsten Voraussetzungen zur Verringerung der Befallswerte.

1 Einführung

Mit der Krautminderung bei Kartoffeln werden die Voraussetzungen für schalenfeste Knollen, eine vollmechanisierte und verlustarme Ernte sowie eine sichere Lagerung geschaffen. Bei der Pflanzkartoffelproduktion kommt die Notwendigkeit zur Erhaltung eines am Gesundheitswert und der Pflanzknollenausbeute ausgerichteten Abtötungstermins hinzu. Das alleinige Krautschlagen reicht in seiner Wirkung nicht aus. Es stellt weder die vollständige Unterbrechung der Verbindungen zwischen Kraut und Knollen noch die Unkrautfreiheit bis zum Erntetermin sicher. In einem zweiten Verfahrensschritt wird daher ein chemisches Sikkativ appliziert.

Zur Zeit sind in der Bundesrepublik Deutschland drei chemische Mittel zur Krautminderung in Kartoffeln zugelassen, davon darf aber nur ein Mittel in Pflanzkartoffeln eingesetzt werden. Die begrenzte Zulassungsdauer der chemischen Sikkative und die immer stärkere Gewichtung von Umweltfaktoren, auch bei Pflanzkartoffeln, zwingt zur Erarbeitung umfassender Erkenntnisse über alternative Krautminderungsverfahren.

2 Material und Methoden

In den Jahren 1990 und 1991 wurden auf leichten, sandigen Böden der Lüneburger Heide mehrere Versuche zur Krautminderung angelegt. Als Pflegegeräte wurden gezogene Häufelgeräte, zum Teil mit Dammformblechen, eingesetzt. Die Krautminderung wurde mit dem Ziel der Pflanzkartoffelproduktion je nach Reifezeit der Sorten im Monat August durchgeführt. Den Standard stellte das Verfahren Krautschlagen und Applikation des chemischen Sikkatives 'Reglone' (Wirkstoff Deiquat) dar. Als Alternative zum chemischen Mittel wurden das Rupfen und die thermische Minderung des Krautes sowie das dreigeteilte Ernteverfahren (Grünroden) untersucht.

Zum Rupfen des Kartoffelkrautes wurde ein zweireihiges Gerät zusammen mit einem in der Fronthydraulik des Schleppers angebauten Krautschläger eingesetzt. Als Rupfwerkzeuge dienten pro Reihe zwei gegenläufig rotierende, luftgefüllte Gummiballons.

Für die thermische Krautminderung wurde das Kartoffelkraut vorher auf 15 -25 cm Stengellänge geschlagen. Die beiden Abbrenngeräte übertragen die Wärme durch Infrarotstrahlen auf die Pflanzen. Es wurden ein Universalgerät mit durchgehendem Brennraum sowie eine spezielle Ausführung mit einzelnen, an die Dammkontur angepaßten Brennräumen eingesetzt. Bei dem Spezialgerät wird die Wärmeleistung der Strahler durch zusätzlich eingeblasene Verbrennungsluft erhöht.

Die Krautminderung erfolgte bei der dreigeteilten Ernte über Krautschlagen, zum Teil auch in Kombination mit Krautrupfen. Die Kartoffeln wurden mit einem herkömmlichen Schwadleger gerodet und direkt oder nach einer Abtrocknungszeit wieder mit Erde zugedeckt. Das Zudecken der Schwade erfolgte mit zwei großen Hohlscheiben eines Pflegegerätes. Nach einer Zwischenlagerung von etwa drei Wochen wurden die Kartoffeln über ein erneutes Schwadlegen oder die direkte Aufnahme mit einem zweireihigen Sammelroder geerntet.

3 Ergebnisse und Diskussion

3.1 Wiederaustrieb

Durch das maschinelle Krautschlagen wird die Krautmenge bei Pflanzkartoffeln von etwa 30 t/ha auf 4 - 5 t/ha verringert. Das Krautschlagen kann aber nur als erster Schritt eines kombinierten Krautminderungsverfahrens angesehen werden, da Reststengel zurückbleiben, die wieder austreiben (Tab. 1). Dies erhöht die Gefahr einer Virusspätinfektion der Knollen.

Beim Krautrupfen schwankte der Anteil nicht gerupfter Reststengel zwischen 1,9 und 25,6%. Die Unterschiede sind in erster Linie auf das Sortenverhalten und den Zustand des Kartoffelkrautes sowie der Dämme zum Zeitpunkt des Krautrupfens zurückzuführen. Die Intensität des Wiederaustriebes der nicht gerupften Reststengel nimmt mit fortschreitender Abreife des Bestandes ab.

Tabelle 1 Wiederaustreibende Pflanzen (in %) nach Krautminderung.

Termin	9.9	18.9	30.9
Schlagen	40.1	24.0	15.9
Schlagen			
+ chemische Mittel	1.6	1.6	1.6
+ thermisch	14.0	7.8	6.2
+ Rupfen	6.4	1.6	0

Sorte 'Ponto', Krautminderung 28.8.1991

Die Zahl der wieder ergrünten Stauden wies nach der thermischen Minderung eine Schwankungsbreite von 0 - 88,2% auf. Ursache für diese großen Differenzen sind vor allem sortenspezifische Unterschiede (Tab. 2). Bei dem leistungsstärkeren Spezialgerät traten im Vergleich zum chemischen Sikkativ keine Unterschiede in der Austrocknungsgeschwindigkeit auf, während bei dem kleineren Universalgerät eine etwas langsamere Reaktion des Kartoffelkrautes zu beobachten war.

Tabelle 2 Sortenspezifischer Wiederaustrieb der Kartoffelpflanzen (in %) nach Krautrupfen und thermischer Krautminderung.

Sorten Reifegruppe	A sehr früh	B früh	C mittelfrüh	D mittelfrüh	E mittelspät
Rupfen	0	0	5.7	20.6	20.6
thermisch	0	6.7	5.7	2.9	88.2

Um bei der dreigeteilten Ernte das Auftreten von Wiederaustrieb auszuschließen, ist auf ein vollständiges Bedecken des Schwades mit Boden zu achten.

3.2 Schalenfestigkeit

Zur Bestimmung der Schalenfestigkeit wurde ein Handgerät verwendet, das die zum Ablösen der Knollenschale erforderlichen Scherkräfte anzeigt. Nach der üblichen Wartezeit von 14 bis 21 Tagen erreichten alle Verfahren vergleichbare Werte (Abb. 1). Zwischen den drei alternativen Verfahren ergaben sich nur graduelle Unterschiede. Das Krautschlagen reicht für das sichere Erlangen schalenfesten Erntegutes nicht aus.

Beim dreigeteilten Verfahren wird die Entwicklung der Schalenfestigkeit in ihrer Tendenz verstärkt, wenn zwischen Schwadlegen und Zudecken einige Zeit zum Abtrocknen der Kartoffeln bleibt. Ein Einfluß des Krautanteils im wieder zugedeckten Schwad war jedoch nicht erkennbar.

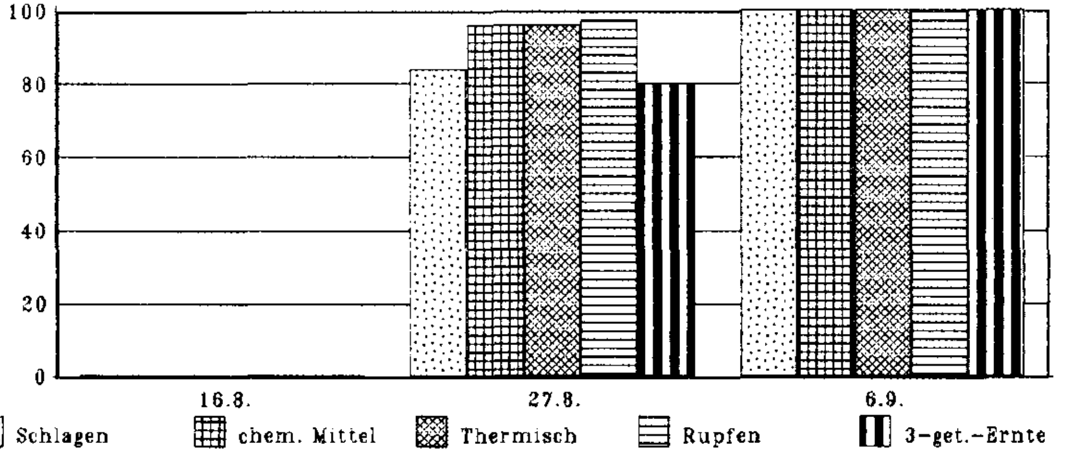

Abbildung 1 Entwicklung der Schalenfestigkeit (in %) nach Krautminderung.
Sorte 'Tomensa'

3.3 *Rhizoctonia-solani*-Sklerotien-Besatz

Im Mittel der Versuche lag der *Rhizoctonia*-Sklerotien-Besatz nach der mechanisch-chemischen Krautminderung mehr im oberen Bereich, während die alternativen Krautminderungsverfahren eine verhaltenere Entwicklung widerspiegelten (Abb. 2).

Das Krautrupfen wies in der Mehrzahl der Versuche geringere Befallswerte als die thermische Behandlung auf. Die günstigsten Voraussetzungen zur Minimierung der Befallswerte bei der dreigeteilten Ernte bietet der krautfreie Schwad mit einer Abtrocknungsphase zwischen Schwaden und Zudecken.

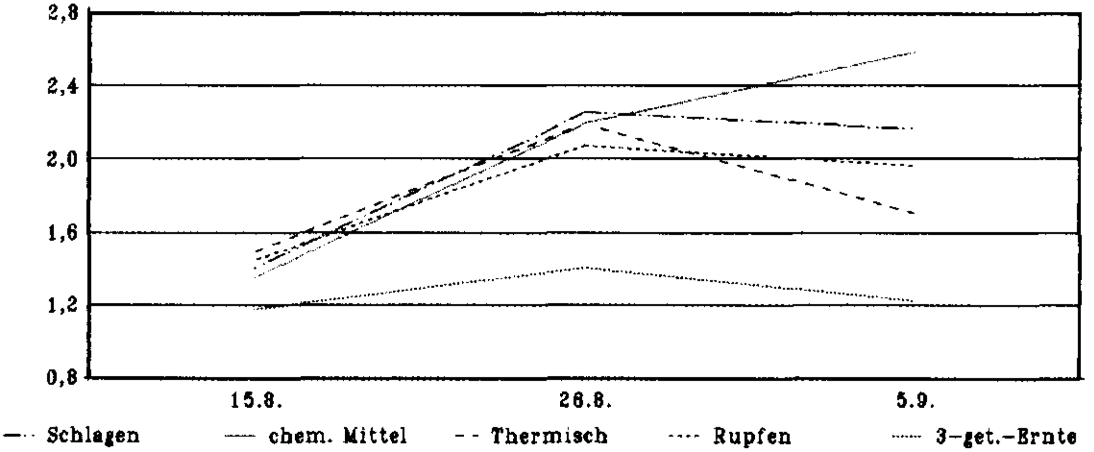

Abbildung 2 Entwicklung des *Rhizoctonia*-Sklerotien-Besatzes auf den Kartoffelknollen nach der Krautminderung.
Sorte 'Tomensa'

3.4 Einsatzfähigkeit der Maschinen

Die Funktions- und Einsatzfähigkeit der für die alternativen Krautminderungsverfahren erforderlichen Maschinen ist auch auf leichten Böden weitgehend gewährleistet. Ihr Einsatz ist aber mit einer geringeren Flächenleistung und höheren Verfahrenskosten als bei der mechanisch-chemischen Krautminderung verbunden.

Damaging Potatoes

Intérêt des materiaux de protection pour limiter l'endommagement des tubercules Mise en évidence avec des tubercules électroniques

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Summary

When a potato falls on a web rod, it must absorb some of the energy of impact. Rubber or plactic coverings help to reduce some of the impact energy wich the potato has to reabsorb, thereby lessening the risk of damaging the potato. Trials with 4 different varieties and 4 different coverings have shown the advantage of rubber covering when the impact energy increases (higher fall height). The evolution of damage index can be used in comparison with the measures of electronic tubers to calibrate the devices in terms of 'damage level'. From impact signals during the handling process the high damage areas can then be detected and be eliminated by increasing cushioning or by reducing drop heights, for instance.

Introduction

L'endommagement est toujours la conséquence d'une force exercée sur le tubercule pouvant entraîner la rupture ou non du périderme. L'amplitude, la vitesse, la distance et la forme du point d'impact sont les facteurs principaux d'explication du niveau d'endommagement atteint. Des différences importantes apparaissent plus particulièrement au niveau des variétés avec un classement possible, grâce au système pendulaire. Pour une même énergie d'impact, la gravité de l'endommagement de type fracture est par exemple en bonne relation avec l'énergie absorbée par le tubercule.
De cette relation, deux voies importantes sont donc à considérer pour améliorer la qualité de la pomme de terre. D'une part, diminuer les énergies d'impact à tous les niveaux de l'arrachage à l'ensachage, d'autre part, mettre l'accent sur les matériaux de protection, c'est-à-dire tout matériau susceptible d'absorber une part de l'énergie d'impact.

1 Energies potentielle et cinetique

Pour un tubercule de 200 g, de vitesse initiale nulle et subissant une chute de 30 cm, l'énergie potentielle acquise est égale à :

$U = 0{,}200 \times 9{,}8 \times 0{,}3$
$U = 0{,}59$ J (Joule)
$U = 590$ mJ

D'une manière générale, les tubercules sont toujours en mouvement avec des vitesses variables avant leur chute.
Par exemple, sur une arracheuse simplifiée dont la vitesse d'avancement est égale à 7,2 km/h (2 m/s) et dont la vitesse linéaire de la chaîne d'arrachage est la même (rapport 1), l'énergie cinétique pour un tubercule de 200 g sera égale à :

$$K = 1/2\ 0{,}2 \times 2^2 = 0{,}4\ J$$
$$= 400\ mJ$$

Au moment de sa chute sur un barreau de la chaîne de tamisage et pour une hauteur de 30 cm, l'énergie d'impact totale est la somme des deux énergies :

$Ei = K + U$
$Ei = 590 + 400$
$Ei = 1000$ mJ

Cette énergie d'impact est élevée, mais il est difficile de prévoir dans la pratique quelle quantité sera réellement absorbée par le tubercule. D'une part, la chaîne de tamisage, constituée de barreaux rigides en matériau dur, possède néanmoins une grande capacité de diffusion d'énergie par son 'flottement'. D'autre part, les tubercules peuvent 'rebondir' et perdre ainsi une quantité d'énergie importante. Les tubercules peuvent être également amortis par la terre transportée ou transmettre une partie d'énergie à d'autres tubercules en contact. Enfin, tous les tubercules ne tombent pas sur un seul barreau mais sur deux selon leur calibre et l'espacement entre barreaux: la surface de contact devient alors plus importante et l'énergie absorbée par point d'impact plus faible.

Compte tenu de ces facteurs, il est expérimentalement difficile de mettre en évidence la qualité de travail des arracheuses, lorsqu'elles sont mises en comparaison dans des conditions équivalentes.
Indépendamment de tous ces facteurs, il convient toutefois de noter que l'énergie d'impact diminue simplement lorsque la vitesse de rotation de la chaîne est plus faible.

De même, le revêtement des barreaux avec des matériaux efficaces permet d'absorber une partie importante de l'énergie d'impact. Des tests réalisés à l'ITPT ont permis de mettre en évidence l'intérêt de certains revêtements.

2 Tests de chute sur barreaux

Des échantillons de 50 tubercules d'un même calibre (50-60 mm) ont été prélevés après récolte sur 4 variétés de sensibilité différente aux endommagements mécaniques : Charlotte, Sirtema, Bintje et Saturna ; sur une chaîne à barreaux classiques (NU) (pas 32 ; diamètre 9 mm) 4 différents recouvrements ont été retenus : (3 barreaux par type) :

- Polyéthylène (PE)
- PVC (PVC)
- Caoutchouc moulé (CM)
- Caoutchouc avec languette (CML)

Les deux extrémités de la chaîne sont reliées entre elles et l'ensemble est monté sur un axe de façon à ne récupérer qu'une partie de l'énergie d'impact, comparable à celle obtenue sur une chaîne d'arracheuse.
Les tubercules tombent de 3 hauteurs différentes sur les barreaux (25, 50 et 70 cm), le talon orienté vers le bas avant la chute.

L'indice d'endommagement est calculé à partir de l'importance des blessures observées après épluchage sur les 50 tubercules de chaque condition :

- blessure légère (L) : < 2 mm : elle disparaît au 1er épluchage
- blessure moyenne (M) : < 4 mm : elle disparaît au 2e épluchage
- blessure grave (G) : elle ne disparaît pas au 2e épluchage

L'indice d'endommagement des tubercules est égal à :

$$I = (2\,L + 3\,M + 5\,G) / 5$$

Les résultats obtenus ne donnent pas de classement différent selon les variétés. Un calcul de l'indice moyen sur les 4 variétés (200 tubercules notés par condition) donne le classement suivant (tableau 1).

Tableau 1 Damage index: Effects of coverings and fall heights.

Covering	Fall height	Damage index
CML	× 25 cm	0.30 a
PVC	× 25 cm	0.50 a
CM	× 25 cm	0.50 a
CML	× 70 cm	0.95 a
CM	× 50 cm	1.35 a
CML	× 50 cm	1.60 a
CM	× 70 cm	3.15 ab
PVC	× 50 cm	3.35 ab
PE	× 25 cm	3.60 ab
NU	× 25 cm	7.15 bc
PVC	× 70 cm	7.50 bc
PE	× 50 cm	9.85 c
NU	× 50 cm	14.60 d
PE	× 70 cm	23.25 e
NU	× 70 cm	28.85 f

(Test of Newman & Keuls at 5% level)

La progression de l'indice d'endommagement avec la hauteur de chute est très nette ainsi que le classement des matériaux selon leur capacité d'absorption des énergies d'impact.

Ainsi, sur une arracheuse, le passage d'un tubercule d'une chaîne à l'autre s'effectue sans dommage avec un gainage en caoutchouc si l'énergie d'impact maximale transmise au tubercule est équivalente à l'énergie potentielle fournie par une chute d'environ 50 cm.

La différence d'indice entre le PVC (3,35) et le CM (1,35) n'est pas significative à 50 cm. Elle n'apparaît pas non plus à 25 cm ou à 70 cm.

3 Indices d'endommagement calcules à l'aide de tubercules électroniques

Des tests de chute ont été également réalisés avec deux différents tubercules électroniques :

– L'IS 100 d'origine américaine
IS 100 : Techmark, inc. USA)
Le tubercule pèse 340 g (O 9 cm) et enregistre des intensités de chocs exprimées en g (accélération normale dans le champs de pesanteur). Les données sont transmises après correction à un micro-ordinateur et peuvent être analysées sous différentes formes.

– Le Bi 90 d'origine danoise (version 1990)
Bi 90 : (Bioteknisk institut, DK)
Le tubercule pèse environ 240 g et enregistre des intensités de chocs. Chaque signal, dont la durée dépend de la force de l'impact, est transmis à un récepteur qui indique l'intensité sur un galvanomètre gradué de 0 à 100.

Pour ces deux appareils, les hauteurs 25 et 50 cm ont été retenues, avec 30 répétitions par condition.

Les résultats obtenus avec l'IS 100 sont regroupés dans le tableau 2.

Tableau 2 Drop test results with the IS 100 (Mean of 30 values).

Covering	Fall height	Mean (G's)
CML	25 cm	24 a
CM	25 cm	83 b
PVC	25 cm	94 bc
CML	50 cm	110 c
CM	50 cm	130 d
PE	25 cm	141 de
NU	25 cm	153 ef
PVC	50 cm	163 f
NU	50 cm	197 g
PE	50 cm	211 g

Le classement est assez voisin de celui obtenu à partir de l'endommagement réel des tubercules. Un coefficient de corrélation r = 0,83 est obtenu entre l'indice d'endommagement réel et un indice calculé à partir des valeurs de l'IS 100
$Is = 1 \times (x > 180) + 1/3 \times (120 < x < 180) + 1/10 \times (x < 200)$.

Les résultats obtenus avec le Bi 90 sont également très voisins. Cet appareil a une échelle de lecture comprise entre 0 et 100. Pour des intensités trop faibles ou trop élevées, il ne donne pas de valeurs moyennes suffisamment représentatives. mais dans la plage des moyennes entre 15 et 85, les valeurs sont assez bien corrélées à l'indice d'endommagement réel ou aux valeurs moyennes de l'IS 100 (tableau 3).

Tableau 3 Correlation coefficients between electronic tubers and damage index.

	Bi 90	Is 100
Indice réel	0,81	0,83*
Bi 90	–	0,82

(* : based on calculated index of IS values)

Dans la mesure où ces appareils ont pour objectif de mettre en évidence les points d'impact susceptibles d'endommager la pomme de terre, il remplacent avantageusement la méthode traditionnelle de prélèvement d'échantillons et de notation des tubercules après épluchage.

4 Nombre de répétitions nécessaires avec les tubercules électroniques

A partir de 30 valeurs, le classement obtenu avec les deux tubercules électroniques pour une hauteur de chute de 50 cm met en évidence une différence significative entre les matériaux PVC, CM et CML (tableau 4) que ne traduit pas l'indice d'endommagement réel calculé à partir de 200 tubercules par traitement.

Tableau 4 Drop test results with BI 90 and IS 100 (mean of 30 values each) for different coverings at 50 cm fall heights.

Covering	Bi 90 (0-100)	Is 100 (g 's)	Ir
CML	28 a	110 a	1.60
CM	51 b	130 b	1.35 NS
PVC	69 c	165 c	3.35

Les deux tubercules électroniques permettent de conclure quant à la meilleure qualité d'absorption d'énergie du CM par rapport au PVC.

Par contre une analyse statistique effectuée à partir de 10 valeurs seulement, ne permet pas de conclure dans un cas sur 3 (tableau 5) quel que soit l'appareil.

Tableau 5 Example of drop test results with BI 90 and IS 100 by taking only 10 values for each test.

Mean of values	Bi 90		Is 100	
	CM	PVC	CM	PVC
x1	35	75	130	171
x2	63	61 (NS)	123	179
x3	52	71	137	140 (NS)
x	51	69 (HS)	130	163 (HS)

Conclusion

L'utilisation des tubercules électroniques pour l'étude comparative de matériaux est possible en remplacement de la méthode traditionnelle par prélèvements de tubercules.

Les deux appareils testés, Bi 90 et Is 100, donnent des résultats comparables à partir de 30 valeurs par point de chute. Pour une utilisation pratique dans l'étude des chaînes de conditionnement par exemple, la méthode d'enregistrement du Bi 90 est toutefois plus souple que celle de l'Is 100 et également moins couteuse. Elle permet de préciser, rapidement les différents points d'une chaîne susceptible d'endommager les tubercules.

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Comparaison de 2 systèmes pendulaires pour la mesure de la sensibilité des tubercules aux endommagements de type fracture

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Summary

The Food Research Institute (IFR) pendulum has been used by ITPT for several years as a method of assessing the susceptibility of tubers to impact damage. More than 1 000 samples of varied conditions have been tested with an impact energy of 760 mJ. The energy absorbed by tubers during impact appears to be a highly accurate criterium of assessing their susceptibility to cell walls fracture.
Another pendulum system (MIDAS 88 P) has been compared to the IFR one. In this system, tubers are impacted twice at the same site, with an impact energy of 150 mJ. 20 cultivars were impacted with the 2 systems, and the correlations between them and between measures and gravity of tuber injuries were found to be excellent.

Introduction

L'étude des relations entre les propriétés physiques des tubercules, mesurées à l'aide d'un système pendulaire, et leur sensibilité aux endommagements a fait l'objet de travaux effectués notamment par Gall et al. (1967, 1990), Umaerus et Umaerus (1976), Bailey (1981), Grant et Hughes (1985), Skrobacki et al. (1989). Dans la plupart des cas, des corrélations significatives ont été observées entre les propriétés physiques des tubercules (notamment l'énergie absorbée au moment de l'impact mesurée par la hauteur de rebond du bras pendulaire) et leur sensibilité aux endommagements, mais le pourcentage d'explication dépassait rarement 50 à 60 pour cent, en raison surtout des difficultés de lecture du rebond et de l'évaluation imprécise de l'indice d'endommagement. Skrobacki et al. (1989) considèrent toutefois, avec un système pendulaire d'origine américaine, que la relation entre l'énergie absorbée et l'endommagement est faible (r = 0.400) et variable selon les variétés.

Grant et Hughes (1985) mettent en évidence, avec le système pendulaire du I.F.R. de Norwich, en Grande-Bretagne, qu'il existe une très bonne relation entre l'énergie absorbée (Eab) et le niveau d'endommagement par fracture de tubercules soumis à un impact dans des conditions contrôlées. Des essais réalisés avec ce même appareil (Gravoueille, 1989), à partir de variétés cultivées en France, confirment ces résultats (r = 0.945) et mettent en évidence qu'indépendamment de la sensibilité du lot de pommes de terre, le coefficient de corrélation entre l'énergie d'impact (Eimp) et l'énergie absorbée est constant pour des énergies d'impact croissantes de 263 à 760 mJ (r > 0.990). Pour ce système pendulaire équipé d'une tête d'impact de 12.7 mm de diamètre et de 4.0 mm de rayon de courbure, c'est avec des énergies d'impact supérieures à 600 mJ que les meilleurs résultats sont obtenus concernant la séparation des différents lots. Sur plus de 1 000 lots d'origines très diverses ayant fait l'objet de tests d'impactage à l'ITPT (Eimp = 760 mJ) les valeurs de Eab varient de 600 mJ (lot très peu sensible) à 730 mJ (lot très sensible). Cet appareil peut être utilisé comme test direct dans les programmes de sélection ou des essais de variétés. Il peut servir également pour les expérimentations de plein-champ afin d'étudier l'influence des facteurs de production sur la sensibilité des tubercules (Gravoueille, Gehanne, Le Corre, 1989 ; van Kempen, 1989).

L'objectif de cette expérimentation est d'étudier l'intérêt d'un nouveau système pendulaire (Midas 88 P) développé en Allemagne par l'institut de Gros Lüsewitz (Gall et al., 1990) et de comparer les résultats obtenus avec les deux appareils.

Matériel et méthode

Le système pendulaire Midas 88 P se compose de deux éléments distincts.

- un système pendulaire d'impactage équipé d'un capteur de vitesse permettant le calcul des énergies absorbées au cours des impacts.
- un boîtier de mise en mémoire et d'analyse statistique des données.

Le principe de ce système pendulaire est d'effectuer deux impacts successifs au même point sur les tubercules à tester.
L'énergie d'impact peut varier de 0 à 370 mJ pour des têtes d'impact de 7-8-10 ou 15 mm de diamètre.

Les propriétés physiques des tubercules sont mesurées et mémorisées instantanément au cours des impacts. A la fin de chaque série, les moyennes et les écarts-types des paramètres sont récapitulés comme suit:

- Eab2: énergie absorbée au deuxième impact
- (Eab1 + Eab2)/ 2: énergie absorbée moyenne des premier et deuxième impact
- Eab1/Eab2: rapport de l'énergie absorbée au premier impact/deuxième impact
- P.I: pendulum index - pourcentage de points d'impact pour lesquels Eab2 < Eab1

L'énergie absorbée au premier impact peut également être calculée à partir de ces valeurs.

Les tests d'impactage sont réalisés avec les deux systèmes pendulaires à partir d'échantillons de 25 tubercules, de calibre homogène (50-60 mm), récoltés à maturité dans les essais de variétés de la Station de Saint-Rémy-l'Honoré. Chaque tubercule est impacté sur ses deux faces opposées les plus planes possibles et en dehors des yeux. Après impactage, les tubercules sont conservés à 20 °C pendant trois jours avant observation de l'endommagement.

Paramètres d'impactage

I.F.R.: Eimp = 760 mJ; tête d'impact: O 12.7 mm, rayon de courbure: 4.0 mm.

Midas 88 P: Eimp = 150 mJ; tête d'impact: O 7 mm.
Ces paramètres sont ceux préconisés par l'Institut de Gross Lüsewitz.

Notation de l'endommagement

L'endommagement externe est mesuré sur une échelle de 0 à 5 (Midas 88 P) ou de 0 à 6 (I.F.R.).

I.F.R.

0: absence d'endommagement
1: rupture de la peau
2: rupture de la peau + écrasement
3: écrasement + éclatement < 5 mm
4: écrasement + éclatement > 5 mm, < 10 mm
5: écrasement + éclatement > 10 mm, < 20 mm
6: écrasement + éclatement > 20 mm.

Midas 88 P (Figure 2)

0: absence d'endommagement
1: rupture de la peau
2: rupture de la peau + écrasement
3: écrasement + éclatement < 2 mm
4: écrasement + éclatement > 2 mm, < 5 mm
5: écrasement + éclatement > 5 mm.

L'endommagement interne est évalué après sectionnement des tubercules au centre de la zone d'impact. La largeur (L) et la profondeur (P) maximales sont mesurées à partir de la surface du tubercule.

Résultats et discussion

Les tests d'impactage effectués avec le système pendulaire du I.F.R. sur les 20 variétés utilisées pour cette expérimentation montrent une forte variation de la sensibilité aux endommagements puisque l'énergie absorbée varie de 606 mJ pour Record (lot 1) à 702 mJ pour Lola (lot 20) (Tableau 1).

L'étude des relations entre l'énergie absorbée et l'importance de l'endommagement confirme les résultats déjà obtenus avec cet appareil puisque les coefficients de corrélation s'échelonnent de 0.810 à 0.918 (Tableau 2).

Tableau 1 Tested varieties (arranged according to their susceptibility measured with IFR pendulum).

Varieties	Damage						
	Dry matter (%)	Absorbed energy (mJ)	Standard deviation	External score	Width (mm)	Depth (mm)	(W+D)/2 (mm)
1- Record	21.7	606	21	2.22	11.14	9.62	10.38
2- Norélia	18.7	622	27	2.02	11.62	9.30	10.46
3- Euréka	19.3	636	28	2.72	11.10	11.26	11.18
4- Résy	19.3	637	27	2.80	13.14	10.70	11.92
5- Mariana	18.2	638	40	2.48	12.76	9.67	11.26
6- Monalisa	18.7	642	26	2.46	12.22	10.94	11.58
7- Apollo	17.9	644	34	3.06	12.80	10.58	11.69
8- Agria	20.3	645	32	2.92	13.42	12.12	12.77
9- Edzina	19.5	646	24	2.98	12.62	11.48	12.05
10- Bintje	21.6	651	34	3.02	14.02	10.40	12.21
11- Ostara	19.1	652	23	2.46	11.98	12.60	12.29
12- José	20.5	664	18	2.96	14.36	12.26	13.31
13- Béa	18.7	670	26	3.82	15.04	15.06	15.05
14- Rosabelle	16.5	674	26	2.88	14.22	10.50	12.36
15- Manon	19.8	675	26	4.04	18.00	12.06	15.03
16- Charlotte	19.0	680	25	4.26	16.06	13.12	14.59
17- Sirtema	19.2	680	28	3.70	16.00	12.40	14.20
18- Rosalie	19.7	680	29	4.16	16.58	13.64	15.11
19- BF 15	18.4	688	25	5.04	16.78	16.24	16.51
20- Lola	17.3	702	20	4.16	18.78	18.46	18.62

Tableau 2 Correlations between damage and absorbed energy (calculated from IFR pendulum means of samples).

	Width	Depth	External score	(width + depth)/2	Dry matter
Absorbed energy	0.911	0.810	0.865	0.918	–0.410

Significance levels (Newman & Keuls tes): 0.430 (5%) -0.500 (1%)

Avec le système Midas 88 P, une forte variabilité entre les lots est également observée que ce soit au niveau de l'endommagement ou des mesures instrumentales (Tableaux 3 et 4, Figures 1 et 2).

L'énergie absorbée au premier impact (Eab1), bien que corrélée positivement avec l'endommagement, n'explique que 63 pour cent de ses variations. Ce résultat est probablement du à l'imprécision de la notation de l'endommagement après un seul impact, et également au fait que, dans ce cas, l'énergie d'impact de 150 mJ adoptée dans cette étude est insuffisante pour provoquer des ruptures des parois cellulaires sur l'ensemble des tubercules des lots les plus résistants (Tableaux 3 et 5). Par contre, lorsque le test est réalisé en impactage double, les paramètres physiques sont nettement mieux correlés au niveau d'endommagement (Tableaux 4 et 5). Les paramètres les mieux correlés avec l'endommagement (Tableau 5) sont l'énergie absorbée au second impact (Eab2) et le pendulum index (P.I) (86 pour cent d'explication), ces deux derniers étant d'ailleurs fortement liés (r = –0.980) (Tableau 6).

La teneur en matière sèche des tubercules n'explique qu'environ 20% des variations de Eab (I.F.R.) et P.I. (Midas 88 P).

Ces résultats montrent que le système pendulaire Midas 88 P fournit une prévision précise et instantanée (à partir des énergies absorbées au cours de deux impacts successifs sur un même point) du niveau d'endommagement par fracture de tubercules soumis au test dans des conditions contrôlées.

L'énergie absorbée au second impact (Eab2) ou le pendulum index (P.I) sont bien corrélés avec l'énergie absorbée (Eab) mesurée avec le système pendulaire du I.F.R. (r = 0,822 et –0,831) (Tableau 6) et les classements des lots obtenus avec les deux appareils sont en bonne concordance.

Le choix d'une énergie d'impact de 150 mJ associée à une tête d'impact de 7 mm de diamètre est particulièrement intéressant puisque, sur une gamme étendue de niveau de sensibilité, le pendulum index varie de 4 à 96 soit pratiquement le maximum de variation possible. On peut condidérer comme très sensibles les lots dont le pendulum index est inférieur à 30 et d'un bon niveau de résistance les lots dont le pendulum index est supérieur à 70 (Tableau 7).

Outre son prix d'achat inférieur par rapport au système pendulaire du I.F.R., le système pendulaire Midas 88 P présente l'intérêt d'une plus grande facilité d'utilisation mais également d'être équipé d'origine d'un système de mémorisation et de traitement statistique des données.

Tableau 3 Results of Midas 88P pendulum : single impacts.

Varieties	Eab (mJ²)	Standard deviation	Damage			
			External score	Width (mm)	Depth (mm)	(W+D)/2 (mm)
1- Record	108.6	7.0	0.98	2.24	1.96	2.10
2- Noreélia	112.5	8.1	0.20	0.98	1.06	1.02
3- Euréka	112.6	6.6	0.52	4.94	3.02	3.98
4- Résy	114.7	10.9	1.00	5.08	3.46	4.27
5- Mariana	120.4	11.4	1.52	7.28	4.38	5.83
6- Monalisa	115.6	10.0	1.14	4.96	3.78	4.37
7- Apollo	117.7	8.2	0.96	5.60	4.42	5.01
8- Agria	113.5	7.6	1.34	5.94	4.10	5.02
9- Edzina	118.3	9.1	1.14	4.80	3.78	4.29
10- Bintje	107.5	6.4	1.02	6.02	4.52	5.27
11- Ostara	114.3	9.1	1.16	5.58	4.38	4.98
12- José	112.3	12.0	1.10	5.54	3.82	4.68
13- Béa	120.9	13.6	1.94	8.16	6.76	7.46
14- Rosabelle	123.7	11.1	1.22	6.32	4.10	5.21
15- Manon	128.8	6.3	2.36	10.16	5.84	8.00
16- Charlotte	126.9	9.9	2.28	7.44	6.14	6.79
17- Sirtema	126.9	9.1	1.80	7.00	5.20	6.10
18- Rosalie	123.9	13.0	1.74	8.82	5.78	7.30
19- BF 15	118.2	13.8	1.22	5.40	4.32	4.86
20- Lola	132.0	14.2	2.34	8.84	8.96	8.90

Tableau 4 Results of Midas 88P pendulum : double impacts.

Varieties	Eab (mJ^2)	Standard deviation	Eab1 /+ EAB/2 (mJ^2)	Eab^1 / Eab^2	PI	Damage			
						External score	Width (mm)	Depth (mm)	(W+D)/2 (mm)
1- Record	98.1	13.9	103.3	1.11	96	1.38	4.24	3.32	3.78
2- Norélia	102.6	11.5	107.5	1.10	96	0.88	4.78	4.16	4.47
3- Euréka	105.7	14.8	109.2	1.07	84	1.44	8.28	5.14	6.71
4- Résy	116.8	21.4	115.8	0.98	50	1.74	7.18	5.45	6.31
5- Mariana	124.6	21.4	122.5	0.97	36	2.48	10.40	8.84	9.62
6- Monalisa	115.6	21.1	115.6	1.00	58	1.86	8.00	5.98	6.99
7- Apollo	117.7	16.4	117.7	1.00	56	1.80	8.7	6.84	7.77
8- Agria	113.8	23.4	113.7	1.00	60	1.88	9.04	6.42	7.73
9- Edzina	123.7	19.0	121.0	0.96	40	2.10	7.68	7.22	7.45
10- Bintje	101.2	17.4	104.4	1.06	80	1.82	6.84	4.68	5.76
11- Ostara	118.8	22.2	116.5	0.96	52	2.04	8.64	7.26	7.95
12- José	113.2	26.2	112.8	0.99	56	2.00	8.10	6.02	7.06
13- Béa	129.6	19.5	125.2	0.93	20	2.28	11.36	9.30	10.33
14- Rosabelle	124.9	19.8	124.3	0.99	46	2.00	9.36	6.88	8.12
15- Manon	132.7	15.6	130.8	0.97	20	3.14	12.14	7.38	9.76
16- Charlotte	132.9	16.5	129.9	0.95	24	2.88	10.38	9.24	9.81
17- Sirtema	130.5	17.1	128.7	0.97	32	2.60	10.80	8.70	9.75
18- Rosalie	133.2	12.3	128.5	0.93	14	2.50	10.78	8.64	9.71
19- BF 15	122.1	23.8	120.1	0.97	38	2.70	11.00	8.42	9.71
20- Lola	140.4	9.6	136.0	0.94	4	3.16	13.18	12.96	13.00

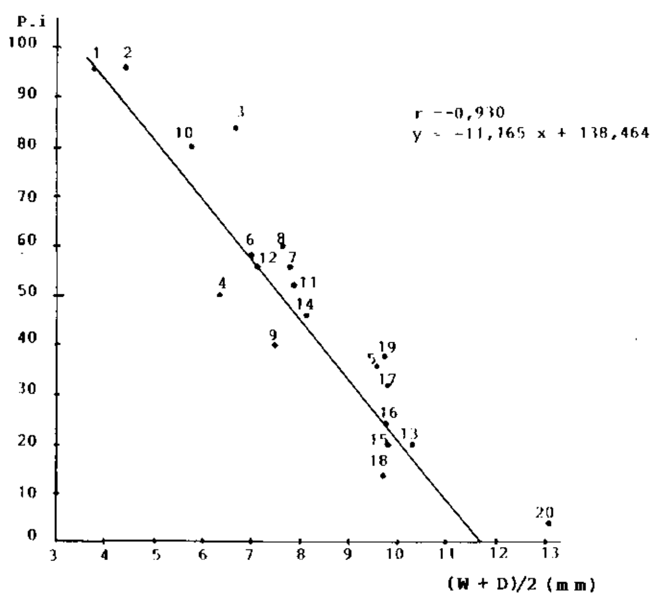

Fig. 1 Midas 88P pendulum - Relationship between pendulum index (PI) and damage.

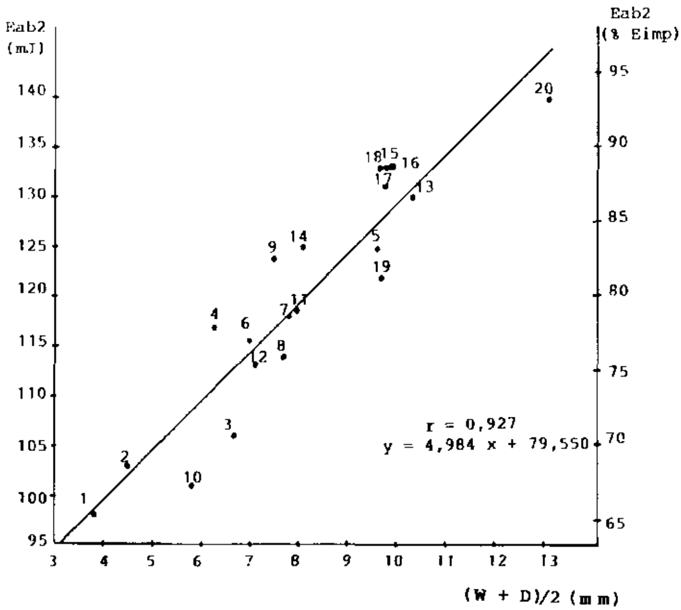

Fig. 2 Midas 88P pendulum - Relationship between Eab2 and damage.

Tableau 5 Midas 88P pendulum - Correlations between damage and absorbed energies.

	Width	Depth	External score	(W+D)/2	Dry matter
Simple impact Eab1	0.760	0.773	0.830	0.789	–
Double impact Eab2	0.897	0.909	0.881	0.927	–
P.I	–0.906	–0.906	–0.905	–0.930	0.437

Significance levels (Newman & Keuls test): 0.430 (5%) -0.500 (1%)

Tableau 6 Correlations of physical factors (absorbed energies) measured with the two pendulum *systems.*

	Eab1	Eab2	(Eab1 + Eab2)/2	Eab1/Eab2	P.I
P.I (Midas 88 P)	–0.877	–0.980	–0.954	–0.939	1.000
Eab (I.F.R.)	0.778	0.822	–	–	–0.831

Significance levels (Newman & Keuls test): 0.430 (5%) -0.500 (1%)

Tableau 7 Relationship* between tuber susceptibility and physical parameters (Midas 88P ; Eimp = 150 mJ ; impact head of 7 mm in diameter).

Susceptibility	Pendulum index	Eab2	
		% of Eimp	mJ
Not susceptible	90	68.5	102.7
Not very susceptible	70	74.6	111.9
Moderately susceptible	50	80.7	121.1
Susceptible	30	86.8	130.3
Very susceptible	10	93.0	139.5

* settled from 110 potato batches (PI = - 3.261 Eab2 + 313.217)

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Improved methods of rapidly developing latent bruising in potatoes

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Summary

The delay between a tuber sustaining damage and the onset of black discolouration termed ·bruising· can be a serious obstacle to optimizing the setting of harvesting and handling machinery.

Methods of accelerating bruising have been evaluated. These include the use of tetrazolium chloride solution, heated, compressed, humidified oxygen, and heated, compressed, humidified air.

The tetrazolium chloride method proved unsatisfactory for certain types of impact. The oxygen method, though successful has safety problems. It would appear from the results of tests that the compressed air method is likely at present to be the most promising and could develop bruising in less than half the time taken for the 'hot box' method. Some variability between fast bruise development methods and natural development of bruises must be expected.

1 Introduction

Unlike external damage which can be quickly identified and quantified with the aid of Catechol staining techniques, internal damage in potatoes which is manifested by black discolouration and termed ·bruising· takes some time to develop. It is common for a period of 48 hours to elapse following impact damage, before the characteristic blackening due to melanin in the damaged tissues reaches full development. Even longer delays before the onset of the blackening have been reported, whilst occasionally, more rapid natural development of melanin occurs.

With a gradual improvement in throughput of potato harvesters in recent years, a delay in identifying the presence of bruising means that the farmer cannot rectify any malfunction in the harvester until perhaps as many as 240 tonnes of potatoes are affected. There is therefore an increasing need to find ways of accelerating the development of bruising which gives comparable results to natural development.

2 Methods of accelerating bruise development

2.1 'Hot box' method

The 'hot box' method of increasing the rate of development of black pigmentation due to melanin was first used in USA and promoted for use on farms by Thornton and Hyde (Washington State University at Pullman).
The equipment consists of an insulated container of variable capacity fitted with a thermostatically controlled fan heater, to circulate warm air round the potatoes placed in stacks of open mesh trays. The air is humidified by blowing it over capillary matting dipping in a water bath in the base of the box. A portable version of the 'hot box' is manufactured at the Scottish Centre of Agricultural Engineering and is available in sizes up to 0.5 tonne capacity.

Potatoes with latent bruising will show characteristic blackening after a period of approximately 12 hours in the 'hot box'. Some users have noted that there is a tendency for the level of bruising in material from the 'hot box' to be slightly higher than for controls stored in a warm room. The 12 hour delay even when using the hot box can, with modern harvesting systems, still be too long to enable a sufficiently rapid response to be made by the farmer to alter harvester settings.

2.2 Oxygen method

In 1973 Duncan showed that it was possible to reveal bruising by storing damaged tubers in oxygen at a pressure of 1.7 bar and at a temperature of 35-37 °C for a period of 5-7 hours.

McRae and Fleming (1981) developed a method of accelerating bruising in a specially designed pressure vessel capable of taking samples of up to 20 kg of potatoes. A series of tests with 10 leading maincrop cultivars was carried out with storage of the potatoes for 7 hour periods in oxygen. The results are summarized in Table 1. There was a tendency for the oxygen treatment to reveal a higher level of bruising than the control which was stored at room temperature for 72 hours. A second test (Table 2) with the cultivar Record gave good agreement with the control after a 6 hours development period. The bruising was divided into ordinary bruising and the more severe version called shatter bruise, where parallel and sometimes forked cracks appear within the blackened tissue.

Table 1 Rapid development of black bruises in 10 cultivars using heated compressed oxygen for 7 hours.

	% Bruising – Mean for 10 cultivars		
	Ordinary bruise	Shatter bruise	Combined
Oxygen tank	29	19	48
Control	19	19	38

Table 2 Rapid development of black bruises in cultivar Record using heated compressed oxygen for 6 hours.

	Mean % Bruising for a range of drop heights 105-150 mm		
	Ordinary bruise	Shatter bruise	Combined
Oxygen tank	13	40	53
Control	8	45	53

2.3 Tetrazolium Chloride method

Beaver (1984) showed that tetrazolium chloride solution could be used to enhance bruised areas in potato tubers. Melrose and McRae (1985) carried out similar experiments using the UK cultivar Record. Tubers were dropped on either a flat steel plate, or a web rod bar, from a height which by experiment was found to avoid splitting the tubers, but caused bruising.

For the tests, a solution of 1 g tetrazolium chloride in 1 litre of water at 30 °C was in a thermostatically controlled water bath with a circulation impeller. Samples of freshly dug tubers were selected and also tubers which had been stored for three months. Table 3 shows results to fresh potatoes, Table 4 for stored potatoes.

Table 3 Tetrazolium chloride treatment (45 min) compared with 14 day natural bruise development in freshly dug potatoes (c.v. Record).

	Tetrazolium treatment			14-day natural bruise development		
Impact surface and drop height	Mean no of bruises per sample of 25	Standard deviation	% Potatoes bruised	Mean no of bruises per sample of 10	Standard deviation	% Potatoes bruised
Flat (350 mm)	0.8	1.0	3.2	5.0	0.9	50.0
Bar (150 mm)	12.2	2.0	48.8	6.3	0.7	63.0

Table 4 Tetrazolium chloride treatment (45 min) compared with 14-day natural bruise development in stored potatoes (c.v. Record).

	Tetrazolium treatment			14-day natural bruise development		
Impact surface and drop height	Mean no of bruises per sample of 25	Standard deviation	% Potatoes bruised	Mean no of bruises per sample of 10	Standard deviation	% Potatoes bruised
Flat (700 mm)	0.9	1.0	3.6	1.2	0.9	12.0
Bar (150 mm)	9.4	1.8	37.6	4.0	1.1	40.0

From the results it was concluded that tetrazolium chloride could reveal bruises caused by impact of the potatoes on web rods for both fresh and stored material. The test proved unsatisfactory for tubers dropped on a flat surface.

An additional test was carried out to see if old bruises could be distinguished from new bruises using the tetrazolium chloride test. Potatoes were dropped, then any resulting bruises were developed in a hot box. The following day the tubers were dropped again to generate a second bruise at another location. The tetrazolium chloride solution caused only a pink colouration in the more recent bruise.

From all the tests carried out it was concluded that though the tetrazolium chloride test was a rapid one, it did not reliably show bruising when a flat impact surface was used, and that such a severe limitation precluded its general use.

2.4 Humidified oxygen

One of the limitations of using pure oxygen from standard cylinders to accelerate bruising, is the absence of moisture. Diffusion of oxygen into the potato tissues occurs through the skin, but particularly through the lenticels which require moisture in order to remain open. It was decided that the vessel used in the 1981 experiments should be modified to allow the passage of the oxygen through a water bath within the pressure vessel, so creating a humid atmosphere. The layout of the vessel is shown in Figure 1.

A number of tests were carried out (Melrose and McRae 1987) with 10 samples of 10 tubers over a range of storage times from 3-7 hours in the pressure vessel. It was found that for the optimum results, a six hour storage period was necessary. There was no significant difference between the samples stored in the vessel and the controls for potatoes damaged by either the web rod, or flat impact surfaces.

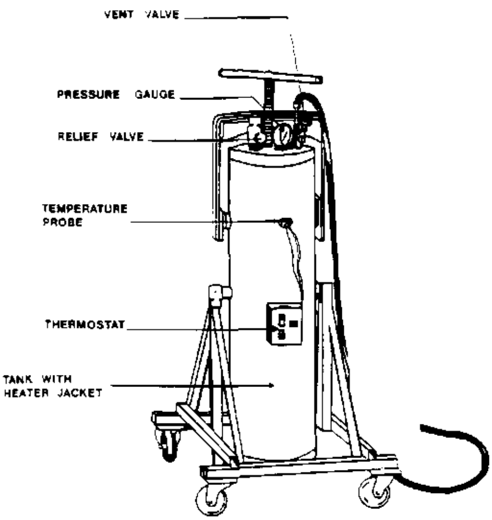

Fig. 1 Layout of heated pressurised tank.

2.5 Compressed air method

Whilst it has been shown that in an atmosphere of pressurized, humidified oxygen, latent bruising can be developed in a period of 6 hours, the technique is not generally suitable for on farm use. The pressure vessel has to be vented before removing the potatoes and this presents some potential safety hazards.

Melrose (1991) using the original pressure vessel modified to receive air from a small portable air compressor, carried out a limited number of tests to compare the effect of humidified compressed air with oxygen on the time to develop bruising in tubers of the cultivar Record. It was, for safety reasons, only possible to operate the pressure vessel at 3 bar. Table 5 shows that generally there was a tendency for the compressed air test to show lower bruising levels after 5 hours than the controls (except in test 1). Test 5 was run for 6 hours and this gave an almost identical result to the control.

Table 5 Bruise development using compressed air at 3 bar compared with natural development.

Test no	Impact surface	Compressed air			Control 14 days at 20 °C		
		Mean no of bruised potatoes per test[1]	S.E.	% Bruising	Mean no of bruised potatoes per test[1]	S.E.	% Bruising
1	Flat	6.1	0.39	61	5.4	0.60	54
2	Flat	4.1	0.38	41	5.8	0.59	58
3	Flat	4.8	0.59	48	6.1	0.53	61
4	Flat	3.9	0.50	39	5.1	0.53	51
5	Flat	4.8	0.47	48	4.7	0.45	47
6	Bar	3.5	0.58	35	4.1	0.56	41

[1] Mean No of 10 samples each of 10 potatoes

Note: test no 5 was run for 6 hours instead of 5 hours.

2.6 Humidified oxygen using peeled compared with unpeeled tubers

Though oxygen diffuses through the skin and lenticels of tubers it was considered possible that faster diffusion and therefore a faster development of melanin in bruised areas would occur if the skin were removed. Melrose (1992) found that there was some advantage in peeling prior to the treatment with oxygen particularly for damage caused by impacts on flat surfaces. But, careful peeling to avoid removal of near surface tissue damage was required and in most of the tests, differences between peeled and unpeeled potatoes were not significant.

It should be noted that in conducting all the tests which involved accelerating bruising development, problems were experienced in obtaining sufficiently high bruise levels without causing external damage. There appears however to be no alternative to artificially created bruises to ensure relative uniformity in size and location.

3 Conclusions

Of the techniques used to rapidly develop latent bruising in potatoes which have suffered impact damage, the treatment of the tubers in a pressure vessel in an atmosphere of humidified, heated compressed air, appears to be currently the most promising one. Further development to enable pressures up to 10 bar to be used in a specially designed pressure vessel is under way.

The high variability poses a problem in any bruise evaluation system involving accelerated bruise development. The reasons for this variability have yet to be explained.

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A survey of damage to potatoes in a commercial packhouse

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In January 1992 the Research and Development Division of the Potato Marketing Board commissioned a survey of the potential sources of damage to potato tubers passing through its commercial packing station at Sutton Bridge. A common site is occupied by the PMB Experimental Unit and the Board's Commercial Prepacking Station at this address. The Station receives and packs from local growers some 60,000 tonnes per annum. Tuber damage is the principal cause of out grading or rejecting potatoes being prepared for packing.

Although the primary producer (grower) is rightly held to blame for much of the damage the crop is found to contain, a view was held that the Station's handling operations also contributed to the levels of damage finding its way through to the consumer. The survey, which was carried out by Messrs D.C. McRae and J Fleming of the Scottish Centre of Agricultural Engineering, with assistance from O.J.H. Statham of the PMB, provided information about the potential causes of damage in the various lines. Recommendations were also made by SCAE to the PMB about sampling locations and procedures to enable the Board to quantify the damage sustained by the crop before and after remedial measures had been undertaken.

The Board operates two packhouses each with a principal product line but also with subsidiary lines. Each of these were reviewed and deficiencies noted for subsequent remedial attention.

A total of 71 recommendations were made to the Station's management. A high proportion of the potential problems the investigators considered could be reduced or eliminated by a programme of active damage conscious maintenance rather than capital reinvestment.

A survey of the route taken by potatoes passing through the packhouse was also undertaken. On the principal product line within the No. 1 Packhouse, from intake to despatch, potatoes were required to:

1 Travel a linear distance of 97.5 metres over a variety of conveying mechanisms.
2 Negotiate 27 component items of equipment.
3 Be subjected to 28 vertical and 12 horizontal changes of direction.
4 Fall an accumulative 12 metres in the process with an individual worse fall of 1.2 metres.

This exercise served to highlight the long and tortuous route which potatoes must travel in what is a relatively modern packhouse (refurbished 1986). Many of the drops to which the crop were subject were sufficient to exceed the H10 values for some varieties in some seasons and in certain instances to comfortably exceed the H50 values as determined by the SCAE.

Damage sampling locations and sample sizes

Following the visual appraisal of the lines a sampling and analysis exercise was undertaken to obtain an overview of the build up of damage through the system. It was anticipated that once the remedial measures had been undertaken a reassessment would reveal the extent of the anticipated improvement, ie the cost benefit could be quantified.

25 samples each of 25 tubers were taken at random from:

1 The incoming crop (20 tonne bulker).
2 Boxed product at the end of the reception/intake line.
3 The roller dryers after the washers.
4 The feed to the Newtec prepacking machines.
5 Finished product after stacking on a pallet.

20 of the samples were used for external damage assessment using Catechol staining reagent. The remaining 5 samples were used for bruise assessment.

The results were disappointing. The level of variability in the data was sufficiently high to mask most of the differences. The coefficient of variation exceeded 50% and the lowest mean damage index is for the final sampling point !! It was apparent that the incoming material was too variable and that the sample spectrum was changing at the grading point.

The exercise was repeated at a later date. On this second occasion sample replicates were increased to 40 (surface damage) and 16 (bruising). However even higher levels of variation were found and the expected pattern of increasing surface and bruising damage could not be identified. These problems highlight the scale of the logistics problems encountered in taking and assessing large numbers of samples where a high coefficient of variability exists.

Despite the inability to quantify levels of bruising and surface mechanical damage without a large increase in sample numbers and size, the visual systems appraisal readily identified common sense shortcomings. There can be no doubt that the packhouse environment offers as much, if not more, scope to damage potato tubers than mechanical harvesting in the field. The contribution which subsequent handling and marketing activities confer on the crop should not be overlooked by the industry.

Sutton bridge damage audit 1992

Surface damage (mean values)					
Sampling Point	Nos of Replicates	Damage index	% Weight scuffed	% Weight peeler	% Weight severe
1st audit					
1 The incoming crop (bulker)	20	115.7	2.1	21.8	7.0
2 After reception (in boxes)	20	122.7	2.4	24.3	6.9
3 At roller dryers (after washing)	20	131.8	9.6	23.7	7.4
4 At prepacking (after grading)	20	124.4	4.8	24.1	6.9
5 In outers (on pallet)	20	93.1	7.1	15.9	5.6
CV %		53.9	112.4	67.8	95.8
Significance		NS	***	NS	NS
2nd audit					
1 After reception	40	171.3	3.2	21.3	15.0
2 At roller dryers	40	103.4	4.3	11.3	9.4
3 At prepacking	40	103.2	7.8	13.3	8.0
4 In outers	40	144.0	8.0	12.3	14.2
CV %		47.5	134.7	76.7	66.0
Significance		***	**	***	

Sutton bridge damage audit 1992

Bruising (mean values)				
Sampling point	Nos of replicates	% Unbruised	% Slight	% Severe
1st Audit				
1 The incoming crop (bulker)	5	73.6	6.4	20.0
2 After reception (in boxes)	5	80.0	5.6	14.4
3 At roller dryers (after washing)	5	87.0	5.6	7.2
4 At prepacking (after grading)	5	75.2	8.2	16.8
5 In outers (on pallet)	5	80.8	3.2	16.0
CV %		10.3	57.0	50.6
Significance		NS	NS	NS
2nd Audit				
1 After reception	16	79.2	7.5	13.2
2 At roller dryers	16	68.0	9.7	22.2
3 At prepacking	16	74.0	8.0	18.0
4 In outers	16	73.2	8.8	18.0
CV %		17.0	60.7	61.2
Significance		NS	NS	NS

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