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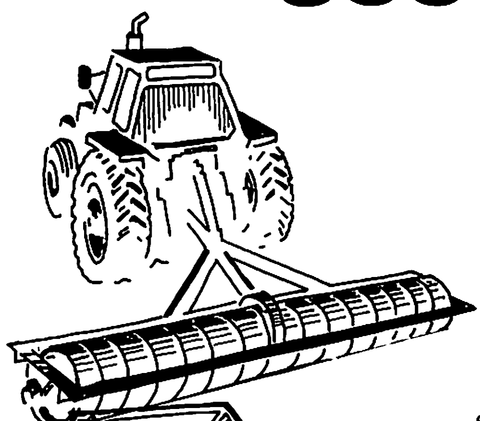

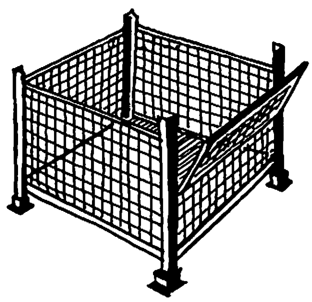

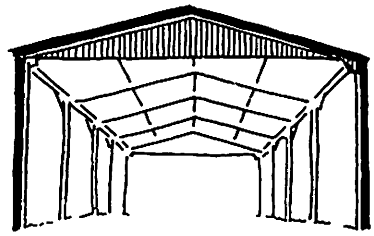

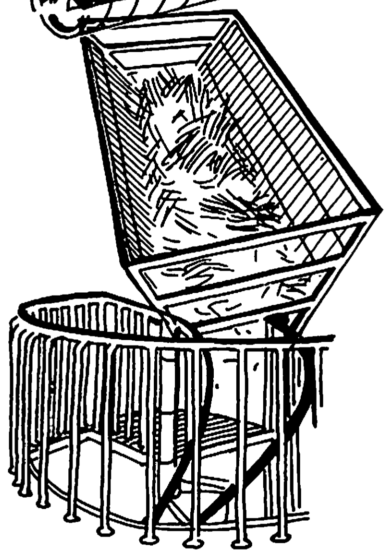

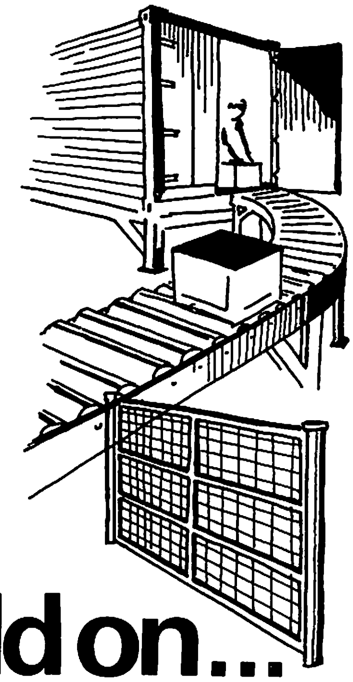

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Cover: The prototype Standen Stalwart 3-row self-propelled harvester showing the defoliator

The production of vegetables for processing

What price mechanisation? asks A J Gane

NO sooner did man turn his thoughts to staying put long enough to warrant scratching the soil surface with a pointed stick and deliberately sowing a few seeds, only to beat out the resulting grain some months later, than he began in one way or another to cause damage both to the land and his produce.

The last fifty years has probably seen the most rapid rate of development of all time in mechanisation, as in so many other fields, but an increasing amount of attention is being focused, quite rightly, on the aspects of damage caused by machines, and of excessive wastage of produce, expensively produced.

It is probably true to say that damage to soil structure is mostly caused, not through any fault of machines as such, but through their misuse, either in the form of the wrong choice of implement or, just as frequently, the choice of the wrong time, in relation to soil and weather conditions. Decisions in respect of the latter are often difficult, especially perhaps in the case of preparation for vegetable crops for processing, where each crop is but a part of a substantial dovetailing operation keyed to factory throughput. There is no doubt, however, that too little attention is paid to conditions below the soil surface; conditions which markedly influence the degree of success achieved in crop production. Compaction, smear and other maladies are seldom exposed to view, and indeed their presence or absence is rarely checked by the farmer.

Research in progress at PGRO has firmly linked poor seed vigour with physical damage, so that drills and even cleaning plants are now being studied to ascertain where such damage occurs and how it can be reduced if not eliminated. Harvesting losses, too, are substantial and in many cases we have a widening gap between 'produce grown' and 'produce for consumption'; losses occur at many different, often unidentified and unsuspected points along the way. Produce may be left in the soil, left on the surface, or damage in harvesting, handling, transporting and processing.

Clearly a degree of loss is inevitable, but when a survey of one particular crop suggests that very often well over 50% of products grown fails to reach the consumer, it is surely time to take a very serious look at what we are doing, especially since the profitability of many crops is not what it was.

The Autumn National Conference of the Institution held in Norwich in 1976, which was the first to be held in conjunction with a Branch, was held under the title of 'The Waste Makers', and reviewed the losses incurred in harvesting and storing a group of important arable crops. The call went out for funds to be made available for tackling these problems, and has been echoed by JCO's. The work is expensive to undertake, but far less expensive than ignoring the wastage occurring daily in the absence of the determined approach repeatedly called for. Agriculturists, engineers and advisors are in agreement as regards urgency and profitability. Let us hope that the talking will soon be done, and that the means will be provided for positive action.

The recent Spring National Conference at Peterborough on 'Mechanisation in the Production of Vegetables for Processing' drew attention to many developments in this important field, but the Conference Chairman, Sir Francis Pemberton, sounded a note of warning right at the start, reminding us that 'we grow produce to sell'.

So damaging the seed that we fail to maximise yield, so poorly harvesting a crop that half of it remains in the ground, or so carelessly handling it that it is unacceptable to the processor or the housewife, are common practices we can ill afford.

Forthcoming National Conferences

Autumn 9 October 1979
Tillage equipment design and power requirement in the eighties.
At the National Agricultural Centre, Stoneleigh.
(This Conference is being organised by the Royal Agricultural Society of England, in association with the West Midlands Branch of the Institution).
Convener: Mr R McD Graham.

Spring 25 March 1980
Electronics in Agriculture
At the University of Newcastle, Newcastle-upon-Tyne.
(This Conference is supported by the Institution of Electrical Engineers, in association with the Northern Branch of the Institution).
Convener: Mr D J Greig.

Annual 13 May 1980
Agricultural Engineering for the 21st Century
(Venue: to be announced).
Convener: Mr J Matthews.

Autumn 14 October 1980
Details will be published later this year.

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The titles of papers will be announced as and when they are made available.
Registration forms are normally distributed to members in the UK 6-8 weeks before each Conference.
Overseas members requiring registration forms should inform the Conference Secretary (Mrs Edwina J Holden) at the Silsoe Secretariat.
All enquiries concerning Conferences should be addressed to:
Mrs Edwina J Holden, Conference Secretary, The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU.
Telephone: Silsoe (0525) 61096.

Mechanisation in the production of vegetables for processing

Drills and drilling

K A McLean

Introduction

TABLE 1 indicates the estimated area of vegetables grown in the UK during the harvest season 1976/77. The area of sugar beet and cereals is also shown and it is important to observe that the total area of all vegetable crops exceeded that of sugar beet by only 5%, while by contrast the area of cereals exceeded that of vegetables by a factor of approximately 15.

Table 1 Vegetables

Estimated cropped area UK 1976/77

Peas (green)	57,000	hectares
Peas (dry)	30,200	
Cabbage	24,600	
Carrots	15,500	
Cauliflower	14,300	
Brussels sprouts	13,400	
Beans — runner and french	12,900	
Lettuce	7,400	
Onions (dry bulb)	7,300	
Turnips and swedes	5,200	
Beans — broad	4,300	
Other	20,100	
	212,200	
Sugar beet	202,400	
Cereals	3,165,200	

This explains why manufacturers of drills concentrate almost exclusively on the design and production of units for sugar beet and cereal crops. Hence the majority of vegetable crops are established with drills which were not primarily designed for that purpose while at the same time fundamental differences exist between agronomic and management aspects of such crops:—

(a) When vegetables are grown in succession to provide crops which can be harvested over an extended period, high drilling rates are not necessarily of great importance.

(b) The development of drilling techniques which advance the harvest date of vegetable crops destined for processing are not necessarily advantageous as crop processing schedules must be maintained.

(c) High emergence factors are often more important with vegetables in order that crops of the required unit size and quality are produced. In addition the high cost of some vegetable seeds necessitates precise drilling to ensure economy in the use of seed (eg sugar beet seed 9 kg/ha at £3.11/kg = £27.99/ha. Brussels sprouts, F1 seed, 0.5 kg/ha at £425/kg = £210/ha).

(d) The size distribution of vegetable seeds is much wider than that of sugar beet and cereal seed while at the same time many vegetable seeds are of a shape which makes them extremely difficult to drill.

Collectively these factors dictate that the selection of a suitable drill for the establishment of a specific vegetable crop for processing is often a compromise, no single drill being suitable for all such crops. Hence the range of drill types which are used include:—

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Paper presented at the Spring National Conference of The Institution of Agricultural Engineers, held at The Key Theatre, River Embankment, Peterborough, on Tuesday 20 March 1979.

1. "Unit" drills:— (a) Non spacing, used to produce a thin line of seedlings for subsequent thinning.
   (b) Spacing drills (or precision drills) which are intended to sow single seeds at discretely selected intervals.
2. General purpose/cereal drills.
3. Fluid drills.

While collectively this range of equipment makes possible the establishment of vegetable crops for processing, research into improved techniques is taking place in a number of areas. A description of some of these developments is the subject of this paper.

The evaluation of spacing drill performance

It has frequently been shown that most vegetable crops for processing give the best results with regard to seed economy, evenness of growth, ease of thinning and efficiency of harvesting if sown individually at predetermined spacings. However, in the absence of an official testing scheme in UK, the ability of spacing drills to achieve this objective when drilling vegetable seeds has rarely been evaluated. In most years the British Sugar Corporation evaluates the performance of all such drills which are entered for the National Sugar Beet Spring Demonstration using a distribution recording technique developed at the National Institute of Agricultural Engineering (CHITTEY, 1967). Although this evaluation is made in the sugar beet crop, the results are applicable to many vegetable crops because the assessment is now carried out using pelleted, monogerm seed which is similar in size and shape to some vegetable seeds.

A diagrammatic representation of the performance of spacing drills can be obtained if measurements of the spaces between seedlings are presented in the form of histograms as shown in fig 1. The length of spaces between the plants is shown along the bottom of the histogram while the height of the columns represents the percentage number of spaces of each size. It follows that in a histogram illustrating the performance of a good drill the highest columns should form a well defined group close to the target spacing. Since the failure of one seed to emerge doubles the spacing between adjacent seedlings there should be a secondary and smaller peak of columns at twice the target spacing. At the extremes of the histogram the columns showing the number of seedlings spaced either very closely or very wide apart should be considered. The former indicates that more than one seed has been sown at some plant stations, while the latter shows that either cell fill is incomplete or that mechanical damage to the seed during drilling has prevented its germination. Spacing drills whose performance histograms form a relatively flat contour should be regarded with suspicion as such a contour indicates relatively random emergence of the crop. Figure 1(a) illustrates the effect of increasing the speed of a conventional spacing drill on its performance. The drill was operating with pelleted monogerm seed at a target spacing of 15 cm. The number of seeds spaced less than 1 cm apart increased slightly at higher forward speeds, but at a reasonable rate. However, at the higher operating speeds the number of seeds sown at the target spacing decreased and the number of gaps exceeding 45 cm in length increased considerably. These results show that at the higher operating speeds the seed selecting mechanism was unable to operate as efficiently, so in order to achieve a satisfactory distribution at acceptable work rates increasing the width of the drill should be considered.

Distribution requirements of vegetable crops

The evaluation technique described was made with drills set to deliver seeds at regular intervals. However the cost of some vegetable

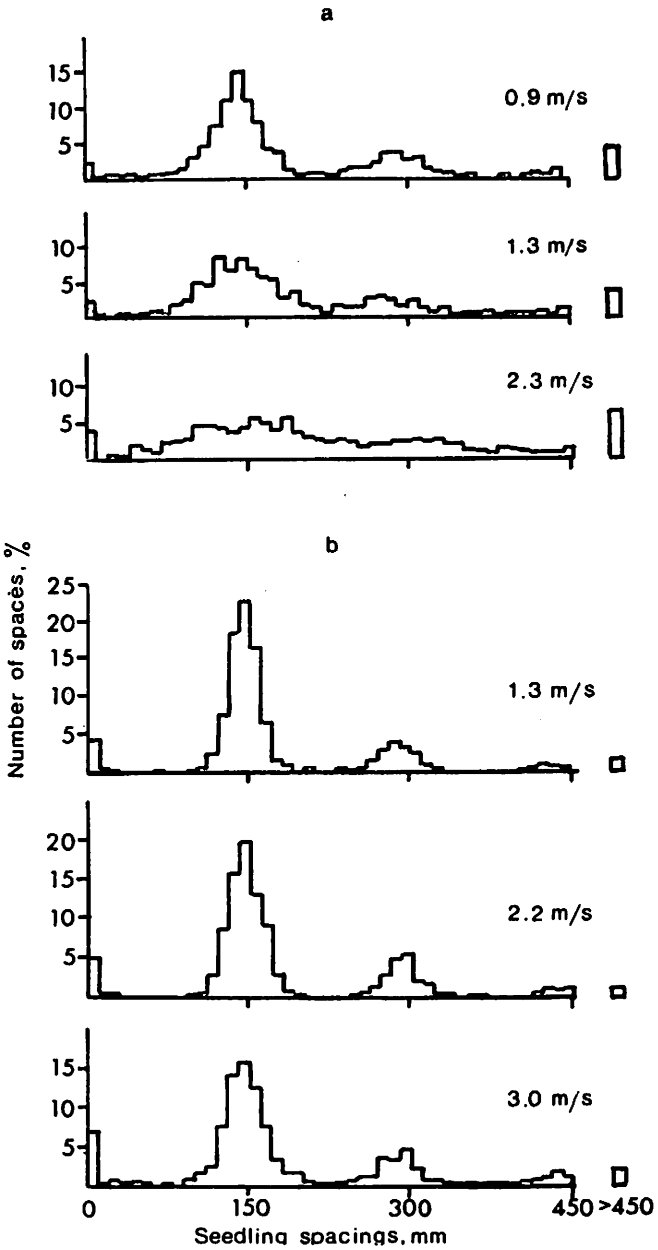


Fig 1 Precision drill performance
(a) Typical commercial drill
(b) NIAE two-stage drill (courtesy NIAE)

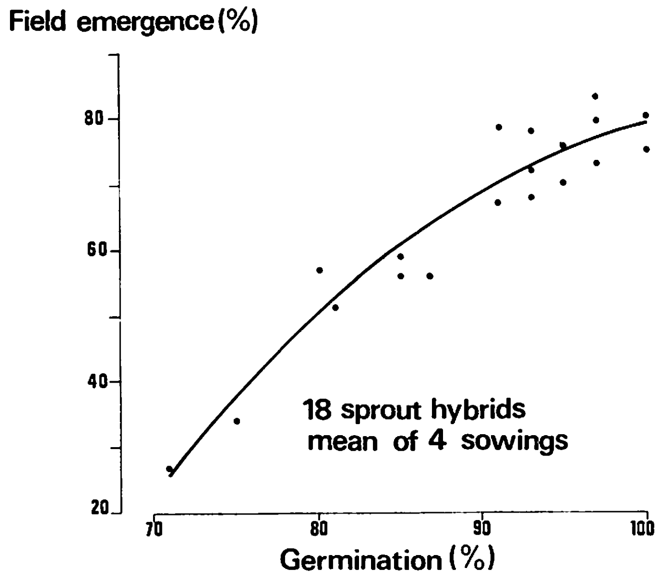
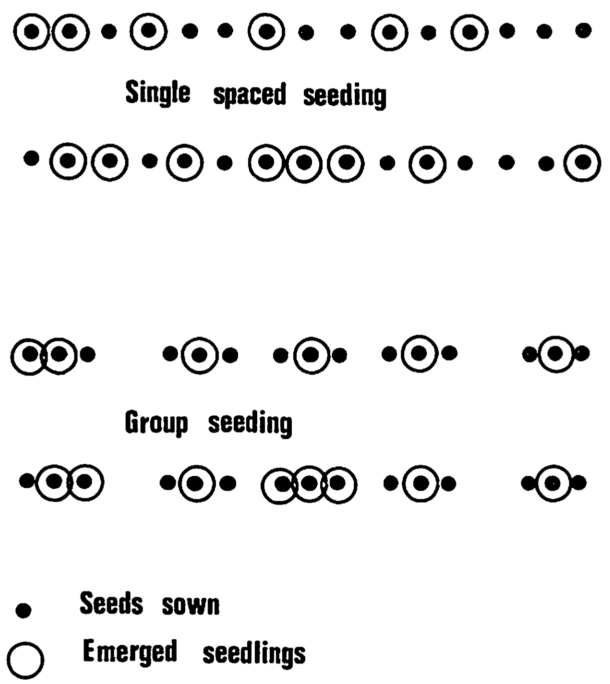


Fig 2 Relationship between germination and field emegence of Brussels sprouts (courtesy SHRI)

Fig 3 Emergence patterns of single spaced and group seeding



seeds is very high, so the most economic use of such seed must be made. Work at the Scottish Horticultural Research Institute (Hegerty 1977) has emphasised the importance of using seed with a high laboratory germination percentage. Not only does this result in fewer dead seeds being sown but, in the case of brussels sprouts, the ability of the viable seeds to emerge is also apparently linked to the germination percentage as shown in fig 2. How can these factors be used to ensure the optimum distribution of seedlings to achieve a uniform stand of plants capable of producing a high percentage of the required size grade of sprout? Figure 3 shows a comparison between the probable patterns of emergence when the same number of seeds is sown at regular intervals and in groups. Group seeding concentrates seedlings into the area in which they are needed although the percentage emergence is exactly the same as that of the seed sown in single lines. The number of seeds to be sown in each group must be linked to laboratory germination percentage. The higher the laboratory germination, the smaller the number of seeds required per group and the more regular will be the distribution. Table 2 shows the number of seeds required per group at various levels of laboratory germination, to ensure that an acceptable distribution is achieved.

Reference to fig 2 shows that brussels sprout seed with 88% laboratory germination will have a 65% probability of producing a seedling. Hence if only one seed per station is sown there must be a 35% probability that it may produce a gap. If two seeds are sown per station the probability of gaps would be reduced to 35% of 35 = 12.2%. If three seeds were sown the proportion of gaps would be 35% of 12.25 = 4.3%. Similar calculations can be made for other levels of laboratory germination.

Other factors to be considered concern seed rate and distribution, optimum plant density and row width. The optimum (ie most economic) plant density is not usually that at which the highest

Table 2

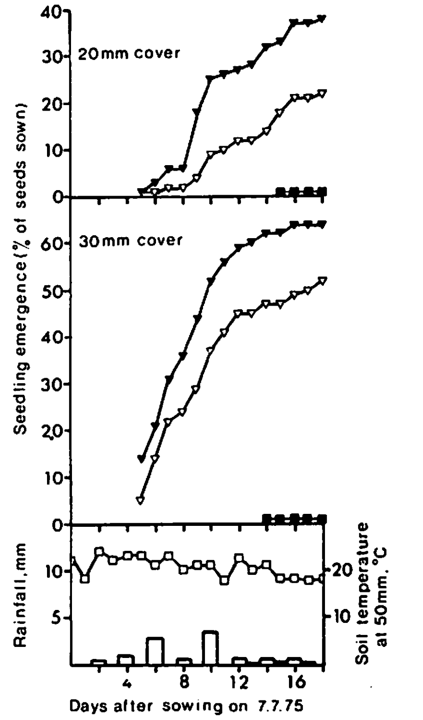
Laboratory germination	*No of seeds/group*
87% or above	3
85–87%	3
80–84%	4
78–80%	5

yield is obtained because of the high cost of seed. Row width is important with regard to the requirements of harvesting machinery. Experiments conducted at the Processors and Growers Research Organisation (King J M 1976) have shown that the optimum row width for dwarf beans is approximately 20 cm, but until recently it has been necessary to use 40–50 cm rows in order to facilitate harvesting. However the use of self propelled harvesters with full width picking heads which can traverse the rows, has overcome this problem.

NIAE two-stage drill

Figure 1(a) shows how the performance of a typical commercial drill deteriorates with increasing forward speed. Research at NIAE (Bufton 1977) has shown that when seed delivery conditions are optimised by matching the peripheral speed of the delivery mechanism to the forward speed of the drill, and at the same time keeping the seed release height as low as is practical, there is a marked improvement in the accuracy of seed spacing. However, optimised seed delivery conditions cannot be achieved simply by increasing the speed of the metering mechanism, as this would result in poor cell fill. The NIAE approach has been to separate the functions of seed metering and seed delivery so that the separate components can operate at their optimum speed. Figure 1(b) shows the effect which this principle has on the distribution achieved.

The experimental drill also incorporates several other features which can result in improved performance. Dry surface soil can be moved aside to allow a rough, flat bottomed furrow to be opened into moist soil and considerable improvement in performance was obtained when the dry surface soil was not mixed with that used to cover the seeds. A press-wheel can be used to press the seeds into the moist furrow bottom which also helps to prevent them being moved during the covering operation. The operating depth of the coulter is controlled by a single depth wheel which enables ground contours to be followed more closely than would be possible with a twin wheel arrangement. Figure 4 shows the effect of the removal of dry cloddy surface soil and of pressing the seeds into the furrow bottom in order to provide an improved environment for the development of the seed. The experiment was deliberately carried out under dry seedbed conditions in July.



Key: ▿ Dry or cloddy surface soil moved aside
▾ As ▿, and seeds pressed into furrow bottom
■ Commercial comparison drill

Soil moisture at sowing Depth, mm	%wet basis
0–10	2.6
10–20	3.3
20–30	4.2
30–40	7.2
40–50	13.1

Fig 4 Performance of NIAE two-stage drill (courtesy NIAE)

Direct drilling

Interest has recently been shown in the establishment of vegetable crops for processing by direct drilling them into soil which has not been disturbed after harvesting the previous crop. The technique is attractive with the processed pea crop in an attempt to help overcome the problem of high labour demands on arable farms in the spring. In addition direct drilling can improve the flexibility of drilling programmes as a result of minimising the constraints caused by adverse soil working conditions. An observation study was carried out in Essex in 1978 when crops of peas were established by both direct drilling and conventional methods. The yield of direct drilled peas averaged 2.4 tons/ha, while the crop established by conventional methods averaged 2.7 tons/ha. However the vigour of the direct drilled area was noticeably better and the crop was less mature at harvest on 26 August (22.4% moisture content cf 18.4% moisture content). Had harvesting of the direct drilled crop been delayed until it had reached the same stage of maturity it is likely that there would have been no yield penalty.

As a result of interest in this topic an experimental drill has been developed by Plant Protection Limited to facilitate investigation into the direct drilling of crops at precision drilled standards of seed spacing. The equipment consists of a conventional direct drill, with pneumatic precision drilling units attached to the standard disc coulter assemblies.

Furrow watering

An alternative method of improving the environment in which seed is located is by furrow watering. The Flowgrow system was developed by a vegetable grower as an alternative to irrigating seedbeds prior to drilling. The principle is one of pumping water into the furrow which has been made by a drill coulter, after seed has been dropped into it, but prior to the coverer causing the furrow to be filled with soil.

The equipment is similar to a band sprayer but conventional nozzles have been replaced by lengths of 6 mm copper tubing which are clamped to the drilling units between the coulter and the covering components. The volume of water applied varies with soil type, the upper limit of volume being that at which water expelled from the soil surface by the press-wheel causes wetting of the press-wheel with subsequent build-up of mud.

Evaluation trials carried out by ADAS in 1977/78 have been disappointing as a result of wet springs during which heavy rain fell soon after the trials had been drilled. Table 3 shows results of a trial with autumn sown onions.

Indications are that furrow watering caused earlier emergence, but that rain which fell from 16 August onwards provided sufficient water for germination of all treatments.

A modified version of this technique is being promoted by another company (Flowsow) in which a viscous fluid, instead of water, is pumped into the furrow. It is claimed that the viscous fluid disperses less rapidly from the vicinity of the seed than does water, hence further improving emergence. However trial data to substantiate this theory is not available.

Fluid drilling of vegetable crops

The extent to which uncontrollable factors can influence the establishment of crops of vegetables from seed has long been recognised. Such factors include seedbed conditions, moisture status,

Table 3 (Mean No seedlings per 3 x 1.83 m)

Treatment	*Date*			
	26/8	*30/8*	*31/8*	*8/9*
No water	1.2 (.004%)	107.5 (37.3%)	144.8 (50.3%)	192.5 (66.8%)
2550 l/ha	1.2 (.004%)	132.8 (46.1%)	163.5 (56.8%)	199.2 (69.2%)
3853 l/ha	2.5 (.008%)	141.0 (48.9%)	164.2 (57.0%)	196.5 (68.2%)

(Bracketed = % emergence)

soil temperature, etc. An attempt was made to quantify these "field factors" (Bleasdale 1963) and they are acknowledged in seed rate calculations,

eg Weight of seed (kg/ha) =

$$\frac{10 \times \text{required population/m}^2 \text{ of field}}{\text{No of seeds/10 g (000's)} \times \text{\% germination} \times \text{field factor}}$$

However, the greater the field factor and the lower the percentage germination the less regular will be the distribution of those seedlings which do emerge.

It was in an attempt to achieve greater control over field factors that the investigations into the fluid drilling of vegetables, in which a viscous gel is used to support pre-germinated seeds during drilling, were carried out at the National Vegetable Research Station (Salter 1978) the developments being based on a technique originally used in attempts to establish grass seed in pastures (Elliot 1966).

It has been established that in order to obtain the maximum possible advantage from the system distinct techniques are necessary;—

(a) To pre-germinate the seed to the required stage of development.
(b) To store the germinated seed until required for drilling without deterioration and further development taking place.
(c) To separate germinated from non-germinated seed.
(d) To transport and drill the pre-germinated seeds in the required pattern.

Methods of achieving these objectives have been developed to a stage which has established the commercial credibility of the technique. As far as produers of vegetable crops for processing are concerned the major shortcoming of the system is the lack of a drill capable of producing brairds to a pre-conceived distribution pattern. Existing fluid drills can be likened to thin-line non-spacing units. However, techniques are available whereby individual pre-germinated seeds can be selected and individually placed into soil blocks, so it is anticipated that it will be possible to incorporate the mechanism into field scale fluid drilling equipment to give precision spacing of germinated seeds.

If such revolutionary techniques are to be adopted and mastered by managers and operators, distinct advantages must be achieved, so initially it is likely that the greatest benefit will be found in those areas where specific problems exist rather than with crops which can be satisfactorily established by conventional methods. Carrot seed is irregularly shaped and difficult to drill. The emergence of fluid drilled carrots has been increased by 20% and the early yield of bunching carrots increased by 18%. Some cultivars of celery require light before germination will take place and as a result 90% of this crop is transplanted in the UK. However, it has been shown that pre-germinated, fluid drilled crops can be established in-situ. The temperature at which field tomatoes will germinate is 25°C, which renders the growing season in the UK too short for satisfactory cropping. However, fluid drilled crops have been established with pre-germinated seed with soil temperatures as low as 10°C.

Other potential advantages of establishing vegetable crops for processing by fluid drilling methods include the use of the aqueous carrier for incorporating nutrients, fungicides and insecticides. Dwarf french beans have been successfully inoculated with Rhizobium bacteria during the fluid drilling process (Hardaker and Hardwick 1977).

Plastics mulching

During recent years the only widespread use of plastics for advancing crops has been plastics tunnels ranging in size from "walk-in" structures to "cloche" types. They are all supported by metal hoops, are costly and labour intensive. Two recently introduced plastics mulching techniques may revolutionise the use of plastics in field cropping, the objective being to raise soil and air temperatures beneath the mulch and by so doing advance maturity and increase crop yields. The first is the use of perforated "floating" mulches. The perforated plastics film is laid over the ground after drilling or transplanting and the edges are mechanically buried to provide anchorage. As the crop grows it raises the film so that the crop itself acts as a supporting structure and a low tunnel is created. The perforations in the film allow it to stretch as the crop grows, while at the same time gas exchange and water movements through the film can take place. The approximate cost of the film is £750/ha.

The height to which crops grow will in some instances preclude the use of this technique. The alternative is the use of plastics mulches, through which the crop grows. The technique was investigated in the UK many years ago, but was not adopted for a number of reasons:

(a) Costs.
(b) Difficulty in disposing of plastics mulch after the crop has been harvested.
(c) Mechanical problems associated with laying plastics at acceptable work rates.
(d) Synchronising perforations in the mulch with the spacing of the pre-drilled seedlings.

Recently developed technology has overcome most of these problems. Unsupported plastics mulches are not required to stretch to accommodate growing crops and hence as perforations are not required, much thinner films can be used. Hence costs are reduced. Disposal problems have been overcome by producing photodegradable films with finite life. Such plastics can be formulated to degrade after 30–120 days, when they form harmless inert powders. Films can now be laid mechanically at normal drilling speeds, but in order to ensure alignment of seedlings with the holes through which they are to grow, the seed must be drilled through the film. During earlier work pre-perforated mulches were used which often resulted in only a small percentage of correct seedling/hole alignment. It is in the development of machinery which can simultaneously lay plastics film and drill through it that further development must be carried out to ensure the success of the technique.

In 1977/78 ADAS simulated the technique by hand planting crops of sweetcorn and runner beans through plastics mulches. In the trial with sweetcorn the mulch did not increase the total number of cobs produced, but the number of cobs in the large class was increased by 81% (plus 54% by weight), while the total number of marketable cobs was increased by 51%.

With runner beans (Foster 1977) the highest yield was obtained with clear degradable mulches, when the overall yield advantage over unmulched plots was 260%. The yield advantage at first pick was 516%.

Conclusions

In spite of few drills having been developed specifically for the establishment of vegetable crops for processing, the wide range of unit and general purpose drills which is available makes this possible. Little is known about variation in plant distribution and its effect on vegetable size and quality. However, this does not appear to be a major problem, the majority of current development being concerned with optimising seed environment prior to, and after emergence. The perfection of such techniques may make possible more economic use of costly hybrid seed and may make feasible the production of crops which are now considered to be "on the fringe of their required environment".

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Automatic transplanting

W Boa

Introduction

IT is self evident that the high yielding even maturing crops that are required for processing cannot be achieved from poor or uneven plant stands. Hegarty (1976) demonstrated that low plant stands often found in agricultural practice may be due not to factors dependent on the weather but to soil tilth, fertiliser level, seed or soil infection and seed drill performance – over all of which there is, theoretically, some control. His work involved multiple sowings of four crops over a three year period and arose from differing interpretations of the field factor concept used by Bleasdale (1963) for estimating seed rates for crops that are drilled to a stand. He concluded that it should be possible to improve the prediction of seedling emergence by allowing for a constant level of seed loss (based on the grôwers experience of his own soil type) rather than a variable level of loss embodied in the field factor.

With transplanted crops the first uncertain stages of crop establishment including emergence can take place in a controlled environment. Greater precision is therefore possible. Unfortunately, most of the published work on the subject omits reference to processing crops. Thus, for example, in experiments to provide continuous cropping of lettuce from May to November, Hartmann and Wuchner (1968) found that optimum quality throughout the season resulted from the use of transplanted seedlings rather than direct seeding. An additional advantage of transplanting was demonstrated by Gray (1978) in experiments comparing transplanting lettuces with dry seeding and fluid seeding chitted seeds. The spread of maturity was unaffected by the method of seeding in two of three experiments and in the experiment which included transplanting the spread of maturity was significantly lower in the transplanted than the drilled crops.

Although more precise control of the harvest date and more uniform crop maturity are clearly advantageous, transplanting is not used for all the crops for which it is technically suitable. To a great extent the reason is that manually fed transplanters are expensive to operate. In a theoretical study Eastwood and Gray (1976) calculated costs and returns for four methods of establishing field lettuce. They observed that transplanting permitted better land use than drilling in that 2.4 crops per year could be grown compared with 1.7. Total costs of growing crops were higher with both machine assisted manual transplanting and fully automatic transplanting than with either direct drilling to a stand (impractical for lettuces with present technology) or drilling and thinning. Labour costs for automatic transplanting were, however, 18% lower than for drilling and thinning. Automatic transplanting also showed no disadvantages compared to drilling and thinning when profitability was considered at a range of prices and different levels of percentage of the crop sold. In table 1 which is based on a table in Eastwood's and Gray's paper three levels of plant loss are considered. Practical experience has shown that plant loss with transplanting is usually more than 10% less than with drilling. (B E Bransden, private communication). The low level of plant loss given in the table therefore represents 10% loss with transplanting and 20% with drilling. The corresponding losses for the medium level are 20% and 30% and for the high level they are 30% and 40%.

From the research data that have been quoted it is reasonable to assert that an automatic transplanting system may often be applicable to crops that are now drilled and thinned on the grounds that any additional cost is likely to be recovered from improved crop quality and evenness of maturity. Replacing machine assisted manual transplanting with automatic transplanting has additional advantages. It will get the job done more quickly – at least 1.6 km/h instead of 0.4 km/h – and with no more than one third of the labour force.

Previous work

Thirteen years ago NIAE (1966) measured rates of working of four current transplanters. Net rates for cabbages spaced 360 mm apart ranged from 1300 to 1700 plants/operator hour and with more closely spaced cèlery and leeks they were about 15% faster. With all machines, turning on headlands and replenishing plant trays reduced the work rate by 20-25%.

Three of the four machines current in 1966 are still available and one of them accounts for about half of purchases. The labour requirements of more recent machines are similar (Labowsky 1978).

Research and development aimed at reducing the amount of labour needed for transplanting has been undertaken in the USA, Japan, Holland, Bulgaria, Nigeria and the UK. Some of the machines which have been developed or postulated have employed automatic feeds and hand filled magazines. Others have relied on hand-assisted feeds and magazines of blocks or containers in which the transplants are grown and a few have been fully automatic with mechanical feed mechanisms working from magazines of blocks or containers in which the transplants are produced.

Machines where a mechanical feed mechanism works in conjunction with previously hand filled magazines of plants can be capable of very high rates of working. Thus, for example, Trayanov (1973) reported on an experimental unit where bare root transplants were carried sandwiched in a canvas roll which was unreeled as the machine moved across the field. A forward speed of 5.5 km/h was achieved with cabbages spaced about 300 mm apart. This is more than ten times the rate achieved with hand fed machines. Holmes (1971) reported that a Japanese machine where plants in paper pots were fed from hand filled tray type magazines was much faster than conventional hand-fed transplanters. A two-row automatic planter for cassava cuttings developed in Nigeria by Odigboh (1978) also worked at a high forward speed but relied on hind-filled magazines. For none of these three machines had there been an assessment of overåll labour requirements but Holmes observed that the amount of labour needed for loading the magazine was too high to countenance the use of the method with sugar beet although it gave a 25% increase in yield.

The Japanese paperpot system where plants are grown in hexagon paper rings glued together to form a honeycomb has been

Levels of percentage plant stand harvested at which zero net income occurs under each of four systems of lettuce establishment

Crop Loss	*Low*			*Medium*			*High*		
Price/lettuce	*2p*	*3p*	*4p*	*2p*	*3p*	*4p*	*2p*	*3p*	*4p*
Direct drilling to a stand	55	29	20	65	34	23	73	39	26
Drilling and thinning	62	33	23	72	39	26	84	45	30
Automatic transplanting	63	33	22	70	37	25	80	43	29
Machine assisted manual transplanting	75	40	27	87	45	30	96	50	34

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used for a manually assisted high speed transplanter. A single-row unit on trial in Israel was reported (U M Peiper, private communication 1977) to have had an operator who used a hand held rake to detach a line of pots from the block in which they were grown and place it on a conveyor which discharged into a plant metering mechanism.

Last year, Mann (1978) reported that a French company was developing a three row transplanter where a seated operator separated lines of peat blocks from the mats in which they are produced and placed them on to conveyors feeding automatic metering mechanisms at ground level.

No performance data for the Japanese or French machines are available in the UK, but it seems likely that both should be capable of working rates about three times as fast as completely manual machines. They are thus slower than machines where an automatic feed is used in conjunction with hand filled magazines. One of the machines, however, was developed by a company previously associated with a hand filled magazine machine, so it is reasonable to assume that their overall labour requirement is likely to be less.

Only one fully automatic transplanter, where the plants are mechanically metered from magazines in which they were grown, is known to have been developed to a stage where it could be subjected to field trial. Huang and Splinter (1968) reported that the machine was designed to plant two rows of tobacco 1.1 metres apart with the plants spaced 560 mm in the rows. For each row two cartridge grids holding 220 peat pots each 45 mm x 45 mm x 50 mm deep were carried on a horizontal plate 600 mm above ground level. The grids were moved automatically in a programmed manner so that as the machine moved forward two plant spaces the grids moved longitudinally or laterally so that four pots matched holes in the grid carrying plate. At forward speed of 3.2 km/hr, with one operator for its two rows the machine gives a labour productivity increase of about 750% and does the work in less than a third of the time needed for a manually fed machine. Unfortunately, the mechanism employed demanded wide plant spacings both in the row and between rows and the peat pots that were used too expensive for most field vegetable crops.

Another fully automatic machine was investigated by Kuiken (1969) in Holland. It involved the use of peat block grown transplants but did not proceed beyond the stage of laboratory trials because the mechanism needed to separate the blocks was too complex.

More recently Brewer (1978) has postulated an automatic transplanter system where the plants are grown in bandoliers which lend themselves to the use of simple feeding and metering mechanisms. The system has much in common with the one on which NIAE had then been working on for over two years.

Fig 1 NIAE bandolier blocks. Top — 2 week old lettuce plants Bottom — 6 week old autumn-sown bulb onions.

Research and development at NIAE

At the outset it was decided that NIAE work on transplanting should cover a range of field vegetable crops and take account of all aspects from seeding to transplanting. Systems with bare root transplants were, however, excluded because the design of a transplanter for them was likely to present considerable difficulty and their horticultural disadvantages compared with systems for block or container raised transplants were believed to outweigh their logistic advantage.

The project has therefore involved blockmaking, block handling and transplanting machines. In addition collaborative experiments have been carried out by the National Vegetable Research Station and ADAS experimental horticultural stations to investigate optimum container shape and the range of crop species and transplant ages that can be accommodated in the block size selected for first experiments.

At first, experiments were carried out to investigate the use of an additive to strengthen pressed peat blocks and make them more easily separated (Boa 1975). This was unsuccessful so it was decided to devise a containerisation system which could be used with a transplanter having a simple unattended mechanical feed.

Cylindrical blocks arranged in a bandolier (fig 1) were adopted because their attachment one to another permitted them to be fed in an orderly queue through a transplanting machine. Forming, wrapping and arranging them on trays called for a relatively simple blockmaking machine.

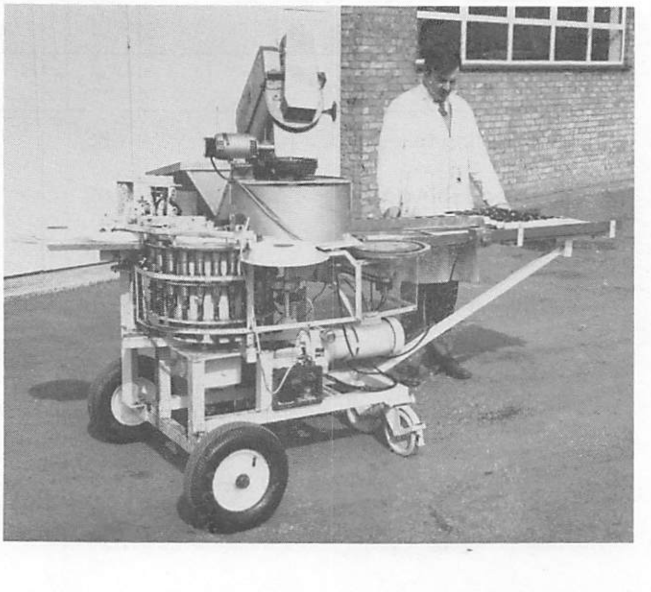
The design of the blockmaker (fig 2) was determined by the sequence of operations it had to perform:

(i) meter dry compost from a bulk supply into a series of block forming sleeves
(ii) add a measured amount of water to each block
(iii) compress the block so that the added water is evenly distributed throughout the compost
(iv) wrap paper or plastics film round the block while it is still enclosed in its forming sleeve
(v) punch a depression in the top of the block to receive a seed
(vi) sow a seed into the depression
(vii) withdraw the sleeve leaving the block wrapped and supported by the paper and connected to its neighbours
(viii) arrange the blocks on trays.

Two seeders were developed for use with the blockmaker. One which has a simple horizontal plate feed is adequate for pelleted or spherical seeds or for sowing groups of six to eight onion seeds. The other is a fluid seeder working on a vacuum principle and is for natural or chitted seeds. It is more complex than the plate seeder but its use can result in savings of up to £2/thousand blocks when natural seed is used instead of pelleted. The seeder will also allow advantages of chitted seed described by Salter (1978) to be exploited if reliable means can be found for separating germinated from dead seeds.

During the development of the blockmaker it was deemed important that the machine should work well with proprietary, readily available, peat-based blocking composts. Sedge peat, which

Fig 2 NIAE experimental blockmaker



accepts water instantly, gave better blocks than sphagnum which when used with conventional blockers is usually soaked for 24 hours.

The wrapping material from which the bandolier was made was the subject of much experiment. For first trials 80 gm/m^2 high wet strength kraft type paper was used with one side coated with a pressure sealing latex adhesive. This was unsatisfactory; the paper was quickly weakened by fungal attack so that the bandolier had no tensile strength when the seedlings were ready for transplanting. A 60 gm/m^2 paper coated on one side with 12 gm/m^2 polyethylene and on the other side with latex adhesive was adopted temporarily to allow development to continue while a search was made for materials which would retain their strength until the blocks were transplanted and then degrade over a period as the crop developed. Advice from PIRA (1978) helped in the selection of possible materials. Two of these have given promising results in trials and have the added advantage of being acceptable to heat sealing without adhesives.

The development of the blockmaker can now be considered to be complete. The present experimental machine produced many hundreds of thousands of blocks and is capable of working at a rate of about 10,000 blocks/h. An improved design has, however, been prepared to make 12,000 blocks/h and to produce blocks of different heights if that is proved to be desirable.

Until the development of the blockmaker had been completed it was undesirable to study the design of transplanters in any great detail; the choice of wrapping material was likely to determine the design of the mechanism for separating and planting the blocks. At a relatively early stage of the project, however, it was observed that few current transplanters could be relied on to maintain accurate depth control and upright planting at forward speeds in excess of 1.5 km/h. One machine which was satisfactory in both of these respects was also relatively simple to adapt to automatic feeding. Recent trials suggest that it should be possible to have an automatic single row transplanter ready for field trial this summer.

One of the first functions of field trials of the single row transplanter will be to investigate the logistic problems associated with block planting. If the minimum number of blocks to be carried on a transplanter is specified as those required for a single pass across a 200 metre field, a six row unit planting lettuce will carry about 5000 blocks. At even a modest speed of 1.5 km/h the machine will use over 500 blocks/minute.

Experience with experimental blackcurrant harvesters (Kemp and Boa 1972) has shown that boxes measuring about 750 mm x 500 mm x 125 mm deep and weighing 10 kg each can be handled by a reasonably fit man at a rate of about 3/minute. Similar sized flat trays hold just over 200 bandolier blocks and weigh less than 4 kg. They will therefore be the first size to be tried.

Collaborative horticultural research

At the start of the project block shape and size were decided in an arbitary fashion. Many plant raisers use 40 mm cubical blocks for outdoor lettuces and celery and some use 30 mm ones. Blocks 37 mm diameter and 40 mm high therefore seemed a suitable starting point: they were the same width as the larger blocks in common use and their volume was greater than that of the smaller ones.

It was, however, desirable to obtain experimental data to confirm that the block size and shape were satisfactory in horticultural practice and that planting them in their wrapping would not have adverse effects.

Experiments at NVRS (1978) when lettuce plants grown in paper covered blocks of different diameters and heights were transplanted into dry soil showed that transplant check was least with tall blocks. In the extreme conditions of the trial 40 mm was the minimum height that did not give appreciable transplant check.

To confirm the suitability of the blocks for a range of vegetable crops and different ages of transplant four ADAS experimental horticultural stations and one experimental husbandry farm carried out a series of field trials. The crops in the trials were field lettuces, autumn cauliflower, summer cabbage, Brussels sprouts, spring sown bulb onions and self blanching celery and for each crop four ages of transplant were chosen. In each trial samples were weighed two weeks after planting to compare rates of establishment. When the crops were harvested their yields and evenness of maturity were measured. The results of the trials are recorded elsewhere (Boa and Harrison 1979). Here it is sufficient to observe that the blocks produced satisfactory transplants for all of the crops and all of the ages in the trial. In every crop the penalties that resulted from the use of the largest transplants were acceptable.

Experiments to determine the effects on transplant check of leaving the bandolier wrapping on the block or removing it were carried out at Kirton Experimental Horticultural Station (1978). In the conditions of the trial the check that resulted from not removing the wrapping was too small to be of economic importance.

Future work and acknowledgements

This year work on transplanting at NIAE will be concentrated on the development of a fully automatic transplanter and on solving the logistic problems associated with it. For this work a single row transplanter will be used but throughout the trials due consideration will be given to the fact that future commercial machines will span between three and six rows with no more than one operator.

The development of the transplanter and its associated equipment has depended greatly on collaborative horticultural research aimed at finding the practical limitations within which the system can be used and at establishing how to get the best from it. An excellent start on this facet of the project was made in last years trials and it is hoped that they can be extended to include other aspects.

Grateful acknowledgements is made to staff members of the Plant Physiology and Statistics Sections at NVRS and ADAS Experimental Stations at Efford, Kirton, Luddington, Cawood and Mepal for their work in planning and carrying out last years experiments and analysing the results. Thanks are also due to Peter Grundon of NIAE who has worked on the project since the beginning.

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Crop sprayers

J M King

Summary

THE requirements of crop sprayers for use in vegetable production are defined and some of the recent developments in machines and associated spraying aids are presented. The implications of new spraying techniques and the use of low ground pressure carrying vehicles are discussed.

Introduction

If this paper had been written ten years ago it would have been difficult to find sufficient "new developments" in crop sprayers. Since then a remarkable number of innovations has taken place which in the next five years could lead to a radical change in spraying equipment and techniques. During the 1960's and early 1970's, the emphasis was on the development of a whole range of new chemicals with comparatively little thought of how they were to be applied accurately to the target. The simple crop sprayers developed to apply the early hormone weed killers in cereals performed quite adequately when used with these relatively unsophisticated materials. With the newer agrochemicals, where accuracy of application and timing of the operation are much more important, such machines were inadequate and for many years the only real up-dating was to make them bigger. This brought them into line with the general trend towards larger equipment, operated by a smaller workforce, but did little to improve their technical efficiency. In recent years, however, the whole idea of the conventional crop sprayer, mounted or towed by a tractor and using hydraulic nozzles to apply the chemical in large volumes of water has been questioned, and several exciting alternatives are being developed. The purpose of this paper is to bring these developments together and to try to suggest where they could improve the application of agrochemicals to field scale vegetable crops, particularly those grown for processing.

The requirements for crop sprayers in field vegetables

Before discussing the new developments it is important first to define the particular requirements, in order to be able to see how closely they match our ideal.

Accuracy of application

Inaccurate application can lead to crop damage due to the overdosing of herbicides affecting either plant stand, growth, yield or maturity, while to the processor the most important aspect can be unevenness within the crop, which results in reduced quality of produce. On the other hand, underdosing of herbicides may fail to eliminate a weed problem, leading to lower yields and, if weed fragments either contaminate the harvested produce or interfere with the harvesting, the whole crop may be lost for processing. Similarly with insecticides and fungicides; because of the very high quality standards demanded in processing, any failure to control a pest or disease may have very serious and costly repercussions.

Timeliness of application

In order to match the high standard of husbandry necessary in the production of these crops, the application of chemicals, which forms such an essential part of present-day husbandry, must be possible under a wide range of conditions. Delay in controlling weeds, pests and diseases can have serious economic significance to the grower and processor. Many field vegetables are sown to carefully controlled sowing programmes and even routine spraying can take place over a long period as each crop reaches the necessary stage of development. Spraying equipment must therefore be versatile in relation to weather and field conditions. The effect of wind causing unacceptable drift is probably the most common limiting factor to sprayer use, but wet soil conditions which prevent the passage of tractor and sprayer are also common factors which limit spraying days.

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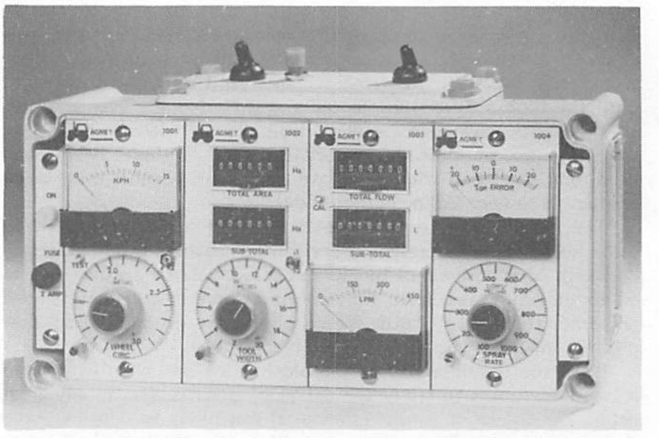


Instrument for mounting in tractor cab to measure speed, area, flow rate of chemical through sprayer and indicated error from planned output (copyright Agmet Instrumentation Ltd)

Workrate

When a pest or disease problem endangers vegetable crops it may be essential for large acreages to be treated quickly. At present the most practical way to do this, particularly when treatment is needed when the crop is fully grown, is to use aircraft; for example many acres of dried peas are sprayed annually for control of pea moth *(Cydia nigricana L)*, and vining peas for aphid *(Acyrthosophon pisum)* or pea midge *(Contarinia pisi L)*. After drilling, soil-acting residual herbicides need to be speedily applied while the land is in suitable condition, and later if post-emergence herbicides are to be applied at the correct stage when the weather is satisfactory there is again considerable pressure to carry out the work as quickly as possible.

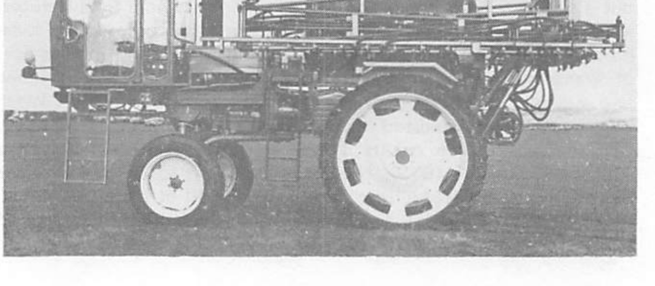
Specialised equipment

Certain vegetable crops require specialised spraying equipment. Tall crops such as broad beans need high clearance sprayers, while in brussels sprouts drop-leg sprayers are essential if satisfactory cover of lower leaves and buttons is to be achieved. In row crops such as dwarf beans or brassicas the use of inter-row shielded sprayers can still be valuable in dealing with weed or volunteer crop problems. Many chemicals are formulated as granules to tailor their effects to particular needs and equipment is required which can apply them either overall to the soil or during or after drilling along the crop rows. A single type of sprayer may not be possible where a range of vegetable crops feature in the rotation, but with the apparent desire of the producer for greater simplification, many will demand the necessary chemicals which can be applied by his existing crop sprayer, or conversely the development of multi-purpose sprayers.

Safe operation

Sprayers used in vegetable crops must be capable of applying a wide range of materials, some of which are of a toxic nature. It is an

Modern large, self-propelled, high clearance crop sprayer (copyright Modular Chemical Vehicles)



important requirement of modern machines that operator safety is of the highest order, and convenience and comfort will enable him to complete his task efficiently.

Developments in conventional sprayers

Before discussing the various changes which have taken place with new forms of sprayers it would be useful to review the stage of development which has been reached with conventional machines fitted with hydraulic nozzles. Thinking back to the simple sprayers used 20 years ago it may seem that little has changed apart from their size, but other important developments have been made in relation to certain features.

Accuracy

If the application is to be accurate, nozzle output must be constant along the boom. Education is important not only to ensure that operators replace worn nozzles, fit comparable sizes along the boom and do not damage them when cleaning, but also to indicate to nozzle manufacturers the fine tolerances which are required in their products. In the survey of farm sprayers carried out by ADAS and reported by Rutherford (1976), extremes of throughput between the nozzles giving the highest and lowest output along the boom were recorded and 13% of sprayers were found to have nozzles where the maximum/minimum throughputs varied by 200–300%. The number of sprayers with faulty nozzles giving worse than 10% variation from the mean on the sprayer was also recorded and 10% of machines were found to have more than ten faulty nozzles on a boom. Two-thirds of the machines in this survey were less than three years old. It was concluded that the standard of sprayer operations was at a similar level to that which prevailed ten years earlier and that there was considerable room for improvement.

Faulty operation of sprayers is another obvious area where accuracy can be lost. Rutherford (1976) reported that with 11% of the sprayers investigated in the survey there was a 20 and 30% difference between the operators calibrated and actual spray volume rate, and in one case the error was more than 50%. Considering that 57% of the operators in the survey had received no special instructions on the operation of the sprayers, such errors might be expected. Several excellent training schemes, principally through the Agricultural Training Board, are currently available and it is to be hoped that in the future employers will ensure that a very large proportion of operators receive this vital specialised training. In the long term it may well be that operator training is made obligatory. Aids to matching swaths have received attention for many years and various methods are available. The simplest are the foam blobs deposited from the ends of booms and said to last for 30 minutes even in wind or drizzle. A further sophistication of this system is the use of light cells on the underside of the booms to sense the foam blobs. The driver is informed whether he is on line by a series of lights on a control panel in his cab. This is the NIAE system in which triangular mirrors at the end of each boom reflect back the line of foam blobs to a double mirror on the bonnet of the tractor. Probably the ultimate in techniques for accurate driving is the prototype closed circuit TV system under development by Pye, which uses cameras on the end of the boom to view the actual line of foam blobs and picture them on a monitor in the tractor cab. Various robot markers are now available which are pre-set to the bout width and move across the field at the push of a button in the cab to indicate to the driver where his next bout is. Lawrence (1977, 1978) has reviewed developments in swath matching aids.

One of the newest electronic approaches to the problem of improving accuracy of application is a tractor cab unit which measures forward speed, area covered and flow rate of chemical, and these recordings are then computed and indicated to the driver as the percentage error over or under the intended application rate. The driver can stabilise the error needle by either adjusting his speed or regulating the spray pressure. Another system works on the principle of regulating flow of chemical more closely to tractor ground speed. A pump attached to the pto drive, which is in fixed ratio to wheel speed, gives the same volume every revolution and thus delivers the same volume over a fixed distance. Linked to this is a special manifold which will always by-pass a fixed proportion of the pump output and which is calibrated for the desired application rate.

The use of "tram lines" as an aid to accurate application must not be discounted in vegetable crops. Their use is already becoming established practice in cereals and particularly when a number of spray applications are required, they are very valuable in simplifying the operators' task and in preventing an unnecessary number of wheelings. Even in row crops the tractor wheels can damage the crop unless a sufficiently wide-wheeling is purposely provided, and in crops such as dwarf beans where narrow rows are now being used, tram lines will become necessary to allow post-emergence applications to be made without damage to the crop. Although some pea growers are already trying tram lines the untidy growth of this crop may not allow them to remain easily defined later in the season.

Timeliness of application

Crop sprayers with a high work rate obviously allow large acreages to be treated quickly but probably the most important contribution which could be made would be to reduce drift, thus allowing spraying to take place on days when wind would normally be too strong. Attempts have been made to develop additives which when added to the spray tank reduce drift by reducing the formation of very small droplets in the spray pattern. It is too early to say whether this line of research will be successful, but obviously it would be of considerable importance if it could be made to work. The discovery by Dr Dombrowski that hot gas blown across the paths of sprayer nozzles eliminated the smallest spray droplets could be most important. Both tractor exhaust gases and propane from cylinders mounted on the sprayer have been used and it has been calculated that a 30 nozzle sprayer would use approximately 0.68 kg of propane per hour. Not only is it claimed that by eliminating the fine droplets drift in windy conditions is considerably reduced, but the technique could allow the use of lower volumes. This could open the way to low volume spraying through conventional nozzles with minimum drift, and the results of the development work taking place will be eagerly awaited.

Yet another approach has been to take the electrostatic painting principle where the spray droplets are exposed to a high potential electric charge, thus setting up an electrostatic field, so that the droplets become strongly attracted to the item being coated. This work at Sheffield University has shown that in the laboratory as little as 4% of the spray applied through a conventional hydraulic sprayer nozzle is deposited on barley plants, the remainder falling on to the soil. Using electrically charged droplets, however, 80% of the spray was deposited on the crop. Laboratory tests showed that it worked equally well on different leaf types from waxy cabbage and sugar beet to hairy potato and upright cereal leaves. Field tests with fungicides and insecticides showed improved spray deposition and penetration and it was used successfully with an ultra low volume sprayer. The electrostatic crop sprayer is a complicated and potentially more expensive approach to reducing drift than the Dombrowski principle and it remains to be seen if the results of the work, originally funded by NRDC, are commercialised.

The application of chemicals to the soil can be carried out using low pressure jets which produce large droplets which do not drift excessively. This technique has recently been developed by Ciba/Geigy as the "7 gallon system" for the application of soil-acting residual herbicides, particularly in the autumn to winter cereals. Although primarily designed for autumn applications it obviously has other potential uses and at PGRO the system has been compared in peas to conventional spraying at 280 litres/ha, using the pre-emergence pea herbicide containing terbutryne plus terbuthylazine. Tests carried out over two seasons did not suggest that the results of applications made with low pressure jets at 80 litres/ha were any different from those made at 280 litres/ha. While the system can be used with a normal farm sprayer the reduction in volume lends itself to other possible uses, and Ciba/Geigy have fitted it to the rear of a corn drill. In the PGRO tests the drill sowed the crop, in this case peas, and the pre-emergence treatment was then applied to the seedbed immediately behind. Used in this way there is no opportunity to roll the seedbed to provide a firm level surface for the pre-emergence herbicide and under some conditions it is possible that this could be detrimental to its performance. It could, however, just as simply be fitted behind a roll. Sprayer attachments are already available which can be fitted to cultivators, rotovators or power harrows to apply materials which require speedy mixing into the seedbed. There are technical problems to overcome to ensure that the correct dose is applied, since it is more difficult to keep the tractor speed constant when using cultivation or drilling equipment, but all these approaches are based on the desire to reduce the number of times that tractors pass over the ground and to apply the chemical at the optimum time.

Work rate

Using tractor-drawn or mounted sprayers the speed over the ground is limited principally by the need to provide a reasonable level of driver comfort in an unsprung machine. Maximum speeds must be considered to be in the region of 8–10 km/h. On uneven ground, added problems are boom whip or "bounce" leading to poor spray distribution and excessive wear and tear on equipment. The approach to improving work rate is either to increase the size of

Experimental low volume spray bar attachment fitted to the rear of a standard corn drill

conventional sprayers by having wider booms and larger tanks, or to use a different carrying vehicle which can move comfortably at speed over uneven ground. The range in size of sprayers is considerable and there is no doubt that machines are available which are capable of speedily treating large acreages. The largest are self-propelled, with up to 30 m booms and 4000 litre tanks and they have substantially improved rate of work compared to smaller machines. Byass and Lawrence (1976) calculated that at a speed of 8 km/h a sprayer with a 9 m boom, spraying only, had a potential of 29 hectares in four hours. Increasing the boom to 18 m increased the potential to 56 hectares, but the greatest increase possible was by raising the ground speed to 20 km/h, when even with a 12 m boom the potential was 98 hectares. With an 18 m boom the work rate when applying 200 litres/ha at 8 km/h with a 30 minute stop for filling, as would be the case if the sprayer had to return to the farmyard, was 34 hectares in four hours. By reducing the filling time to ten minutes, as might be possible using "bowsers" the potential could be increased to 47 hectares. Nation (1978) discussed the use of a mathematical model to investigate the effects of varying application rate, spraying speed, boom length, and field size. While large sprayers answer some of the questions regarding rate of work they also create problems. Wide booms do not easily follow ground contours, although pivoting booms are available, and controlling "whip" or "bounce" in a 30 m boom poses considerable problems to the engineer. Sprayer boom movement is a subject which has received attention at the NIAE (Nation 1978). Manufacturers have their own ways of controlling boom movement which are effective to a point, although they cannot be claimed to eliminate the problem completely. By far the most important problem with such sprayers is the weight of the machine and the water. A moderately sized mounted sprayer, fully loaded, could weigh 5 tonnes, but the weight of larger machines could exceed 6 tonnes. Thus although less of the land is affected by wheelings, due to the wide-booms, the weight of the machine could limit its use when the soil is wet. Elliot (1978) has suggested that the answer lies in the use of light low ground pressure vehicles, such as the Argocat and Garron, which could be used at speeds of up to 20 km/h applying materials at low volume. Their ground clearance and payload is low, however, and since not all materials can be applied at low volume it may be necessary to consider four-wheel-drive trucks which, suitably sprung and geared, could also travel at 20 km/h. It seems likely that in the future we could see the change to fast low ground pressure vehicles as the platform for spraying equipment. Recent work testing the use of low ground pressure vehicles fitted with a hydraulic nozzle sprayer is reported by Cussons and Ayres (1978).

Low ground pressure vehicle fitted with sprayer

Specialised equipment

While considerable effort may be extended to improve machinery used in large acreage crops, such as cereals, financial considerations dictate that the effort put into smaller crops is correspondingly lower. In spite of this, if a genuine need for specialised equipment exists some part of the industry will usually supply it. Under this heading are some of the following:—

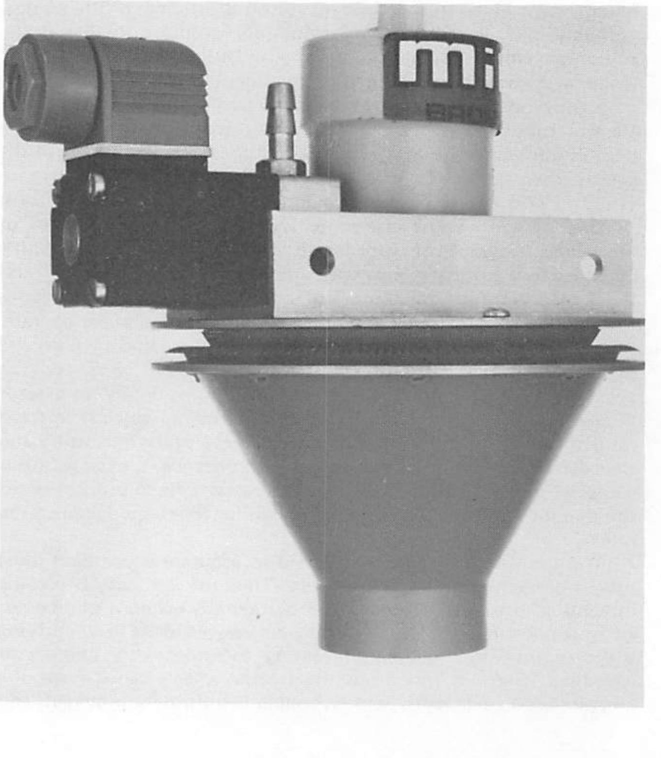
(i) Inter-row sprayers
(ii) Band sprayers
(iii) Drop-leg sprayers
(iv) High clearance sprayers
(v) Granular applicators, either for overall application or localised placement.

Useful developments have taken place in all these areas in the last few years although further improvements are still possible.

New forms of spraying

Controlled droplet application (CDA) has been under investigation for several years; it is now being commercialised and could be a very important advance. The principle of feeding spray liquid on to a spinning disc to produce droplets of a more constant size than those produced through a hydraulic nozzle is well known (Frost 1978). By controlling the droplet range to those of a useful size, by excluding the very fine droplets prone to drift and the very large drops which would run off the target, it was deduced that lower overall volumes of carrier could be used with this system. A significant amount of experimental work has already been conducted comparing the performance of chemicals applied at low volume through spinning discs (CDA) to applications made with conventional hydraulic nozzles, either using low or medium volume, Ayres (1978), Baily *et al* (1978), Grosjean and Cook (1978), Harris *et al* (1978), Lavers and Stovell (1978), Mayes *et al* (1978) and Phillips (1978). Much of this work has been concerned with cereal herbicides for general weed or wild oat control, but other crops and weeds such as winter beans and bracken have also featured in some of the experiments. In general, the conclusions have been that with pre-emergence soil-applied and trans-located post-emergence herbicides, CDA applications with droplets in the region of 250 pm, have given

Spinning disc controlled droplet applicator (copyright Weed Research Organisation)



acceptable although in many cases slightly lower levels of control, compared to conventional applications made at higher volume with hydraulic nozzles. The performance of contact herbicides applied with CDA sprayers is less certain and there has been relatively little experimental work carried out in the UK with fungicides and insecticides.

CDA offers two big advantages over hydraulic nozzle spraying. First there is the reduction in drift, achieved by the elimination of the very small droplets which, linked with the reduced volume necessary with the technique, produces advantages which cannot generally be obtained from the normal use of hydraulic nozzles. The reduction in volume can, as we have seen earlier, lead to very important logistic gains in work rate, and such a system is ideal for mounting on the light low ground pressure vehicles already discussed. More development of work is necessary before firm conclusions can be reached on the value of CDA in a wide range of crops. The results in cereals are sufficiently encouraging to suggest that at least with certain materials the technique could be commercially acceptable. Research has also shown that results obtained with one material cannot be extrapolated to others, and work must be undertaken to test the various materials used in agricultural crops. At PGRO (1978) work has already commenced evaluating the use of CDA to apply herbicides in peas and beans and in the future this will be extended to include insecticides and fungicides. Investigations into CDA spraying have caused researchers to query application rates currently used with hydraulic nozzles and in many instances it has been found that volumes of approximately 50 or 100 litres/ha have performed as well as 200 litres/ha or more. Using high pressure nozzles may be satisfactory for applications to the soil; they are less likely to be satisfactory for spraying plants due to the large droplets produced.

So far only the use of spinning discs to produce relatively large droplets has been discussed, but they can be used to produce very small droplets, below 100 pm in size, which drift readily in moving air. The principle is used extensively in some overseas countries and the spraying technique is sometimes referred to as "drift spraying". The machine under development in the UK uses very low volumes of between one and five litres/ha to achieve a bout width of between 10 and 40 m, depending on wind speed and the height of the spinning disc atomising head on the mast. Little published data is available on the performance of these sprayers although limited tests were carried out by Lake, Frost and Lockwood (1978) checking spray deposition at various heights and distances from the atomising head. The results suggested that the spray diffused, resulting in deposits being obtained several metres above the height of emission. In a wind of 4.8 m/sec it was concluded that 32% of the spray was deposited within the first 5 m from the emission point, and 46% between five and ten metres, but small quantities could be detected up to 50 m away. The chemical used is highly concentrated with little or no dilution with water as is normally carried out with other spraying systems. The use of more concentrated chemical and the method of drifting the spray in very fine droplets necessitates special clearance through the Pesticides Safety Precaution Scheme and to date no chemicals have received clearance for use through this machine.

Conclusions

Spraying is becoming a highly sophisticated operation using expensive purpose-built machines, many of which are the result of refinements carried out over many years. Electronic aids to improve the accuracy of application through conventional sprayers are now in use, and this must be taken to be a sign for future developments in this rapidly expanding market. Spraying is just one of the many farm operations where electronics could be potentially valuable. A wide range of equipment is available to help the operator match up his bouts, and here again electronics are featured. The use of tram lines may be another approach to accurate spraying which could be exploited by vegetable producers. Against the background of increased sophistication to ensure that the sprayer is operating at the correct speed and application rate, and that the bouts are evenly matched, it is very disturbing to study the ADAS sprayer survey and note the appalling inaccuracies in individual nozzle output, the differences between calibrated application rate and those achieved in the field and the low percentage of operators who had received training. This must surely be an area where the general standard of spraying could be measurably improved at relatively little cost.

The problem of drift, which at best is inefficient and which can be costly if adjacent crops are damaged, and which can reduce the number of spraying days preventing treament at the optimum stage, is being tackled in several novel ways. The Dombrowski method of blowing hot gases across the paths of sprayer nozzles appears to be a relatively cheap and easily adapted system which could be used on conventional sprayers fitted with hydraulic nozzles. The electrostatic principle whereby droplets are attracted to their target is a very interesting approach, but one which appears to be more difficult to utilise without expensive specialised equipment being produced. Controlled droplet application could, by concentrating the droplets into the 200 to 300 pm range, reduce drift thus allowing spraying to be done in windier conditions and, because of the reduced volume, increase the work rate. There does not seem to be a place in specialised vegetable production for ultra low volume drift spraying, using droplets smaller than 100 pm. The application does not appear to be sufficiently controllable for use in vegetable crops where it is essential that the results of chemical treatments are predictable.

Commercial controlled droplet application sprayer (copyright Horstine Farmery Ltd)

Developments where either the number of wheelings are reduced, as is the case where low volume sprayers are fitted to drills or cultivating equipment, or where fast low ground pressure machines are used to transport the equipment, could in the future be very important to growers of vegetables. Those concerned with the production of these crops are continually reminded of the effects of tractor wheels on soil structure and the resulting crop growth. The increasing number of applications of chemicals to each crop emphasises the need to reduce the damaging effects of tractor tyres. Once low ground pressure vehicles have become established for a specific purpose there seems little doubt that they will then be critically examined for a multitude of other purposes. Low ground pressure tyres, although very expensive, can be fitted to conventional tractors if there is a genuine desire to reduce the effects of wheelings and this would then remove some of the drawbacks associated with big sprayers carrying large quantities of water.

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Harvesting legumes

C M Knott

Summary

A REVIEW of the development and recent advances in mechanisation of harvesting vining peas, broad beans and dwarf green beans for processing is presented. The impact of these harvesters on the industry and the implications of their effect on varietal and agronomic aspects of the crops are discussed. Attention is drawn to the need for comparative tests to be made by independent organisations to assess performance, quantify losses and identify their sources.

Introduction

Harvesting techniques and increasing reliance on "convenience foods" by the consumer have combined to give a situation where vining peas, dwarf green beans and broad beans have developed from "market garden" to "farm crops". Once machines became available, hand picking declined in the UK and large scale production for processing became established.

Legumes are among the most demanding in their requirement for efficient and reliable harvesting equipment, and their complete harvesting is now highly mechanised. Labour requirements have been further reduced, the minimum of material is transferred from the field, output is high and an advanced stage of development and efficiency has now been reached which is seen in few other vegetable crops.

Harvesting vining peas

The largest capital investment for the industry is in the processing factory and this must be fully utilised for the 56,000 hectares of vining peas grown in the UK. There is only a short time during which the crop's maturity is at a suitable stage for processing, and the aim is therefore to maintain a steady supply of peas at optimum quality, and in quantity matched to the daily intake requirement.

Development

Initially the mechanisation of pea harvesting consisted of three operations, cutting, carting and vining. By the late 1950's the cost and labour involvement of hauling the entire haulm to static viners and the disposal of waste was becoming prohibitive and mobile viners were developed. There was an attempt to combine viner and cutter, but the disadvantage of cutter breakdown resulting in the cessation of vining was seen to be too great. A development in a different direction took place in the 1960's in the USA, with the self-propelled pea pod picker (Chisholm-Ryder Company Inc 1962, 1965). Since shelled peas deteriorate far more rapidly than peas in the pod, the vine was cut, and pods stripped and transported to the factory for shelling. Attempts were also made in the UK by the NIAE (Sharp, J R; Boa, W 1967 and 1960) to strip pods from their haulm in the field, partly with a view to increasing the pea acreage for fresh market. There were problems associated with these developments. It was not possible to strip pods off the brittle vine without leaving stalk attached to the pods. In practice, opened pods and loose peas in the sample produced taints and off flavours, and reduced storage time to less than six hours. None of these machines was marketed in the UK.

The basic threshing principle of one beater within a hexagonal screen drum (diagram 1) remained unchanged until a German firm

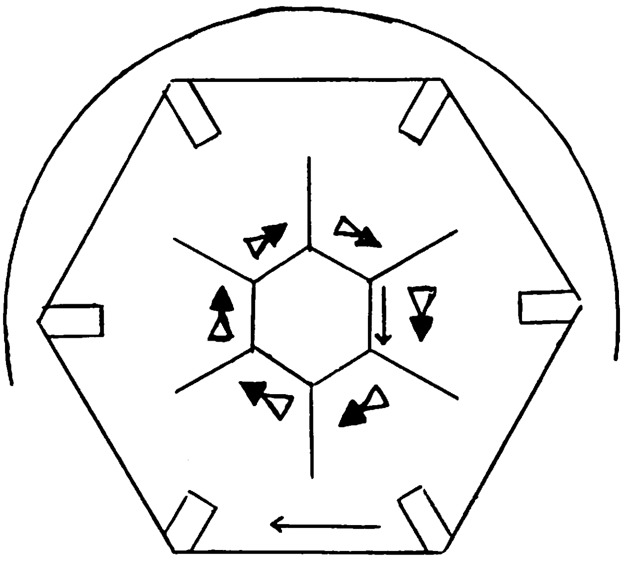

Fig 1 Part of cross section of mobile viner, conventional one beater system

in the 1960's developed a prototype "satellite" vining system incorporating three beaters and a smooth cylindrical drum. This method was found to give a highly intensive threshing of the haulm, and improved output. Year 1975 saw the introduction of a machine by an American company into the UK, with what was described as a "planetory" vining system (diagram 2). This consists of a central beater, surrounded by four smaller ones. Centrifugal action and the speed and direction of rotation of the beaters move the vine round the system so that there are six impact points. The sequence repeats continuously and the peas escape through a large clear area of smooth plastics coated wire screen which is kept clean by a full length brush. The net result is increased capacity of about 30% and since the peas can escape quickly, damage is reduced.

Modern viners are equipped with pneumatic cleaners; pod removal chains return full pods to be vined again; screens are kept clean with full length brushes; automatic self-levelling devices maintain optimum drum position on slopes, and hoppers can be dumped "on the run" so that harvesting is continuous.

Pea cutters also underwent improvements, and self-propelled models became available. Centre delivery cutters were introduced to avoid the problem where the first swath fell on the uncut crop, and these also produced a lighter and less tangled windrow, allowing more efficient vining. Most cutters used today are of centre delivery type, and there has also been a trend in the last eight years towards the use of augers rather than windrowing canvases. Augers are more durable and less prone to blockage and breakdown, particularly under wet, weedy conditions.

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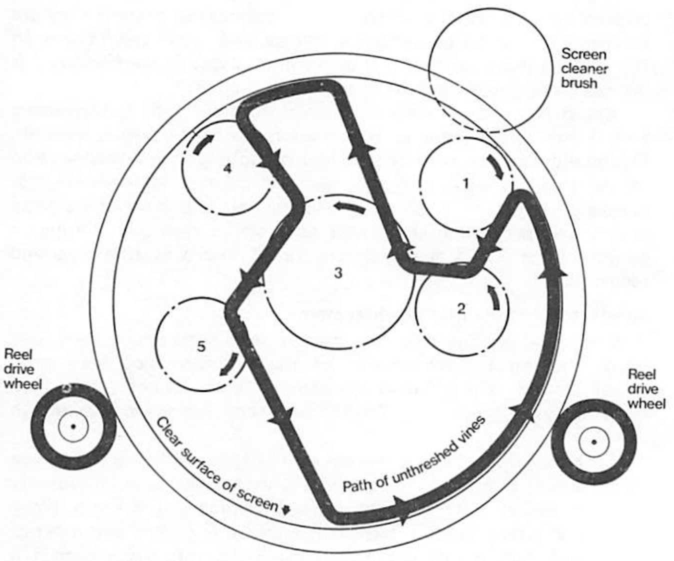


Fig 2 Part of cross section 'Planetory' vining system (FMC Corporation Ltd, H_2 viner) five beaters

The new pea harvester

The most recent and possibly the ultimate advance is the complete pea harvester. The principle was first introduced by a German firm using a tractor-mounted picking reel. The first self-propelled machine on trial in this country was manufactured in Belgium by an American company. An hydraulically driven picking reel of variable speed and adjustable height, it consists of a rotating drum with steel tines which comb off pods together with some vine. These are elevated into a high output viner of "planetory" type. Thus, instead of cutting peas and then vining them in a separate operation, the harvester carries both tanks. Strictly speaking the machine should be termed a "reduced intake" viner since some haulm as well as pods are combed off by the picking reel, but the generic term of pod-picker seems to be well established, and is the one most used by the industry today.

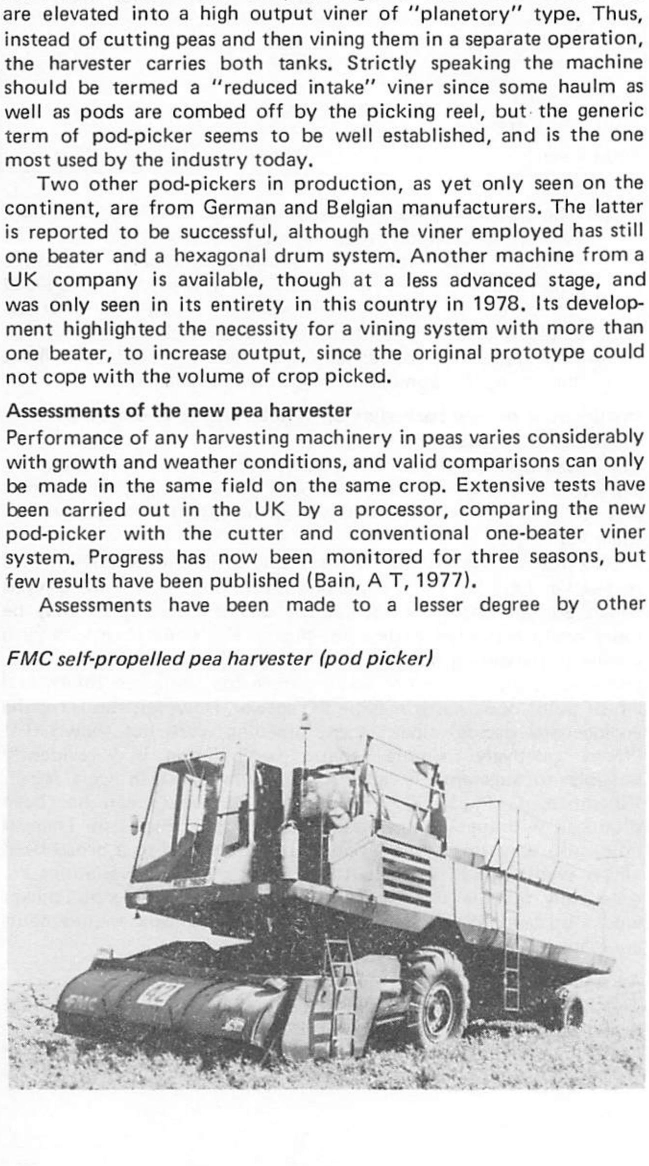
Two other pod-pickers in production, as yet only seen on the continent, are from German and Belgian manufacturers. The latter is reported to be successful, although the viner employed has still one beater and a hexagonal drum system. Another machine from a UK company is available, though at a less advanced stage, and was only seen in its entirety in this country in 1978. Its development highlighted the necessity for a vining system with more than one beater, to increase output, since the original prototype could not cope with the volume of crop picked.

Assessments of the new pea harvester

Performance of any harvesting machinery in peas varies considerably with growth and weather conditions, and valid comparisons can only be made in the same field on the same crop. Extensive tests have been carried out in the UK by a processor, comparing the new pod-picker with the cutter and conventional one-beater viner system. Progress has now been monitored for three seasons, but few results have been published (Bain, A T, 1977).

Assessments have been made to a lesser degree by other organisations and most tests have compared the pod picker with conventional one-beater viners, rather than planetory systems. No results are available for comparison between different pod-pickers, but more opportunities will arise in 1979 where machines may be working side by side. There is a substantial need for work to be carried out by independent bodies and since tests tend to interfere with the smooth running of the harvest, complete co-operation of the processors concerned would be essential.

FMC self-propelled pea harvester (pod picker)



Conclusions from observations and figures obtained are that *the development of the pod-picker represents a distinct improvement over existing pea harvesting machinery* for the following reasons:—

(a) Harvesting is carried out in one operation. This obviates the need for a pea-cutter, often the source of breakdown and crop loss, and ensures produce is vined fresh.

(b) The speed of harvesting will allow one pod-picker to harvest at least 280 hectares in a normal season. Figures quoted for harvesting rates give a seasonal average of 0.53 ha/h compared with 0.25 ha/h for conventional viners. The difference suggests that one pod-picker could replace two viners and one cutter, and hence reduce the labour requirement by two men. In practice it is usual to carry more cutter capacity than theoretically necessary for the viners in use, to allow for breakdown. Purchase price of the new harvesters is high, starting at £72,000, but this is not very much more than equipment they would replace, assuming this were ever necessary at one time.

(c) Losses in the field due to inefficiency of the picking real are very low compared with those attributed to the cutter, which under bad conditions can be as high as 10%. Losses from the apron and threshing operation of the planetory system have been consistently lower than for conventional vining. It is not yet possible to identify sources of loss at some points, for example suction fan cleaners, where discharge is unrecognisable and may include good peas and whole pods, as well as damaged peas and extraneous vegetable matter (EVM). Thus, increasing fan speed will reduce EVM and damage levels but may reduce yield of good peas as well. However, one would expect measurements of EVM to be lower for the new harvester in view of improved cleaning facilities and damage to be less, since beating is gentler and there is a large area of clear screen for a quick escape.

(d) It has become apparent that the pod-picker is better able to operate in crops where cutters experience difficulties, ie crops with very short straw or, in the other extreme, are heavy with long vine, or are weedy. In the two latter situations the pod-picking reel will collect a smaller proportion of haulm and leave many weeds behind, and thus throughput of the viner section is higher. The following figures from a processor's trial illustrate this:—

Type of crop and yield tonnes/ha		*Field conditions*	*Output ha/h*	
			Pod-picker	*Conventional viner*
Very short straw	4.34	dry	0.96	0.62
Heavy haulm, long straw	14.06	wet	0.52	0.21

Other results show, similarly, that the pod-picker has an increasing advantage over the conventional system as crops become thicker and vines longer. To obtain maximum otuput, however, the operator must adjust the picking head to take as little vine as possible, whilst picking all the pods. In some crops 85% of total vine is picked up, in others only 50%. The average is probably 60-70%.

It is also easier for the self-propelled pod-picker to harvest awkward corners in a field, whereas previously they may have been left unharvested.

(e) The general impression is that the pod-picking machine copes well under wet and muddy conditions and on steep gradients. Steering capabilities for one machine were seriously hampered by the inability of small rear wheels to climb out of ruts and an option on four wheel drive will now be available. In some situations, however, the new pea harvesters sank into a waterlogged silt soil through sheer weight, where conventional viners continued working.

Among other points worth considering are road travel speeds.

The maximum for the pod picker is 25 km/h, but a processor's calculations from timings throughout the season have shown that average move times use about 4% of the 1000 hour season and are very similar to that for viners. Another point connected with transport is picking reel width and this must be sufficiently wide (3.2 m for one machine) so that wheels supporting the viner section do not run over the unharvested adjacent crop. Is there a possibility that a wider reel in two sections (as seen recently on a dwarf bean harvester) which tip up for road transportation could be used and output increased further?

Implications of new harvesters on agronomic and varietal aspects of vining peas

Observations during the last three seasons, whilst the new pea harvesters were operating in the UK, Australia, New Zealand and the continent in vastly different crops and weather conditions, suggest the following implications:—

Varieties

Little work on pod-picker/variety interaction has been carried out so far, but it is the general opinion that all commercially grown varieties can be harvested successfully with the machine. A breeding advance which may prove of value could lie in production of multi-podded varieties like Puget, in which most pods are carried at the top of the plant enabling a reduced amount of vine to be picked. A recently bred semi-leafless mutant type may also have an advantage since it is less prone to rotting at the base of the stem because of reduced leaf area and tendrils which bind the crop together reduce lodging. In some crops in a wet season, basal rotting in conventional types means that the picking reel pulls up nearly all the vine.

The breeding of a variety tailored to mechanical harvesting should always be borne in mind but yield, quality and disease resistance are usually given first priority. Unfortunately, breeding programmes take several years, while changes in mechanisation are often more rapid. In peas, however, improved harvesting speed and efficiency is largely due to advances in plant breeding.

Extremes of crop growth appear to be less important than when cutting is involved and perhaps choice of variety for a particular soil type and climate may not be as important.

Agronomy

The effect of large stones, which can break cutterbars, and clods, which may contaminate windrows with soil, is not as disastrous to the picking reel of the pea harvester, although under some conditions small stones may be picked up by the reel.

The importance of efficient weed control to prevent competition with the crop and contamination of produce is still vital, but the effect of a weedy crop on a pod-picking machine is less than on a cutter and viner. Cutters experience great difficulty in crops infested with knotgrass, chickweed and couch, and picking up a windrow containing a large bulk of wild oats greatly reduces work rate of a mobile viner, causes stoppages and blocks screens and cleaning mechanisms. Contamination of vined produce with weed debris such as mayweed and thistle heads creates problems for the processor. Therefore weed infested crops are often bypassed in favour of more manageable ones. The new pod-picker does not appear to encounter such difficulties with a wild oat infested crop, and neither will the picking reel collect mayweed heads.

Cultivations after harvesting with the new machines are claimed to be easier, since the spent haulm is discharged more evenly over the field, but for this same reason collection of haulm for silage is not practicable.

There has been much concern expressed recently about the effects of heavy machinery on soil structure. Ruts produced by wheels of pod-pickers (weighing 17 or 12 tonnes empty depending on the make) when working in the unusually wet season of 1978 were deeper than those from the tractor (5 tonnes) and viner (10 tonnes), which was not surprising.

It must be borne in mind that soil compaction is less when soil moisture content is low, normally during the pea season, and at least there is opportunity after peas to carry out subsoiling or similar operations.

Harvesting broad beans (vicia faba)

No machinery has been specifically developed for harvesting broad beans, and if the processor had to depend on handpicking and podding machines in the factory, it is doubtful whether the area grown would have reached the 4100 ha (approximate) it is today. It is possible that the market potential for the crop is not yet realised. There is an increasing interest in allocating separate processing lines for the whole season, whereas at present they are harvested in a short period between peas and dwarf green beans. In this event a more critical look at current harvesting methods, which are not ideal, could result in an improved product.

Broad beans are harvested with peacutters and mobile viners fitted with larger mesh screens, thus more debris passes through. Pneumatic cleaners must be efficient because serious discolouration of the produce occurs if pod, leaf and other plant debris is not removed during or soon after vining, and the interval between vining and processing should be as short as possible. Wilting in windrows for 12-24 hours before vining improves threshing and recovery.

Assessments of the new pea harvester

The new pod-picking machines may be used successfully for broad beans, but so far assessments of their performance have been rather limited, and often in the form of observations rather than statistically analysed trials. The following conclusions may be drawn so far:—

(a) Harvesting rates are increased, and those of more than three times that for conventional viners have been frequently recorded, with the pod-picker travelling at 6.5 km/h. When harvesting directly, less plant material is picked and most of the stalk is left behind on the field, thus viner output is increased.

(b) Total field losses for direct harvesting, including those from picking reel, unthreshed pods and elevator and apron losses are reported to be no greater than for the cutter and viner method. In some cases they are shown to be less and the following figures are from a processor's trial (Bain, A T, 1978) in a crop with theoretical yield of 2.71 tonnes/ha.

	Total field losses	
	tonnes/ha	*% of theoretical yield*
Cutter + viner (1 beater system)	1.02	37.6
Cutter + viner (planetory system)	0.81	29.9
Pod-picker	0.65	24.0

(c) The pod-picker has also been used successfully to pick up a wilted windrow of broad beans. .The only advantage to be gained for the latter method could only lie in a possible improved extraction and threshing efficiency, and reduced percentage of EVM. A fresh broad bean pod is more brittle and prone to fragmentation than one which has been wilted and debris in the sample may be increased for direct harvesting. No comparative figures are available.

Implications of new harvesters on varietal and agronomic aspects of broad beans varieties

The broad bean most commonly grown for processing in the UK is Threefold White, which holds its pods at right angles to the stem and is 1.5 m tall or more; it has been harvested successfully with the pod-picker.

No quantitative studies of harvesting different varieties with a pod-picker have been made but one would anticipate that varieties which are too short for satisfactory use of a pea cutter may be more easily harvested with a pod-picker. Plant characteristics with a view to harvesting directly with a pod-picker could be improved, and pods which are more easily detachable, easier to thresh and which point downwards may be the answer. However, this is for the engineer to decide, since recent breeding work has shown that "from relatively simple genetic manipulation it is evidently possible to substantially alter the growth habit in *vicia faba*". (Chapman, G P, 1977). For example, a field bean has been produced with many erect pods near the top of the stem. There is no reason why this feature cannot be transferred to a broad bean which would simplify the cutting operation. Many variations are genetically feasible and a plant easily harvested with a pod-picker would be bred. We must see to it that the engineers' requirements are made known to the plant breeder.

Agronomy

The pod-picker works best in the same direction as drilling, for broad beans. Efficiency is reduced in a gappy crop of uneven stand, where plants which have no neighbour for support may be lodged by the picking reel, and are consequently difficult to pick up.

Harvesting dwarf green beans (phaseolus vulgaris)

Dwarf green beans remain suitable for processing for several days, unlike peas, but the crop must still be harvested at the right maturity stage if the maximum return is to be obtained.

Devolopment

The introduction of mechanisation for dwarf green bean production is more recent than for peas. The ultimate aim is to supply the processor with whole, undamaged beans, separate and not held together as clusters, and free from extraneous matter such as leaf, stem, stones or soil. The principle of mechanical harvesting was introduced in the USA as a "once over", rather than selective operation. The first harvesters were tractor drawn. Basic principles (diagram 3) consist of a longitudinal picking reel revolving alongside the row, and the combing action of the tines attached to the reel removes pods from the plant. Pods are elevated into the machine together with leaf and debris, which are separated pneumatically and the pods collected in bags or pallet boxes. The reel is inclined to the direction of travel, so that upper pods are removed before the lower ones. Two-row machines, where reels contra-rotated so that only one elevator was necessary, then followed.

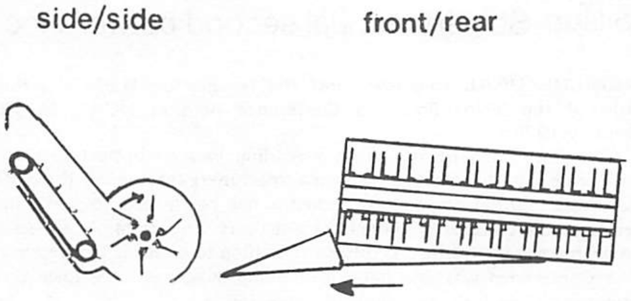


Fig 3 Longitudinal picking reel

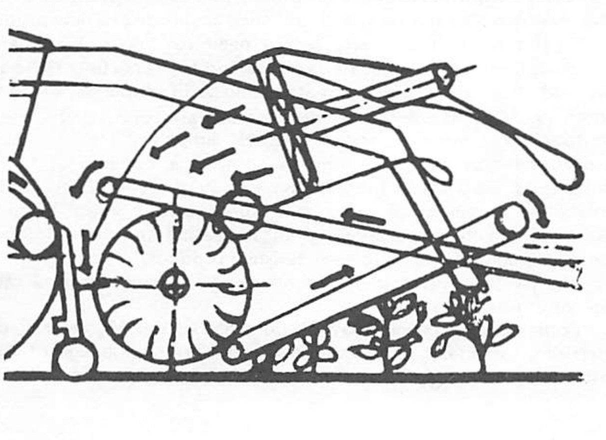
The along-the-row picking principles had several disadvantages. Headlands were required for turning, and were sometimes drilled and harvested before the rest of the field but were frequently left bare. The machine could only harvest crops on row widths greater than 40 cm because of the width of wheels required to support the machine and the width of the picking reel.

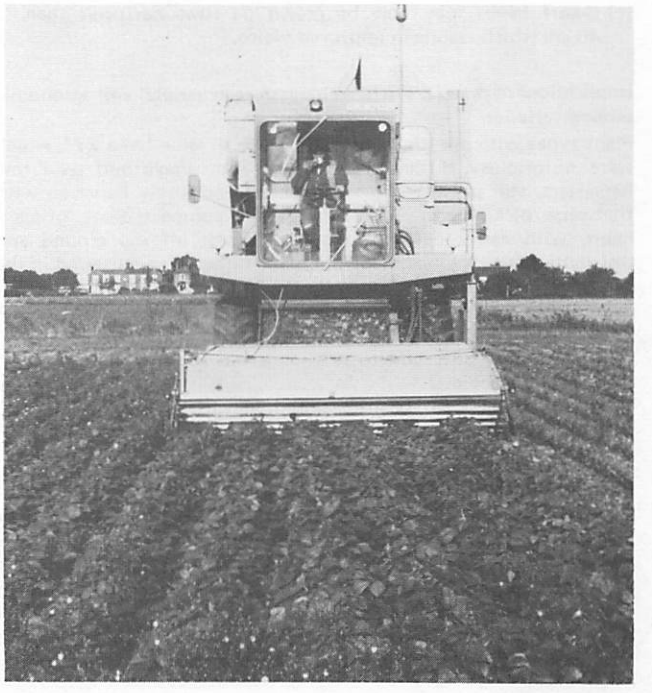
Trials at PGRO, (PGRO, 1963-1968) showed that plant density and row width factors have a considerable effect on yield. They demonstrated that in wide rows, intra-row plant competition was a limiting factor and in narrow rows, where a more square planting arrangement can be used, a higher density could be justified. Conclusions were that the most profitable plant arrangement, after seed cost consideration, would be a final stand of 43 plants/m^2 on 14 cm rows with plants ideally arranged in a more square planting pattern. It was therefore suggested on the 1960's (Gane, A J, 1966) that machines should be designed to harvest these narrow rows.

Multi-row harvester

The first multi-row harvester was developed in Germany and had a picking reel set transversely so that harvesting could take place in any direction, either along or across the rows. A revolving inclined belt at the front of the machine presented plants to the forward driven picking reel, where they could be picked from bottom to top. Other designs of multi-row harvesters are now marketed, one

Fig 4 Multi-row transverse picking reel, inclined front conveyor (FMC Corporation Ltd, green bean harvester)





Ploeger dwarf green bean harvester (UK agents Mather & Platt Ltd)

self-propelled with a basic picking reel and no front belt attachment and another a tractor-mounted machine of UK design built by an American company (diagram 4). The latter has an inclined conveyor, which is driven in a manner so that plants are laid towards the forward driven reel and picked top to bottom, and then as the machine moves forward, from bottom to top.

The width of pick for these machines varies from 2.1 to 3 m, and the most recent introduction on the Continent is a model with split picking reel 4.5 m wide, which tips up for road transportation. Beans are collected now in bulk tanks of 1.5 tonnes capacity. Two, and sometimes three pneumatic cleaning mechanisms are incorporated using blowers or suction fans. Manufacturers vary in their approach to cluster removal. The twin-row harvester simply removes clusters by catching them on projecting pins on an elevator and they fall back on to the field. It is claimed that the double picking action of the multi-row harvester with inclined frontal conveyor, makes de-clustering unnecessary. Other multi-row harvesters employ cluster-breakers and whilst clusters are not lost on the field, damage caused to all produce can be very high. An observation test carried out on a machine by PGRO compared samples just before passage through the de-clustering unit with those from the tank, and indicated that 30% (by weight) of beans were damaged (ie $\angle$ 50 mm length) by the cluster breakers and the percentage of clustered beans found in the sample was reduced from 19 to 2%. The de-clustering device has now been altered. The damaged beans deteriorate very rapidly and samples with a high percentage of damage can be rejected. However, processors maintain that clusters are more of a problem than damaged beans, unless of course a whole bean pack is being produced, and also that de-clustering mechanisms in the factory are more fragile.

Assessments of multi-row harvesters

Several comparative tests between two machines have been carried out by processors, but few results have been published.

The multi-row harvester has the following advantages compared with a twin row machine:—

(a) Harvesting rate is considerably higher for a multi-row harvester, and depends on the width of picking reel for a particular machine. The manufacturers estimate a *maximum* work rate of 0.4 ha/h for a twin row harvester.

(b) Since the multi-row harvester can operate in any direction, fields may be easily opened up, thus avoiding uncropped headlands. Accurate drilling and matching up rows is not as important. For a twin row machine, drilling must be accurate and spacing between rows and passes even, since the distance between the harvest units cannot be altered in work. The high driving accuracy required of the twin row harvester operator to avoid losses, is no longer essential and this was particularly difficult in wet conditions.

(c) Dwarf beans may now be grown on rows narrower than 40 cm which results in improved yields.

Implications of dwarf green bean harvesters in varietal and agronomic aspects varieties

Plant types with a bushy, lax habit, eg Bush Blue Lake 274, which were notoriously difficult to harvest with single and twin row harvesters, still present problems for the multi-row harvester with transverse picking reel. The ideotype is a compact plant, of erect habit, with easily detachable pods set well off the ground and distributed over the height of the plant rather than clustered in the centre.

A good root structure prevents the plant being uprooted. A certain quantity of foliage is necessary to protect the pods from bruising by the tines and to provide a mat to help carry the pods through the machine.

Many dwarf green beans assessed in variety trials have these required characteristics.

Agronomy

Inter-row hoeing cultivations, where soil piles up round the plant base, and a cloddy stony seedbed, are to be avoided for efficient mechanical harvesting, and the former appear to present more of a problem to the multi-row than the longitudinal harvester. Although the multi-row harvester is designed to work in any direction, in practice picking at right angles to the rows is less efficient because the picking reel tends to bounce when crossing uneven ground and tractor wheelings, and on wide rows plants cannot support each other.

The most important implication of the multi-row transverse picking principle is the removal of restriction on row width, so that more profitable narrow rows can be utilised.

A herbicide programme can be used to control a broad weed spectrum and wide rows for inter-row hoeing should not normally be necessary.

However, several years after the introduction of multi-row harvesters, it is still current practice in the UK to use 45 or 50 cm row widths. This may be for a variety of reasons, but in any event there are no specialist drills currently available which will sow narrow rows of 14 cm (Knott, C M, 1979).

Conclusions

In the future, further advances might be made if:—

1. Test programmes to assess performance and quantify waste and its sources are mounted by independent bodies.
2. There were closer contact between the rather remote disciplines of plant breeding and engineering.
3. More consideration of whether the value of crop wasted outweigh the cost of time carrying out operations which may be better suited to the factory, eg de-clustering dwarf beans.
4. Adoption of all systems to maximise yield, eg narrow rows for dwarf beans.
5. A more critical look were taken at current harvesting methods for broad beans, eg pods harvested in the field and podded in the factory would solve some major problems.

Assessments of the economic implications and efficiency of harvesting peas and broad beans using the new picking principle, and dwarf green beans with multi-row harvesters have now been made by processors and growers.

In spite of the advantages of the transverse multi-row harvesters some dwarf bean growers, whose acreage may not be able to justify the expense, may in any event prefer two tractor drawn twin-row machines to maintain harvesting if breakdown occurs.

In the case of peas, a choice is to be made between continuing with the old system, or converting to the new. Although the new generation of pea harvesters has great advantages in terms of output and in some cases, yield, and cost is not very different from the machinery it could replace, the most important factor in their success will be reliability. With each advance in mechanisation of the pea crop, loss during breakdown becomes more significant, and if one of these expensive machines replaces two or more viners, the cost in terms of breakdown will be two or more times as expensive in terms of time, the most vital of all factors in this harvesting operation.

Acknowledgements

Information for this paper was collected from many sources, and the author is indebted to all those who assisted, in particular, members of the following companies: FMC Corporation (UK) Ltd, Mather and Platt Ltd, Birds Eye Foods Ltd, Findus Ltd, Smedley-Ross Foods Ltd and the Processed Vegetable Growers Association.

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Silsoe Society annual second conference

AGRICULTURAL Engineers and the balance of Trade was the title of the Silsoe Society's Conference held at NCAE on 23 January 1979.

The main benefit for those attending was an opportunity to deliberate on the reasons why the machinery sector of the UK based agricultural engineering industry has performed so badly in terms of the balance of trade in recent years. This certainly appears to be the case for finished products according to a recent DoI report. The Conference was also helpful in giving delegates some ideas on how to cope with the problems of exporting.

Mr Frank Moore, sales director of Howard Rotavator Company Limited gave a long list of criteria which can be applied to products to see if they are 'ideal' for exporting. Only one out of the four main Howard ranges really satisfied these criteria demonstrating how difficult it is to find products which are suitable for export. Mr Richard Danby showed how a small company can innovate in a very specialised way and develop products which can satisfy many of Mr Moore's criteria. Mr Danby's company, RDS (Agricultural) Limited is rapidly expanding its export sales by providing products, which when incorporated into expensive capital equipment, can monitor critical functions, giving more efficient operation and thereby cutting costs. Mr J Whenray of Technical Help for Exporters discussed the various rules and regulations in overseas countries particularly in Western Europe, concerning operator safety, environmental protection and road safety. This was another session which tended to give the impression that exporting is more involved with problems than opportunities. Fortunately, Mr Whenray's THE organisation is well equipped to help the small and large companies find a path through the minefields of national rules and regulations.

Mr Eric Frederikssen, product planning manager of Massey-Ferguson (Australia, Africa and Asia), gave a very comprehensive review of the whole process of new product development for export markets. The other two papers looked at the balance of trade more from the importing point of view. Mr Phillip, commercial director of Bamford Limited gave a very clear explanation of why his company has imported both ideas and finished products. Decisions about the import of products are not made on impulse but after a thorough review procedure to establish whether or not the company has the resources and time to produce a new product internally. Mr Phillip clearly sees a need for financial assistance for design and manufacturing facilities and for exporting. He is also worried about the problems of attracting good people back into the industry. Mr Avis, marketing director of Farmhand (UK) Limited, a machinery importer, spoke last. He emphasised a number of points, perhaps the main one being that a number of foreign companies were establishing themselves in the UK, firstly with a marketing organisation only but subsequently they begin to assemble locally, incorporating an increasing number of locally produced components into their finished products.

The day gave participants a good blend of topics and some cause for optimism.

Copies of the papers may be purchased from Mr Peter Leeds-Harrison, Secretary, Silsoe Society, c/o National College of Agricultural Engineering, Silsoe, Bedford MK45 4DT. Price £4. *R W Hill.*

Harvesting roots

R J Upton

Introduction

I AM talking to you as a farmer, specialising in growing carrots, and as chairman of an agricultural development company, named Reed and Upton Limited. My talk is basically about harvesting root vegetables for processing, but I am sure in the same context I should consider everything from sugar beet to potatoes, including such roots as carrots, red beet, parsnips, radish, turnips and onions. These all have the common problem of growing in earth, clods and stones, from which they have to be separated in all conditions, varying from drought to flood, and produced to the customers, undamaged and perfect in shape and texture. This is a condition which is virtually unobtainable at the present time, unless at enormous cost and wastage, for which the final customer is often not prepared to pay. Are these customers being asked to pay for a gold bar when they would be perfectly happy with a copper bar?

For example, canning carrots are delivered to the processor at £43 per ton and they end up on the shelf at 15p for 14 oz, which is £384 per ton; against this they can often buy fresh carrots at 8p per pound, which is £179 per ton, or they can dig their own at a cost of about £50 per ton.

Returning to processing, can the carrot farmer produce the product at a lower price? I would consider that he is at breaking point, especially if the risk is to continue as this year when he ends up by ploughing in half his crop. Is this due to the supermarkets demanding such a high standard in a can? — and then asking a price at which they seem quite incapable of selling the merchandise.

But to talk like this, although it is true, and not react as a farmer, would be out of character for that profession!

Crop establishment

So, how does the farmer react and what help is he getting from the agricultural engineer to enable him to plant and protect and then produce the perfect crop. Firstly, the crop must be grown on soil suitable for the process of growing and harvesting; although, we must realise that unlike America, we have limited resources of ideal soils for any crop. So, we must make the borderline soil more perfect and we must make the perfect soil last longer. The borderline can be drained and have the stones removed and be handled with kid gloves during ground preparation. The perfect soil can be sterilised more often to allow for continuous specialist crop production; on a visit to Belgium two years ago, I noticed that this seemed to be standard practice for carrot growers.

Ideal plant populations must now be achieved either in rows or beds, and furthermore insure that those planted come to fruition. At the moment due to uneven germination, up to 50% of seeds sown just become weeds within the crop, robbing it of moisture and nutrient and never coming to fruition. Drills and planters have improved but often 20% of the land is spoiled by wheelings, for one reason or another. Compaction produces unshapely produce and clods, which require sorting before sale. Those of us growing cereals have seen the furrow press drills working directly behind ploughs; we realise that somewhere herein lies one of the answers, since we need never again touch fields treated in this way, helicopters doing all further weed, pest and disease control. Even using 60 ft sprayers with 3 ft compaction reduces yields by 5%, and 80% of the industry in this country survives on this margin on turnover.

Having calculated our optimum plant population, we must take the gamble out of achieving it. Obviously, irrigation and fluid drilling are steps forward. The time of drilling is another vital element; the good grower has an instinct for the right day and the good farmer has his field ready and his tackle ready to go on that day. From that moment the die is cast and the time scale up to maturity and perfection of the crop is set.

R J Upton MA JP, Upton Suffolk Farms.

Paper presented at the Spring National Conference of The Institution of Agricultural Engineers, held at The Key Theatre, River Embankment, Peterborough, on Tuesday, 20 March 1979.

Harvesting and storage

This is where, sadly, root farmers and processors become miles apart. The root crop is always considered by the processors to be storable in the ground or in a shed, and they use this as a buffer to their factory production. This has been so clearly demonstrated in the past two years, with the carrot crop. Carrots have been drilled for presentation to the factory, on a 100 day cycle, only to be denied delivery — due to the green bean crop being harvested for an extra 30 days. What happens then is that the carrots start to deteriorate and cease to be what they were drilled for, ie perfect small carrots. Who bears virtually the entire brunt of this disruption? The grower; often at enormous financial loss to himself. There is also another loser and this is the processor; he now has a product which has passed its peak, is more expensive to process and less saleable. In fact this is disaster all round, only helping to produce a more expensive article for sale; close liaison with the factory field staff on root crops, is just as important as it is with surface vegetable processing.

Despite what I have said, roots are storable and therefore a percentage will be stored in the ground or in sheds, to extend the processing factory's season and as we all know, only the best are worth storing in either way. Very seldom is it possible to make a silk purse out of a sow's ear! So what ever the line of production is, direct from the land to the factory or from a store to the factory, it is still vital to achieve all the optimums.

Having planted in perfect conditions and achieved our plant population, we must nurture our crop so that each and every one is a perfect specimen, not stunted by weed growth or mutilated by pests or disease. Then we can take steps to harvest our perfect crop and deliver it to our customer in the same perfect condition. However we all know at the present this is not achieved; the question is why is this not achieved?

Sadly, harvesting machinery is asked to work in field conditions often totally unsuited for the crop. This is so clearly demonstrated in the potato crop. Fields that are too wet are invariably late planted, the crop is then late in maturing and the field is a quagmire at harvest. On top of this the crop has not been burnt off soon enough and the skins are not set, so in this instance the machine is not to blame, but the farmer. No machine will make a good job; in fact neither should be there, the crop or the machine.

We then have the stony field, it seems almost madness to me that potatoes and stones should be sorted out in a shed, not on the harvester. How well we remember that potato harvesting demonstration on a very stony site, where you were almost blinded by the chips of potatoes flying about in all directions from the potatoes dropping on stones already in the trailer. Even taking the stones off the harvester is one stage too late; the stones should not be there at all. Enormous progress has been made in this direction and I was surprised to hear that one small company making stone and clod removing machines had already sold 300 of its machines. The debate goes on, should stones be removed, buried or windrowed on top? All I do know is that on some soils if they are removed the workable soil depth can decrease by 3 inches, not a happy thought! On some lighter soils, stones are essential, they act as enormous reservoirs of heat and prevent total erosion by wind. With the arrival of irrigation, these soils are being commonly used for root growing and the exclusion of stones at harvest is being arrived at by the use of top lifting harvesters, whereby the crop is lifted from the ground by its green top and only severed from the product when well clear of the soil, thus leaving the stones and clods on the field.

This means of harvesting is used universally on all the roots I first mentioned, except for potatoes, and has developed from the tractor drawn single row machines to the one which my own firm developed, being a self-propelled two-row machine, which is now manufactured and sold by Mather and Platt. The initial purchase of this type of harvester is expensive, but it has enabled large areas of stony light land to produce a worthwhile break crop of root vegetables. But with the disadvantage that green leaf is essential for the successful working of this type of harvester, another method will have to be used when the green leaf has died off, though increased use of nitrogen on carrots has prolonged the season by about three weeks and late or second crop carrots can further extend the season by one month. Once again an example of planning in conjunction with the processor, because top lifted carrots in stony conditions will suffer less damage than if timing goes amiss and they have to be lifted with their accompanying stones.

Another essential of any harvester is that it should remove from the soil as much of the product as possible and leave behind as much of the unwanted as possible. The top lifter tends to do just that, even passing the weed roots and stem back to earth; but a stage comes when the green top becomes weak and the crop becomes lost and a balanced decision on cost of production and loss of crop has to be made. Essentially harvesters should not lose the product, because maximum turnover and yield is essential from every acre planted and planned for harvest; yet even in this day and age we accept a 10% loss, eg £30 per acre, when harvesting sugar beet. Surely this must be wrong, and we all know what a change in the weather neams; this so easily rises to 20%, a fantastic figure.

This raises another aspect of harvesters, ability to harvest large acreages when conditions are ideal, a situation often affected by the producers pocket rather than the machine. How often you see harvesters working under farcical conditions, when it is obvious that the harvester was never of a size capable of dealing with the acreage grown, not a design fault but a planning fault. Maybe the crop should not be there at all and certainly the possible working days within a harvesting period have never been thought about. Of course there are exceptions and that is where the 'go anywhere — anytime' harvester comes into its own. Extremely expensive but often paying for itself in a remarkably short time by producing a fresh product, when no other harvester can move — a fresh market machine, you might say, but also producing for the processor when all his other suppliers are not supplying and we hope endearing the producer to him for life! Thank heavens we still have this personal relationship, which builds up a feeling of confidence between the supplier and the processor and the consistency of supply is something he must have, which is founded on contracts honoured by both parties.

The 'go anywhere — anytime' machine is partly here, but nearly all harvesters have to produce their product into a trailer while travelling, and sadly to date, the 'go anywhere' trailer is not in universal use, but progress is being made. Of course, these 'go anywhere' machines leave their trail as was so clearly demonstrated in the harvesting of sugar beet on heavy land. Some land took years to recover and broke the hearts of many sugar beet farmers, but the higher price of cereals cheered them up and the sugar beet disappeared. The resultant damage and decline of sugar beet growing on heavy land was definitely partly the fault of the processor, by failing to realise and accommodate the producers by taking the heavy land product first, which would have allowed them to harvest and replant with wheat, when the conditions were best, and allowed the light land farmer to leave his crop in the ground when it was still growing. Once again a blinding example of co-operation between grower and processor being essential for the full usage of the growers' main investment — his land and the processors investment, his factory.

We have not mentioned the commonest form of harvester of roots as yet, that is the hoover type of digger in its multitude of forms. Starting with the simplest, digging and depositing on the ground, to be picked up by hand. This is still often the cheapest in the case of potatoes, and causing the least damage as long as the product is placed gently in the box or bag and not thrown from 3 ft, not jumped on and treated with equal care by the processor; then going on to the complete hoover harvester depositing in bags or trailers running alongside, and in some cases having a hopper attachment to obviate running on the field.

All sadly have their points which cause damage, which are common to all types of harvester; drops too large, traces not protected, forward speeds too great causing impact damage, incorrectly set or lack of variable speeds of all traces and separators, tyres running adjacent to crops, changes of direction, product dropping on product. Nearly all these faults are caused by having to design a machine that will actually move on the land, in fact faults of construction or design; but how nice it would be if the processors or the government or farmers did a really extensive survey on where the damage occurs and how serious each is, so we could concentrate on the most serious first. Remember one firm giving away soft rubber boots, so when you trod on your potatoes in the bulk loader you did less damage? Would not have nine inches extra on the side of the lorry been the answer so that no spreading of the load would have been necessary? How many elevators have swan necks and a probe to raise it at the appropriate time? You will all say very easy when loading lorries, not so easy in the field when the harvester stops and the trailer doesn't! Maybe more thought should be given to the level of the trailer bottom.

Can we do anything about the obvious other faults? The angle of the shear should not be excessive, trace speeds should be variable and changes of direction should be cut to a minimum. Harvesters should be offset to the side of the crop, if possible, and delivery to trailers should be looked at carefully.

We now get to the treatment of the produce during the delivery to the store or processor, when all the same facts apply as in the harvester; but there is no doubt that the least done to the crop from the moment it leaves the ground the better which goes back to the growing of the perfect crop, in as near perfect conditions as possible.

Looking ahead

What of the future? I am sure you will see root vegetables going the same way as corn growing. The combine is an essential implement of the corn harvest, and many farmers now plan the rotation around that one machine, to ensure that it is more fully used over a longer time. This allows for a smaller machine working for a longer season on a given acreage. The second investment of the corn dryer and storage is entirely dependent on the combine harvester and its times of action.

The same will occur with the root harvester; the grower, due to financial pressures, will have one universal machine of high capacity and his rotation will be centred on that machine, and woe betide the processors who fail to understand this inevitable progress. The grower will expect his harvester to be working from June to December, and in the case of carrot growers — through to March. It will work within a very tight season schedule, passing from one root crop to another, possibly even doing the sugar beet on the way. Short term storage will become an automatic ancillary to this machine, since even the combine takes time to be set up for each particular crop. Traces and shears will be changed quickly and possibly shift driving will become part of the weekly scene. If this is not achieved, machinery costs are going to become so high that produce will be so expensive as to be unsaleable, or will the machine once again give way to hand labour? I think not — the 30 hour working week is on its way; or will they spend their leisure hours "picking their own", dispensing with the processor?

Looking at America, this has not occurred, but here again we are so different. Here no city dweller is more than ten miles from a field and nearly all those fields could grow his essentials and some of his luxury food; but despite all this — I am sure growing for the processor will continue as long as both parties plan with the realisation that a great deal of the success of harvesting the perfect product is timing, and timing goes with forward planning, which will take into consideration economics and stability for the future with forward contracts.

In and out is expensive, and to the canned potato it was death! We do not want too many more crops like that, otherwise a talk on the harvesting of roots for processing will become as necessary as the dodo!

Information for designers

AN International Symposium entitled "Information for designers" will be held at the University of Southampton, 11 to 13 July 1979. Full details can be obtained from the Design Group, Dept of Mech Eng, University of Southampton, and a discount of 15% off the registration fee is offered to members of IAgrE.

The following paper titles are among those which will appear in the programme:

The Designer and the Information Broker.

Project Documentation Flow Within Industry With Particular Reference to the Designer.

Reliability Information as a Basis for Safe Designs and Satisfied Customers.

Essential Information for Product Design.

Reliability Data Banks and Data Exchange.

The Costing of Turned Components at the Design Stage.

Presentation of Climatological Information for Building Designers.

The Contribution of Timing Charts to Mechanism Design.

Harvesting of brussels sprouts: an account of one processor's approach

N B Elvidge

Introduction

IT IS emphasised that this paper deals with the experiences of an individual processor in attempting to modernise his system for handling brussels sprouts. It does not assume that all processors' requirements in terms of quality in its various aspects and of size are necessarily the same, nor that they would find the same solution appropriate to their needs.

The problems of preparing this crop for processing have been concerned with removing the sprouts from the stem, known as 'pulling' when effected by hand, or 'stripping' when effected by machine, and the subsequent preparation of the detached sprouts for processing, known as trimming. Sometimes the two operations were combined. This preparatory work was carried out variously in the field, in satellite trimming stations and in the factory itself. Various forms of stipper which involved passing the cut stalk through an aperture involving fixed or rotating knives were devised and were used widely in the industry. Later several systems of mechanical trimming were introduced and some of these are being adopted by processors.

Historical

Nine years ago, after some fifteen years of experience in growing and harvesting and trimming brussels sprouts, Findus and its associated companies had resorted to a series of permutations on the stripping/trimming theme.

1. Hand pulling in the field and hand trimming at the factory.
2. Bringing cut stems into an outstation and stripping and trimming by hand in one operation, using a knife.
3. Mechanically stripping cut stems in an outstation and trimming by hand at the same place.
4. Essentially similar to (3) but with the stripping operation performed on trailers in the field.

At this time the company had proved a satisfactory in-factory trimming system and were in the process of expanding it, but the lack of a parallel field development to provide a reliable supply of suitable raw material was all too apparent.

Any specification for such a supply drawn up that time would certainly have embodied the following points:—

1. Sprouts hand pulled — because the natural point of abscission is nearer to ideal for subsequent trimming than could be reliably obtained by any other then available stripping method. This is particularly true in relatively immature crops. Other methods gave rise to more over-trimming, resulting in yellow outer leaves or under-trimming — leaving a long butt.
2. The material should be fresh. No attempt was made at that time to define this in terms of hours but it was felt that quality deterioration resulting from delay between harvesting and processing was more serious than had been generally recognised and under some circumstances could be very rapid — giving rise to discolouration in the butt area, general loss of colour and deterioration of flavour.
3. There should be a minimum of grading or mechanical sorting in the pre-factory operation since bruising so incurred would render the delay factor more critical.
4. A maximum size of 35 mm, but with a fair proportion, say 30%, less than 25 mm.

There would have been of course further specifications as to flavour, colour, shape, freedom from pests and diseases etc., but those factors are not of immediate concern.

The factory input required at that time represented approximately the output of 250 hand pullers working in average crops. These would be spread over a good many farms, they would be on piecework, their availability would be subject to the weather, school holidays and in particular to offers of more lucrative work, such as potato picking. The natural reluctance of workers so employed to pull small sprouts meant that field or shed grading was essential, and made it likely that by the time they returned to the crop for the next pull a quantity of oversize sprouts would await them. All these factors combined to make control over input tenous both for quantity and quality.

The project

An approach was made to the company about this time by a G W Richardson, a North Lincolnshire blacksmith who had for some years taken an intelligent interest in various aspects of brussels sprouts handling. He had several ideas to offer, and in particular was able to demonstrate a rudimentary rig on which he rolled deleafed sprout stalks round a rubber-faced drum past a wall of rubber fingers. In terms of detaching sprouts it was not very efficient, but those which were detached came away cleanly, giving a similar effect to hand pulling, and the damage was minimal. Perhaps the most impressive and potentially important factor was that performance appeared to be largely unaffected by the manner in which the stalks were presented to the rig — they could be literally thrown in from a distance. In this it differed from any previous system and seemed to hold forth the possibility of the first truly mechanised harvester.

Agreement to develop the idea was reached with the inventor and a four stage plan was evolved.

1. To build a scaled-up stripper based on the original rig and test it indoors for a season, bringing stalks to it, and taking this opportunity to experiment with different materials and machine settings.
2. To design and construct a trailed machine with hand-feeding facilities to prove the reliability of the system in field conditions.
3. To devise a cutting/retaining/feeding system to handle the standing crop and
4. To build this into a self-propelled harvesting machine.
5. To consider the possibilities of designing a deleafing machine either as part of the harvester, or more probably, for use in a separate operation.

No attempt was made at this time to impose a timetable as it was felt that the variable input capability from a small section with many other interests, together with anticipated materials problems, would impose limitations which could not be forecast.

Stage 1

Stage 1 lasted for one season by which time a worthwhile stripping capability had been established and cleaning systems had been tested which were meant to separate the spent stalks, leaf stalks and other debris from the detached sprouts.

By this time the stripper had reached a state of development not far removed from the current version. The motive force is provided by a rotating steel drum about 1.5 metres long and 1 metre in diameter and surfaced with a soft rubber-based material. The surface of the rubber is laterally grooved to provide a tractive profile. About half the circumference of the drum is enclosed by a multiple sprung framework which carries a number of independently sprung static bars. These have a rubber surface suitably profiled to act in opposition to the drum, to which they are arranged peripherally.

Behind and between the static bars are arranged rows of rotating rubber stripping fingers. As the sprout stalks progress round the drum they are rolled as the static bars bear upon them. The static bars retract from the pressure of the individual stalks, allowing the stripping fingers to bear upon the sprouts. As the sprouts are detached they fall through the framework and go on to be cleaned, while the spent stalks are carried round to the end of the frame and rejected. Figures are presented in the Appendix.

N B Elvidge, Agricultural Operations Manager, Findus Ltd.

Paper presented at the Spring National Conference of The Institution of Agricultural Engineers, held at The Key Theatre, River Embankment, Peterborough, on Tuesday 20 March 1979.

Some tests were carried out with stalks which had not been deleafed but although in some circumstances stripping was not seriously impaired the mass of leafy material could not be easily shed, resulting in frequent stoppages. The tests were abandoned.

Stage 2

Two strippers were mounted on a viner chassis complete with a storage hopper. Each stripper was fed by a flighted elevator from ground level. In two separate operations the plants were first deleafed and then cut and windrowed by hand. It may well have been possible to mechanise the latter operation but this was not considered worthwhile in view of the overall programme.

Two machines of this kind were constructed and over the next five years each successfully harvested some 120 acreas of crop annually. They gave rise to few problems and maintenance costs were reasonable. It became obvious, however, that not only was the feeding of the elevator from the windrows very heavy work, but that however skilful and industrious the operator, it was not possible for one man to feed the stripper at more than about two thirds of its capacity. On the other hand two men hindered each other. This gave extra incentive to push on with the next stage.

Stage 3

This was initiated after two seasons' experience with the Stage 2 machines. It was based on a second-hand combine harvester chassis and so inherited considerable limitations in the way of weight distribution, wheel arrangement and general layout. This was not thought to be important since the intention was to use the machine solely as a vehicle for the development of a cutting/retaining/elevating system. The plan was to sever the stalks near ground level with a single rotating disc (twin discs were tried but discarded), to support them simultaneously between two tiers of lugged belt which would maintain them in an upright position and convey them back to the base of a flighted elevator. As they were released by the belts divertors would turn them to lie across the elevator which would deposit them in the stripper.

After two seasons' work a degree of effectiveness was achieved which gave rise to thoughts of drawing together all the accumulated experience into a purpose-built harvester and a list of requirements was drawn up towards which the machine should aspire.

1. As far as possible an all-weather capability — this is not to say that it would necessarily be desirable to work in all conditions — especially of frost.
2. Hydraulic drive to give infinitely variable speed to all elements.
3. Four-wheel hydrostatic drive to give good traction and, more important, accurate steering in wet conditions.
4. Good weight distribution and wheel and tyre selection to give minimum soil disturbance.
5. Maximum weight 10 tonnes loaded.
6. Improved cleaning to give as near as possible a "hand pulled" sample.
7. Adjustable cutter height probe to give possibility of leaving spoiled bottom sprouts.

Although up to this stage the bulk of the machinery associated with the project had been constructed in the company's agricultural workshops, Findus had no aspirations to become machinery manufacturers and it was at this stage that it was decided to call in Mather and Platt with whom Findus had a history of technical co-operation, and with them to establish a joint design team with a view to their manufacturing the machine for the company's use.

The first machine became operational in November 1977. For the 1978 season three more machines were constructed to a slightly modified design and the first one brought up to the new design standard.

In the recent season the whole of the company's planned acreage of brussels sprouts was harvested mechanically and the opportunity was taken to move into bulk handling from the field. Some ten or twelve loads were sent in from each day's work ensuring that fresh material was constantly available at the factory.

All post-harvest cleaning, grading and sorting operations were removed to the factory.

Problems arising during development

Most of the delays encountered arose from difficulties in the identification and selection of suitable materials, particularly for the drum coating and for the retainer/conveyor belt. For the drum coating a kind of foam rubber effect was necessary, giving gentle handling and yet with adequate friction. A material with close cellular structure was eventually selected which, whilst exhibiting these properties, allowed no ingress of moisture, thus avoiding heavy wear in frosty conditions.

Early models incorporated a jointed conveyor belt with mechanically attached lugs, but after problems with tensioning, tracking and susceptibility to moisture an endless belt with a man-made fibre base and a multi vee section was adopted. The lugs were moulded on.

Discussion

In considering how far the original aims of the project have been achieved it is important to understand the capabilities and the limitations of the machine.

The skill of the operator is certainly at least as important as on comparable machines, perhaps the most important aspect of his job being the synchronisation of ground speed and retaining belt speed in order to obviate drag which may cause premature detachment of buttons.

The crop must be grown for the system, since apart from such obvious precautions as not using a five row drill in crops to be handled by a two row harvester, it is important that the plants are reasonably upright or at least that the rows are discernible. In some soils shallow ridging helps to achieve this and at the same time gives the debris from deleafing a chance to settle in the furrows so as not to interfere with the cutting disc.

Some varieties strip more easily than others, but all strip well enough provided that the space between individual sprouts on a stem allows for a little sideways leverage. Densely packed sprouts in any case give rise to off-shapes which are undesirable in that they are difficult subsequently to trim mechanically.

The machine is capable of harvesting around two acres in an eight hour day, depending upon crop density and height.

In common with other mechanical vegetable harvesting operations the extraction rate or proportion of potential yield achieved varies with the state of the crop and the operating conditions.

Major damage is not a serious problem and is caused more often by the knives of the deleafers than by the harvester.

The harvester takes the crop as it is, it has no means of excluding undesirable raw material other than by adjusting the height of the cutting disc. If it can be accepted that the less mature the crop the lower the incidence of defects, it follows that early harvesting is desirable. It might be thought that the yield penalty so incurred would be significant, but if the oversize fraction is ignored and the crop considered as purely for freezing this is not necessarily so.

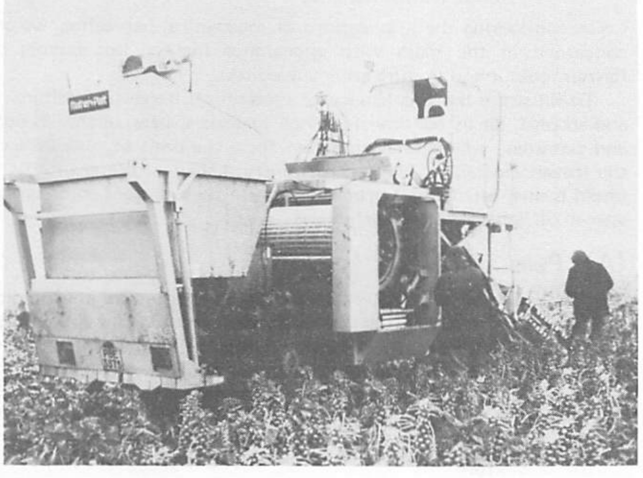
Experience shows that the value of the oversize fraction is so unreliable as to be discounted for budgetary purposes. Two distinct further advantages arise from early harvesting, however. Firstly the balance of the mix of sizes moves towards the smaller end of the spectrum, presenting the possibility of increasing the pack of the more valuable small sprouts, or indeed of reducing the maximum size for the whole pack. Secondly it appears that early harvesting has a significant effect in reducing the incidence of severe internal browning. This has been demonstrated over several years of running with parallel hand pulled and mechanically harvested produce. On the basis that the longer the plants stand in the field the greater the risk of blemish of one kind or another, the harvest season is planned to finish by Christmas and for this reason late varieties are not used in the programme. Perhaps the greatest risk in extending the season is of bronzing caused by freezing winds and when this penetrates beyond the very outer leaves difficult decisions on the extent of trimming are called for.

In following a course aimed expressly at improvement in quality and security of supply substantial savings have been made. The hand-fed machines gave rise to a reduction in the delivered price of the order of 20%. It is too early to say what further savings may be made by the SP machines but it will be considerable. Potential savings from the use of such machines will in any case depend on the contracting/harvesting system currently used, on the nature of the final product required, and on the factory facilities available. For the future much work remains to be done on the relative suitability of varieties, on growing methods particularly in reference to plant populations and arrangement, and on ways of defining the optimum time for harvest of individual crops. Now that this new system has been evolved and accepted within the company, all field trials work on sprouts will be carried out with its specific needs in mind.

Of the original development plan the item concerning mechanical deleafing remains but so far nothing more substantial than a great deal of thought has been invested in it, along with research into work carried out elsewhere. Because of the changing nature of the petioles in terms of rigidity and firmness of attachment to the stem it appears that in our climate a series of different problems of detachment are presented during the season. Whether they are all capable of solution by the application of a single mechanical principle and within the financial limitation of the potential savings must be in some doubt.

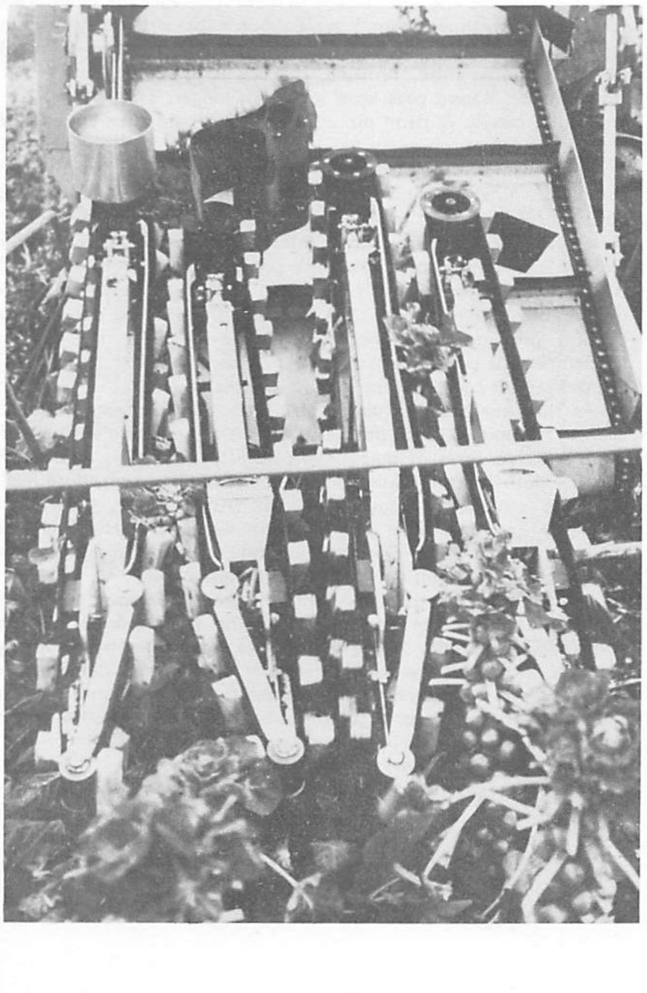
Conclusion

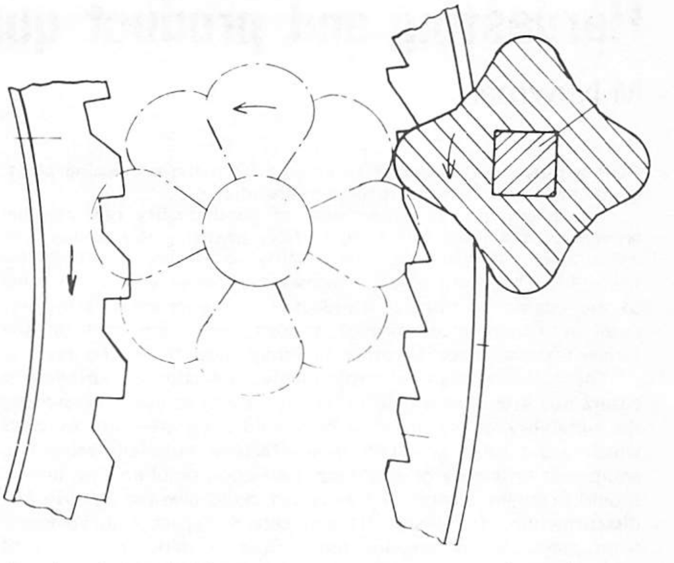
This has been an account of the practical application of an idea to the problems of harvesting a crop which appeared to involve particular difficulties. Whilst not pretending to have achieved the ultimate solution it may at least claim to have demonstrated the possibilities of a new approach to the crop — an approach which offers opportunities of rationalisation of production and improvement of quality in a product which has not always been presented to the public to its own best advantage.



The sprout harvester in action

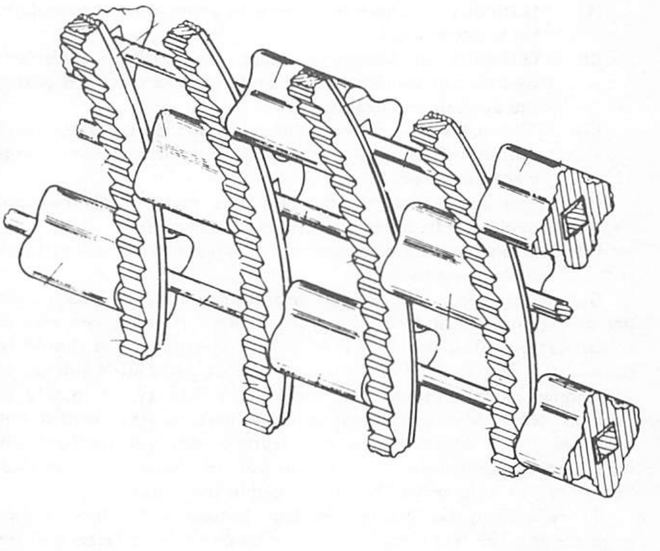
Two-row cutting head





Section of drum (left), rotating brussels sprout stem (centre) and serrated static bar and picking fingers (right)

Section of frame, showing static bars and inset picking fingers



Obituary

Mary Elizabeth Ferguson Bomford (1898-1979)

MRS BETTY BOMFORD — founder of the Douglas Bomford Trust in 1972 — passed away peacefully at home at Bevington Hall, Salford Priors, on 22 March 1979, following a terminal illness.

A kind and gentle person, who liked to keep in the background, she took a keen interest in the activities of the Trust which she established in memory of her husband, the late Douglas Bomford.

The Bomfords have farmed in Worcestershire for many generations, and one branch of the family in particular helped pioneer the mechanisation of all the basic operations in farming. For the greater part of this century Douglas Bomford was a leader in this pioneering work, which was not solely confined to the practical aspects, but extended also to the educational side of agricultural engineering. He was always anxious to encourage younger men of promise to develop their career further, and there are many in the agricultural engineering industry who can speak with gratitude of his kindness and practical help.

Since the Trust was founded it has been able to provide a measure of financial help for nearly 30 applicants, thus enabling them to undertake particular projects or complete courses for which their resources were otherwise inadequate, and for which no other sources of funds could be found.

Harvesting and product quality

M Newman

FOR a satisfactory product to emerge from the processing plant, good quality raw material is the first essential.

The planning and achievement of good quality raw material arriving at the factory is a *team effort* involving the grower, the agricultural manager and the quality controller (or technical manager). This team effort becomes even more vital when some of the operations hitherto conducted in the processor's factory, such as trimming of brussel sprouts, are conducted on the farmer's premises or in other buildings away from the factory.

The technical manager's role involves selection of varieties, to ensure due attention is paid to quality as well as yield. In assessing the suitability of raw material he should draw attention to issues which could cause problems in the factory, especially related to equipment efficiency or additional inspection requirements, and he should highlight quality factors which could give rise to customer dissatisfaction. The housewife and caterer expect high standards from preserved convenience foods. Just as milk comes out of bottles, so peas and beans come out of packets or cans.

Mechanisation, related to harvesting, trimming or other types of preparation prior to receipt into the factory has probably, in recent years, been the major influence on quality of harvested crops. Mechanical harvesting provides answers to some of the following problems:—

(1) Difficulty in obtaining labour in some areas, particularly for seasonal work.
(2) Difficulty in obtaining labour to work in inclement weather, in buildings used only for short periods during the year, or unsocial hours
(3) The need to minimise direct labour costs, particularly during inflationary times and times of relatively large wage increases
(4) The harvesting of adequate raw material of the right quality to be harvested within a short season
(5) The execution of operations which are extremely difficult to conduct by hand.

But what about the effect and implications of mechanical harvesting, storage and trimming on quality? Is this given enough consideration? And if the answer is "not always", what should be done about it? The technical manager cannot stand aside and ignore techniques which improve raw material availability, or quality or product costs. Mechanical harvesting is here to stay. And if one looks at those vegetables — and fruit — not yet mechanically harvested in most cases it is a question of "when" rather than "whether" techniques will be introduced in the future.

There should be greater contact between the food design engineer and the technical manager or quality controller so that the quality needs of the process industry are clearly identified and unsatisfactory quality features are catered for during design and prototype construction stages. Emphasis must be given to the need for a focal point of contact so that quality issues can be discussed more fully with researchers and equipment manufacturers. Those people involved in the purchase and operation of harvesting, trimming and storage sometimes appear to believe that the processing factory can handle *any* material, bringing it up to standard whatever the damage or foreign material levels. Whilst the factory can do much in this respect, it is unwise to rely on it too heavily and I would counsel people involved in field operations to discuss quality problems with factory management as early as possible.

Perhaps an outline of 'quality' would be appropriate here:—

1. Packaging
2. Flavour
3. Colour
4. Texture
5. Appearance
6. Microbiological factors
   (a) safety
   (b) shelf life on defrosting
7. Chemical consideration of pesticide and herbicide residues
8. Product temperature

Under appearance, there can be considered a number of categories thus:—

(a) Defects or variations concerned with the product itself eg blemishes, damage, trimming defects, size
(b) Extraneous vegetable material
   (i) associated with the product eg pea pod, bean leaf
   (ii) not associated with the product eg thistle or daisy heads
(c) Foreign material
   eg stones, animal material

In considering the implications of mechanical harvesting, we are concerned in the main with appearance factors, but factors of flavour, colour and texture are involved too.

To illustrate the importance of mechanical harvesting, trimming and storage, let us consider four raw materials, peas, beans, sprouts and potatoes, which taken together form the basis of over 90% of the frozen vegetables sold in this country. I shall also refer briefly to broad beans, carrots and broccoli because they present some rather special difficulties, or opportunities.

(A) Peas

The processed vegetable industry has always regarded the quality of the pea pack as a matter of prime importance, since peas represent the most popular frozen green vegetable in the UK. Aspects affecting quality therefore, receive close attention.

The efficiency of the vining operation can affect the quality of peas received into the factory in a number of ways:—

(a) Flavour
(b) Texture
(c) Damage
(d) Foreign material

We all recognise the importance of the time period between vining and blanching, on flavour and texture. Flavour deteriorates with increasing time. Natural pea flavour is lost and 'delay flavours' develop. The *rate* of deterioration depends on a number of factors including temperature, bruising, damage and contamination with vining liquor. Sound peas keep for much longer. This, of course, is seen quite clearly in hand picked pods, which are then shucked by hand.

Recognising the importance of delay prior to blanching, freezing companies limit the period between harvesting and processing. Most companies try to keep it to a maximum of 2-3 hours. However, if the expected time, due to distance between field and factory is likely to exceed 4½ hours, pre-cooling to give extended life is practised. Advantages of pre-cooling have to be balanced by the undesirable effects of pre-cool flavours. In order to get the best flavour, growing areas should be fairly close to the factory. Remember it's only when the peas are blanched that the enzymes responsible for the deterioration are inactivated.

As the time between vining and blanching increases there is a change in texture and the skins become increasingly tough. In more extreme cases of delay, the peas after re-heating and plating become dull in appearance. During the re-heating procedure itself, the peas exhibit a tangy somewhat fruity odour. Clearly the processor can and must exert control on delays. However, any action that the viner operator can take to reduce bruising and damage to the peas during vining must be welcomed.

I want now to turn to the very great relevance the vining operation has on the appearance of the final product. To my knowledge, all quality standards for peas make reference to foreign material, extraneous vegetable material (EVM) and damage. Tolerances, if any, are shown in the quality standard and although these vary from company to company, grade to grade, the sort of figures normally quoted are as follows:—

	Defect category	*Tolerance*
(a)	Foreign material	Nil
(b)	EVM	
	(i) associated with the product	1 piece/kg
	(ii) not associated with the product	1 piece/4 kg

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Paper presented at the Spring National Conference of the Institution of Agricultural Engineers, held at The Key Theatre, River Embankment, Peterborough, on Tuesday, 20 March 1979.

(c) Damage — crushed peas, loose cotyledons and skins 5% w/w

Furthermore, in view of the effect of certain aspects of processing — particularly blanching — on partially damaged peas, resulting in the production of more loose cotyledons and skins, attention must be drawn in the vining operation to the incidence of *cut* peas, ie those with a split in the testa more than 1/3 or 1/2 of the circumference. As well as splitting further during the process operations, pea flavour and nutrients are liable to be lost from such peas. Moreover, some companies are becoming increasingly unhappy about cut peas in the final pack. They are regarding them as defects and introducing tolerances for them in their standards.

In the above context any controls which can be introduced or technical developments coming forward which alleviate the problems are to be encouraged. In this regard I must refer to the potential advantages of the new self propelled reduced intake viners, maximum throughput viners or pea picking machines, manufactured by companies such as FMC and Mather and Platt. At first it seemed that the very nature of their operation, by which the need for cutting is eliminated and the tins operation leaves behind the main vine, represented an improvement the risk of stones getting into the bulk box being much reduced. One hoped too that problems due to foreign EVM would be reduced. Information on trash levels is summarised in table I, this confirms expectations from these machines:—

Table I Peas — Trash levels

Variety	*Viner type*	*Average*	*Range*
Foreign material (stones and soil)			
Sprite	Self propelled	0.00	
	Traditional trailer	0.01	0 to 0.1
Puget	Self propelled	0.03	0 to 0.1
	Traditional trailer	0.34	0 to 1.0
Scout	Self propelled	0.02	0 to 0.1
	Traditional trailer	0.01	0 to 0.1
Foreign EVM			
Sprite	Self propelled	0.00	
	Traditional trailer	0.04	0 to 0.4
Puget	Self propelled	0.04	0 to 0.2
	Traditional trailer	0.53	0 to 2.3
Scout	Self propelled	0.02	0 to 0.1
	Traditional trailer	0.13	0 to 1.2

As far as EVM is concerned, I understand that the improvement in levels with the self propelled viner largely results from the removal of the larger pieces.

Table 2 Peas — Damage levels

Viner type	*Splits and skins*	*Cut Peas*
Self propelled	1.3	5.5
Traditional trailer	7.2	7.2

From table 2, there is no doubt that split and skin levels have been greatly reduced — resulting in a saving in transport costs for 'waste' material going into the factory. However, we cannot be sure that this improvement results from less damage being inflicted on the peas or from an improved blowing facility on the viner.

In interpreting the results I have to emphasise that strict comparison between the machines is not fair, in that unlike the self propelled viners, the traditional trailer viners were not new machines. Nevertheless, they do comprise the results of investigations into the quality implications of using the new type of viner under practical conditions over a difficult season. I am advised that not all companies find these quality advantages with the new type of viner. One company, I believe, is putting in additional stone traps in the factory because of greater levels of stones experienced during the 1978 season. It will be interesting to hear the experiences of companies on this subject.

Other advantages, including the point that such a viner replaces 1½ — 2 of the trailer type viners, and obviates the need for cutters are no doubt well known.

One cannot leave the subject of peas without making a reference to the development of leafless and semi-leafless varieties which, if successful, will surely aid the vining operation and help to reduce the level of EVM received at the factory.

(B) Dwarf beans

Prior to the advent of mechanical harvesting, the bean processing industry was accustomed to receiving its raw material in net bags. The principal quality issues concerned maturity, windrub, and occasional loads showing significant disease levels. Foreign material was virtually unknown, and EVM problems were restricted to the occasional cluster which required to be broken up to enable the beans to be snibbed. The beans themselves were undamaged, and therefore harvested material could be held not just for hours but sometimes days prior to processing. Holding in chillrooms prior to processing was a common practice.

It was clear that mechanical harvesting would bring problems. We expected maturity to be more variable since the whole crop is harvested at the same time, but after the first year or two, experience has shown that with the use of appropriate varieties linked to good field control. Overmaturity is much less of a problem than was originally envisaged.

It quickly became obvious with mechanical harvesting that additional inspection and cleaning equipment would be necessary to remove EVM and stones. Added impetus was given to stone removal by the fact that, if not conducted, one could get severe damage to slicer blades. It was clear that removal of EVM should be effected early in the line and this is particularly the case with leaf material to prevent blocking up the snibber apertures. With present day harvesters and cleaning equipment leaf material is much less of a problem except during wet weather. The efficiency of blowing facilities appears to have improved.

Returning to the problem of clusters, this has been more prominent in the 1978 bean season. In fact we found that the incidence of clusters was approx five times higher in 1978 than in 1977. Presented with high levels of clusters, it is important that the factory has adequate inspection facilities and that it is equipped with de-clustering units.

Processors have a small tolerance for stem ends — generally around 4 per kilo. Tolerances for bean stalk material are very tight — generally 1 piece per kilo.

I now turn to the question of bean breakage which we also found to be a greater problem in 1978. During mechanical harvesting, beans are broken and this has two principle repercussions. Firstly, the ends turn brown with time due to oxidation. When found in the final product they are designated as blemishes but also suggest to the purchaser that material which is not of very good quality — not fresh — has been used. These brown ends are more conspicuous (and more seriously regarded) when beans are packed in whole or cut styles. Recognising the need to avoid sliced, cut or whole beans with brown ends, the industry has introduced much tighter time controls covering the period between harvesting and processing. In general it aims to process within 12 hours of harvesting and many companies aim for shorter periods. The second reason for concern about broken beans is their affect on appearance of the final product. In the sliced bean pack, so traditional in this country, slice length is an important consideration. Strict control on short pieces and a requirement for a certain percentage by weight exceeding 40 mm (some use 50 mm) in length are normally quoted in product standards. This means that depending on grade, a standard may state a maximum of 30% w/w short pieces (defined as units less than 25 mm or 35 mm) and require a minimum of 40% long pieces (defined as pieces longer than 40 or 50 mm).

In the increasingly popular larger size packs, control on slice length assumes greater importance due to separation in the pack — with the smaller pieces falling and remaining at the bottom. Short broken pieces of bean aggravate this problem, giving rise to more short slices. Indeed the very short pieces may be sliced diagonally or at right angles to their length due to the way they approach the slicer baldes.

Undesirable though broken beans are for the sliced pack, they constitute a more significant problem with the whole and cut style packs. Most people believe that in the whole and cut styles one gets better bean flavour and texture than in sliced beans. Whole beans are gaining in popularity, particularly in catering spheres.

Cut beans represent something of an enigma. Tried on many occasions, but without any real success, there is some evidence now that this style is becoming more acceptable to the British palate. Suffice to say that the industry is keen to supply both products of high quality and this includes considerations related to the use of broken beans. We do not want our whole bean packs containing short pieces arising from breakage during harvesting. Neither do we want either style to show pieces with ragged ends. So for all these reasons, pressure is on those concerned with the mechanical harvesting to minimise bean breakage — and levels of clusters, EVM and stones. Clearly the more that can be done in the field the better. Correct adjustment of the machine, and attention to running speeds of the harvester represent critical factors. Operator training and experience also constitute important considerations in mechanical harvesting of green beans. I have already indicated improvements in blower performance. In the last 2-3 years we have seen in this country the introduction of multi-row harvesters and to see these machines operate is a very impressive sight. I hope that future developments — whether in variety selection or machinery modifications — will reduce further problems associated with EVM, particularly in wet weather, the incidence of clusters, and bean damage.

(C) Brussels sprouts

Mechanisation of sprout harvesting prepares the raw material for processing and includes trimming. It is an issue which, from the quality standpoint has proved rather contentious in some respects

Mechanised harvesting and trimming have been available for several years, but they have been slow to catch on, due to the concern felt about the resultant quality. The position is different from peas, and to some extent beans, where on the whole traditional values regarding quality have not been threatened either by the advent of mechanical harvesting, or indeed by changes in harvesting techniques. Furthermore in the case of these vegetables, no actual trimming operation is involved. Varying size and shape and differences in type of defect combine to make mechanised harvesting and trimming of sprouts a difficult operation.

Mechanical sprout trimming is frequently carried out away from the factory at grower trimming stations, but whatever the location, the objective remains the same, ie to prepare the raw material so that only blanching, cooling and freezing need be conducted afterwards. The detailed objectives of the trimming operation are to produce a sprout in which:—

- (a) The butt is cut cleanly and smoothly at an angle of 90° to the vertical axis.
- (b) Ragged butts due to poor trimming are regarded as defective.
- (c) There is no butt extending below the point of attachment of the outermost leaves.
- (d) Brown and otherwise discoloured butts will be trimmed away.
- (e) Natural damage due to disease etc is removed.
- (f) Overtrimming, resulting in the outer leaves being no longer attached at their base in the butt, is avoided.
- (g) There should be no cutting into the head of the sprout.

In general, satisfactory quality during hand trimming (whether of loose sprouts, or sprouts attached to the stalk) is achieved by peeling back damaged, discoloured or loose outer leaves, and then making a transverse cut across the butt, thereby removing such leaves and producing a smooth butt end.

The quality aims of mechanical and hand trimmed sprouts should be the same, but this has proved difficult. Experience with machine stripped and trimmed sprouts has revealed some problems in trying to remove natural damage and achieving a well trimmed butt, whilst avoiding overtrimming and cutting into the head. A number of questions spring to mind:—

- (i) Is it possible to achieve consistently a higher quality product from machine trimmed sprouts?
- (ii) Is the difference in quality between mechanically trimmed and hand trimmed sprouts significant in consumer terms?
- (iii) Could arrangements be made either at the trimming station or at the processor's factory to inspect and further trim the sprouts, bringing them up to the standard of the hand trimmed product?
- (iv) Should companies accept the lower quality of mechanically trimmed sprouts for all their standard outlets, and if not can the sprouts be assigned to specific outlets whose quality standards may be less demanding?

I am going to discuss mechanisation of sprout preparation primarily in the context of the first two points. Today, I am more interested in determining the nature of any problems and how to solve them, rather than considering how any recognised differences can be accommodated. Most technical managers have experienced the problem of being hung up over some technical aspect of quality subsequently discovered to be not important to the consumer. Furthermore, it is right that traditional approaches to quality should be questioned, and revised from time to time in the light of changing consumer attitudes. Probably, most people in the vegetable industry accept that when considering defects, natural damage (ie disease, discolouration, blemishes, etc) is more objectionable than mechanical damage. Consumer research supports this. The advocates of mechanical harvesting and trimming of sprouts agree that natural damage should be removed.

No-one likes to see over-trimming resulting in loss of the outer green leaves, so that there are only yellow sprouts left. These present an unattractive, somewhat insipid appearance and imply to the consumer that the original quality was poor necessitating major surgery. Mechanical trimming must be controlled to strike the right compromise between removing natural damage and preventing over-trimming. The situation is made more difficult because mechanical trimmers cannot differentiate between sprouts with natural damage and those without, and, unlike the hand trimmer, cannot be selective in applying different levels of trimming depending on the severity of any natural damage present.

Scalped sprouts may be regarded by the housewife as an indication that the processor had removed areas of natural damage, but many people at home cut unprocessed sprouts in half, particularly the larger ones, prior to the cooking operation, and eating quality (ie flavour and texture) is not affected. Although I understand the logic involved in these arguments, I confess to a reluctance to accept the case for having sprouts in our top grade packs with significant mechanical damage — at least whilst we have a choice in the matter. If necessary, I think there is a case for considering a tolerance for scalped sprouts, but I would make it a small one, otherwise we shall not get the machinery improvements linked into the use of specific varieties more suitable for mechanical harvesting and trimming that a number of us are looking for.

As regards the butt itself, one can understand the argument for accepting a slightly corrugated surface and also the point that an angled butt doesn't really represent any significant quality drop. However, we must express concern about very ragged units, heels, or sprouts to which part of the stalk, or main leaf petiole is attached. Elongated butts — whether they be due to inadequate trimming or loss of outer leaves during handling or freezing, are clearly unsatisfactory, and constitute detrimental appearance factors. Our observations with at least one type of machine available is that a number of sprouts may miss the trimming blades altogether, and others receive a rather inadequate trim.

One final point not usually reflected in quality standards is that rubbing and handling during harvesting and trimming may produce a surface which is less bright and may cause some damage to the outermost leaves producing a slightly 'tatty' appearance. In considering mechanical harvesting and trimming of sprouts, it is important to consider other factors:—

- (i) Hand trimming of sprouts is expensive, and will increase further in cost, as wages rise and inflation continues.
- (ii) The direct labour costs associated with mechanical preparation are lower. Admittedly there is a high capital cost initially in the purchase of the equipment.
- (iii) Labour in sufficient quantity may not be available in all areas, either for field work or for trimming purposes. The situation may be aggravated by the seasonal nature of the job.

These situations will force growers and processors increasingly to consider mechanical harvesting and trimming techniques, and it is my hope that pressure will be brought to bear on food engineers and others so that current quality problems can be minimised.

In which areas should attention to directed in the future? Mechanical preparation of sprouts for processing can be divided into two operations:—

- (i) Removal or stripping of the sprouts from the stem.
- (ii) Trimming the butts of the sprouts which have been removed from the stem.

Dealing first with the strippers, in nearly all existing machinery the principle of removal of sprouts from the stem is similar. The knives tend to follow the contour of the sprout stem. In general terms the sprouts are cut, as opposed to being broken, from the stem. Perhaps with more adjustment to the knives and their operation, it might be possible to achieve more trimmed sprouts at this stage.

As far as the trimmers themselves are concerned, we are looking for improvements in presentation of sprouts to the knives in order that only the butt is trimmed and scalping is avoided. Rapid adjustment to settings of the knives, presentation channels, and pressure pads must be of high priority to compensate for differences in sprout shape, size and blemish level.

Some of the problems can be reduced by selection of varieties, and indeed we must continue to develop varieties better suited to this type of operation. We are seeking sprouts which grow out at a large angle (ideally 90°) to the vertical axis of the stem; sprouts should be round (not oval) when viewed from above to assist size grading prior to trimming. For most preparation systems I favour a sprout which is round or slightly pear shaped and which has a definite butt. This helps orientation in the trimming section of the machines. Very pear shaped sprouts, which some people favour, tend to be 'leggy' and therefore less attractive. Texture is not so compact, particularly near the base, and the outer leaves are more susceptible to damage during trimming and processing. On the other hand, round sprouts which closely hug the stem are more liable to damage during the stripping operation.

I have dealt at some length with quality issues, and I have referred to the difficulties brought about by the material being so variable. I must point out too that some of the problems mentioned are much less apparent with some commercial machines available. Indeed I hope that in the discussion, some people will say they have experienced excellent results with machine harvested and trimmed sprouts. If so it will indicate that the improvements I am seeking are already here if only one selects the right varieties and machinery, and strictly controls the operation. However, I suspect there is still, in most cases, room for some improvement.

(D) Potatoes

When one considers chips (or french fries) texture, colour and appearance constitute important factors. Texture is largely determined by the specific gravity of the raw material and process conditions. Colour is associated with the level of reducing sugars in the potato, and this is influenced not only by variety but also storage conditions, particularly temperature. However, I want to concentrate on factors influencing the appearance of the product, ie the incidence of blemishes, slivers and small pieces. Final product specifications depend to a great extent on the level of such defects, companies adopting different standards depending on their strategy and outlets. Catering outlets are often very demanding when it comes to the quality of french fries. In view of the widely differing standards, I quote to relevant sections in the UEITP standard for french fries:—

External defects	*Maximum*
Total	40
Gross and Major	14
Gross	5
Sorting defects	
Total	12%
Short Pieces	6%

In interpreting these, it should be emphasised that they constitute the minimum standard.

As far as blemishes are concerned, much depends on the quality of the raw material. Unlike peas, beans and sprouts, much of the potato crop for processors is stored prior to use. This certainly applies to potatoes held from December until the end of the season in May or June. The method of storage therefore is also important in preventing deterioration.

The principal causes of potato deterioration during storage are:—

(a) The development of gangrene due to Phoma.
(b) Rot due to Fusarium, and other micro organisms.
(c) Bruising or blackspot following mechanical damage during harvesting and handling.

These together with respiration losses can give rise to yields in May or June which are 20% lower than those experienced in October or November using the same varieties. In addition french fry producers find it not only more difficult, but also more expensive to meet established quality standards towards the end of the season. In certain years, such as 1975 and 1976 when potatoes were not only in short supply but also of very poor quality the situation was particularly difficult. In those years even the housewife complained bitterly about the quality of potatoes. Action must be taken to improve the quality of potato available both to the processor and the housewife. A major part of potato deterioration prior to and during storage results from blackspot associated with bruising, and other types of mechanical damage. To improve the situation, attention must be directed in the following areas:—

1. Selection and development of varieties which are disease resistant and resistant to bruising.
2. Growing in soils where stones are not prominent.
3. Harvesting potatoes with equipment and under conditions which will minimise bruising, and other mechanical damage.
4. Holding of potatoes in stores designed for the purpose with due attention to temperature, humidity and spray treatment.
5. Avoiding damage during handling.

We must be more *specific* in defining precautions necessary and practices to be observed. Harvesting must be at temperatures no colder than 7°C using equipment which does not damage the potato. In this context the method of lifting, nature of equipment surfaces, drops during transfer, and speed of operation must be closely examined. The question I want to ask is whether our problems are dur primarily to lack of knowledge about how to harvest, handle and store properly, lack of availability of suitable equipment, or lack of application of knowledge already exisiting. If failure is due in some way to insufficient knowledge, clearly we must ask for the necessary research. If we are still seeking improvements in machine design, what a clear opportunity there is for the design engineer. However most people seem to believe that although there are gaps in our basic knowledge, the *principal* problem confronting us concerns application. If so, perhaps a very specific code of practice on the subject would help.

A number of people are attempting to develop improved sampling schemes for potato raw material incorporating bonuses for good quality and penalties for poor quality. I believe this principle is a good one which should encourage the good growers aiming to produce high quality potatoes for the process industry. However experience shows that the devising of such a quality system is not a simple matter and great care is needed in the choice of quality factors and tolerances to ensure benefit is obtained both by grower and processor. It is understandable that the grower wants some form of recognition for his efforts to provide potatoes of high storage quality, and if a bonus is paid, the processor needs to be certain this is reflected in better product quality, higher yields, or lower labour costs. There is a need for price and quality to be linked more closely than has sometimes been the case in the past. Undoubtedly quality sampling schemes for potatoes are rather more complicated than those for peas or beans. In Holland, too, the subject is securing attention, and a system devised by the IBVL Research Station based on the incidence of blemished potatoes is undergoing trials.

Of course we must have regard to the size of potatoes used for french fry production, including the level of small potatoes and the nature of the grading operation to remove them. Small potatoes are undesirable because they give rise to more short peices and slivers, and also because high peal losses are incurred in processing them. The grading operation must be conducted with suitable equipment and under strict controls to minimise bruising effects.

(E) Broad beans

Historically the pods were received into the factory in bags, and the broad beans removed in small podding units. Over the past 10 years, mechanical harvesting has been increasingly applied in this country.

Wilting after cutting is particularly important with this vegetable to facilitate removal of the beans from the pods, minimise damage, and reduce EVM levels. In the wet summer of 1978 wilting proved difficult, necessitating long periods after cutting prior to vining. Probably due to the effects of the wet weather we experienced higher levels of EVM coming into the factory.

EVM contamination is more important with this vegetable than with peas since the pod matures quickly and becomes discoloured, eventually turning black. A piece of dark pod in the final product can easily be seen and is sometimes mistaken for animal material by the housewife. Clearly controls in harvesting must minimise this type of contamination.

Bruising of beans is very liable to occur during vining, particularly with coloured flower varieties which are preferable for flavour and texture. The market for broad beans is unlikely to expand in any significant way by the processing of triple white varieties at high tenderometer readings. However, bruising of coloured flower varieties — which after blanching is recognisable as a deep purple stain — must also be minimised by careful attention during harvesting.

Bean damage represents an area of concern, since loose skins and cotyledons (the latter being very different in colour from the skin) are very obvious in the processed product. Damage is less likely at high TR's when the beans begin to separate from the pod at the hilum but at that stage the skins become more prominent — often tough — and the cotyledons very mealy. Hence one must look to the harvesting procedure itself rather than harvesting in the overmature state to solve the problem.

(F) Carrots

The product style of this vegetable is very much influenced by choice of variety and method of planting, the size of carrot being very much determined by spacing between plants. In principle one can use *time* to determine root size rather than spacing, but a strategy based on this approach tends to be uneconomic.

One is searching here for varieties such as Amsterdam which do not have a pronounced depressed crown and which to a large extent can be topped in the field, rather than the factory. This is particularly important when small size carrots are required in large quantities — as is the case for the baby carrot pack. More research, then please, into "Topless" carrot varieties!

However care is necessary during harvesting to prevent mechanical damage which often takes the form of longitudinal splitting of the roots. This is particularly a problem with the larger roots of varieties of the Amsterdam type. Such roots will not be suitable for sliced carrots — or roundels as they are sometimes called — in view of the detrimental effect on product appearance.

(G) Broccoli

I am including this much under-rated vegetable, because researchers report that mechanical harvesting investigations hitherto have not been very successful. Of course in the case of broccoli, damage to the buds comprising the inflorescence must be avoided, and careful trimming of the spear conducted to achieve a quality product. Appearance is of major importance in this vegetable. There is no point in ending up with a product in which the buds have become detached from the head leaving just stem material, or branched stems, even though the flavour of the latter may be good. No doubt further investigations will be conducted in this difficult area and I hope the researchers will be successful, particularly if the result leads to commerical benefits for the grower, processor and housewife.

Conclusion

I hope in this paper I have highlighted the importance of mechanical harvesting, storage and trimming techniques on quality, as seen through the eyes of a technical man in the frozen food industry.

Inevitably I have concentrated on problem areas, or areas requiring close control. The need, however, for such close control — particularly on the interval between harvesting and processing — can bring quality advantages not emphasised with hand harvesting. Thus products such as beans and sprouts tend to be frozen much sooner after harvesting than in days prior to mechanical harvesting with potential benefits as regards flavour and texture.

I conclude by emphasising again the need for a team approach towards growing, harvesting, storing and trimming vegetables for processing. To the team comprising grower, agricultural manager and company technical manager, I hope I have made a small contribution to encourage membership by the food equipment design engineer.

Mechanisation in the production of vegetables for processing

Edited summary of discussion

Paper 1 — Drills and Drilling, by K A McLean

Mr R J Upton (Upton Suffolk Farms) observed that, contrary to the findings of Mr McLean, he had found that seeds always benefitted from being watered after sowing. The case reported by Mr McLean in which initial advantages of watering subsequently disappeared, when comparing controlled experimental plots, had not been experienced on his farm.

Mr McLean emphasised that his experiments had been conducted in difficult years when the soil was already wet and indeed further rain had occurred after sowing. This tended to nulify the effect of watering trials. With reference to fluid drilling, the results had been conflicting. The one or two days gain achieved by sowing earlier in the season were often offset later by the effect of longer day-length.

Mr W J Elliott (NSCA) asked "what was the main source of the advantage to be gained from plastics mulches?"

The speaker thought that the main advantage was one of temperature, although it was not yet clear whether a floating mulch was superior to a soil mulch through which the crop had been drilled. Trial work to assess the various advantages was to be undertaken this year.

Paper 2 — Automatic Transplanting, by W Boa

Mr R F A Murfitt (NCAE) asked if there were any advantages in soaking soil blocks before transplanting. Mr Boa observed that it was conventional, when transplanting blocks, to soak them before this operation. A question then arose of the benefit of leaving the wrapper on the block when transplanting occurred. Did any problem arise from failure of roots to grow out of the block. The answer, said Mr Boa, was to irrigate immediately after transplanting if these facilities were available. Roots tended then to grow readily downwards.

Mr H Stirling (Gunsons Sortex) enquired, with reference to the single seed selector developed by NIAE:

1. "How was chitted seed separated from non-chitted and non-viable seed?"
2. "How was chitted seed separated from non-chitted and non-blocks?"

Mr Boa agreed that the separation of chitted seed from non-chitted and non-viable seed was still a problem. Two methods of separation had been used:—

1. By exploiting the greater surface area of chitted seed compared with non-chitted seed in a moving column of water, and
2. By utilising the small differences in specific gravity which existed between chitted and non-chitted seed.

Neither of the two techniques was really successful, and in practice separations needed to be repeated to cream off from the original seed batch as much chitted seed as possible.

The single seed selector as developed at the NIAE was capable of placing single seeds into soil blocks with a 90-95% accuracy, with no doubles. The unit was reliable in operation.

Mr G Dixie (Lawrence Gould Consultants Ltd) asked:—

1. "Was it anticipated that the wrapping material for the bandolier of blocks would be impregnated with nitrogen to assist decomposition by bacteria in the soil?"
2. "How would the NIAE block making system be integrated into the overall farming system?

Mr Boa explained that future trials involving transplants in blocks with the wrapping material intact or removed may provide information on this point, but as the amount of wrapping material used was small compared to the soil volume in the field, little if any nitrogen would be required.

In reply to the second part of the question, the speaker anticipated that the bandolier system of soil blocks would be taken up by specialist plant propagators to serve the industry as a whole.

Mr C Brutey (NFU) understood that the bandolier material now employed was paper. Had it not originally been plastics and what were the reasons for changing? Mr Boa explained that two materials were currently on trial.

a. Paper with a biodegradable coating of plastics on one side,
b. Paper with an appreciable plastics content. Plastics were needed which material must retain its strength for an appropriate period to allow satisfactory transplanting (eg 12 weeks for celery) but the total life to degradation had to be of the order of 6 months.

Paper 3 — Crop Sprayers, by J M King

Mr R J Upton (Upton Suffolk Farms) enquired of the speaker if the present range of control equipment for use with sprayers would be superseded by the silicon chip?

Mr King considered that progress in this direction was inevitable, and that the cost of sophisticated control equipment could be recouped by greater precision in the application of spray chemicals, for example by a reduction in over-dosing.

Mr McClelland (Dorman Sprayer Co) observed that with the increasing use of electronics and their ever improving reliability, developments in the accuracy of sprayer control could be expected, particularly in the matter of metering of the fluids.

Mr R F A Murfitt (NCAE) pointed out that no mention had been made of hovercraft as vehicles for spraying. Mr King replied that it was very early days to make authoritative comment on this possibility. Certainly hovercraft would reduce compaction and improve accessibility. Mr Brutey observed that these vehicles had been investigated some years ago and problems of crop flattening and blowing of the spray had been experienced.

Mr A J Barratt (Brentwood) enquired of Mr King whether or not we should see a move away from the use of sprays towards an increasing application of granules. The speaker did not foresee this as a possibility. Certainly granules were suitable in some cases, for example where slow release of insecticide was necessary, but there were many instances where quick and thorough cover was required.

Paper 6 — Harvesting of brussels sprouts, N B Elvidge

Mr R F A Murfitt made reference to the use of the Mather & Platt Brussels sprout combine harvester, and asked:

1. What method was used for deleafing?
2. After deleafing, what length of petiole was acceptable to the machine?

The speaker replied that deleafing was normally undertaken by men using knives, although "rings" were sometimes used. After deleafing the machine would accept a petiole length of about 100 mm.

Mr J S Whitehead (Fifegro Ltd) asked if trimming was necessary subsequent to the harvested crop having been delivered to the factory in fresh condition. Mr Elvidge observed that a thorough answer to this question was difficult — bulk handling had changed peoples views on this matter. Swift delivery of sprouts with minimum handling rendered further trimming unnecessary, particularly with smaller sprout size.

General discussion period

Mr R Walton (Plumpton Agricultural College) enquired of Mr King why the controlled drop application of certain herbicides gave slightly lower levels of control than the same herbicides applied through conventional hydraulic nozzles?

Mr King said that no reason was precisely known, although the difference in control probably involved drop size and the spray deposition on the crop despite the fact that translocated herbicides were used in trials at the PGRO. It was emphasised that whilst CDA had been shown in trial work to be inferior to conventional hydraulic nozzles, the results in terms of weed control were still acceptable.

Dr D J White (MAFF) sought opinion on the breakdown of photo-degradable plastics used for mulching when buried in the soil.

Mr K McLean indicated that the edges of photo-degradable plastics films buried in the soil did not decompose in the absence of sunlight. However, complete breakdown normally occurred when the film was exposed to light by subsequent cultivations.

Mr A D Wilcher (Hestair Harvesters) wished to know the views of growers, harvesters, and processors on the matter of 'topless carrots'. Mr Upton observed that the grower, faced with the eternal problem of economic balance, was perpetually seeking improved varieties which did not require topping (eg the Amsterdam varieties). The small baby carrot market particularly depended on this factor. Mr J How (Wold Farm Foods) saw the need for two basic types of carrot. First the Amsterdam type which was topped in the field for the baby carrot market. Secondly, larger carrots which were topped after harvesting, for dicing purposes.

Mr C Brutey (NFU) queried the problem of weight of pea podders and traction in wet seasons.

Mrs Knott stated that at least one manufacturer of a pea podder was aiming to reduce the gross weight by 1.25 tonne. Self-propelled harvesters fitted with 4-wheel drive were considered to be essential to assist traction of these heavy machines in wet conditions.

M J Milne of Mather & Platt indicated that any reduction in the weight of the harvester should not be achieved at the risk of affecting machine reliability. In time a compromise would be obtained in which gross harvester weight would be related to field traction and machine reliability.

Mr R F A Murfitt (NCAE) asked if quality of produce was dependent on what the purchaser would pay rather than what the grower would produce. Mr Newman observed that quality and cost go together particularly in the matter of processed food, so that high price convenience food must have built-in quality.

Potatoes were particularly difficult to assess by quality sampling schemes, however; peas and beans were easier. If a scheme could be devised which provided growers with encouragement as well as penalties this would improve the quality of produce very significantly.

Mr H Stirling (Gunsons Sortex) asked if colour sorting had a significant role to play in maintaining quality standards in frozen food markets. Mr Newman saw this as a very important development — some companies had already begun applying the technique to peas, french fries, carrots etc, and he saw the use being extended in the future.

Mr T C D Manby (NIAE) asked that each of the day's speakers should nominate the areas of investigation and activity which he would most like to see pursued in the near future. Mr Upton wished to see investigations into the economics of production and of spray use. Mrs Knott was anxious for a reintroduction of NIAE tests, particularly leading to a decision on the relative merits of pod pickers and viners. Mr Newman echoed this plea for a reintroduction of comparative testing. Mr King saw the need for more investigation on low ground pressure vehicles. Mr. McLean looked for the development of British machines which would lay polythene film and drill through it. Mr Elvidge saw the need for a satisfactory de-leafer for sprouts.

Introducing something different

IN this issue of THE AGRICULTURAL ENGINEER we offer the first of a series of review articles which will have a strong "practical" flavour. Our objective is to deal with a wide range of topics, at the rate of one or two per issue, in a manner which will be of immediate value to the practising agricultural engineer. Currently available machinery, equipment and techniques will be commented upon in the light of modern farming ideas. This time we feature a contribution by John Mott, of the Norfolk College of Agriculture, on the subject of Growing and Harvesting Sugar Beet.

This addition to the Journal content will not affect the customary inclusion of reports and edited papers from Institution conferences or the increasing number of submitted papers of engineering, scientific and administrative significance which are published. Rather, the number of pages in each issue will be increased slightly to accommodate the additional material.

The Editorial Panel will be pleased to receive members' comments concerning this development.

In immediately forthcoming issues, reviews of the subjects of Tramlining, Irrigation in Britain and Spraying are anticipated.

Editor

Growing and harvesting sugar beet

John Mott

Summary

A BRIEF look at the developments there have been in the growing and harvesting of sugar beet during the past two to three years.

Fertiliser application

In order to reduce compaction of the soil in the spring, there is an increasing number of farmers applying the bulk of fertiliser on the stubble in the autumn. This will usually be a blended mixture of phosphorus, potassium, sodium and magnesium, which is then cultivated into the soil before ploughing.

The nitrogen cannot be applied in the autumn because of leaching. If applied less than two weeks before drilling there is a loss of plant population and it is often impossible to have this two week gap. Horstine Farmery Limited have been doing trials with Brooms Barn Experimental Station and the British Sugar Corporation and it looks as if placement of the nitrogen, either side of the row, either at the time of drilling or soon after, gives the best results, although many farmers are broadcasting the nitrogen after drilling.

Weed control

About 95% of beet is now sprayed with herbicides due to the lack of hand labour. The practice of band-spraying simultaneously with drilling is declining, many farmers band-spraying as a separate operation after drilling. Many herbicides are applied and incorporated in the soil before drilling, others are applied pre-emergence or post-emergence.

Drilling

By 1969 all sugar beet was being drilled with precision drills and by 1978 about 98% of the crop was grown from pelleted monogerm seed, with some 80% of the crop drilled to a spacing of 12.5 cm or over to reduce hand work.

Until recently, drilling speed had been kept to 3-5 km/h because at faster speeds the seeds tend to bounce in the furrow bottom resulting in uneven spacing. At the 1978 Sugar Beet Spring Demonstration, drill performance trials were conducted which showed that the Matco-Fahse Monocentra and Monoair and the McConnel Monosem 502 maintained good spacing up to 8 km/h. The Monoair is a pneumatic drill in that air suction holds the seed on to a cell plate. The McConnel Monosem pneumatic drill did not perform so well. The Standen Tank drill, with a very large cell wheel, also gave disappointing results.

The Rowcrop Department of the NIAE has developed a drill which is capable of maintaining good spacing up to 12 km/h. It is done by realising the seed at minimal height and zero horizontal velocity relative to the furrow bottom, and by pressing the seeds into the furrow bottom.

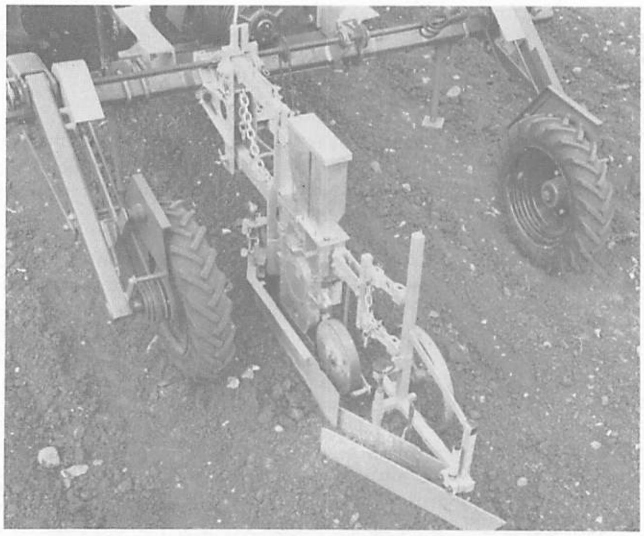
In addition to spacing the seeds evenly, this drill ensures that the seed is deposited in the part of the soil which is best for germination. Dry or cloddy soil is moved to one side and a furrow opened with a non-smearing coulter so that the seed is put into moist soil. The seeds are not displaced during covering. This drill is now being manufactured by David Thomas Limited.

As beet drills become larger, and many farms are drilling ten or 12 rows at a time, it becomes imperative to fit a monitor such as the RDS Planter Monitor. These are fitted in the cab and give instant warning of seed stoppage or coulter blockage.

Wind erosion

In many areas, wind erosion just after drilling can be a problem. Four ways of overcoming this problem have given some success: planting rye between the rows, spreading factory waste lime in March-April, spraying the soil with Vinamul and planting straw between the rows.

The Rye Guard technique consists of drilling rye in a good



The NIAE prototype high-speed precision drill (courtesy NIAE)

seed-bed in late September or early October using a drill adjusted to leave tramlines in which the beet will eventually be drilled. Gaps of 22 cm are left with 50 cm centres with three rows of rye between each gap. In the spring the rye is burned off, using two applications of Gramoxone.

In the Ipswich area, trials have been conducted using factory waste lime to form a crust on the seedbed. The lime is applied in a slurry-like state using a moving floor type of spreader at a rate of 15-17 tonne/hectare.

Elveden Estates in Suffolk have had success with Vinamul, a water-based synthetic resin dispersion specifically developed for stabilising light mineral and sandy soils against wind erosion, but not suitable for high organic soils like the Fens.

The fourth method of combating the wind is straw planting which has been practiced in the Ely area since 1970. Mr Shropshire, of Barway, Ely, and Mr Rice, of Prickwillow, have both developed machines to plant straw and later models are designed to take big round bales. The straw is laid at right angles to the rows and pressed in by a disc. For best protection one row of straw is needed for every five or six rows of beet.

Harvester performance

Before looking at what changes have been made in harvesting equipment it will be as well to examine existing harvester performance. At the autumn demonstration in 1977 an assessment was made on the 20 machines entered.

For output the Moreau 5-row self-propelled harvester was best at one hectare per hour, with one man and the SMC 2-stage harvester at just under one hectare per hour. Single row harvesters averaged approximately 0.20 hectares per hour, although individual machines ranged from 0.14 to 0.27 ha/h. The 2-row machines, the Armer Salmon and the Ransomes Hunter, achieved 0.46 ha/h, more than any of the 3-row single-stage harvesters.

Quality of work was assessed for cleaning efficiency, trash removal and under-topping. The best results were from the single-row single-stage complete harvesters and the worst machines were the five and 6-row multi-stage systems. The Standen Rapide and Cyclone achieved the best cleaning, the SMC and Herriau 2-stage system the worst, but stones may have been partly to blame. Trash removal was best in the two Standen Rapides and Ransomes 33B, these machines also being best at topping. The Standen Rapide fitted with the NIAE topper achieved the highest score.

There was a staggering average root loss of 3.75 tonnes per hectare for the 20 machines. These losses ranged from 1.51 t/ha for the SMC 2-stage up to 5.64 t/ha for the Armer Salmon 2-row. The average for single-row complete harvesters with lifting wheels was 4.7 t/ha while the loss for multi-row machines with share or disc lifter was 2.2 t/ha.

It must be remembered that these results were obtained during a 2-day demonstration when ground conditions were hard and the soil stony.

John Mott, of the Norfolk College of Agriculture & Horticulture, is organiser of the Norfolk Farm Machinery Club.

Types of harvester

There are harvesters to suit all types of farms. They can be one, two, three, five or six-row. They can be trailed or self-propelled. They can be complete or split into two or three stages, sometimes mounting one stage, the topper, on the front of the tractor and a lifter or lifter/loader on the back. Some have a bulk hopper, others need a trailer alongside all the time.

It is interesting to see what percentage of the crop is lifted by each type of harvester. The latest BSC figures available are for the 1977/8 crop and are:

Single row, side elevator	5%
Single row, tanker	36%
Single row, self-propelled	22%
Two-row self-propelled	2%
Three-row	28%
Five or six-row	7%
Others	0.2%

The Rowcrop Department of the NIAE is involved in a long-term research project examining the lifting action of many types of wheels, discs and shares and comparing root losses and soil forces. In the topping project careful and detailed examination of the nature of the crop and the dynamic behaviour of wheel and knife-type topper has led to the development of the NIAE lightweight topper which is now being manufactured by Debat Engineering Co and is offered as an option on some machines. The feeler wheel is light in weight to prevent overtopping. The frame is light to give quick response to varying beet sizes. The knife arm can swing sideways against a spring to prevent blockages. Ransomes have developed a lightweight trailed topper on the 33B with parallel linkage resulting from experience on the Hunter and study of NIAE and other work. The NIAE is now working on a completely new topper but no details are available yet.

Hestair Farm Equipment Limited, who have had much experience as importers of the Herriau multi-row machines, introduced a single-row trailed tanker harvester last autumn, the Whitsed 101. It is a completely new machine suitable for practically all soil types. It has a tank of 2291 kg mounted well forward of the wheels to give weight transfer and a folding discharge elevator to produce a compact transport width. Unique in this size of machine is the use of continental webs and flanged sprockets for the conveyor and elevators. Used in conjunction with nylon strips and rubber covered idler wheels to reduce wear it is remarkably quiet in operation.

The Cougar, a 3-row trailed side elevator harvester was introduced by Armer-Salmon at the 1978 autumn demonstration. It is quick to attach to the tractor, there being only one hitch pin, two hydraulic pipes and two cable controls. The amount of cleaning can be varied by changing sprockets.

The Field and Vegetable Department of the NIAE has developed a completely new cleaner after four years of research. This cleaner has been incorporated in Standen's new 3-row self-propelled harvester, the Stalwart. The cleaner consists of four cylindrical cages 25 cm in diameter, each pair contra rotating inwardly towards a plain oscillating roller. Each cage is made up of 12 spring steel rods 1.6 cm in diameter and 1.5 m long. The rods are located in tangential slots in three support discs equally spaced along the central drive shaft. In use the rods are flung to the outer ends of the slots by centrifugal force. The cleaner assembly is pivoted and a hydraulic ram can alter its angle of slope towards the rear between 5° and 15°.

Beet, clods, stones and trash are fed on to the cleaner assembly and the less dense beet bounce down and off the rear of the cleaner on to the elevator. Soil and trash pass between the cages. Stones and clods push the rods inwards thus being able to pass between the cage and the oscillating rollers. NIAE says that experience during two seasons showed that the increased cleaning capacity of the experimental machine reduced losses and dirt to a level normally associated with considerably easier soil conditions.

A further development on the Stalwart is a defoliator similar to a drum mower. It consists of three turbo-rotors having three auger-type flights with knives at the bottom of each flight. These rotors revolve at 825 r/min, being driven by a hydraulic motor. Leaves are thrown out to the side, a hinged flap controlling the distance. The height of cut is mechanically set on the lift ram and when the defoliator is lifted the hydraulic motor is cut off. A similar defoliator is used on the Rational Nova where the tops are taken up an elevator into a dump box.

Much of the losses in harvesting can be attributed to the lifting wheels going off the row. Several sophisticated self-steering devices have been developed such as the Armer Salmon but recently guide skids have been found to be ideal, simple and foolproof. They consist of twin 4 cm round bars which run down either side of the roots guiding the lifter onto the row. The guides are slightly wider at the front and slightly down at the rear. The leading ends are bent up and out to prevent trash building up. These guide skids have been developed by the BSC in conjunction with Standens who now incorporate them on all harvesters. On the Stalwart the whole of the lifting unit can slide sideways and in addition each pair of lifting wheels can castor. J W Blench sell these guide skids for other harvesters.

As harvesters become larger, and bigger tractors are used to pull them, there is a problem with tyres being too large to pass along 45 or 50 cm rows without pushing beet sideways. The Standen adjustable coupler enables a pair of rowcrop wheels to straddle the row.

As with combine harvesters, function monitors are now being fitted on sugar beet harvesters. The Ransomes Hunter has a three channel unit to indicate to the operator what is happening in areas he cannot see. The Standen Stalwart has two pressure gauges in the hydraulic drive circuit. The operator maintains a speed which keeps the pressure just below pressure relief level so that the harvester works to maximum capacity.

There appears to be a trend from single to three-row systems, but the Moreau importers, Fords (Salhouse) Limited, say that their trend is from 3-row to the self-propelled 5 or 6-row AT64. They

The Armer-Salmon Cougar trailed 3-row harvester

Harvesting both roots and tops from 6 rows at a time with the Moreau AT64 on J D Alston's farm at Kenninghall, Norfolk

sold their first AT64's in 1974. In 1976 they sold two machines and were told by the BSC that there was a total potential of ten machines. However, they sold four in 1977, nine for the 1978 season and to date 11 for 1979 season, making 28 machines working this year.

About a third of their self-propelled machines are with individual farmers, a third with contractors and the remainder with groups of two or three farmers working together. One interesting aspect of these harvesters is that some contractors are joining forces with a transport company and by pooling all their customer's permits are going from farm to farm shifting huge quantities of beet in the most economical way.

There have been three developments in the Moreau AT64 recently. The digger chain has been replaced by two extra turbines to give better cleaning and less wear and the side elevator chain has been replaced by a rubber continental webb, again reducing running costs. A new optional feature is a variable speed hydraulic drive to the discharge elevator which is set just fast enough to clear the beet. It is a help when changing trailers; the harvester still has to halt but the driver can leave the defoliator, lifter and first stage of the loader running so that he can get going again much sooner when the trailer has been changed. When turning on the headlands, everything can be left running except the discharge elevator.

Sugar beet tops

According to a BSC survey in 1977, 75% of tops were ploughed in, 18% fed in situ, 6% carted off to feed and 1% dried or ensiled. If tops are to be removed it is best if they can be loaded directly and not put down on the ground or they will be contaminated by soil particles. Both Standen and Moreau sell lacerater blowers fitted to their defoliators. Several makes have elevators taking tops straight into trailers direct from the topping unit. Some farmers are loading with self-loading wagons.

Transport and loading

With the higher capacity harvesters large trailers are needed. These usually range from ten to 15 tonnes and if fitted with the large single balloon wheels are easier to pull than the tandem axle trailers with smaller wheels. It is important that these trailers are fitted with hydraulic or pneumatic braking systems if they are to travel on a public road. Tapered trailers are easier to empty.

Forklifts and loading shovels are being used more and more for loading beet. Ideally, the beet should be stored on a concrete pad and be loaded through a cleaner of some sort to remove soil. As lorries and trailers become higher there is a need for a greater reach on loaders and cleaner elevators.

Many farmers this winter had to cart their own beet to the factory because of the lorry drivers strike. We could well see farmers doing more of this in the future.

World meeting of agricultural engineers

THE 9th International Congress of Agricultural Engineering (CIGR, *Commission Internationale du Génie Rural*) is being held 8-13 July, at Michigan State University, East Lansing, Michigan.

Scientists and researchers from around the world will present more than 130 technical papers related to current agricultural engineering advancements. Session topics include presentations on soil and water, agricultural structures; agricultural machinery; electricity utilization and management of farm routines.

All technical presentations representing 36 countries will be available. The sessions will be simultaneously translated in French, German and English.

CIGR Congress details may be obtained by writing to: CIGR, Agricultural Engineering Department, Michigan State University, East Lansing, MI 48824, USA. Those who wish to also attend the ASAE meeting should write to: American Society of Agricultural Engineers, 2950 Niles Road, St Joseph, MI 49085 for details.

Letter to the Editor

A call for hard data – As a basis for design work in LDC's

IN Volume 33, No 2, of The Agricultural Engineer the main feature was a report of the conference, "Are small tractors appropriate", held at Silsoe in March 1978. It will seem odd to many members that the TRANTOR tractor was not mentioned nor discussed. It is surprising, therefore, to find that agricultural engineers at ICRISAT, India, Institut Kirilo Savic in Yugoslavia and at Tinkabi in Swaziland are producing work which largely points away from conventional agricultural tractors. Furthermore, a paper was given at the 1978 Power Farming Conference by John Lawton, formerly of ICI and now in Saudi Arabia, which called for a transport tractor and which severely criticised modern tractor design. Dr Von Oppen at ICRISAT, India, states "tractors as they are cannot be expected to contribute to development and food production in India". Furthermore, R Thillainayagam in a contribution, "Role of Road Transport in Rural Development", states "without farm to market transportation it has not been possible to make the shift from subsistence farming to commercial agriculture".

I have looked carefully at the papers presented at the Spring national conference and the conclusions seem to vary from, "each situation should be viewed on its merits", (Kilgour); "but conceptionally all development projects commence with the problems and potential of the individual LDC farmer and farm", (Pollard and Morris); "a much more elastic country by country approach is indicated", (C G Cattermole); etc, but in no case is there a recognition that improved vehicle use statistics are needed to help the designer. The Mexican contribution recognised their absence and the availability of inaccurate data in that country, but there was no call for a statistical basis of tractor use at the conference.

Whilst at Manchester University, some of my research students were rather appalled at the absence of user statistics about British farming and so collected some about tractors, Land Rovers and trucks on different kinds of farms in UK. Mr W S H Taylor's thesis (Faculty of Technology) was examined by Claude Culpin, a most eminent researcher as far as the agricultural engineering profession is concerned, and seems to have disappeared without trace. I can find no reference to that work which seemed to me then, and seems more to me now, to be generally useful and specifically useful as a reference point against which to develop more useful work in respect of tractor and farm equipment design.

It is not my intention to state that the TRANTOR is or is not a contribution to LDC rural development since my views are quite obvious, and the reason why I am chairman of the TRANTOR company! What is important, if we are to continue to try to lead the world in design concepts, is to present data in support of LDC arguments of a scientific kind. Far too much time, it seems, was spent on ploughing and cost and price based criteria and too little on transportation, rural development and collectivisation.

When the whole statistical picture of food production "from seed to mouth" is examined, I suspect that the current agricultural tractor will have a place but one about half as big as current world productivity capacity.

I should like to think that the excellent work of ICRISAT and Professor Micic in Yugoslavia is known in UK and used at the next conference in the series planned in connection with developing countries.

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3 Towers Close, Poynton, Cheshire.

THE TRANTOR is not a small tractor and so was not considered at the conference. "Vehicle-use statistics" as a term was not perhaps mentioned but some of the speakers implied that improved information was of vital importance, I agree with the comment that perhaps too much time is spent on ploughing but other workers, notably R Wijewardene, have not yet managed to show conclusively that there are real alternatives.

Perhaps progress could be made by some of the LDC's collecting the relevant information so that those able to develop the design concepts have a better chance of proposing a feasible solution.

John Kilgour