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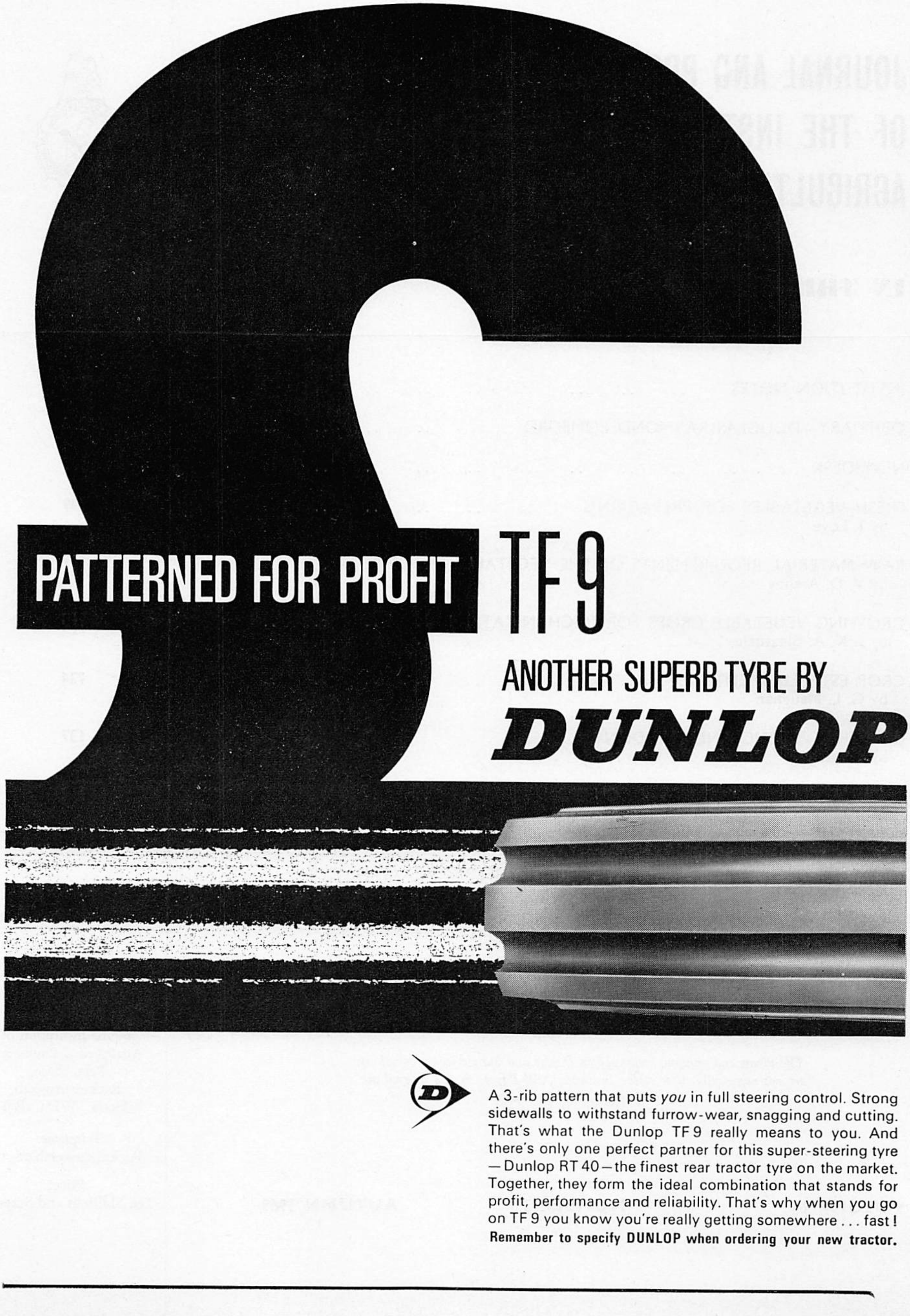
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INSTITUTION NOTES

Winter Solace

After the long, hot summer, thoughts turn once more to the long, cold evenings! Colour television may not fill them all, especially those on which the Institution will be holding its lecture meetings, technical visits, social occasions and the many other events that form the myriad pattern of I Agr E activities all over the country.

All members should by now have received their Winter Session Booklet giving details of seasonal fixtures right through to May 1970. The booklet has been designed to fold into the back of the Membership Diary, so that dates of special interest can be easily and quickly reserved.

It is not always realized that a member is entitled to attend *any* meeting listed, and not just those in his own Branch. Thus, if a member on the move finds himself one night in a town where an Institution meeting is taking place, his attendance will be not only legal but also very welcome.

A lot of work has gone into the country-wide programme. The organizers make nothing out of it except the satisfaction of seeing a meeting well attended and its mission accomplished. It is only the membership at large who can make that happen. Every member should make the effort to support his own Branch activities, not forgetting the opportunity to bring along his professional, non-member friends and colleagues. Some of these guests may well end up wondering why they are not members of the Institution and feel encouraged to do something about it.

Ergonomics Anyone?

A specialized subject, admittedly, but one which got the Institution's national season off to a lively enough start on 4 September. Under the general title of 'Ergonomics in Agriculture' four papers and a discussion forum comprised the programme of the Institution's Autumn National Meeting at Loughborough University. Content ranged over workload assessment in agricultural tasks, some studies of combine-harvester operation in Holland, worker-training and the development of operational skills, and quality inspection of horticultural produce.

The comment has been heard that this meeting went a long way to clarify existing knowledge of this difficult topic. This is a tribute to the Convener, John Matthews, of NIAE, who accepted the formidable task of putting the programme together and nursing it to fruition. It is hoped to publish most of the proceedings in the Spring 1970 issue of the *Journal*.

Togetherness

It helps to have friends. Especially when it comes to the hefty business of running full-scale conferences.

There are two big occasions coming up in 1970, where the Institution is happy to be in joint harness with other organizations. The first will be our Spring National Meeting on 25 February which is being run in association with the Electricity Council, itself an Affiliated Organization of the Institution. EC will be gathering most of the material for the programme under the general title 'Automation in Farming'. It should have a direct appeal to a widely-based audience from the Institution and elsewhere. More details can be found on page 106 of this *Journal* and in the current Winter Session Booklet. Further announcements will follow.

The second joint occasion in 1970 will be in October when I Mech E and I Agr E are to hold a two-day symposium in London on light tractor development. It's too early yet to give precise details but it is known that the Working Party, under the chairmanship of Dave Manby of NIAE, are well advanced with arrangements for an ambitious, mammoth programme of truly international flavour and appeal.

Talking of I Mech E, it is worth noting that our Institution will again be using their premises for the Annual Conference ('Cultivations'), the Presidential Address and the AGM, all on 12 May. The Annual Dinner will take place that evening at St Ermin's Hotel, London.

Talk Talk Talk

Like President Nixon, the Institution has a large, silent majority. Your opinion is wanted.

In 1969, the *Journal* has introduced several new features such as 'Newsdesk' and 'Branch Notes'. In 1970, it will appear completely re-styled, with scope for even further editorial treatment and diversity of content. What would members like to see more of or less of? Write to the Hon. Editor, c/o the Institution. One of the new features in the *Journal*, incidentally, will be a Viewpoint section, which will publish correspondence from members, where the views or opinions expressed could well be of interest to the membership at large.

OBITUARY

DOUGLAS RAYMOND BOMFORD

Past President and Honorary Fellow of the Institution of Agricultural Engineers

Douglas Bomford, of Bevington Hall, Evesham, died on the 23rd September, 1969 in the London Hospital, at the age of 75. Educated at Mill Hill School and Wycliffe College, Glos., he was studying medicine at Edinburgh University when at the outbreak of World War I he was commissioned in the 2/8th Battalion, the Worcestershire Regiment which, after a period of defence duties on the East Coast, went to France in May 1916. He was twice wounded, thus acquiring a permanent disability which he bore with the indomitable courage which he exemplified throughout his life. After the War he renounced his medical studies to follow the family tradition of farming coupled with agricultural contracting.

His grandfather, Benjamin Bomford of Pitchill, near Evesham, was a 19th century pioneer of steam ploughing and large scale farming, and later his sons Raymond (Douglas Bomford's father) and Benjamin firmly established the family business of R. & B. Bomford, which Douglas joined in 1918. In addition, in conjunction with Harry Evershed, they had earlier founded the well-known company, Bomford and Evershed Ltd., famed for steam rolling and dredging, which has since become an important manufacturer of agricultural implements—the result of Douglas Bomford's engineering skill and foresight over many years. He retired from business in 1967 having merged his own company, Bomford Bros. Ltd., with the Bomford and Evershed enterprise.

An unassuming man of great personal charm, yet endowed with iron integrity, determination and extraordinary vision, Douglas Bomford's influence profoundly affected the course of the agricultural industry in this country. In August 1927, when the financial situation of farmers was critical and corn growing unprofitable, he wrote and published a book entitled 'Corn in England' which explains in clear and simple terms the causes of and remedy for the unprecedented situation which existed at that time. His conclusion that the problem of rising costs and diminishing returns could be met only by increased output, improved productivity and the correct and efficient application of mechanization is as valid today as it was 42 years ago. In 1930, realizing that the days of the horse and steam tackle were numbered and that they would be superseded by the tractor, he began to devote his inventive brain to the design of implements to make the fullest use of the new motive power, and it is perhaps in this sphere that he made his greatest contribution.

He may well be best known for his work on the multi-furrow reversible plough—he made a scientific study of mould-board and skim design, and was convinced that good farming started with good ploughing. He worked closely with the late Colonel Philip Johnson of Roadless Traction on the perfection of the half-track tractor as a cheaper and no less efficient version of the crawler tractor, and in conjunction with F. W. McConnel he invented the 'harvest thresher' which removed the grain from standing corn leaving unbroken headed straw in superb condition for thatching and other uses. It was an ingenious low-cost machine designed to meet the needs of the small farmer. One of these machines has pride of place at the National College at Silsoe.

Typical of his advanced thinking was the Bomford Midget Tractor, based on the Morris Cowley engine and chassis, which was introduced about 1930. It featured fully mounted implements and retracting strakes, both of which could be controlled from the driver's seat with the tractor in motion. He invented many other aids to agriculture and horticulture—these included hedge and grass verge cutters, transplanters, irrigation systems and

Please turn to page 151

NEWSDESK

New Horizons for the Engineering Profession?

Rationalization of Qualifications and Titles for Engineers

The Council of Engineering Institutions (CEI) convened a special meeting of its Board on 4 September 1969 to discuss the establishment of a registration organization for qualifications and titles at all levels in the engineering community.

At this meeting the following resolution was passed unanimously:—

> "The Council of Engineering Institutions will, in collaboration with other interested parties and subject to the agreement of the Privy Council, initiate the formation of an organization to create and administer a composite register covering the principal sections of the engineering community, currently Chartered Engineers, Technician Engineers and Engineering Technicians"

It was further agreed that a Working Party, consisting of one representative from each of the fourteen Institutions within CEI, and under the Chairmanship of Sir Arnold Lindley, would be set up forthwith to implement the resolution, and its first meeting would be held at an early date.

The first duty of this Working Party will be to prepare a submission to the Privy Council to get agreement to such modifications to the CEI Charter and By-laws as may be necessary and then to determine which other interested parties should be invited to collaborate.

Sir Arnold Lindley is Immediate Past President of The Institution of Mechanical Engineers and Chairman of the CEI Membership Committee. Sir Arnold became Chairman of the Engineering Industry Training Board when he retired as Chairman and Managing Director of GEC in 1964.

Commenting on the above proposals, Mr R. Gresham Cooke, CBE, MP, Chairman of the Standing Conference for National Qualification and Title (SCNQT) comprising 41 organizations said: 'I am sure the Standing Conference for National Qualification and Title which over the past 20 months has been working towards the establishment of nationally accepted titles for Technician Engineers and Technicians, will be pleased that the CEI agrees with what the Standing Conference has been advocating—namely the setting up of a separate organization to create and administer a system of qualification and title. The Conference will be pleased to collaborate with CEI in the terms of the Resolution passed by the Board of CEI as a follow-up to the talks which have already been held between the two bodies.

Another important result of the work of SCNQT and its specialist committees (a notable feature of which has been the ample opportunity given for consultation between member organizations' representatives and their Councils) is the general acceptance of the Higher National Certificate and the City and Guilds of London Institute's Full Technological Certificate, as the technical awards appropriate for a qualified Technician Engineer—a title adopted not only by SCNQT but by CEI, Mintech, Industrial Training Boards and many more. Added to these technical educational requirements are firm stipulations on training and superior experience. Appropriately lower levels will need to be established for Technicians.

All this can be regarded as a major achievement for SCNQT. The exercise spanned a widely diversified field of engineering interests—from agriculture to quarrying, building and lighting, automobiles to welding—with all manner of titles, qualifications and standards for entry and grading of members.

There is plenty of evidence that the 95,000 Technician Engineers that SCNQT represents, will welcome a national title. Now everybody must work together towards a common goal which, when reached, should prove of inestimable benefit, not only to engineering but to the country as a whole.'

I Agr E has been a member of SCNQT since its inception, and has been represented throughout by the Institution Secretary, Jon Bennett. He has also served on the Qualifications Sub-Committee of SCNQT, which had the task of drafting criteria for nationally acceptable standards of academic attainment, training, experience and responsibility that might be expected to apply to engineering technicians throughout industry.

The Institution is well-placed on behalf of the agricultural engineering sector to take full advantage of whatever common title and qualification is agreed. The revised Member grade (MI Agr E), with its emphasis on diploma-level attainment and ability is ideally tailored to the proposed national arrangements and paves the way for the Institution to become the registering and sponsoring authority for the agricultural engineering community.

Much remains to be done and further announcements can be expected soon. A full report will appear in further 'Newsdesk' features.

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FRESH VEGETABLES FOR PREPACKING

by

JOHN LOVE B SC*

Presented at the Annual Conference of the Institution in London on 15 May 1969

SUMMARY

The self service system of retailing fresh vegetables in supermarkets, involving prepacking, has led to a better knowledge of the consumers' preferences. This knowledge can now be used to give guidance to the grower on what to grow, how to grow it, when to grow it and to some extent on how much to grow.

The requirements of prepacked vegetables are that they should be fresh, of good quality, clean and attractive appearance, free from diseases, rots, mechanical damage, and with a minimum of waste. Rootcrops are generally of smaller root size than normally accepted on the wholesale market and this has meant new sowing and harvesting techniques aimed at high plant densities to give adequate yields, and mechanical harvesting to overcome the shortage and expense of hand labour. Hand harvesting of other vegetables, also, is becoming more difficult and expensive but the introduction of mechanical harvesting will require more uniform crops, and a high degree of growing skill. Examples of how individual crops are being grown and managed to meet the housewife's requirements are given.

Two major problems emerge from mechanization, namely the increased amount of damage resulting in the crop leading to higher wastage, and the vastly greater harvesting capacity requiring the short-term chilled storage of the harvested crop.

CHANGES IN MARKET REQUIREMENT

The self service system of retailing of fresh vegetables involving prepacking into units of retail sale has led to a better knowledge of what the customer prefers. She is able to choose the size and type of vegetable according to her needs or tastes. This knowledge can then be passed down to the grower almost direct, and guidance can be given on what to grow, how to grow it, and to some extent at least, on how much to grow and when to grow it. This information can also be passed on to the plant breeder and seedsman so that new varieties can be developed to meet these needs.

What then are these requirements, as we see them, in the light of our experience in our shops? The produce must be of the right quality and size range, there must be a good and adequate supply with continuity and the price must be fair, to both consumer and producer.

* Horticulturist, J. Sainsbury Ltd.

Quality is hard to define but might be summed up as having freshness, and a good clean attractive appearance, being free from pests, diseases, rots, taints and mechanical damage, and last but not least, having good, or at least acceptable, flavour, an important criterion if future sales are to be maintained. The size range of root crops are generally smaller than for the wholesale market, firstly because of consumer preference and secondly because of the requirements of prepacking in smaller units of 1 lb and 1.5 lb weight.

An evenly graded pack adds to sales appeal; there is the suggestion that cylindrical carrots packed in line may sell quicker than jumble packs of stump rooted carrots. Small size can be taken too far, however, for the housewife soon objects to scraping or peeling very small roots. On leafy crops large cabbage, of over 4 lb and Brussels sprouts greater than 2 in. diameter are slow sellers but good medium to large cauliflowers are in demand. Nevertheless, although the aim should be to grow the crop with a high proportion of the popular size, we know and you know that it is impossible to get all the crop that size so we have purposely made our specifications to cover a reasonable range of sizes and weights in order to take as much of the crop as possible, at the same time offering the consumer a choice according to her needs.

Continuity of supply is important in that we require to keep our displays filled and from the long-term sales point of view, when the housewife fails to find the fresh produce she wants she will go to the frozen food or canned alternatives or even do without.

The town housewife is even further alienated from the country than her mother and she is not particularly concerned if frost, snow, flood or drought has made your job even more difficult and costly in providing the supply and quality of fresh vegetables. She is not even aware in many cases of the crop seasons in that she can buy celery for nearly twelve months of the year, and there are many other crops which we can sell over a far longer period than traditionally. Continuity of supply can be obtained by cultural techniques such as successive drillings and the use of varieties of differing maturity or by storage, involving strawing over of crops in the field, clamp or barn storage of harvested crops or the use of chilled stores for short term buffer stocks or long term storage to extend the season. Another aspect of this continuity is that packing sheds are kept operating over a longer period, overheads are reduced and labour more easily retained.

CONSIDERATION OF PARTICULAR CROPS

Beetroot: Small sized roots, 1.25-2.25 in. in diameter are ideal. A high plant density is required to obtain this size range and an economic yield. Herbicides used as band sprays have made this possible, but 14 in. rows are still needed for mechanical harvesting. For prepacking this crop is sold as a cooked, peeled and dipped table-ready product.

Carrots: While stump rooted types such as Chantenay are still important the cylindrical types such as Amsterdam, Nantes or Berlicum are gaining in popularity. The Amsterdam or finger type is a specialized crop which requires the right soil type and a high plant density to obtain root sizes of 20 to 30 to the lb compared with the 4 to 6 roots per lb of large Ware type carrots. Harvesting of such small roots is difficult, but is now almost fully mechanized in Holland using rows 2-3 in. broad or double or treble rows grouped together.

Parsnip: Precision drilling of pelleted seed looks promising as a technique to obtain good, uniform roots to give 4-6 to the lb; this is much smaller than the traditional market requirement. Careful lifting and handling is required for this crop as it bruises easily.

Radish: This is only a small crop but with some potential as a salad ingredient. We will not reach the scale of production seen in the U.S.A. but even so, a crop like this well exemplifies continuity of production by successive sowings and the possibilities of mechanical harvesting, topping, grading and packing.

Leeks: The necessity to offer the housewife an article with as little waste as possible is well shown in this crop. The bulky, inedible foliage is trimmed off and varieties capable of giving 8-10 in. stems when direct drilled are now being used.

Mechanical harvesting has taken much of the back-breaking work out of lifting, but we are still faced with high labour costs in cleaning and trimming. This high cost of preparation also applies to salad onions, for which there is an unsatisfied demand. Ideally 4 to 6 leeks per 1 lb pack are required.

Celery: Good quality, 16 oz sticks; clean and trimmed of roots and extraneous foliage and outer petioles, are required. Direct drilling is being practised with variable success, and field celery can now be mechanically harvested. But, once again, there is a high cost of preparation which machinery will only partly overcome. A 12 month demand is probably present, although at the moment good home supplies only exist for about 6 months in succession.

Cabbage and Cauliflower: Basically the problems of these two crops are similar, with cauliflower being the more difficult. Continuity of supply and uniformity of crop are two vital aspects. Direct drilling and the use of F_1 hybrids, although the seed is expensive, will probably be normal cultural techniques to give uniform crops which can be mechanically harvested and handled into bulk bins, using the Universal type harvester. Standards of husbandry will require to be high to give continuity of cabbage with heads weighing 1.5 to 2 lb and cauliflower of 4-6 in. curd diameter. The very high rate of mechanical harvesting will also require some form of refrigerated short-term storage, which is made doubly necessary by the uneven weekly pattern of demand because of the peak 'end of week' shopping habits.

Before leaving cabbage, however, mention must be made of the white storage cabbage, invaluable for the winter and spring trade, and cabbage greens, now no longer 'spring greens' to us because of their virtually 12 month consumer demand. But in both cases quality must be good.

Brussels Sprouts: Mechanical harvesting is with us and the closer plant spacing of 21 in. and 24 in. square are supplying the 1-1.5 in. graded sprout without too much of 0.75-1 in. baby sprout, or the 1.5-2 in. larger sprout. This large sprout is still in demand and is in fact smaller than many of the traditional Bedfordshire market sprouts. F_1 hybrids, direct drilled and mechanically harvested, are promising, but one great problem remains in that such methods only give us good regular supplies from September to the end of January at the latest. More work is needed to obtain varieties or techniques which will give us mechanically harvestable sprouts, without undue waste in the form of loose, blown and slimy sprouts.

THE PROBLEMS OF MECHANIZATION

1. Mechanical damage is often too high, especially in roots and potatoes.
2. The once-over harvest technique is often contrary to our requirements in that all the crop, good, bad or indifferent, is harvested and requires further grading and trimming. This aspect of mechanization appears to be neglected.
3. Mechanical harvesting will require the crop to be cut at its optimum time, which will not necessarily be the time of highest consumer demand, so short-term storage will be required.
4. Cultural techniques will require to be of a very high standard and crops will have to be restricted to those soil types or areas for which they are most suited. There will need to be greater specialization of production.

Lack of labour has meant the virtual disappearance from the market of good quality green peas in pods and fresh dwarf french beans as the processor can offer a mechanically harvested alternative. Other fresh vegetables could go the same way unless a continuity of supply of good quality can be provided.

ABSTRACT OF PAPER

'Fresh Vegetables for Prepacking'

Prepacking into units of retail sale for self service shops and supermarkets has brought with it greater knowledge of consumer tastes. To meet these preferences growers and packers will require to supply the right size and quality of produce with continuity. What is required and how it is being achieved at the moment is described for a range of row crops vegetables. The problems of mechanical harvesting and the need for adequate grading and storage is stressed.

RAW MATERIAL REQUIREMENTS OF THE VEGETABLE PROCESSOR

by

V. D. ARTHEY, M SC, PH D*

Presented at the Annual Conference of the Institution in London on 15*May* 1969

The raw material requirements of the vegetable processor would not be a difficult subject to deal with if it were simply necessary to state the characteristics required in such material by canners and quick freezers. But inevitably the word quality must creep into such a topic and as soon as this occurs the whole subject becomes a debatable one because the term quality is interpreted differently by as many processors as there are available to discuss it. It is for this reason that the subject is not as easy as it sounds. Nevertheless quality of raw material as a basic requirement of the processor is vitally important since the canner and quick freezer relies on excellence in his raw material to ensure a high quality final product. However good the process and handling in the factory might be, no processor can produce an article of high quality from inferior raw material.

Levels of Quality

The Oxford dictionary describes quality as indicating a 'degree of excellence' but this is only one aspect of its interpretation since the term is also relative. Many processors will consider that their products are superior to those of their competitors and such products are described as being of better quality. This leads us to consider the various aspects of quality by which products can be compared with each other in certain measurable respects. Quality assumes a different meaning according to the point at which it is applied in the succession from seed purchase through sowing, crop management, harvest, transport, factory operations and processing to inspection of product quality, and the attributes looked for in the raw material will differ from those assessed in the final product even though they are all closely related.

The grower is interested in ease of management in the field, production of high yield within the specifications provided by the processor, and suitability to mechanical harvesting. The processor on the other hand, is interested in those attributes which make his pack attractive and acceptable to the consumer; for example, attractive appearance, pleasant flavour, agreeable texture, and an absence of defects.

Whilst the processor might not consciously accept the fact, he recognises three broad levels of quality in the raw material. The first can be called *maximum quality*—This is the quality of the raw material which will give the processor the opportunity to produce the very best possible product without regard to raw material production costs, other conditions such as those of processing also being maximum. It is of course, totally uneconomic for any commercial processing to be carried out along these lines but the ideal may serve to assist the processor in indicating the heights of quality which his products might achieve under constantly improving methods of production. It also enables him to process from time to time those products of exceptional quality which he needs on special occasions. Certainly some products imported into this country may approach these standards but usually this is only because the Government of the originating country sees fit to heavily subsidize such exports, no doubt for political reasons.

Optimum quality is a much more realistic level to achieve and by this is meant the production of the best quality product from raw material which has been produced with some economic advantage to the grower. Optimum quality is the best practical answer for both grower and processor. It prevents vegetables from becoming too tough to be acceptable for processing and prevents the processor from persuading the grower to harvest before any yield advantage, and thus financial return, becomes apparent. It is not, however, an easy state to define since the many advantages, such as quantity, to the grower are not similarly related to the quality advantages to the processor. In vegetables the two most important attributes that are employed to determine optimum quality are nearly always maturity with yield versus product texture. In most of the quality work carried out at Chipping Campden, it has been found that texture of the final product is one of the most rapidly changing qualities when related to rate of maturity of the crop in the field. As vegetables mature so they toughen and at very immature stages they may produce high quality processed foods, but it is not a viable proposition for the grower to

* Agricultural Adviser, Fruit and Vegetable Preservation Research Association.

produce and harvest them at this stage. Thus, some loss of product quality has to be sustained to allow the maturity (and consequently the yield) to develop to favourable economic proportions. This stage can be pre-determined and in many crops can be measured on the raw material. Thus with peas, canners require their raw material at a tenderometer reading of 120 (freezers at 100) which corresponds to a yield of 87% of maximum and produces a product with a texture value which is only 80% of that which could have been obtained had the crop been harvested at maximum maturity for canning. A similar procedure is now being developed for broad beans now that this crop can be harvested mechanically.

Although optimum quality is the aim of all growers and processors, it is not achieved regularly in practice. Certainly this is true of conditions in the United Kingdom where extremes of weather are often such that when a crop has reached optimum maturity it cannot be harvested because of inclement weather. Similarly favourable weather conditions may cause many crops to ripen simultaneously and the processor is unable to cope with an over-abundance of raw material. Thus the majority of canned and quick frozen products are processed at stages which are not optimal for each particular fruit or vegetable.

The third broad level, therefore, can be described as *acceptable quality* and this may be defined as a measure of the limits by which the raw material may deviate from optimum quality without sufficient impairment of product quality to render it sub-standard or unacceptable. These limits will vary from processor to processor and depend very largely on season. Thus processors with high standards of quality will insist that their raw material deviates only slightly in certain attributes from the optimum whereas those following a more liberal policy of quality control will allow a greater deviation from the optimum. The effect of season can be very marked; years in which the supply of certain raw materials is scarce will necessitate greater limits of acceptability to allow the factory to meet its production target and in such years there is always a danger that to achieve full production the limits of acceptability may be so widened that the selling power of the product is minimal.

Acceptability of Material

The limits of acceptability for any factory should always be carefully fixed for each vegetable according to the factory's capacity to handle material of inferior quality. The more the raw material deviates from the optimum the greater the attention required in the factory and the situation rapidly arises where material of such quality becomes uneconomic to handle. Sometimes for special reasons, this does not stop the factory from accepting such material but the decision to continue handling an uneconomic sample of raw material is a policy one and taken at high level.

The limits of acceptability should be defined in the contract relating to all crops coming under this method of negotiation between grower and processor. This enables the grower to determine the processor's intentions and assures the processor that the grower is encouraged to meet the specifications as nearly as possible. For example, in the case of peas grown under contract, the highest prices are paid for those peas which are harvested nearest to the stage of optimum maturity and progressively lower prices are paid for peas which deviate more and more from the optimum. Conditions other than maturity will also apply, of course, especially where vined peas are delivered to the factory from the grower or growers co-operative.

Not all crops are grown under contract however, and here the limits of acceptability are defined in the specifications for each crop by the processing companies concerned; specifications for carrots, for example, will lay down the percentage of roots affected with certain physiological disorders which are permitted in any one consignment. If the percentage of affected roots is greater than the specification permits then the acceptance of the load becomes a matter for negotiation.

To summarize at this point, *maximum* quality is an ideal which, although attainable under perfect conditions, is not acceptable for economic reasons and is rarely achieved in practice. *Optimum* quality is to be sought since this can be achieved with economic success in the United Kingdom and gives results which satisfy both processor and grower. *Acceptable* quality is a measure of the limits to which each processor is prepared to go before he rejects a sample as unsuitable or sub-standard.

The term quality can equally apply to the performance of the crop in the field and again is relative since in any one crop, varieties, areas and methods of production will cause variations in raw material. It is not the purpose of this paper to deal specifically with this aspect of quality although it should be clearly understood that all processors are well aware of the fact that the raw materials they use should possess advantages in the field such as high yield and ease of production and that there are in fact items which render a variety suitable or unsuitable for processing.

It is now necessary to pass from the broad discussion of quality and to examine in more detail what the vegetable processor is seeking in his raw material. The items of quality which each processor will look for will vary considerably from company to company and vegetable to vegetable but can be collected together under five major headings: colour, flavour, texture, absence of defects and size grading.

The major vegetables packed by processors in the United Kingdom are processed peas, garden peas and carrots and these will be considered in the second half of this paper in relation to the five broad attributes of quality indicated above.

Texture

It has already been intimated that texture is one of the most important quality items of any vegetable for processing and is the one which will be paid most attention by the processor in relation to his final product. Vegetables are tender when immature and toughen the longer they are allowed to remain in the field, thus time of harvest is a very important consideration in relation to this item. In many vegetables, the correct stage at which the crop should be harvested is not clearly defined but in others, the determination of effect of maturity on quality has received much attention by research workers. The crop to which most attention has been paid is the garden pea, for which the tenderometer is used to determine when the crop has reached the correct stage for either canning or freezing. Whilst tenderometer readings of 120 and 100 indicate optimum maturity for these two processes respectively, acceptable maturity varies considerably from these two points on the tenderometer scale due to erratic weather conditions and the need to maintain production in the factory at what is one of the busiest times of the year. Thus peas may be accepted for canning from 90 up to as high as 150; samples from the higher readings often being used for second grade packs.

The tenderometer is also used to determine the texture of broad beans for canning. Recent work at Chipping Campden has indicated that optimum maturity for this crop occurs at a tenderometer reading of 140 but it is recognized that some manufacturers prefer to can more tender beans at readings of 120-130 and others, claiming that the consumer prefers tough beans, uses samples with a tenderometer reading of about 160 or more. The use of a tenderometer for the broad bean crop has become important since the advent of mechanical harvesting which has meant that, instead of a range of several days being necessary to hand pick the crop, a mechanical harvester can handle several acres per day thus requiring a more accurate determination of time of harvesting.

The broad bean and the garden pea are vegetables which are shelled from pods and their texture can be assessed adequately by the tenderometer. Other vegetables toughen in other ways and the toughening effect of maturity is not readily detected by such an instrument. The method used for broad beans and garden peas cannot be used for dwarf beans and here, one of the best estimates of the rate at which the crop matures is the linear growth of the seed within the pod. This method can give a fairly accurate determination of pod quality providing that sampling of the crop is carefully carried out. Optimum maturity for canning and freezing occurs when the seed length, taken from the most mature seeds from the most mature pods, reaches approximately 8 mm and 10 mm for freezing and canning respectively depending on variety. Needless to say, beans are often harvested at more mature or more immature stages than this but nevertheless still yield pods which are within the acceptable range of maturity.

Texture of immature potatoes for canning is measured practically by yet another parameter—that of specific gravity. This method is designed to ensure that tubers do not crack or disintegrate on canning. It only requires a single potato to suffer from breakdown or complete disintegration to cause a serious deterioration in product quality. Many varieties of potatoes become unsuitable for canning as they mature due largely to the increase in dry matter content of their tubers. The specific gravity above which potatoes may not be acceptable to the canners is 1.075. This is contrary to the requirements of the frozen chip manufacturers where the specific gravity should be above 1.075. A high dry matter content (high specific gravity) is also required for production of dehydrated potatoes and crisps.

Texture of carrots in commercial packs is not a very variable factor although season and variety can have their effects. The best carrots are canned before Christmas and in the New Year some samples tend to become spongy and soft. Unsuitable stocks of carrot seed may lead to excessively firm textures.

Colour

This aspect might be described as the most important *initial* effect of quality on the consumer since it is by the appearance of the pack of vegetables that many products are sold. This applies particularly to frozen products in transparent packages but also has an effect in canned food where the housewife on opening a container will accept what she sees or throw the product away and not buy that brand or vegetable again.

As with texture the requirements of each processing method differ. One of the most obvious cases is the garden pea where pale-seeded varieties are preferred for canning and dark-seeded ones for freezing. This is very much a varietal characteristic and where possible canners will contract for pale-seeded peas such as Surprise, Dart, Canners Perfection etc. The canner, however, wishes to process peas continuously for the whole of the short concentrated season and will not always be able to obtain pale-seeded varieties for the six week period. He then has to choose the most suitable intermediate or dark-seeded varieties and thus, Sprite, Lincoln and even Dark Skinned Perfection are canned. In fact it appears that more dark-seeded peas than light ones are processed in the United Kingdom at the present time.

The freezer can only use dark-seeded peas for his pack since, unlike canning, no artificial colour is added and the attractiveness of the product relies entirely on the natural colour of the peas.

The broad bean is another vegetable where the selection of the correct variety is important especially in canned foods. Most varieties contain a chemical which causes beans to turn brown on canning and, of course, such varieties must be avoided for this purpose. It is for this reason that the variety Triple White is the most widely used broad bean for canning because it does not contain the offending chemical; a few other varieties are also suitable. The problem is not so acute for freezing and sometimes varieties of broad beans unsuitable for canning are used because of their better flavour.

The same problem arises in dwarf beans, but to a lesser extent. In general, only those beans with white seeds are used for canning or freezing. The coloured seeds of some bean varieties not only cause the product to appear a little patchy but the presence of the chemical may turn the brine cloudy. This applies in particular to runner beans, where scarlet runners should never be used for canning. For freezing of dwarf beans, the problem is not so great because the beans are harvested before the seeds have coloured, and there is no brine to become cloudy.

The colour of the carrot is one of the reasons for its great popularity in the United Kingdom being a most useful second vegetable and particularly attractive to children. The colour of the carrot should be fully developed—immature carrots are sometimes too pale for canning. A deep bright orange is required after canning and the ability of a sample to produce a good coloured product depends very much on the selection of the right seed stock from a reputable seed-house. Carrots grown on sandy soils are said to be better coloured than those grown on peats.

As with the foregoing vegetables, the colour of immature potatoes depends on variety. Some potatoes yield tubers which have a white flesh and are consequently unsuitable for canning. A bright cream colour is associated with home cooked new potatoes and new potatoes for canning should resemble these in colour. Suitable varieties are Maris Peer and Royal Kidney. For dehydration white fleshed varieties are used and the colour of frozen potato chips and potato crisps is directly related to the reducing sugar content, which, if too high, will cause both products to become too dark.

Flavour

This is the most personal and subjective aspect of quality and is the most difficult to judge. All products should possess a full natural flavour but in peas the best quality products are said to be sweet rather than mealy. The flavour of peas is automatically determined with texture since the tenderometer readings at which peas should be harvested ensures that flavours are acceptable. The flavour of garden peas is very different to that for processed peas because the latter are harvested at full maturity. They are regarded as two different vegetables by processors. Mint flavouring is often added to pea products of all types.

Mint essence is also added to enhance the 'new' flavour of canned potatoes and this may sometimes mask the true potato flavour. Nevertheless the raw material should possess a good natural new potato flavour.

Size

The relative sizes of the pieces within a can or frozen package are measured as a separate item of quality for several vegetables. It is considered that the best packs show little or no variation between the size of their individual pieces. In the method of quality assessment employed at Chipping Campden and by many processors, mature potatoes, processed peas and spinach are not size graded but all other vegetables are assessed for this item of quality.

Garden peas are canned by most processors as 'from the pod', that is, ungraded, and the general size of pea is then determined by maturity and variety. Processors are constantly seeking smaller peas and products containing such peas are advertised to the public as being of superior quality. Sometimes peas are processed as *petit pois* and for this pack the small peas (up to and including 11/32 in.) are graded out. On the continent of Europe *petit pois* packs are produced from very small round seeded varieties but these are not in use in this country at the present time.

Broad beans are not size graded before canning but variations in size of seed occur from variety to variety. For example the variety Minerva produces seeds which are considered to be too large for canning.

Carrots for canning have been the subject of much investigation by the Plant Physiology Department of the National Vegetable Research Station at Wellesbourne. It has been shown that crops with a high percentage of carrots within the size range required by the canner can be produced by giving careful consideration to planting time, seed source and density. The most popular pack on the market is canned whole carrots which should be 0.75 in. to 1.25 in. at the shoulder and not more than 3.5 in. long. For the less popular packs of sliced and diced carrots, the shoulder diameters should be not more than 1.25 and 2 inches respectively.

Shape in carrots is also important and the canner requires conical roots for whole carrot packs. Varieties in the Chantenay stock are almost exclusively grown for canning although there is a growing demand for Amsterdam types for 'baby' carrot packs.

Immature potatoes are also influenced in size by plant density and crops for canning are planted much closer than those grown for the ware market. So far no special varieties have been produced for the canning trade but some may appear in the future which yield most of their tubers in the size range of 0.75-1.5 inches.

In a similar fashion Brussels sprouts can be grown at close spacings to yield sprouts within the size required by the freezers, that is, 0.75-1.25 inches.

Absence of defects

Defects may be many and varied but crops for processing should be as free as possible from such problems. This subject requires a paper to itself and it may be easier to list the major problems for each vegetable.

CARROTS: Cavity spot, clayburn, five o'clock shadow, various forms of cracking, bruising, carrot fly, green crowns, over and undersized roots.

POTATOES: Mechanical damage, deep eyes, unusual shapes, oversized tubers.

PEAS: Loose skins and cotyledons, presence of extraneous matter such as pieces of pods, tendrils, stones etc.

BROAD BEANS: Badly broken beans, rogues, stained seeds, extraneous matter such as pods, soil, stones.

DWARF BEANS: Broken beans and those infected with moulds, bruising etc.

The defects which may appear in canned and packaged products can originate at any point along the line from seed source to can filling in the factory and, therefore,

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GROWING VEGETABLE CROPS FOR MECHANIZATION

by

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INTRODUCTION

Today, turnips are not considered an important vegetable crop, yet it is to this crop 250 years ago that we owe the origins of the mechanization of arable crops in this country. It was, of course, Jethro Tull (1731) who showed how the drill he had invented could be used to grow turnips on which sheep were folded during the winter. This crop, managed in the way Tull proposed, took the place of the traditional fallow and the second Viscount Townsend integrated it into farming practice in his famous Norfolk four-course rotation. The idea of a seed drill had been put forward by Worlidge in about 1650 but it needed Tull, who had that blind enthusiasm which is almost the prerogative of the mistaken, to show how it could be used to allow a new horse-hoeing husbandry. Tull was mistaken because he believed that by putting the crop into rows and cultivating between the rows with the horse-hoe, he divided the soil into fine particles that could be digested by the roots. He achieved success because he obtained good weed control and thus increased yield.

Robert Billing grew carrots using essentially the same system that Tull had proposed for turnips. He has described his growing system and the yields he obtained, the latter being given in cartloads per acre. He always allowed himself a percentage increase on his actual yields to allow for those roots "taken by the poor of the parish". We must again realize that even carrots were regarded rather as food for cattle than for humans. In times of famine when peasants had to resort to eating roots, the roots they ate were turnip and carrots normally intended for cattle. The present popularity and almost exclusive use of these crops as human food may seem to some to be a sad reflection on our supposedly affluent society.

In the mid-18th century vegetables for human consumption were grown in market gardens near to the centres of population. The carts which took the produce to town returned loaded with night soil or manure from the town stables where cows as well as horses were kept. The system of cropping used in the market gardens employed only hand-labour: there was no concession to mechanization. The land was divided into 'beds' the width of which was governed by the reach of a person working from the narrow paths which divided them. The crop within each bed was as uniformly distributed as possible, this being usually achieved by broadcast sowing and subsequent thinning. Weeding was done by hand and often by children. This was vegetable growing as described by Abercrombie (Mawe and Abercrombie, 1779) in the latter half of the 18th century. It must be assumed to have been evolved over the centuries as a system capable of giving high yields per unit area because in the circumstances of these times, when labour was cheap but good land in close proximity to towns was scarce, business pressures would exert a Darwinian influence in this direction. Our own experimental work has confirmed that, in weed-free conditions, such a system of growing crops uniformly distributed in beds produces higher yields per unit area than conventional row cropping.

I have argued elsewhere that our present and increasing ability to control weeds by herbicides removes our dependence on inter-row cultivation for weed control and makes it desirable to re-appraise our present preoccupation with row-cropping. The aspect of this argument that I wish to enlarge and emphazise in this paper is that the adoption of row cropping for vegetable production was not a conscious decision taken in the light of scientific evidence but rather the result of drifting on a sea of human inertia at the mercy of the winds of economics.

Industrialization, starting in the early to mid-18th century, led to the development of expanding urban communities, who were supplied with vegetables transported by horsedrawn carts travelling up to 15 miles to markets. The radial spread of towns took the land formerly used for market gardens which thus had to move to other land and brought the 'gardeners' into contact with neighbours who were farmers practising row-cropping techniques. At the same time the cheap and abundant labour, characteristic of peasant communities, was drained away to the factories and weed control

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therefore became a problem. Further, farmers sold for human consumption the root crops intended for cattle because there was an insatiable demand for food as the result of the explosive increase in population. The coming of the steam railways made it possible to bring vegetables from further afield. The return journey still carried the manure but former farming areas now came within the compass of the demand for vegetables. Thus, a generation of farmers who had experienced nothing other than Tull's row cropping techniques began to apply them to vegetable production. Thus the loss of cheap labour formerly used for weed control and the spread of vegetable production to areas where row cropping was established for arable crops began to exert an irresistible force resulting in the changing of established systems. Further impetus for this change continued into the present century; for example, the depression of the cereal markets in the 1930's made farmers look for other cash crops and some turned to vegetable growing.

The nature of the vegetable growing industry is still changing (Anon. 1967) and during this period of change, from about 1750 to the present day, we have had the advent and growth of what is normally referred to as scientific farming. There were the improvers of livestock like Bakewell and the Collings brothers, the introduction of chemical fertilizers and the setting up of the Board of Agriculture and Fisheries. Perhaps the most striking change in the rural scene arose from the introduction of sources of power other than man and beast. Steam driven traction engines pulled the plough and pumps developed for mines delivered irrigation water. Early in this century the internal combustion engine began to replace the horse, not only on the land but also in the towns. This change increased the power available but removed the traditional source of soil fertility. Fortunately, our knowledge of how to replace horse manure with chemicals has at least kept pace with our need to do so.

The increased power from internal combustion engines did not, however, affect the basic system of arable cropping. Tull's widely spaced rows were not changed when it no longer became necessary for them to allow for the passage of a horse. There was, however, a gradual realization that rows as widely spaced as Tull suggested were giving lower yields than were attainable with closer rows. Thus his suggestion of rows six feet apart for small grains had been modified to rows 12 in. apart by the late 19th century. More recently this realization has become backed by experimental evidence (Holliday, 1963) which indicates that even closer row spacings than the long-current seven inches should be used.

ASSESSING IMPROVEMENTS

The evolution of the mechanization of arable crops suggests to me that, whilst Tull was concerned to create a better environment for the plants, expediency has been the force behind most subsequent mechanization. This may seem unjust because developments in mechanization have increased yields as compared with—what? Usually these comparisons are made with those obtained by adopting current commercial methods—but what if these methods are poor? My historical introduction is intended to suggest that current practice in vegetable production deteriorated with the slow spread of mechanization. To improve what is, or was, so patently poor and at odds with the high-yielding and traditional mid-18th century market garden techniques is not difficult. Indeed, it can be argued that it was too easy, because almost any modification of current practice resulted in improvement and hence numerous innovations were, and perhaps still are, constantly vying for adoption. This seems to me to be the present position in potato production where numerous improved and mechanized systems of culture are blossoming. If I am to suggest that we should not use current practice as our standard I must suggest an alternative. It seems to me that the only meaningful standard of lasting value is that which may be termed maximum attainable yield per unit area. Such a standard does not exclude proper appraisal of economic factors. Indeed I would claim that it is the only criterion which enables a proper economic assessment to be made because, for example, loss in yield can be set against savings in harvest costs. The objective of mechanization can, within this scheme of thinking, be defined in different ways. To me the definition of most interest is that mechanization should have as its objective the cheapening of the cost of producing the maximum attainable yield. An objective which allowed for less than attainable yield is likely to be of decreasing value as this century advances, for let us never forget the prediction that the world population will double in the next thirty years. Thus, if we are even to maintain the present miserable status quo, with two thirds of the world population under-nourished, we must double food production before the year 2000 A.D.

My definition of yield throws a considerable responsibility on the scientist working on economic crops, for he must quantify maximum attainable yield and explore alternative methods of obtaining this yield, for some methods will be more amenable to mechanization than others. Further, the philosophy of engineers will have to undergo a change of emphasis. They must be prepared to recognize the full implication of working with living material and to play an important role in creating the environment likely to give the attainable yield. Your willingness to adopt this philosophy will depend upon your appreciation of the biological problems and the co-operation offered to you by crop scientists. Useful co-operation can only begin when these scientists have acquired some knowledge of the systems likely to give potential yield and the rest of this paper will be devoted to outlining some of the knowledge we have and some problems pertinent to mechanization.

DEFINITION OF POTENTIAL YIELD

With some vegetable crops various definitions of maximum attainable yield are possible. Whilst most people would accept that we can, for our present purpose, ignore yield other than that of the edible parts of our vegetable crops, not everyone would agree on what part of this yield should be classed as being of the desired quality and one must also accept that different qualities are required for different purposes. The most unambiguous definitions of quality that exist are for crops intended for processing and within this group of crops the one with the most objectively defined quality is peas.

THE PEA CROP

About a quarter of the total of 400,000 acres of vegetable in the United Kingdom is devoted to this crop. Of this 100,000 acres, about half, go for freezing, a third for canning and the remainder are sold in the pod. Twenty years ago two thirds of the crop was sold in the pod but the convenience of the frozen, dehydrated, or canned pea has changed the pattern and brought with it a precise definition of quality which depends upon the use of a tenderometer (Martin, 1937). Because this instrument is so widely used to control quality, other criteria, such as the size of the peas, have become increasingly important as giving one brand of packaged pea an edge over rival brands.

My own work with this crop has been concerned with the effect of plant population and pattern of plant arrangement on yield. Briefly the results obtained have shown that, over the range tested, yield increased as the distance between rows decreased but that the relationship between plant density and yield was erratic. Sometimes yield increased as plant population increased over the range of 3 to about 10 plants per ft^2, at other times it decreased and occasionally there appeared to be an optimum density within this range; often increasing density had little effect on yield. At present we do not know the reasons for these discrepancies and one must therefore examine the results and suggest a plant population likely to give a satisfactory yield in the majority of circumstances. Our results with the variety Dark Skinned Perfection indicate that 8 plants per ft^2 is such a population. Other workers (King, 1966) have concluded that 11 plants per ft^2 should be used. Faced with establishing a pre-determined population in rows about 7 in. apart, a grower has a number of factors to consider which become even more pertinent with the smaller seeded vegetable crops. I will, therefore, defer consideration of this aspect until later and pass on to the husbandry of the established crop and in particular its irrigation.

My colleague, Dr P. J. Salter, has shown that the yield of peas at given tenderometer value can be greatly increased by irrigation at the early flowering stage and again at the time of pod swelling (Salter, 1963). Water applied before the earlier of these stages served only to increase the weight of stem and leaf and did not increase yield. Further, even when there had been rain or irrigation just prior to these stages of growth and the deficiency during them would have been minimal even without additional irrigation, a response was obtained to irrigation that was almost equivalent in magnitude to that obtained with crops held in much drier soil until this time. The apparent reason for this dramatic response to irrigation is that during the flowering and pod swelling stages of development, root growth virtually ceases (Salter and Drew, 1965). The roots become dependent on water flow to their absorbing surfaces and cannot grow into regions of moist soil. Irrigation (or rain) at this time keeps the water in the soil moving to the surfaces of the non-growing roots and enables water absorption to continue at these vital growth stages.

The average crop of peas can be expected to give a gross return of about £100 per acre, which is not high in relation to some other vegetable crops, but, because the correct timing of irrigation can give such a marked increase in yield, increasing the gross return to about £150 per acre, there is no doubt that irrigation would, by and large, pay. Growers, however, do not generally irrigate the pea crop, the reason being that moving conventional irrigation lines through the crop would cause damage that could reduce yield. Further, even though it may pay for the labour required, it is not usually feasible to have sufficient labour available. This non-availability of labour is, of course, often the basic problem which mechanization is called upon to solve, and it would be easy for the crop scientist to say that solving this particular problem of making the irrigation of peas practicable is an engineering problem. This is not my view. Before we turn to the engineer we should explore the biological solution, namely, the breeding of peas which do not show such a marked reduction in root growth at the onset of flowering and pod-swelling. If this solution fails there may be other biological methods of modifying the growth of the pea plant or otherwise minimizing the likelihood of physiological drought limiting yield. Only if all conceivable biological possibilities have been explored are we entitled to claim that such problems must become the province of the engineer. My main reason for saying that first priority should be given to the biological solution is that it is likely that such a solution can be sold in the seed packet and hence be cheaper and more readily accepted.

CROP ESTABLISHMENT

The seed is, of course, the foundation on which a good crop depends. It must contain the correct genetic potential and be provided with an environment which will enable it to achieve the desired expression of this potential. Whilst it is customary to quote the sowing rate for vegetables in pounds per acre I am pleased to say that many growers are now aware that what really matters is the number of plants they manage to establish. This is because the number of plants per unit area is a potent factor in determining total yield and, often more important, the size of the individuals that comprise a given total yield. Thus, growers have been encouraged to calculate the seeding rate required to establish a desired population by taking into account the number of seeds per unit weight and the viability of this seed. There is still an element of guesswork in this procedure because not all the viable seed, as measured by standard laboratory germination tests, will emerge to give plants. The proportion of the viable seed that will emerge depends upon conditions in the seed bed—which are often not all that could be desired.

Unfortunately the crop scientist cannot define precisely ideal seed bed conditions but it is possible that certain features of our present techniques of sowing could be improved. I will for the moment take it for granted that the seed can be delivered in a reasonably metered manner and concern myself with the soil environment. Most of our vegetable seed is small and traditionally sown by a technique which involves parting the surface soil and making a groove in the underlying wetter soil. The standard coulter often produces a smeared base to this groove or furrow especially if conditions are adverse and onto this smooth surface the seed is dropped. Dry soil is then dragged on top of the seed and, almost as though to heap indignity upon it, the whole is rolled.

In biological terms the object of sowing can be defined as placing the seed in moist soil in such a manner as to give it good contact with the available water but at the same time preserving adequate aeration and ease of penetrability for the emerging root and shoot. With small seed good contact with the soil water implies a fine tilth and the mechanical preparation of a fine tilth seems to demand drying soil conditions. Further, the successful passage of most of our seed drills requires a dry surface so that at least some of the water that should preferably be available for germination seems to have to be lost before we can mechanize soil preparation and seed sowing. If in inserting the seed in the soil we bring more moist soil to the surface and drag dry soil on top of the seed we are further reducing the likelihood of successful growth. The mechanization of the seeding of a crop should be seen as not only requiring the accurate metering of the seed but as involving the creation of a suitable environment for the establishment of a plant from that seed—even to the extent of the seeding machine creating a locally suitable environment. Perhaps the seeder should prepare a cell of soil bringing it to the tilth required and then deliver the seed together with the water required for germination. Alternatively the soil could be replaced by material delivered by the seeder if plants are to be fairly widely spaced. It does seem odd that we persist in making a seed-bed in the whole of the ground to be cropped whereas if we were growing summer cabbage we could prepare 4 in.^{2} for each plant which at a spacing of 18 in. $\times$ 18 in. means we need only prepare 60 yd.^{2} in each acre.

With such widely spaced crops transplanting is the traditional method of field establishment but there is now an increasing tendency to direct drill these crops. The reasons for this are varied but one major factor is that modern herbicides enable us to reduce the weed problem that was formerly avoided by transplanting. Although it is possible to sow a continuous and thin line of seeds and chop out or otherwise kill the unwanted plants some growers prefer to string sow—that is to sow a few seeds fairly close together at each station where a plant is required. One reason for this is that it produces a more regular spacing than thin-line sowing whilst reducing the amount of seed required. Regular spacing is, of course, more desirable in vegetable crops than in, say, sugar beet because it gives each plant a similar opportunity and hence a crop which is more uniformly of the size required for market. It is a simple matter to calculate how many sites will have at least one plant if the percentage field emergence of the seed is known and it is assumed that the distribution of non-viable seed is random. The figures given in Table 1 were obtained by making such calculations.

TABLE 1

Seeds sown per site	*% of sites with at least one plant for the given level of field emergence*				
	50%	60%	70%	80%	90%
1	50	60	70	80	90
2	75	84	91	96	99
3	87.5	93.6	97.3	99.2	99.9

If we consider what happens with 80 per cent field emergence, a number of relevant points emerge. Firstly, and somewhat obviously, one seed on each site will give an 80 per cent stand with no subsequent thinning. If we sow two seeds then 96 per cent of the sites will have at least one plant and it follows that 64 per cent of the sites will have two plants. Thus, to achieve this extra 16 per cent of sites with a plant we have had to double our seed bill and carry out a thinning operation at about two-thirds of the sites. It seems reasonable to ask the crop scientist what percentage of the sites need to be filled and what he can do to provide seed with a high enough field emergence to eliminate any requirement for thinning. American work (Pauli and Harriot, 1968) has shown that when the crop scientist and engineer combine forces to produce on the one hand seed with the maximum potential for establishing a plant, and on the other hand the best practicable environment for that seed, then lettuce crops with a 95 per cent stand can be grown without any thinning. For practicable purposes I feel that this level of stand is acceptable as we must expect that the law of diminishing returns will apply and that the effort needed to fill the remaining 5 per cent of sites would be prohibitively large and indeed is seldom achieved even when thinning is employed. Surveys of Winter Cauliflower crops in Cornwall have revealed that, even with this transplanted crop, growers sometimes have populations 20 per cent lower than those they intended (Cavell, 1967).

HARVESTING

So far I have dealt with two examples where, in vegetable crops, there is at least a partial or potential biological solution to what at first sight might appear to have been a straightforward mechanization problem solely within the province of the engineer. The need for this combined approach is, in my view, even more apparent when we consider the harvesting of many different kinds of vegetables. The simplest type of harvesting operation to mechanize is one in which the crop can be destructively gathered and all the plants are non-selectively harvested on one occasion. Unfortunately most vegetable crops are traditionally considered to be crops which need to be harvested on more than one occasion. In some crops individual plants are gathered as they reach peak condition for market whilst others, which are not yet ready, are left for some future occasion. Amongst crops of this kind are lettuce, cauliflowers and cabbage and we can term this harvesting as whole-plant serial harvesting. With other crops each plant produces parts which mature and are gathered leaving immature parts, on these same plants, to grow until they too are ready. I have already referred to peas which were traditionally this kind of crop although we now harvest them destructively on one occasion. Other examples of this kind of crop are beans, both dwarf and runner, and Brussels sprouts. This cut-and-come-again harvesting is often termed as picking-over or non-destructive harvesting but it would seem less ambiguous to refer to it as part-plant serial harvesting.

Both whole- and part-plant serial harvesting were regarded in the past as desirable in commercial horticulture because continuity of supply to markets was readily achieved. The successive harvests of a single crop spread the supply of that crop over a period and even if other crops had to be used to maintain supplies over a season, the spread of each crop tended to minimize the precision needed to ensure at least some continuity of supply. Thus breeding by selection was often directed towards maintaining a spread of maturity and cultural techniques which tended to spread maturity were not disadvantageous. The need to mechanize the harvesting of these traditionally serially harvested crops presents problems. If the engineer alone were asked to solve them he would have to develop a machine which, say for lettuce, could detect when a plant was adequately hearted for market and then cut that plant for market. Such a machine has been invented, so it is possible to mechanize this type of harvesting although the development of reliable and non-damaging detectors of market maturity must be difficult and it is unlikely that any one detector would be useful on more than one kind of vegetable.

With part-plant serial harvesting the problems are even greater although for some crops, notably cucurbits, the engineer has shown that he can successfully exploit the differences in size and in the adhesion to the parent plant which exist between mature and immature plant parts. It is, however, evident that the mechanization of harvesting would be simpler, and hence cheaper, if serial harvesting could be dispensed with and replaced by single pass destructive harvesting.

The crop scientist concerned with vegetables has been working to this end for a number of years and in some crops I can report considerable success. I have already referred to the now well-established destructive harvesting of peas and dwarf beans. Both these crops come in the traditional class of being of the part-plant serially harvested type and you will recall that the solution to the problem lay in increasing the plant density. Even with those crops of this type where the seed or fruit is not the part required, increasing the plant density has proved to be a potent method of synchronising maturity. For example, with Brussels sprouts which are intended for picking-over the evidence (Haigh, 1964) is that spacing of less than 30 in. × 30 in. is unlikely to increase yield per acre. However, when a single destructive harvest is planned closer spacing does increase yield and a spacing of 21 in. × 21 in. is now commonly adopted.

This close spacing, which has made single destructive harvesting a possibility, has created new problems and aggravated others. For example, the effective application of both translocated and contact insecticides is much more difficult in a closely spaced crop and modifications to conventional sprayers have had to be made (Coaker, 1967). Further, whilst the mechanization of harvesting remains at its present imperfect level, it is often desirable to manually deleaf the plants before they are gathered. Increasing the population increases the number of plants that have to be de-leafed and limits access for this operation. This increase in plant number and poor access are also disadvantages when the crop is "stopped" about six weeks prior to harvest. This stopping consists of manually removing the apical tuft of young leaves together with the main growing point. Its effect is to divert growth into the upper sprouts on the stem and produce a higher yield of more uniform sprouts (see Figs. 1 and 2). Dr Thomas at Wellesbourne is seeking to replace this manual stopping with a hormone spray and is meeting with encouraging results. He is also hopeful that de-leafing may be achieved by suitable sprays (Fig. 3). Thus, we again have the apparent need for a machine being possibly met by a biological technique.

The stripping of the sprouts from the stem, however, appears to be a problem where the crop scientist can make a rather more limited contribution. Varieties differ in their spacing of sprouts on the stem and the form of their attachment to the stem. These differences mean that it would be possible to breed or find varieties which could be stripped satisfactorily by a given machine whilst other varieties might be far less effectively stripped. Close co-operation between the engineer and the crop scientist is again seen to be very desirable.

I have endeavoured to tabulate the various stages in the Brussels sprout crop indicating what I believe to be the possible engineering and biological solutions to the mechanization problems that arise. For some stages these two solutions are mutually exclusive whereas for other stages the biological solution would, in fact, not solve the problem but would make mechanization less difficult. I have already dealt with many of the items in this table and you will by now have gathered that I believe that at least some of the problems are best tackled by the crop scientist. This means that I am being somewhat perverse in my definition of mechanization in suggesting that in the context of vegetable production it means the elimination or reduction of hand labour rather than causing a machine to perform a function formerly done by hand. At the bottom of the Table I have introduced two aspects of the production which I have not so far discussed; these are grading and succession.

GRADING

There are, perhaps, few mechanisms more primitive than the average grader used on vegetables. Grading is usually

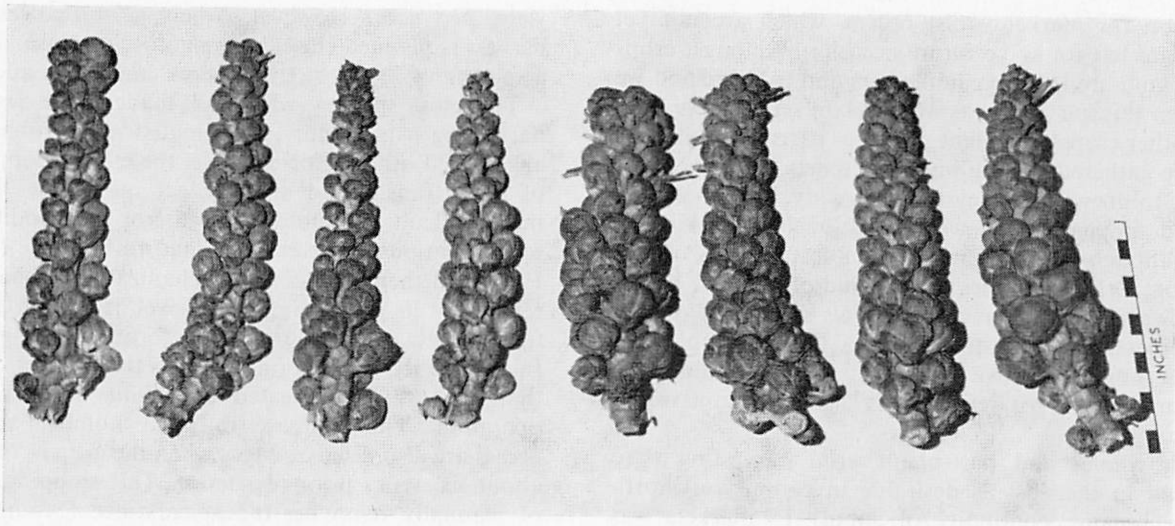

FIG. 1 shows the effect of "stopping" and plant density on Brussels sprouts var. Avoncross.

From left to right—Four plants spaced at 18″ × 18″ and four at 27″ × 27″. Stopping treatments at both spacings were from left to right, 17th August, 31st August, 27th September and untreated.

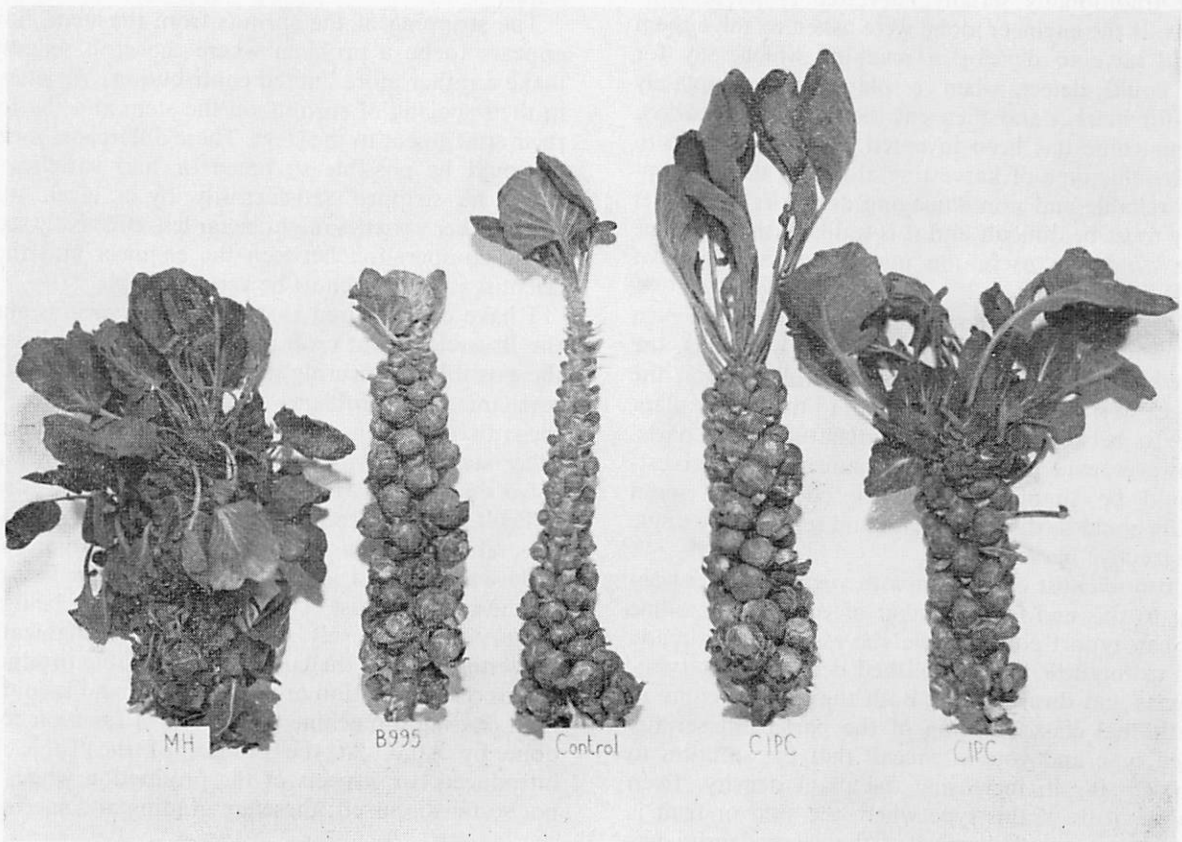

FIG. 2 shows the effect of chemicals with growth-regulatory action on Brussels sprouts var. Avoncross.

Left to right—Maleic Hydrazide, Alar, Untreated control, CIPC (low dosage) and CIPC (high dosage). Note the similarity between the sprouts on plant receiving a low dose of CIPC and stopped plants in Fig. 1.

FIG. 3 shows the effect of 2-chloroethanephosphonic acid (ethrel) as a Brussels sprout defoliant, and the way its effect can be counteracted by the use of a senescence-delaying chemical (kinin).

Left to right—untreated, ethrel treated, ethrel+kinin treated.

done by shaking the produce through a series of riddles of a range of dimensions. In recent years other mechanisms, such as diverging belts and rollers have been introduced but the basis of grading remains the same—namely one or at the most two dimensional. If a grower is grading carrots for prepacking he can, with these conventional graders, separate the crop into diameter classes but the essential sorting of these diameter classes into lots where all the carrots are of a similar length has to be done by hand. Sales of prepacks through chains of super-markets demand not only a high degree of uniformity within each pack but also a high uniformity between packs. This is because the vendors are anxious that the housewife should not rummage through a pile of packs to find one to suit her needs. Their uniformity will usually make her accept the one at the top of the pile. This requirement is imposing new standards which the pounding stone-graders of yester-year do not enable us to meet. Further, there is the additional requirement of a uniform weight in each pack. It seems to me that, at least for some crops, automatic weight grading (Anon., 1969) is becoming increasingly attractive. Weight grading might even be of some value in sorting carrots into length grades for if diameter grading were followed by weight grading it seems likely that the longer carrots would have the greater weight.

GROWING FOR A REQUIRED SIZE

The damage for crops which fall within narrow size limits has led to the development of special methods of growing. My own work on carrots has made it possible to obtain, amongst other things, high yields of the size of carrots required for canning, namely, 0.75-1.25 in. diameter. These carrots, which are all of the Chantenay type, are often produced on contract for a cannery, the grower having no outlet for oversized roots. Some are able to use these oversized carrots as cattle food but considerable tonnages are dumped each year. We feel that more research may enable us to reduce this wastage and a programme of experiments is now in hand in co-operation with some of the Experimental Horticulture Stations of the National Agricultural Advisory Service. I would, however, like to explain to you some of the difficulties that are pertinent to certain aspects of mechanization. High yields of small roots can only be obtained by using high plant densities. If these high populations are sown at wide row spacings the gross overcrowding within the rows reduces total yield and gives a high proportion of distorted roots with green crown. This undesirable greening occurs because the carrots are forced up out of the ground by the overcrowding. We have shown that the difficulty can be overcome by spreading out the plants more evenly. This gives considerable increases in yield even at low plant densities but is essential if a quality product is to be produced at high density. The bed system of growing (Bleasdale, 1963) was evolved to enable growers to spread the plants out. In essence, the system consists of growing the crop in beds that can be straddled by a tractor and within each bed there are usually 12 rows with an inter-row spacing of 3.5 in. Although dividing the field into beds confers several advantages of a minor nature the main reason it is done is to make it possible to harvest the crop by using modified two-row potato harvesters or similar machines specially designed for the purpose. However, in a bed the rows next to the wheeling encounter less competition than rows within the body of the bed. This reduced competition enables the carrots in the outer rows to grow faster so that at any given harvest date they are larger than those in the more central rows. This increases the variation in size as compared with that which would be expected if it were possible to crop the whole field with close rows. Because harvesting beds of this size with elevator-diggers presents difficulties many growers have modified the system to produce units that can either be harvested with modified single-row potato harvesters or, less commonly with a top-lifter. These various modified systems I generically term mini-beds. They all suffer from the considerable disadvantage that they increase the proportion of the total crop that occurs at the edge of a bed and hence tend to give even more uneven crops than conventional beds. Indeed, where each mini-bed consists of three closely spaced rows it is possible to get almost complete suppression of the growth of the centre row.

Because plant density is such a potent factor controlling size it seems reasonable to try and reduce the size of the carrots in the outer rows of beds by sowing relatively more seed in these rows. However, it seems equally likely that this will increase the competitive influence of the outer rows and so tend to reduce the size of carrots in the inner rows of a bed with little net improvement in the uniformity of the crop. Perhaps a more promising approach would be to somehow put the outer rows of a bed at a disadvantage as compared with the inner rows. One way of doing this might be to use a smaller seed size to sow the outer rows, because smaller seed gives smaller seedlings. These and other possibilities are being investigated as part of the programme of work to which I have already referred. It is, however, evident that if we could crop the whole field with rows about 3 to 4 in. apart we would eliminate edges and hence the variability associated with them. Further, it is likely that we would increase yield. The factor preventing us from advocating this solution is the non-availability of a suitable side-mounted harvester.

I have dealt with this example at some length partially because I hope to interest some of you in helping us to solve the problem. The more general point to be made is that the modern requirement for uniformity can make it necessary to envisage quite radical changes in our mechanization of vegetable crop production.

CONTINUITY OF SUPPLY

The winter supply of carrots is largely met by continuing to lift from the field roots that have been protected from frost damage either by earthing over when the rows are far enough apart or by strawing over if close rows are used. If this system of storage is to continue to be used, and this seems likely as it is cheap and effective, then harvesters must work on crops when the tops have died, and in very wet soil conditions. A continuous supply during the growing season is, of course, maintained by producing crops from successive sowings made at suitable plant densities for the planned date of harvest. Commercial growers are accustomed to doing this and we hope that experiments in progress will help them to do it more effectively in the future. However, with other crops, as I have already mentioned, a continuous supply in the season of availability is traditionally maintained by successive harvests of single crops with relatively few sowings being made in order to achieve succession. The desire to mechanize harvesting has led us to seek methods of reducing the spread of maturity within a single crop to such a level that one destructive harvest is practicable. I have already referred to the techniques that have made this possible in the Brussels sprout and Dr Salter has carried out work at Wellesbourne directed towards enabling single destructive harvest of that most variably maturing crop—cauliflower. With both Brussels sprouts and cauliflowers there is the problem of establishing a programme of sowing dates and varieties likely to give a suitably continuous supply. Further, because many of the existing varieties have been bred to give a spread of harvest maturity, plant breeders must breed and select new varieties. To this end we are carrying out controlled environment studies to determine the environmental factors that determine curd initiation in cauliflower so that we can more rigorously select strains with the desired properties. Dr Salter's work (1969) has shown that even with existing varieties which under commercial conditions are harvested over 6-8 weeks, it is possible by suitable management alone to reduce this time to about 2 weeks and with the more suitable varieties about 80 per cent of the crop can be harvested in a marketable condition at one destructive harvest. The unpredictable nature of our climate can, however, upset the best laid schemes and storage in times of plenty to meet the demands in times of scarcity therefore has a vital role to play. The engineer, of course, has an important role in designing stores but this falls outside even my definition of mechanization. However, this need to store vegetables does have implications for mechanization.

Minimizing damage during harvesting and grading can considerably prolong storage life. A more important aspect of storage is, however, its potential for enabling us to carry out mechanized harvesting when conditions are favourable. For example, if the carrot crop could be stored cheaply then harvesting could be completed in conditions more favourable than those normally encountered in December and January. If we extend this reasoning we can argue that crops should only be grown at those times of the year when maximum yield can be obtained, and should then be stored to meet future needs.

However, even the canning industry seems to expect the vegetable growing industry to produce vegetables over long seasons and this is not unreasonable when the high value of the processing plant is considered. Thus, there are economic reasons, even in that area of the industry where quality is most clearly defined, why time of year can affect the economic value of a given yield per unit area. Similar considerations apply to supplies sent to market and serve to complicate the concept of maximum attainable yield as the standard for assessing the value of a particular mechanized system of growing. Perhaps it is so complex that we will never achieve this ideal of objective assessment. In striving we must, however, appreciate that the efficient mechanization of vegetable growing depends upon realizing that the growing of a crop is a complex operation and a similar end result may be achieved in several different ways. Close co-operation between the crop scientist and the engineer is essential. Both must learn to understand each other's point of view and appreciate the limitations of each other's capabilities. I hope that this paper will further such understanding.

MECHANIZATION OF BRUSSELS SPROUTS CROP

Phase of Crop	Operation	Task or Possible Solution: Engineer	Biologist
Plant establishment	Transplanting from seed bed	Satisfactory planters are available	Wellbeing of transplants of good potential
	Direct seeding	Create environment for seed Space seed Thin out unwanted plants	Eliminate thinning by use of 'super' seed
Growth	Pest and disease control	Devise suitable sprayers and granular applicators	Breed resistant varieties
	Stopping	Evolve a machine to replace manual operation	Find spray to achieve same effect
Harvesting	De-leafing	Evolve machine to replace manual operation	Find spray to achieve same effect
	Stripping of sprouts from stem	Making effective non-damaging stripper	Breed varieties which strip easily
	Grading	Sort into sizes and eliminate unmarketable sprouts	Grow crops with no unmarketable sprouts
	Succession	Create suitable storage conditions	Find varieties and cultural methods to achieve a continuous supply

REFERENCES

ANON. (1967). *Horticulture in Britain, Part I, Vegetables.* London: H.M.S.O. p. 430.

ANON. (1969). 'New Weight Grader Pleases Bramley Growers'. *Comm. Grow. No.* 3816, p. 266.

BILLING, R. (1765). *An Account of the Culture of Carrots; and their great Use in Feeding and Fattening Cattle.* London: J. Dodsley, p.31.

BLEASDALE, J. K. A. (1963). 'The Bed-system of Carrot Growing'. *Minist. Agric. Fish Fd. Short Term Leafl.* No. 27.

CAVELL, S. (1967). 'Results of a NAAS survey of Winter Cauliflower Growing in Cornwall'. (Unpublished).

COAKER, T. H. (1967). 'Insecticidal Control of Cabbage Root Fly (*Erioischia brassicae* (Bouche)) in the Axillary Buds of Brussels Sprouts'. *Ann. appl. Biol.*, **59**, 339-47.

HAIGH, J. C. (1964). 'Spacing Trials with Quick-freeze Brussels Sprouts'. *Expl. Hort.*, No. 10, 80-9.

HOLLIDAY, R. (1963). 'The Effect of Row Width on the Yield of Cereals'. *Fld. Crop Abstr.*, **16**, 1-11.

KING, J. M. (1966). 'Row Widths and Plant Populations in Vining Peas'. *Misc. Publ. Pea Growing Res. Organ.*, No. 18.

MARTIN, W. M. (1937). 'An Apparatus for Evaluating Tenderness in Peas'. *Cann. Trade*, **59**, 29.

MAWE, T., ABERCROMBIE, J. and others (1779). *Every Man his own Gardener.* London: Crowder, Robinson and Goldsmith. 8th edn., p. 486.

PAULI, A. W. and HARRIOT, B. L. (1968). 'Lettuce Seed Selection and Treatment for Precision Planting'. *Agric. Engng., St. Joseph, Mich.*, **48**, 18-22.

SALTER, P. J. (1963). 'The Effect of Wet or Dry Soil Conditions at Different Growth Stages on the Components of Yield of a Pea Crop'. *J. hort. Sci.*, **38**, 321-34.

SALTER, P. J. (1969). 'Studies on Crop Maturity in Cauliflower. II Effects of Cultural Factors on the Maturity Characteristics of a Crop'. *J. hort. Sci.*, **44**. (In the press).

SALTER, P. J. and DREW, D. H. (1965). 'Root Growth as a Factor in the Response of *Pisum sativum* L. to Irrigation'. *Nature, Lond.*, 206, 1063-4.

TULL, J. (1731). *The new Horse-houghing Husbandry, or an Essay on the Principles of Tillage and Vegetation.* London.

Index to Advertisers

CROP ESTABLISHMENT

by

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Presented at the Annual Conference of the Institution in London on 15 May 1969

SUMMARY

The paper commences by reviewing some of the agronomic aspects which influence the manner in which by tradition various rowcrops are grown. After discussing designs of precision drill the paper examines some of the factors affecting their performance and in particular the relationship between seed/cell size. Transplanters are considered to be very limited in their range of crops and output. The paper discusses some of the experiments carried out with mechanical thinners and concludes that with the modern trend towards wider seed spacings of monogerm seed such machines may return to favour with growers of sugar beet. The current interest in selective mechanical and selective chemical thinners is likely to expand if such machines can be produced at an acceptable price.

INTRODUCTION

For the purposes of this paper Crop Establishment is taken to mean the production of a crop in the field to a required pattern or distribution. Each crop has its own particular spatial arrangement, although work by Bleasdale *et al*[1 2 3 4] has often shown that the traditional arrangements, which may have been dictated by some consideration now forgotten, are not necessarily the highest yielding. In practice, the spatial arrangement finally adopted is a compromise between that which is likely to produce the maximum yield and that which can be fitted in most conveniently with existing implements or practices.

Spaced rowcrops fall into two broad categories depending on the dictates of the outlet through which the final crop is utilized and the manner of harvesting. Thus on the one hand there are crops such as lettuce and various forms of cabbage, in which there is a trend towards once-over harvesting and which are marketed with very little further grading. It is desirable to produce entire crops with as little variation between individual plants as possible, in fact it is essential to obtain a high degree of uniformity between individual plants. In the other category of crop, uniformity in size and shape is not considered so important and the prime object is to obtain the required number of plants per unit area. Crops such as carrots, potatoes and sugar beet fall into this category and are all subjected to some form of comparatively sophisticated grading or processing before being passed on to the consumer.

The establishment of a crop is influenced by factors some of which are principally of an agronomic nature while others involve adapting or designing machines for a particular purpose and are considered problems of mechanization. A precise differentiation is not possible because so many of the factors must be a combination of both.

On the agricultural or biological side may be listed:

(*a*) the condition of the seed-bed
(*b*) the quality and type of seed
(*c*) the weather immediately before and also after the sowing or planting of the crop
(*d*) the availability of a successful and reliable method of weed-control.

Factors which are primarily aspects of mechanization include:

(*e*) the design of the seed drill in relation to the seed
(*f*) whether the crop has to be transplanted
(*g*) the manner of reducing the line of seedlings to discrete individual plants
(*h*) the effects, if any, of plant spacing on the method and standard of harvesting.

AGRONOMIC ASPECTS

(*a*) Seed-bed condition

The actual preparation of the seed-bed lies outside the scope of this paper. Nevertheless it is important to appreciate that the majority of the subsequent operations in the growing of the crop are concerned with the removal of surplus plants and that there are few, if any, occasions when plants can be added to the crop. It is therefore particularly important that the conditions should be such that the greatest number of seeds are able to emerge simultaneously. The fact that, when sold, each lot of seed complies with certain statutory minimum

*National Institute of Agricultural Engineering

germination requirements unfortunately does not guarantee a predictable field emergence. In practice field emergence varies over quite wide ranges[5 6], see Table 1.

TABLE I—FIELD EMERGENCE

% Number of seeds emerging

	Year 1		Year 2	
	Centre x	*Centre y*	*Centre x*	*Centre y*
Sugar beet A	47	34	56	74
Sugar beet B	48	45	62	84
Maize A	66	20	75	49
Maize B	72	34	71	34

When carrying out experiments to study the mechanizing of the swede crop Roebuck[7] recorded the spacing between plants before singling for a number of intended spacings from which it can be deduced that the emergence of the swede crop ranged from 30% one year to 83% in the following year.

It is the range between maximum and minimum which gives rise to the subject of this paper for, were it possible at the time of sowing to predict with any degree of certainty the percentage of seedlings that are to emerge, it would in theory be a comparatively easy matter to adjust the seed rate to produce the required population. It is necessary to add the qualification 'in theory' because there is often an appreciable range in emergence within any field so that a suitable seed rate at one end of the field may be inadequate at the other. It follows that the grower must exercise every care to ensure that he does not create avoidable differences within the seed-bed and in this respect there is growing appreciation of the importance of (a) using reversible ploughs to avoid deep open furrows or high ridges, (b) producing a comparatively level and flat soil surface that will not contain furrow crests which have been weathered with comparatively deep un-weathered valleys between them, (c) care in the use of curved tine cultivating implements that tend to bring up to the surface the cold wet soil lying four inches or more down and (d) working the soil in successive stages downwards so that the depth of the implements increases with each operation rather than the reverse.

The type or condition of the field has to be matched to the seeds or plants that it is to receive and here the skill and knowledge of the grower plays an important part in the successful establishment of a crop. The most common practices are either to sow the seed in situ or to transplant after raising the plants in carefully controlled conditions within a nursery bed.

Wayman[8] has summarized factors affecting crops which (a) are usually drilled direct in the position in which they are to mature and (b) are usually transplanted—see Table II for abbreviated details. In this same analysis the author has also attempted to rate the difficulties in the mechanization problems encountered at different stages of the crop. The crop acreages are listed in 'Agricultural Statistics' Great Britain (M.A.F.F. 1964/65) and various data have been added such as row width, plant spacing etc., but since wide variations occur throughout the country these must be taken as guides rather than fact.

(*b*) Quality and type of seed

The variation in size and shape of the seeds has an important bearing on the regularity of spacing between seedlings. Uniformity in size and regularity of shape can materially affect the 'drillability' of seed and while the cruciferae family possess these characteristics to a high degree, those of the umbelliferae (carrots, parsnips), compositae (lettuce etc.) chenopodiacae (red beet, sugar beet, etc.) are the exact opposite.

A considerable amount of work has been reported in numerous journals, and in a recent publication, Mohsenin[9] attempts to place under one cover the most significant research reports on physical characteristics and properties of plant material. Numerous methods of assessing the following criteria for describing an irregular object such as a seed are listed: shape, roundness and sphericity.

In 1961 the Seed Trade Association of the United Kingdom introduced a range of seed sizes in which twenty-four sizes each of 0.25 mm range are specified and identified by the letters of the alphabet. These limits define the screen size through which and over which a particular grade of seed must pass, and they have gone a long way towards limiting the variation within any batch of seed. In effect the upper screen defines the major axis of the seed which is to be retained whilst the lower screen determines the major axis of the unacceptable seed. There is no doubt that with the more spherical type of seed such gradings are adequate, but a seed shape in which the major axis is appreciably greater than the other two causes difficulties as does a comparatively rough or irregular seed shape. A further difficulty arises with the larger seeds which it is impractical to grade more closely than one millimetre. For example sugar beet seed is often graded "M-T" (7/64 in.-11/64 in.) (2.75 mm-4.50 mm) so that there is more chance of variation in the composition of size fractions within the grade. In this respect the Institut International de Recherches Betteravieres has drawn up a specification in which the ratio or proportion of the size fractions within any one size grade conforms to a Gaussian distribution. Work by Vanstallen[10] with a vertical cell wheel drill has shown however, that a Gauss curve distribution of seed sizes does not guarantee an optimal drill performance. For sugar beet seed in the grade 3.25 mm-4.25 mm (8-10½/64 in.) he obtained the most precise sowing in terms of cell fill when the apex of the distribution curve of fractions within the grade lay between 3.75 mm-4.00 mm.

A further difficulty in producing a line of seedlings, each isolated from its neighbour by a discrete distance, arises in those crops in which the so-called 'seed' is in fact a multilocular (multi-germ) fruit or in crops in which the seed, although monogerm in the majority of cases can produce twins. Sugar beet is a crop which provides examples of these phenomena and until comparatively recently a considerable amount of effort was put into ways and means of reducing, by mechanical means, the multi-germ fruits to more or less single germ units. The principal difficulty lay in the fact that the greatest singleness generally followed the most severe

TABLE II
Details of some rowcrops

Crop	Thous. Acre in Great Britain June 1964	Av. row width (in.)	Av. spacing along the row (in.)	Seed size	Seed shape	Drilled	Difficulties in cultural operation (5=v. difficult) Drill/plant	Weed control	Singl-ing etc.	Harv'-ing
Traditional agricultural crops										
Swedes	353.0	20	8-12	2	1	D	1	3	3	1
Kale and cabbage	250.0	24	12	2	1	D or T	1	3	3	3
Field beans Peas	66.7	24	random	7-6	4-3	D	2	5	—	2
Mangolds	71.9	24	15	4	5	D	4	3	5	3
Sugar beet	442.9	20	10	4	5	D	4	3	5	4
Vegetable crops										
Brussels sprouts	45.7	36	36	2	1	T	3	1	—	3
Cabbages	37.8	20	15	2	1	D or T	3	2	3	3
Spring Brocolli		30	20	2	1	T	3	2	—	4
Cauliflower	21.8	30	20	2	1	T	3	2	—	4
Carrots	27.0	20	6	2	7	D	5	4	5	3
Parsnips	4.5	20	8	3	10	D	5	4	5	4
Turnips	6.1	20	10	2	1	D	1	2	3	2
Beetroot	8.2	20	8	3	4	D	4	5	5	3
Onions	5.5	20	6	2	2	D	3	3	4	2
Broad beans	12.0	20	3	9	3	D	3	3	1	4
Runner beans	19.0	30	12	8	3	D or T	3	3	1	4
Peas—										
pods	20.4	20	random	6	2	D	2	5	—	3
canning	86.6	20	random	6	2	D	2	5	—	3
dry	32.0	20	random	6	2	D	2		—	1
Lettuce	8.7	18	9	2	7	D or T	5	4	5	4
Celery	5.3	36	10	2	5	T	5	3	—	4
Leeks	—	20	8	2	2	T	5	3	—	3
Tomatoes	0.1	30	15	3	7	T	5	3	—	5
Asparagus	1.4	30	20	3	2	D or T	5	5	5	5
Rhubarb	6.2	48	36	3	10	T	5	5	—	5

Seed size: 1 = small
10 = large
Seed shape: 1 = smooth, spherical
10 = rough, irregular
Drilled: Direct (D)
Transplanted (T)

treatment but this in turn produced the lowest recovery rate, so that in practice a balance had to be struck between a high degree of single 'seeds' and an economic return. The first acceptable commercial variety of genetic monogerm seed was introduced into Britain in 1965. This seed was the result of intensive efforts on the part of the seed breeders to incorporate the single germ characteristics which had been discovered in U.S.A. shortly after the war, into varieties that were suitable for growing in Britain. This year (1969) there are no less than 4 monogerm varieties on the recommended seeds list and it is expected that nearly 40% of the British crop will be sown with this type of seed. Unfortunately the monogerm seeds are more plate-shaped than their predecessors and as a consequence sometimes prove more difficult to drill.

(c) Climatic conditions

Climatic conditions, over which there is no control, can play a major part in determining the field emergence that is achieved. Interactions with soil types, seed-bed conditions, the soil working parts of the drill and chemical herbicides are all likely to occur and it is a matter of skill on the part of the grower that he is able to offset any minor differences caused by the weather.

(d) Weed-control

The development of selective chemical herbicides which prevent the growth of weeds without seriously harming the crop has been remarkably rapid and there is now a large number of materials available for some crops. The latest edition of the Weed Control Handbook lists the following as 'the main objects of controlling weeds in cereals

(i) to eliminate competition which may reduce crop yields
(ii) to ease harvesting
(iii) to avoid contamination of the crop with unacceptable vegetation
(iv) to prevent the increase of weeds.

The choice of herbicide most appropriate to a given weed situation is a technical problem. Economic considerations also help to determine the ultimate choice of a herbicide. There is no means of indicating what is the minimum degree of weed suppression to achieve the above objects.'

Similar comments can be applied to rowcrops where in many cases an additional object is to ease the work of thinning.

Traditionally, hand labour has been used in the early weeks of most if not all rowcrops for two jobs—weeding and singling, which have usually been carried out simultaneously; although it has often been necessary to repeat the weeding later in the crop's life. When the weeds can be controlled by chemical or other means in a manner that is both reliable and economic the entire elimination of hand labour then depends upon the successful development of alternative methods of crop establishment. It will be appreciated therefore that successful weed-control is a necessary pre-requisite to total mechanization.

At the present time there are two broad lines of attack available to the grower (a) he can endeavour to plant the crop in a weed-free environment hoping that it will remain so until the crop covers the ground or (b) he can apply a material that is toxic to the weed but not the crop. Unfortunately both techniques have practical difficulties which cause a certain amount of doubt as to their acceptability. The former is frequently attempted by what is known as the stale-seed-bed technique and involves working the land into a seed-bed and thereby stimulating the weed seeds to germinate. The seedlings are killed either by mechanical means or by the application of a non-persistent contact herbicide. If time permits, two or more flushes of weed-seedlings are stimulated and killed in this way before the crop is sown. The manner of killing the weed seedlings is usually dictated by cost, timeliness, soil type and the weather. Harrowing the weeds is slow and can be less effective in wet weather and can cause an additional crop of weeds but does not involve the purchase of chemicals, the price of which may range from £1.5-£3 per acre.

On the other hand selective weed-control by the use of chemicals has not reached the stage of perfection in rowcrops that is commonly expected and achieved in cereals. A number of factors can combine together to produce disappointing results. Some of these materials have to be applied before the crop emerges and if for some reason they fail to control the weeds, then by the time the emerging weeds show themselves it is too late to apply a second treatment. Some are ineffective on particular types of soil. Others have to be applied before the weed seedlings reach a particular stage of growth and if this happens to coincide with the vulnerable stage in the crop growth or the weather conditions are such as to prevent the operation being carried out, only partial success can be expected. Nevertheless remarkable results have been achieved in particular crops and with the money and effort that is being put into this work it is reasonable to expect that sooner or later there will be a material or combination of materials available that will be selective to each crop irrespective of the type of soil and weed flora in which it is being grown. Nevertheless, it is likely that a multiplicity of techniques will be required to meet a wide range of conditions under which crops are grown both in U.K. and overseas.

MECHANIZATION ASPECTS

(*e*) Seed-drill design

The basic function of a seed-drill is to provide a vehicle for transferring the seeds from the container in which they are supplied, to the soil in a pattern and depth that is compatible with subsequent growth of the crop. As such there are two principal parts to the drill (a) the seed metering components and (b) the soil working parts. It is, however, unwise to study one or other of these parts without due consideration of the other, e.g. it would be of little use to produce a seed metering mechanism that was able to segregate single seeds regularly from the mass, irrespective of size and shape, if having done so it then allowed the seeds to fall haphazardly into the soil so that they were buried too deeply or were inadequately covered with dry soil. Conversely the best combination of furrow opener or coulter and covering unit capable of working in all types and conditions of soil is of little advantage if its design does not allow the seed metering mechanism to be placed in the correct attitude in relation to the soil.

Existing seed metering mechanisms fall into three basic types:

(i) horizontal plate or cell wheel
(ii) substantially vertical cell wheel (Figure 3)
(iii) perforated belt (Figure 2)

Type (i) is commonly used in U.S.A. and Canada where the double disc type of furrow opener is favoured because of its ability to cut through crop residues. It is very versatile and it is a cheap and easy matter to change the seed plate to match different seed sizes. Type (ii) is very common in Europe where it is favoured on account of its comparative simplicity and the fact the seeds are ejected close (1.75 in.) to the ground. The seed wheels have to be machined to close tolerances. Type (iii) is also common in Europe and is favoured on account of the fact that the seed is ejected close to the ground (1 in.) and that the seed selecting belts are relatively cheap.

It will be appreciated that because of the manner of seed selection, all the above types of drill metering or selection mechanism rely on the accurate matching of the seed to the cell size so that not only must the seed be closely graded within the prescribed size limits but it must also be more or less spherical or uniform in thickness if two seeds are to be prevented from entering the same cell. Using a perforated belt type of drill Bradford[11] has studied the relationship between the size of rubbed and graded sugar beet seed and cell or hole size. In this work the sample of seed although nominally graded 8/64 in.-10/64 in. contained 70% in the size 8-9/64 in. The distribution from the drill was studied both in the laboratory and in the field and a numerical assessment of the pattern was made. On both occasions the drill unit was run at 2 mile/h (see Table III).

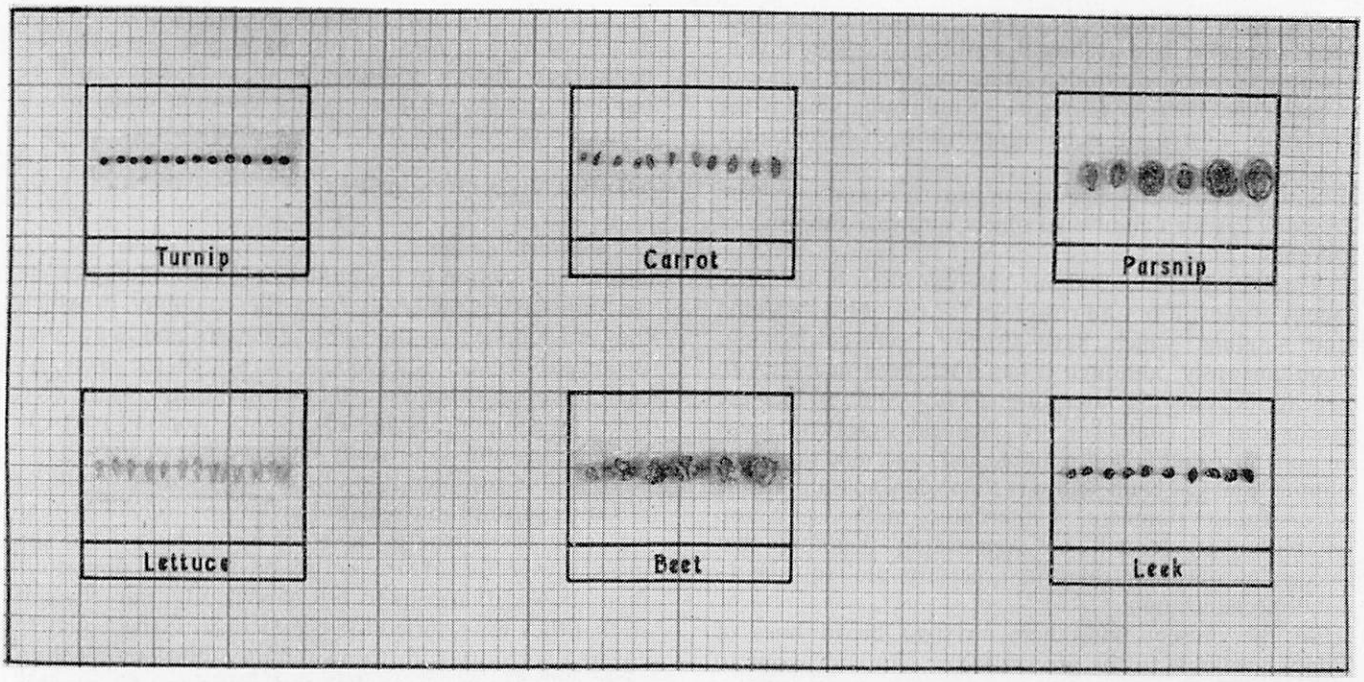

FIG. 1

Variation in size and shape of seeds.

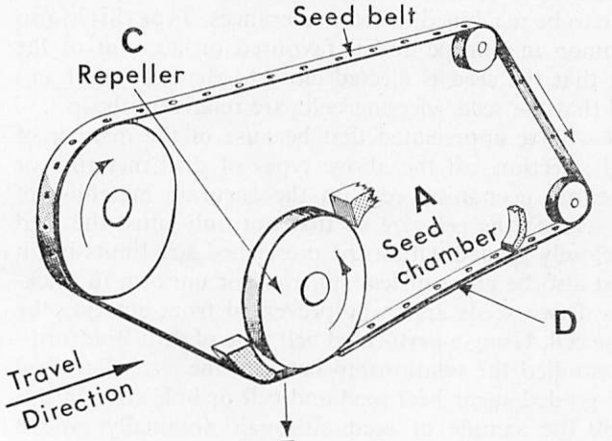

FIG. 2

Belt feed seed selector

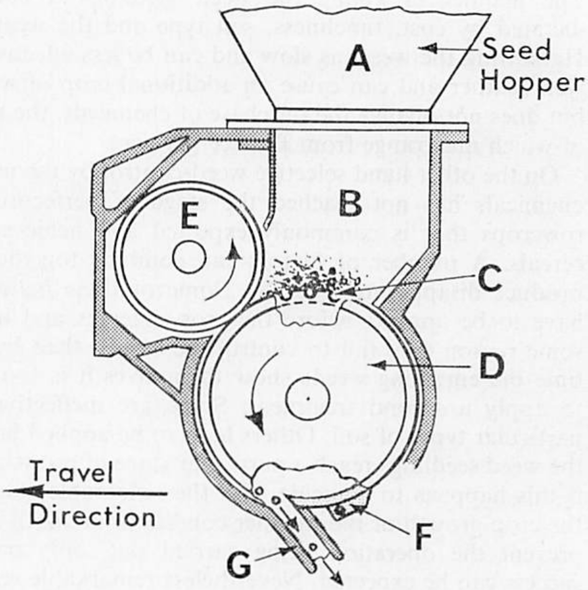

FIG. 3

Wheel feed seed selector

TABLE III
The relationship between seed and cell size

Cell Size	*Singles*	*Doubles*	*Multiples*	*Blanks*
	Laboratory results—%			
13	57.7	—	2.4	39.9
14	76.3	—	2.9	20.8
14.5	85.5	—	4.6	9.9
15	83.6	—	12.3	4.1
	Field emergence per 100 seed hills			
13	30.3	14.7	0.2	54.8
14	34.0	22.5	1.5	42.0
14.5	39.3	21.8	1.4	37.5
15	38.8	23.7	2.5	35.0

The field emergence well illustrates the problems with multi-germ sugar beet seed. In the laboratory it would be almost impossible to identify which 'seeds' would produce two seedlings.

As mentioned earlier some types of seed are naturally flat and these together with small seeds of high value are sometimes coated with an inert substance to form spherical pellets, which greatly improves the regularity of distribution from the drill (see Figure 4).

Averages of the results which were published after the 19th National Sugar Beet Demonstration in 1968 show the improvement achieved when monogerm sugar beet seed was pelleted (see Figure 5).

An alternative to pelleting that has frequently been suggested is the use of some form of suction device whereby individual seeds are picked from the hopper by means of tubes to which suction is applied. Such a device is less likely to damage the seed than any form of mechanical selection although in preliminary work on clover seed Sweetman (1957)[12] showed that two or more seeds were sometimes picked up by one tube, and that this was influenced by (a) the steadiness of the vacuum, (b) size and weight of seed and (c) the speed of the tube through the seed reservoir, coupled with any tendency of the seed to pack in the hopper. It was found to be essential to prevent blockages of the tubes by eliminating any foreign matter in the seed or air-borne grit. Later work, by Copp (1960)[13] described the development of this technique for sowing early generations of wheat crosses. Kemp and Kalbfleisch (1962)[14] reported tests on this equipment on a range of seeds that included cereals, clover, radish, flax and alfalfa. It was found that, with the particular equipment used, twenty rev/min was about the maximum speed at which the needles would effectively pick-up seeds, which with the tractor travelling at 1 mile/h gives a theoretical seed spacing of 8.8 inches when using six tubes per rotor. Seeds which are smooth or near spherical in shape were more accurately dispersed than rougher hulled or non-spherical seeds and that the efficiency of dispensing single seeds was subsequently improved by using seed of uniform size.

A partfrom efficiency of seed selection the performance of a precision drill can be influenced by the speed of the seed selection mechanism through the seed hopper, the trajectory of the seeds at the moment of ejection, the height of fall to the furrow, the furrow shape, the tendency of the seeds to bounce or roll along the furrow and the manner of covering-in the seed.

Unfortunately little is known about the effect of accuracy in seed spacing from the biological point of view and the engineer is faced with the dilemma of how far he should pursue accuracy. Providing some form of plant sensing is incorporated in the subsequent operation of thinning or removal of the surplus seedlings then, within limits, the accuracy of seed spacing becomes of lesser importance. Similarly if the crop is being drilled to a stand, variations of the order of $\pm 10\%$ from the nominal seedling spacing are unlikely to have an appreciable effect on yield or subsequent operations. From the crop establishment aspect the prime feature is that the seedlings should emerge.

Present day precision drills are generally adversely affected by increasing the forward speed and in practice it has been found preferable not to exceed 2.5-3 mile/h for although some machines are able to maintain the desired seed-rate, most, if not all suffer a loss of accuracy of spacing when this speed is exceeded. Greater output must therefore be sought by fitting a greater number of units and thereby increasing the width of the whole machine. It is not uncommon to see 10 or 12 row units on a machine.

Spacing the seeds along a tape is often suggested (Rae, 1968)[15] as offering the possibility of faster sowing in the field, for the slow precise work of spacing the seeds can be carried out under controlled conditions within a factory; however there are a number of practical difficulties to be overcome before such a technique can be applied on a field scale. There are approximately 5 miles of row per acre when sowing in 20-inch rows, the sandwiching of the seed within the tape material increases its thickness and therefore reduces the effective capacity of a spool. A spool measuring 7.25 in. diameter × 7 in. high is estimated to hold 18,000 ft of cabbage seed at 8 in. spacing compared with about 8-9,000 ft of sugar beet seed at 5 in. spacing. It is desirable to be able to select the seed spacing after examining the seed-bed and the tape must be buried in such a way that it neither influences the germination of the seed nor interferes with any subsequent operations.

(*f*) Transplanters

On a commercial scale the act of transplanting can seldom be carried out without severing the main tap root, so that it is of necessity confined to those crops which are grown for their vegetative parts as opposed to those which are truly root crops. In practice this means that most cabbages, Brussels sprouts etc., together with leeks and lettuce are transplanted, while carrots, parsnips and beet are seldom transplanted.

The reasons for transplanting are:

(i) the plants can be raised in a nursery bed where it is possible to give them greater attention and protection

(ii) the crop occupies the field for a shorter period

(iii) it offers an opportunity for selection which implies rejection of any unsuitable plants

(iv) it ensures an optimum plant population.

The main disadvantages of transplanting are:

(i) it requires a high labour force

(ii) the crop may suffer a check due to climatic conditions at the time.

Most transplanters are manually fed machines in which there is one operator to each row. He places the plants into a holding device that carries them down into the soil behind the coulter. The plant is then released by the holding device and secured in the soil by some form of press wheel. The rate of travel is restricted to that at which the operators are able to feed the plants and this in turn is dictated by the space between the plants. In practice[16] it has been found that 1 mile/h or about 2,500 plants per hour are the maxima that can be achieved. Turning, refilling trays etc. reduces this by 25%. The commonest arrangement is to have two or four units mounted side by side across a toolbar. The minimum row width is governed by the space required by the operators when sitting in a comfortable working attitude and is about 24-26 inches. For closer rows the units have to be staggered. In addition to one operator feeding each planter-unit a tractor driver is required. Furthermore, some labour is engaged in the nursery bed pulling and boxing the plants if the planting team is to work continuously.

For these reasons interest is being shown in the feasibility of sowing the seeds at the approximate spacing required in the established crop. This technique which is known as 'drilling-to-stand' overcomes the disadvantages of transplanting but requires a certain amount of adaptation before it can incorporate some of its advantages. The principal adaptation concerns the number of seeds that are sown at each plant position. A plurality of seeds reduces the likelihood of a missing plant, provides the opportunity of selecting the preferred plant but creates the problem of singling or thinning. With crops in which the desired final plant distance is 18 inches or more, the distance between seeds within a group can be as much as 3 inches and yet still maintain an acceptable plant distribution. Theoretically the interplant spaces will range from 12-24 inches if only one in every three seeds emerges. The thinning problem is not then very great whether it be done manually or by some form of selective thinner, for there is a minimum distance of 3 in. between adjacent plants. Where, however, the final plant distance is less than 18 inches a range of spacing between 12 and 24 inches is not acceptable and as a consequence the distance between the seeds within the group has to be reduced to 2.5 or possibly 2 inches so that the thinner or gapper is presented with the more difficult task of detecting and isolating plants within 0.11 seconds when travelling at 1 mile/h.

(g) Thinners and gappers

The difference between these two types of machine lies in the size of the cut territory in relation to the final plant distance. It is generally accepted that thinners make three or more small cuts whereas gappers make a single cut for every plant station. Sometimes machines making two cuts per plant station are referred to as semi-gappers.

Gappers and semi-gappers provide a pre-determined minimum distance between plant stations which can be beneficial in subsequent operations e.g. harvesting of sugar beet. Where the braird is irregular or varies in different parts of the field the operator is often forced to compromise between a setting that is likely to leave too many plants in those areas where the germination has been good and barely sufficient where it has been poor. A thinner, when properly adjusted, is more likely to leave the required number of seedlings over the area as a whole although their distribution is likely to be more irregular.

Both types of machine may incorporate some form of electronic control so that, on making contact with a plant the cutting apparatus is actuated. Machines without such a control unit are sometimes known as 'blind'. Following preliminary work in U.S.A. blind mechanical thinners were introduced into Europe by N.I.A.E. in 1951 and have since been the subject of many field trials. Although mainly carried out in the sugar beet crop these trials have provided much experience that can be applied to other crops. Apart from the extreme vulnerability of lettuce seedlings to loose soil the sugar beet crop combines most, and in some cases many more of the problems found in other crops. In most of the field trials the effect of using the thinner in various forms and combinations has been compared with manual singling of the crop. During the period significant changes have occurred in the characteristics of the sugar beet seed, for instance, the first year trials (1952) included so-called natural seed i.e. the natural fruit containing a multiplicity of seeds which produced a number of closely entwined seedlings making it impossible to leave discrete singles without recourse to hand labour. Since that time natural seed has been superseded by rubbed and graded seed which produces a braird containing a higher percentage of singles. In 1960 the first trials using monogerm seed in conjuction with a blind mechanical thinner were carried out. Within the last three years pelleted monogerm seed has been used. In 1952 and 1953 cup-feed drills were used whereas in all subsequent trials precision drills of one type or another have been used.

Apart from the obvious aspect of reducing the hand labour required to single the crops an important consideration in these trials has been the effect on yield and also the effect on the efficiency of existing harvesters. Both these aspects are indirectly related to the uniformity of plant spacing, and although slightly lower yields have been recorded as a result of mechanical thinning it has often been suggested that part if not all of this difference is attributable to the high standard of hand work. In contrast with normal commercial practice the hand singled plots have always recorded final plant populations very close to the generally accepted optimum of 30,000 per acre. Nevertheless the fact must be accepted that plant populations with irregular spacing are more difficult to harvest mechanically and are liable to result in higher top tare and higher losses due to small roots falling through the machine.

'Blind' machines which are considerably cheaper than controlled or selective machines, can have rotary, pendulum or reciprocating actions (see Figure 6). These three types of action were the subject of experiments carried out by Chittey (1962)[17] who showed that when used in comparatively full and thick brairds of 36 seedling-in./100 in. resulting from sowing rubbed and graded multigerm seed at 1.5 in. spacing, a double treatment with the rotary thinner produced acceptable reductions in terms of seedling-in. in both treatments that were within 10% of the predicted figures. The first treatment with the pendulum thinner, although consistent was about 30% below the predicted figure whereas the second treatment produced reductions that were very close to the predicted figures. With the reciprocating thinner the first treatment was within 10% of the predicted figure while the second treatment was well below the calculated figure.

The differences between machines at thinning time did not produce any great effect on the final yields although no data were obtained on the pattern of distribution of the seedlings so that it is not possible to compare the harvestability of the different plant stands. Operational factors such as depth control, forward speeds, ease of adjustment and versatility influence the functioning of these machines and can therefore vary the severity of the treatment achieved with any particular combination of blades and gear ratios.

Arising from this and other work has been the tendency towards a technique which involves only one passage through the crop. A large scale trial carried out between 1964-1966 by Hanbury[18] involved 31 sites and examined the feasibility of using mechanical thinning in conjunction with low seed rates of 3-6 in. spacing of sugar beet and with chemical weed-control. Where chemical weed-control was effective in machine thinned crops the results showed that in some instances no hand labour was required for crop establishment, although there were mean reductions in yield of 1.3 tons per acre (7%) compared with similar crops that were hand singled. When hand singling was used a saving of nearly 5 man-hours per acre (5%) was achieved as a result of increasing the seed spacing from 1.5 to 3 in., but no further economy of labour was recorded when the seed spacing was increased to 4 in. The results for one year of using monogerm seed in place of the processed multi-germ seed showed a further saving in hand labour of 5 man-hours per acre. It should, however, be noted that at only seven of the thirty-one centres was the chemical weed-control so effective that no hand weeding was necessary, and in these instances between 7-12 man-hours per acre was required in comparison with hand singling times of 23-30 man-hours per acre.

With the arrival of herbicides that allow a crop to be grown free of weeds, it is possible to detect each plant seedling and to use it to actuate some form of cutting mechanism and by programming the action of the cutting mechanism a degree of regularity can be introduced into the resulting crop.

Selective mechanical thinners have been undergoing development in Europe for many years. One design, which was demonstrated in 1947 as a one-row machine and, recently has been marketed as a multi-row machine, has eight small (1 in.) blades carried radially on a rotating high speed head (see Figure 7). When a plant completes the circuit from the feeler to earth the control box activates a solenoid within the rotating head and thereby causes the blades to retract and leave the plant. Controls allow the operator to adjust (a) the length of the cut zone and so determine the minimum distance between plants and (b) the length of the uncut block to suit the size of the seedlings and the distance between seedlings in the original braird. The use of transistors and printed circuits in place of thermionic valves has greatly improved the reliability of the control equipment of selective thinners. Following work in sugar beet in 1965 Strooker[19] reported that the selective thinner worked equally well during the 2-leaf and 4-leaf stages of crop development and that the distribution of seedlings resembled handwork in general outline. However, in contrast to handwork the thinner did not decrease the number of doubles and it left more plants within 6 in. of each other and also created more gaps exceeding 24 in. in length. Strooker also reported that the working speed was less than 1 mile/h and that the working season was likely to be less than that of handwork because the start had to be delayed until the seedlings were big enough to be detectable.

Selective chemical thinners using an interruptable spray of a slightly viscous solution of contact herbicide have more recently been developed and are now appearing on the market in pre-production models. Their principle is very similar to that used in the selective mechanical thinners described above. The sensing unit precedes the plant-removing equipment which remains in action until commanded otherwise. The main advantages claimed for chemical thinners are that (a) they do not disturb the soil within the row so that they augment rather than remove any residual herbicide that may have been applied at the time of drilling, (b) by not disturbing the soil they will not cause the remaining seedlings to receive a check, (c) they will probably be able to work at higher forward speeds.

The alternative arrangement in which the relative positions of the sensor and the plant removing blades are reversed has the following advantages:

(i) the blades are held clear of the row until commanded to cut, thus having a fail-safe characteristic
(ii) the blades are not brought into action until they have passed the selected seedling
(iii) the minimum distance between seedlings can be related directly to the effective blade length
(iv) the length of the block is simply adjusted by changing the distance between sensor and the trailing edge of the cut zone.

Disadvantages of this arrangement lie in the fact that most designs incorporate some form of servo mechanism, either pneumatic or hydraulic, to actuate the cutting blades. This in turn means that the appropriate form of power and reservoir have to be provided. Such assisted cutting produces a very clean cut in the soil and is more akin to gapping in both action and appearance.

Please turn to page 136

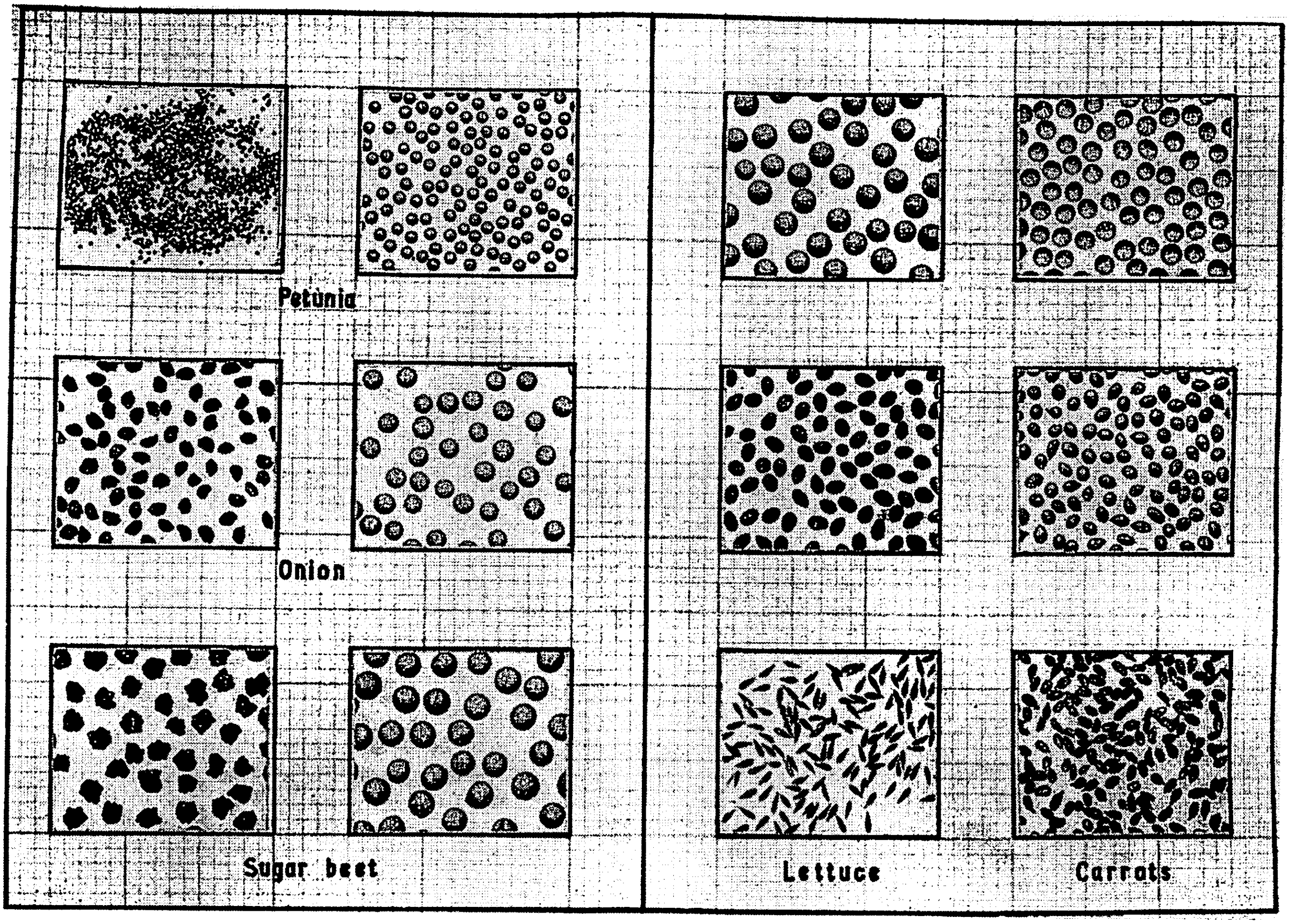

FIG. 4
Pelleted seed

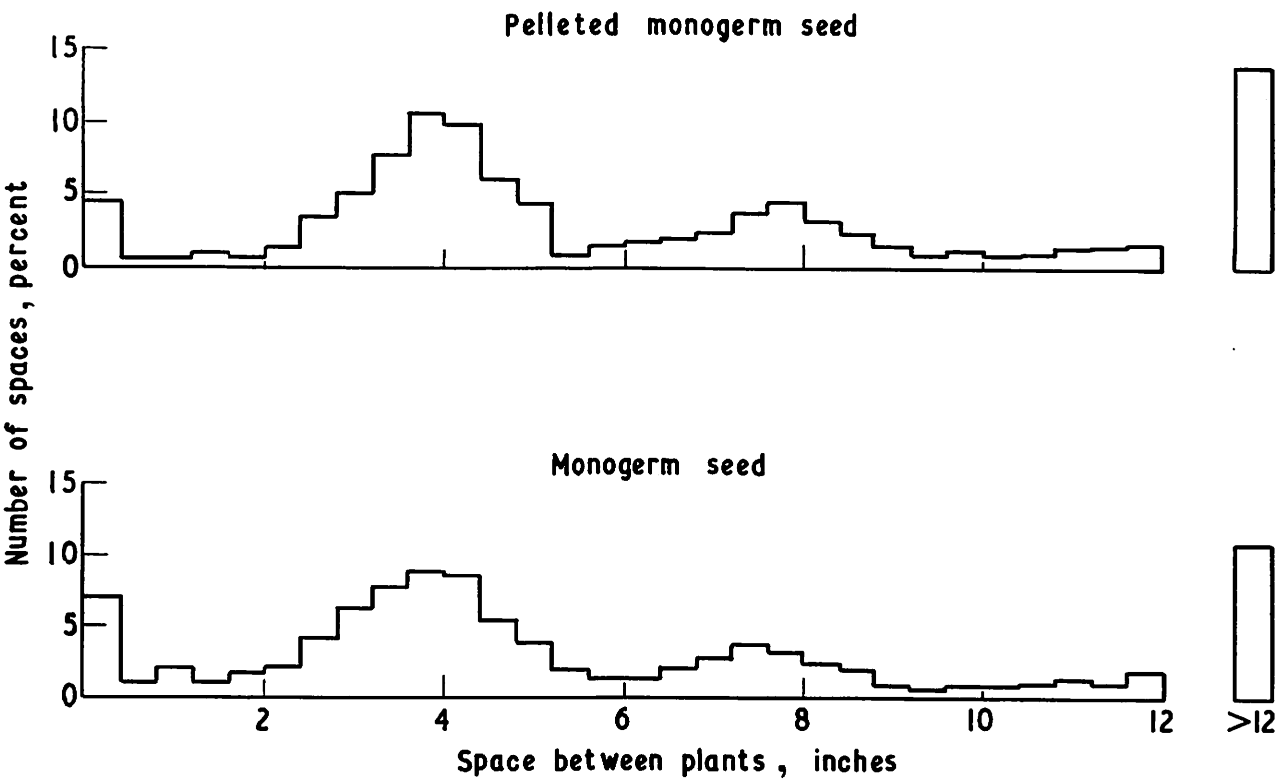

FIG. 5
Plant distributions 1968

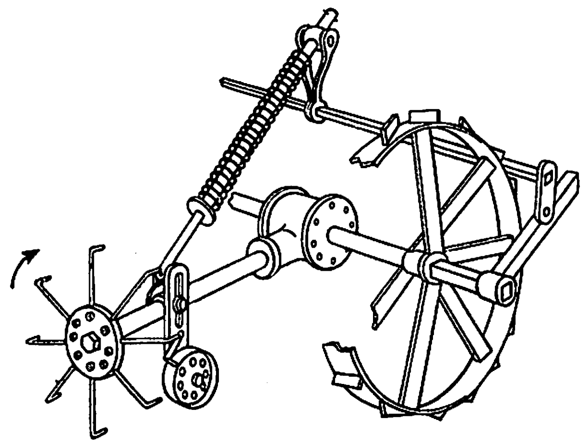

FIG. 6 (1) Rotary head thinner

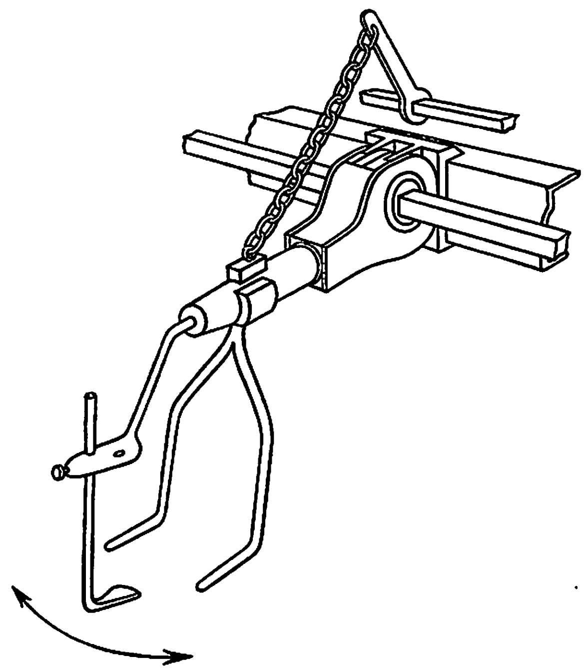

FIG. 6 (2) Pendulum thinner

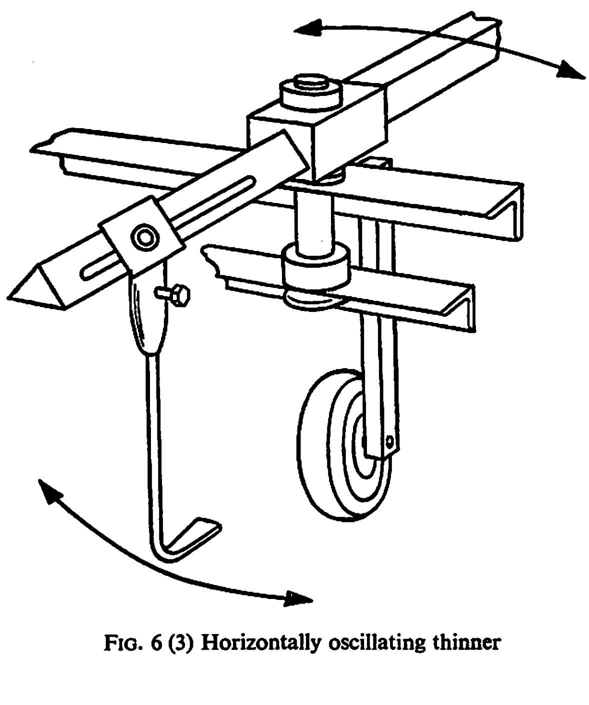

FIG. 6 (3) Horizontally oscillating thinner

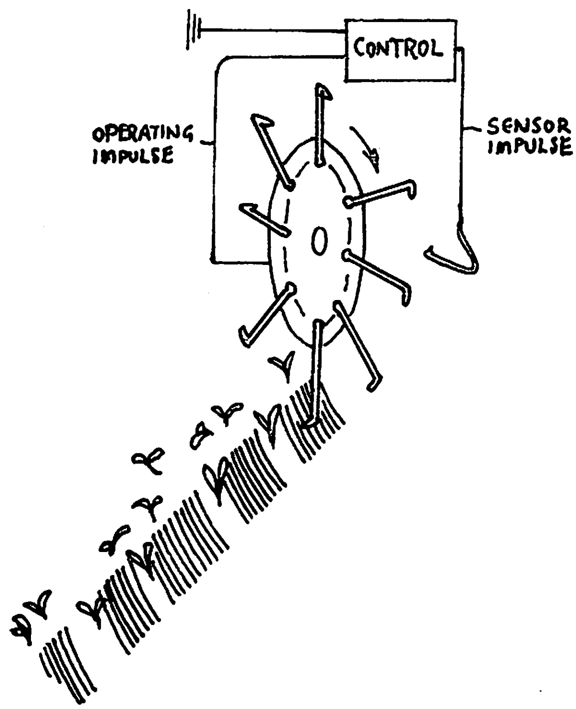

FIG. 7 (a)

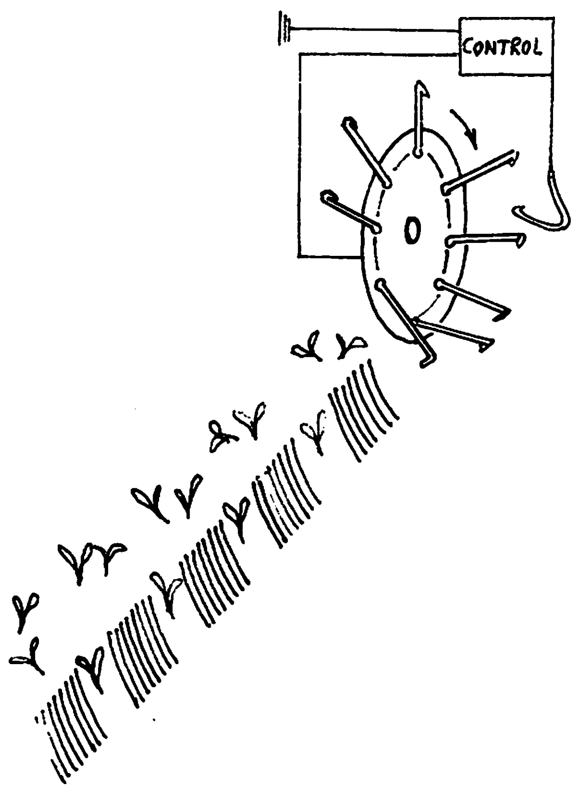

FIG. 7 (b)

Selective thinners.

a, b electro-mechanical c electro-chemical d selective gapper

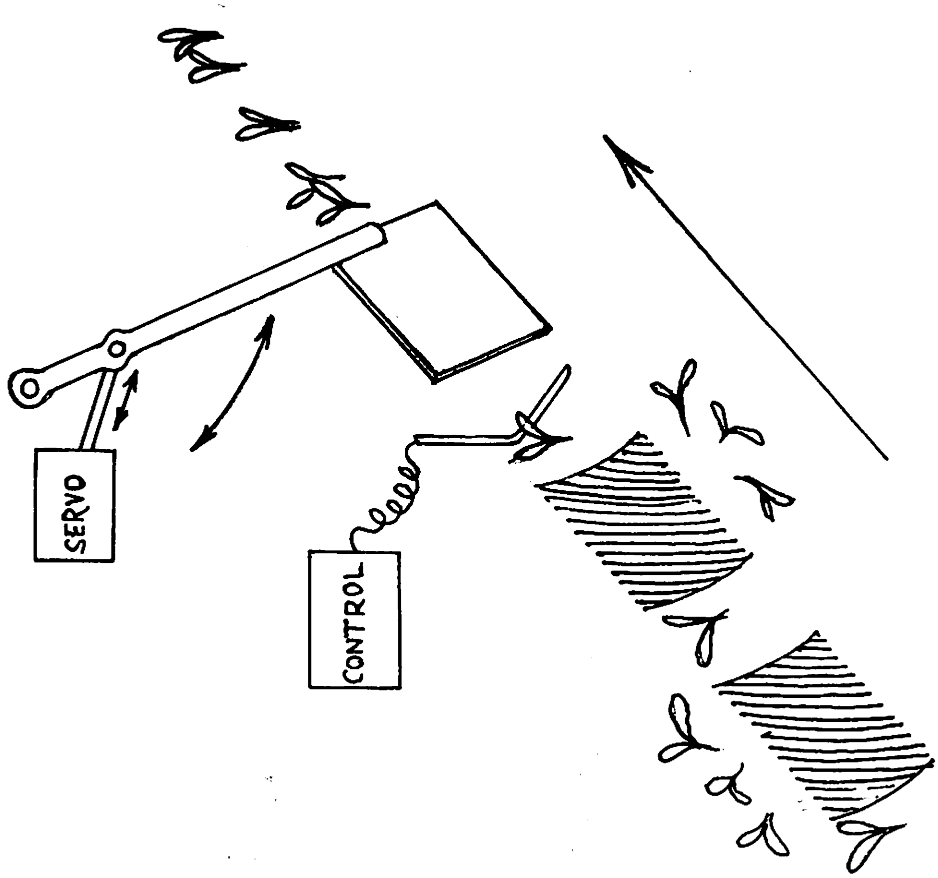

FIG. 7 (d)

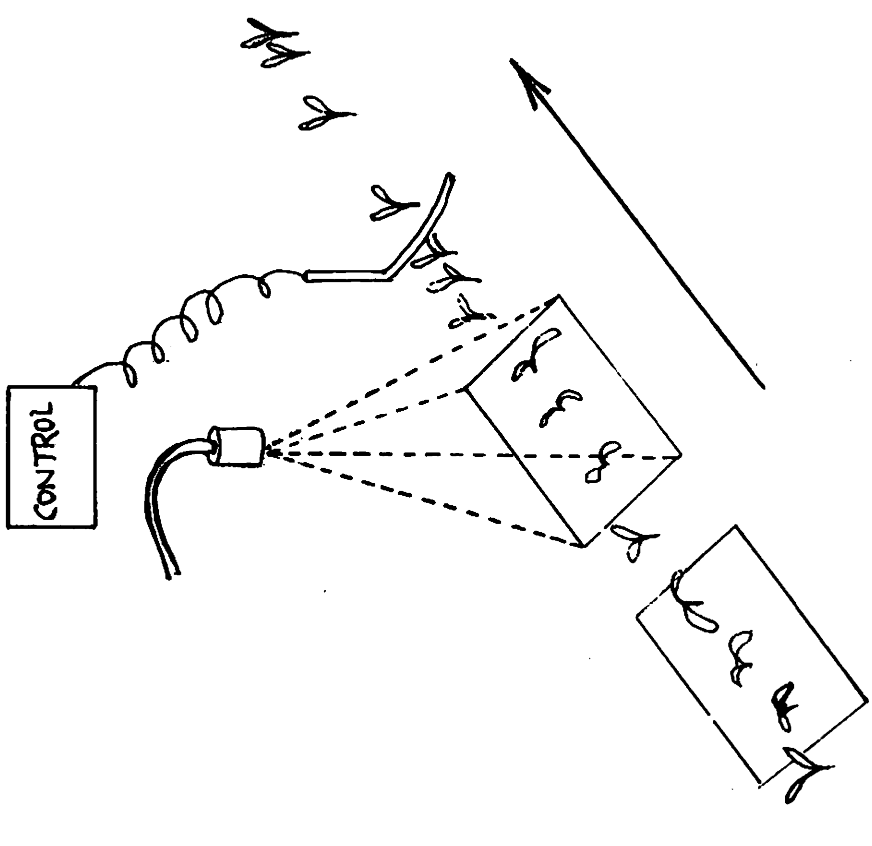

FIG. 7 (c)

continued from page 131

CONCLUSION

In practice blind thinners have not found wide acceptance mainly on account of the untidy appearance of the crop, coupled with the extremes of irregularity in plant spacing which were particularly noticeable in the case of multi-germ sugar beet seed. Newer techniques of seed-bed preparation in conjunction with precise spacing of single seeds have opened up the prospect of using seed rates which in themselves are capable of providing a line of seedlings discretely isolated from one another. However the unpredictable variations in field emergence are such that, at the present time, it is not generally possible to produce all crops by the drilling-to-stand technique so that variations on this theme are likely to prevail for some time. Amongst such variations are different patterns of drilling with and without some form of thinning, probably controlled if such machines can be produced at prices which will be attractive to the growers. The final choice of technique must of course lie with each grower, who will be influenced to a large extent by the market requirements for the crop that he is growing.

ACKNOWLEDGEMENTS

It is a great pleasure to be able to acknowledge the co-operation and assistance in the preparation of this paper that has been rendered by anyone that has been approached. Some of these collaborators are named in the references but many others must remain anonymous.

The author is grateful to H.M. Stationery Office for permission to use the illustrations in figures. Messrs Germains (U.K.) Limited kindly supplied the photographs of pelleted seeds used in figures.

REFERENCES

1. Baker, E. F. I., 'Plant Population and Crop Yield'. *Nature Lond.*, 1964, (204), 856.
2. Bleasdale, J. K. A., Nelder, J. A., 'Plant Population and Crop Yield'. *Nature Lond.*, 1960, (188), 342.
3. Bleasdale, J. K. A., Thompson, R., 'The Effects of Plant Density and the Pattern of Plant Arrangement on the Yield of Parsnips'. *J. Hort. Sci.*, 1966 (41), **4**, 371.
4. Bleasdale, J. K. A., Nelder, J. A. *et al*, 'Competition studies and Spacings of Various Vegetable Crops'. *An. Reps. natn. Veg. Res. Stn., Wellesbourne*, 1959-66.
5. Willey, L. A., 'Sugar Beet Emergence Trials'. *Natn. Inst. agr. Bot.* 1967 and 1968.
6. Bunting, E. S., Willey, L. A., 'Emergence of Maize'. *J. agric. Sci.* 1957, **48**, (4), 447.
7. Roebuck, J. F., 'Mechanising the Swede Crop'. *Exp. Hus.*, 1966, **13**, 54.
8. Wayman, J. A., 'An Analysis of Rowcrop Practices in G.B.'. *Private communication* 1968.
9. Mohsenin, N. N., 'Physical Properties of Plant and Animal Materials'. *Dep. agric. Engng., Pennsylvania State Univ.* 1968, **1**, (1), 58.
10. Vanstallen, R., 'Analyse des facteurs influençant la distribution des graines de betteraves à sacre par des semoirs de précision'. *I.I.R.B. J.*, 1968, **3**, (3), 155.
11. Bradford, C. M., 'Precision Drills and Single Plants'. *Private communication.*
12. Sweetman, I. C., 'A Suction-Operated Precision Seeder'. *N.Z. J. Sci. Tech.*, 1957, **38A**, (6), 577.
13. Copp, L. G. L., 'A Precision Seeder Operated by Suction'. *N.Z. J. agric. Res.* 1960, (4), 441.
14. Kemp, J. G., Kalbfleisch, W., 'Note on the Evaluation of the N.Z. Space-plant Seeder'. *Can. J. Plant Sci.* 1962 (42), 554.
15. Rae, R., 'New Plastic Tape Heralds Sowing by the Yard'. *Comm. Grower*, 1969, 3809 19.
16. N.I.A.E. Users test reports Nos. 495-498, 1966.
17. Chittey, E. T., Maughan, G. L., 'Mechanical Thinning of Sugar Beet. A comparison of different types of thinner' 1962. N.I.A.E. DN/155/CD, unpublished.
18. Hanbury, L. F., Maughan, G. L., 'Machine Thinning of Sugar Beet: Field Trials with Low Seed Rates'. *J. agric. Sci. Camb.* 1968, **70**, 313-321.
19. Strooker, E., 'An Investigation into the Use of an Electronically Operated Down-the-Row Thinner in Beet Cultivation'. English summary of pubn. originally in Dutch. *Inst. Landbouw en rut. Wageningen*, 1966, No. 95.

CORRIGENDUM

SPECIFIC APPLICATIONS OF AIR PHOTO-INTERPRETATION IN AGRICULTURAL DEVELOPMENT PLANNING

In the above-titled Paper by R. G. B. Jones which appeared in the Summer 1969 *Journal* (Vol. 24, No. 2, pp. 55-74) the List of References is incomplete; only references 5.1 to 5.5 were listed. The publishers apologize for omitting references 5.6 to 5.12 which should have appeared as follows:—

5.6 Jones, R. G. B., Hack H. R. and Vincent, V., 'Aerial Photography in Land-Use Planning in the Federation of Rhodesia and Nyasaland', *Sols Africains*, Vol. VII, Nos. 1 and 2, 1962.

5.7 Jones, R. G. B., 'Some Engineering Aspects of Air photo-interpretation in Catchment Development Programmes, *The Photogrammetric Record*, Vol. IV, No. 24, 1964.

5.8 Jones, R. G. B., Keech, M. A., 'Identifying and Assessing Problem Areas in Soil Erosion Surveys using Aerial Photographs', *The Photogrammetric Record*, Vol. V, No. 27, 1966.

5.9 Planning Staff, Federal Dept. of Conservation and Extension, *'Land-Use Planning Procedures'*—Govt. Printer, Salisbury, Rhodesia, 1962.

5.10 Robertson, V. C., Jewitt, T. N., Forbes, A. P. S., Law, R., 'The Assessment of Land Quality for Primary Production' —*Papers of a C.S.I.R.O. Symposium organized in Co-operation with U.N.E.S.C.O.*—Canberra 26-31 Aug. 1968. MacMillan of Australia 1968.

5.11 Soil Survey Staff U.S.D.A.—'Soil Survey Manual'—*U.S.D.A. Agricultural Handbook No.* 18, 1951.

5.12 Wiggill, M. D., 'Contour Ridge Layout in Mashonaland', *Rhodesia Agricultural Journal*, Vol. 52, No. 2, 1955.

CROP HARVESTING AND HANDLING

by

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SUMMARY
Systems for the harvesting, handling and market preparation of a variety of rowcrops are analysed and examples are given of N.I.A.E. development projects.

In one example a tractor trailed single row sugar beet harvester of tanker design employs hydraulic servo-mechanisms to steer the share and control its depth of working. The other example is a handling system for bulky leaf vegetables. Framed canvas bags which hold 2.6 yd³ of crop and collapse for emptying and storage are used for transporting mechanically harvested crops from the field to fixed or mobile packing sheds.

1. INTRODUCTION

In the last twenty years the proportion of the British sugar beet crop harvested mechanically has risen to over 95% and it is possible that rising labour costs may make it necessary in the next decade for many other rowcrops to reach the same stage of mechanization. Recent advances in plant breeding, plant physiology and methods of crop establishment now make it possible for machines to be designed to harvest most of these crops, and agricultural engineers in this country and abroad have already produced harvesters for crops which only a few years ago were considered to be impossible to mechanize. However, when one considers that there are at least five categories of sugar beet harvesters and that the sugar beet crop is relatively simple to harvest in that it ripens uniformly, requires little preparation for market and is resistant to damage, it is clear that there is likely to be a bewildering choice of systems for crops where harvesting is a more complex operation.

A harvesting system may be defined as the process of converting a growing crop into a marketable product and includes machines for cutting or lifting the crop, for handling it in the field and through various operations to the farm gate and for market preparation. Before considering how systems may be analysed for use in selected situations, it is desirable to consider the characteristics of their component parts.

2. HARVESTING MACHINES

2.1 Complete Harvesters

Complete harvesters may be defined as those which produce a finished sample in the field and are the obvious choice for root crops and those where selection and pre-market trimming and grading of individual plants is not usually necessary. In all such crops there is a choice between:

(a) Single and multi row
(b) Single and multiple stages
(c) Continuous side delivery and tanker machines
(d) Self-propelled and tractor towed machines

To a great extent the choice of machines is limited by the scale of operation or by soil conditions. Thus, there are many soils on which root harvesting is best completed under favourable conditions, where heavy machines or those which require several passes through the crop are unsuitable. Similarly a grower with 10 acres can hardly justify an outfit which harvests 12 acres a day. In many cases, however, the grower will have to decide on the relative merits of a number of different harvesting machines. The sugar beet crop, for which there are sufficient recorded data to enable both qualitative and quantitative assessments to be made, may be used to illustrate the basic principles and areas where future development is indicated.

In Britain single row machines which top, lift, clean and load the crop in one pass were favoured when tractors were low-powered and not very plentiful. Now, however, larger growers must choose between operating several single row machines or a multi-row and perhaps multi stage one, and agricultural engineers have to choose between continued development of single or multiple row machines.

The simplest outfit in terms of gang size is undoubtedly the self-propelled tanker harvester where one man is responsible for the entire harvesting operation and perhaps the carting. Such an outfit unloading on a heap at the end of the field achieved an output of 0.37 acres/hour at the 1968 sugar beet harvester demonstration[1] but calculation shows that the output would have been reduced to 0.1 acres/hour if the haulage distance had been 1,000 yards. It is therefore usually suggested that the harvester should discharge into a stationary trailer if the haulage distance exceeds 150 yards—although in fact the output does not decrease until the distance of haul reaches 800 yards[2].

In contrast to the one man self-propelled tanker a multi-row multi-stage machine requires three tractors and drivers to operate the topper, lifter and loader as well as a transport team capable of handling more than

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a ton of crop a minute. Such a machine with a team of 6 or 7 men and tractors could harvest 12.7 acres in an eight hour day[1]: it had an output 4 times as great as the one man self-propelled tanker and a capital cost between 2 and 3 times as much.

In 1964 the N.I.A.E. in consultation with the Sugar Beet Research and Education Committee investigated the idea of a one-man single row tractor-trailed tanker harvester to work at a very high forward speed, on the grounds that one-man operation with a trailed machine has the advantages of the self-propelled tanker with greater flexibility in that the tractor can be removed for other work. It was also thought that a light-draught single row machine might work, at a reduced forward speed, in more adverse field conditions than a multi-row machine. In trials it appeared that where the steersman is replaced by automatic controls the standard of work falls off less at higher speeds as operator fatigue is not involved[3].

In an experimental machine built in 1965[4] a feeler which formed an open horizontal V in contact with the ground straddled the row of beet immediately ahead of the lifting wheels (Fig. 1). The feelers regulated the position of the wheels relative to the row and their depth by means of hydraulic servo-mechanisms. Proving trials over a range of field conditions included one in which the efficiency of the harvester was measured at forward speeds of up to 6 mile/h in comparison with the farmer's machine of the same make. Surface losses from the self-steered machine amounted to approximately 6 cwt/acre and were remarkably constant at all of the forward speeds. Approximately 3.5 cwt/acre of beet was left in the ground at the lower forward speeds but at 4.6 and 6 mile/h, 6 cwt/acre was lost. These figures compared favourably with those recorded at the 1959 and 1962 National Sugar Beet Harvester Demonstrations[5], where hand-steered harvesters equipped with lifting wheels lost about 16 cwt/acre at a maximum overall rate of working of 0.59 acres/hour. Topping efficiency at higher forward speeds was low. Studies showed that increasing forward speed with a conventional ground-driven topper nearly always results in more over-topping, with a corresponding but less marked, reduction in undertopping. Rather surprisingly the trials showed that variations in the braird had little effect, probably because the comparatively heavy topper unit had insufficient time to position itself and so tended to plunge into the crowns instead of riding over them[6].

In the early part of last season, trials of a lightweight topper with a preloaded suspension showed promise of success, but late in the season when the beet had become tough, with a high population of dead leaves and on a much wetter surface the results were discouraging[7].

It would appear that improving topper efficiency at high speeds requires a more complex solution than a low inertia topper. This is not surprising when one considers that about 10 beet have to be topped every second at a forward speed of 6 mile/h, that the correct topping height relative to ground level can vary by 5 in. between adjacent beet[8] and that overtopping by 0.25 in. is equivalent to a loss of 13 cwt/acre.

The difficulties of topping sugar beet accurately at high forward speeds, however, do not invalidate the general conclusion that single row work is advantageous. Even if it is impossible to design a topper to work at 6 mile/h, most of the advantages of the high speed lifter can be retained by using a two-stage system of harvesting in which a multi-row topper would be used. It is probably also true that many of the other row crops that suit complete harvesters will best be mechanized by using the single row high forward speed approach.

2.2. Selective Harvesters

Although considerable efforts were made in the U.S.A. in the early 1960's to provide mechanisms to select ripe plants from immature ones no one in this country has produced a fully automatic selective harvester. The only experimental work on mechanized lettuce harvesting has employed the once-over technique[9] and mechanized harvesting of cauliflowers has been confined to the use of harvesting aids or improved traditional hand methods. Davis and Wheeler analysed the work content of three such methods in 1964-67[10]. They concluded that a method in which the operator cut and trimmed the head only was preferable to that in which grading was also done by the same operator. Given suitably sized crop containers it was better to grade and pack in a well designed packing shed than on the headland or on a harvesting aid moving along the rows of crop (Fig. 2). The reason that the harvesting aid did not show up as the most efficient method of using labour in spite of its fewer elements of work and crop handling sequences was the inability to maintain a properly balanced working team. Although the five men who cut and trimmed the crop were able to help each other without slowing up the overall rate of working, the rate of progress of the unit along the row was in part determined by the rate at which the cutters could inspect the crop. The graders and packers were therefore under-employed in places where there were few ripe heads and overwhelmed where the yield was high.

In the trials the harvesting aid showed a labour saving of 29% over the traditional method and the better of the two improved methods of hand harvesting had a labour saving of 35%. Increases in productivity of between 30% and 100% have been claimed for harvesting aids used for vegetable crops in the U.S.A., but it is very doubtful if a more elaborate aid for cauliflowers would have been more productive than the one which was studied.

Experimental data from trials with cauliflowers, however, cannot be applied to other crops that are harvested selectively. In the cauliflower trials trimming added very little to the time taken to select, cut and throw marketable heads: the difference in times that were recorded was only 2.5%. Experimental work on manual harvesting of lettuces in the U.S.A., however, showed that trimming accounted for more time than selecting and cutting marketable heads[11]. It is therefore reasonable to suggest that improvements in lettuce harvesting are likely to result from re-organization of the work as well as from improvements in handling techniques.

2.3. Simple and Complete Harvesters

Hawkins analysed the advantages and disadvantages of complete and simple vegetable harvesters at this conference three years ago[12]. Most of his analysis is still valid when applied to harvesters where the operations rely on mechanical components. Harvesters like many of the present day potato harvesters and the recently announced American and Dutch combine harvesters for Brussels sprouts rely on teams of men for operations that are difficult to mechanize. The harvested products are therefore similar to those from hand harvesting and may be equally undamaged. Such machines, however, do not exhibit the increases in productivity that are achieved by fully mechanized harvesters, such as the one man self-propelled beet harvester which gives 1200% of the productivity of hand topping and lifting with tractor and trailer haulage. Calculation shows that a potato harvester with four pickers gives 300% of the productivity of hand digging and lifting. On the other hand, with a Brussels sprout combine where stems are fed into the stripping units by hand the calculation is complicated by other operations, such as leaf stripping and inspecting the final sample, for which there is only a limited amount of work study data. One can only estimate that a 3 stripper Brussels sprout combine is likely to give between 140% and 200% of the productivity of traditional hand picking[13].

Assessments of productivity increase from the use of simple harvesters are likely to be misleading. Thus a man with a universal vegetable harvester[9] can cut and load Brussels sprouts plants 10 to 12 times as quickly as with a bill hook. Cutting and loading, however, is not a work element in traditional hand picking and is only one of about six operations in mechanized once-over harvesting. Low productivity in any of these elements or the inclusion of unnecessary elements can reduce the advantages of the simple harvester. Simple harvesters therefore cannot be compared quantitatively with complete ones except as parts of systems that take account of all of the various harvesting operations.

3. MATERIALS HANDLING

As part of the harvesting operation every crop has to be loaded on to vehicles, transported out of the field, unloaded to await further processing or sale and then loaded again. None of these handling processes is productive: they add nothing but cost to the final product[14]. Furthermore most rowcrops are of very limited value compared to industrial materials. Thus for example sugar beet before it is cleaned and loaded is worth less than £6 per ton and Brussels sprouts on the stalk are worth no more than £10 per ton. Short distance transport with agricultural tractors or specialized vehicles based on them is inexpensive[15] and tipping trailers which have been available for many years provide a rapid method of unloading where there is no objection to placing the load directly on the ground. Trailers where the body can be raised have the advantage of allowing loads to be discharged into hoppers and designs where the body can be freed quickly from the chassis allow loads to be stored to await some other process. Self unloading trailers have the virtue of giving a controlled rate of unloading which may be desirable to reduce damage or to provide a steady flow for market preparation processes.

Efficient crop handling, however, depends on efficient loading as well as on cheap transport and unloading. In the sugar beet crop, a sound economic argument can be advanced for running a tractor and trailer alongside a single row harvester only where the acreage is too low to justify the additional cost of a tanker or where soil conditions are too wet to allow one to be used.

The success of tanker machines results from their unloading rates being very much higher than their harvesting rate. A single row unit working at 3 mile/h harvests a tank load of beet in 9 minutes and discharges it in 3 minutes. Because 2 tanks are required to fill a trailer loading time is therefore 12 minutes instead of 18 minutes. The saving in transport that results is apparent when the 6 minutes that is saved is compared with the 14 minutes that is needed for transporting beet 800 yards to a clamp, tipping it and returning empty. A less easily measured but probably more important saving is that the tanker introduces a break point into the harvesting system permitting easier balancing of harvesting and transport.

The provision of break points is particularly important in vegetable harvesting where market preparation is likely to proceed at a very different rate from harvesting and where short term storage may be desirable to allow daily or weekly marketing in spite of adverse field conditions. Unit loads are usually accepted as the best solution to these problems and a vegetable harvester that carries pallet boxes and discharges them as they are filled could combine the advantages of the tanker harvester with those of container handling[16]. A tractor-mounted machine of this type would probably also work satisfactorily when field conditions are too wet for trailer transport.

As a general solution to the handling of produce from the universal vegetable harvester pallet boxes were abandoned on the grounds that in leafy crops very large boxes are required[9]. These are too heavy to be manhandled when empty and are filled too quickly to allow the driver to operate a conveyor which was lowered into the boxes to reduce crop damage.

The success of this system therefore depends upon the bulk density of the crop being handled. In carrots a 1.5 yd^3 box holds about 10 cwt harvested from about 250 yd of single row, but with Brussels sprouts a 2.5 yd^3 box holds 400 stems weighing 800-1,000 lb harvested from a 200 yd row. Thus with carrots it is relatively simple to provide a magazine to hold a supply of empty boxes that can be lifted on by 2 men whereas with Brussels sprouts one can rarely find space for more than one spare box which, weighing 300 lb when empty, has to be lifted on to the harvester by mechanical means.

Recent trials at N.I.A.E. with sling bags (Fig. 3) indicate one possible method of using unit loads with vegetable harvesting machines. The sling bags are based on reinforced paper sling bags which have been used in the U.S.A. and this country for handling materials such as fertilizers in 0.4 or 1.3 yd^3 unit loads.

They are simply large sacks of more or less cubical shape in which the load is carried by means of a sling the full width of the container. The sling extends above the top of the container in the form of loops which pass over the forks of a pallet carrier and not only support the weight contained in the bin but also maintain its more or less square cross sectional shape.

In the first N.I.A.E. design the sling bag was made of jute cloth and fitted with a top frame made from steel tubing with spring steel strips to hold the slings open and at the correct distance apart. A lightweight wooden framework at the base of the bag ensured that it remained flat as the bag was filled and allowed the use of roller track conveyors for moving full bags. A loop of cord under the bag was shortened by a simple windlass on the lifting forks to furl the sides and reduce the height that crop must be dropped into empty bins.

As yet these bags have only been tried with a front loader and in a packing shed: they have not been fitted on a harvester. The present design is 3 ft 6 in. deep, 5 ft wide and 4 ft from front to back. Its weight of 80 lb can no doubt be reduced in future designs. The advantages over standard wooden pallet boxes are:

(*a*) Empty weight is less than one quarter.

(*b*) Empty volume is such that two 2.6 yd^3 bags occupy a space of 5 ft square and 9 in. deep.

(*c*) Damage free filling requires minimum attention by the machine operator.

In the trials it was observed that full bags were no more difficult to pick up than pallet boxes, and although they could not be stacked they could be moved on a roller track conveyor. Moreover (Fig. 4) they were emptied without the aid of a tippler by allowing the sides to collapse as the contents were removed and it appeared that the extra time spent by the operators stooping to reach the Brussels sprout stems was compensated by their not having to operate a tippler and by the speed with which they could push empty bags out of the way and replace them with full ones.

The trials also showed how the design of the bags can be modified so that empties can be placed on lifting forks automatically instead of by hand. More extensive trials are planned for the coming autumn and winter.

4. MARKET PREPARATION

All mechanically harvested rowcrops require some preparation before marketing. Cleaner loaders are an integral part of sugar beet harvesting and at the last demonstration 20 machines were shown to have an average loss of 2.2 lb/cwt[17]—approximately the same as that by roots left in the ground and less than 1/5 of the total losses[18]. The most effective machine reduced the dirt tare by 55%, the average of all machines being 40%.

Specialized machinery for use in packing sheds is also available for the market preparation of carrots, onions, leeks and salad onions. There is, however, no up-to-date comparative data of their performance. There is also a considerable difference of opinion on where market preparation of crops with a high proportion of waste should take place. Celery, cabbages, Brussels sprouts, cauliflowers and lettuces are examples of crops of this type.

Machines of three distinct types are now available for stripping Brussels sprouts: combine harvesters where the crop is cut, stripped and to some extent cleaned (Fig. 5), tractor-mounted or trailed units with or without cleaning attachments where stripping takes place in the field (Fig. 6) and electrically powered units for use in a packing shed (Fig. 7). In all of these units, however, stems have to be fed one by one into stripping mechanisms. It may be argued that the use of packing shed units is disadvantageous in that extra transport is required for carrying waste to and from the shed. However, with a handling method that permits short-term storage of stems the method has the advantage of allowing market preparations to continue when adverse weather precludes field operations.

A mobile packing shed after the pattern of the Hosier milking bail is a possible alternative to field or packing shed strippers and trials with a unit at N.I.A.E. (Fig. 8) have shown that rates of working are similar to those attained in a fixed shed.

The shed which was subjected to field trial in the winter of 1967-68[19] was based on a 4-wheeled trailer having a deck 14 ft long and 6 ft 6 in. wide. Two cradles each 7 ft long were suspended from one side of the trailer to support box pallets of untrimmed vegetables. The cradles each consisted of 2 L-shaped frames connected by struts and diagonal braces and were carried on hinges 3 ft above the deck of the trailer.

Cable operated ramps on frames at the front and rear of the trailers were attached to the lower corners of the cradles and were operated by hand winches which tilted them through 100° allowing operators standing on the trailer deck to remove all the vegetables from the pallet boxes.

The trailer deck formed the working area of the shed and a 4 ft wide extension on the opposite side to the cradles provided space for storing produce. This extension and the roof above it folded against the side of the trailer for transport. The working area was also covered with rigid corrugated p.v.c. roofing and the ends were similarly clad. Polyethylene curtaining around the produce storage extension reduced draughts considerably and, although the crop reception side was completely open, working conditions were reasonable.

When the shed was used for Brussels sprouts two stripping machines powered by an engine-driven generator were mounted adjacent to the crop reception cradles so that each operator had access to the whole length of one box and also to the hand winch that controlled the angle of tip. Chutes were provided to guide waste stems over the edge of the deck into heaps under the cradles. A simple roller cleaner precleaned the sprouts as they were discharged from the strippers and a third operator was responsible for stacking bushel boxes of produce, moving the shed when the piles of refuse became too high and replacing empty pallet boxes with full ones.

The trials showed no major disadvantages of the basic concept but crop handling in pallet boxes 7 ft wide, 3 ft 6 in. from front to back and 3 ft high was unsatisfactory. The empty boxes, besides being heavy took too long to exchange for full ones and their narrow front-to-back dimension although suitable for hand unloading and transport was unsuited to automatic filling from a vegetable harvester. Their depth also was too great for damage-free filling. A canvas hopper with a retractable slide inside the box was necessary but added to the already high unproductive weight that had to be transported across the field.

Self-unloading trailers have been used as hoppers by a Norfolk grower who has a mobile packing shed for field pretrimming of mechanically harvested celery[20] but for N.I.A.E. trials this winter in Brussels sprouts sling bags will be used with a very simple packing shed based on a 2-wheeled trailer (Fig. 9).

5. COMPARISON OF HARVESTING SYSTEMS

It is possible to compare the economic merits of harvesting systems for particular farm situations by making uniform assumptions based on data obtained from field tests of machines. Such analyses with sugar beet harvesting systems show that merit depends not only on technical efficiency but also on how well the system matches the availability of labour and capital on the individual farm[2].

At present, analysis of Brussels sprout harvesting systems is impossible because there are insufficient reliable data on the operation of all the various systems that are either in use or under trial. It is, however, possible to make qualitative assessments based on external factors that limit the use of the various systems. From a block diagram (Fig. 10) it can be seen that hand harvesting in which the workers select the sprouts has only three work elements and that mechanized harvesting has 8, 9 or 10 elements. The increase in the number of operations, however, gives a degree of flexibility which is of value with a crop where the yield and price varies throughout the season and where day to day fluctuations follow a fairly distinct weekly pattern.

The magnitude of the seasonal variations are shown in Table 1 where price data are based on average market prices over the five year period ending in 1964[21]. Yield data of destructively harvested crops which are also shown are based on only one trial,[22] but are fairly typical of the patterns that have been reported elsewhere.

TABLE 1

	Sept.	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*
Price—5 year average (s.d./cwt)	72/7	62/2	45/10	55/1	59/4	59/10
Yield—unreplicated trial (tons/acre)	4.5	5.4	4.3	3.6	4.0	—

Reliance on hand harvesting means that crop will be picked only on those days when the weather is suitable: the grower has little control over the amount of crop that he will send to market on days when prices are usually highest. Employing casual labour usually means that harvesting must start early in the season and continue throughout it. It is even possible that the benefits of mechanizing crop establishment may have to be foregone to retain the services of casual labour over a period of years.

Probably the most important benefit that can result from mechanical harvesting is flexibility: the ability to harvest crop when price and yield are at optimum values. High rates of working and independence of weather are therefore vitally important and may be quantified by reference to meteorological data. Weather averages are usually taken over 30 years but a shorter period shows adequately the difficulties of harvesting Brussels sprouts.

State of ground observations at a meteorological station in Bedfordshire in the 20-week periods from mid-September to the end of January for the seasons 1965-68 show that the code number representing soft and muddy soil surface without pools of water occurred frequently and for long periods[23]. It cannot, therefore, be interpreted as the condition where mechanized harvesting is impossible. Conditions unsuitable for mechanized field work are, however, likely to occur when more than 0.5 in. of rain falls within two days. Such rainfall would cause bad ground conditions to persist for a further 2 days even in the absence of further rain, and rainfall exceeding 0.1 in. would extend the period. In the season 1965-66 such conditions occurred 9 times. The following year there were 4 bad periods and in 1966-67 there were two. Thus in the total of 60 harvesting weeks there were 15 when mechanized field work could not have taken place on a pre-selected day. These periods of bad weather averaged about five days and only 3 of them exceeded a week.

Brussels sprouts can be stored on the stalk without serious deterioration for several days, but stripped sprouts must be marketed without delay. It follows therefore that a system where cutting and stripping take place simultaneously is less advantageous than one where the processes are independent of each other. In the three years that were examined use of the simultaneous method of harvesting would have resulted in the complete loss of 15% of the days available for marketing and the loss of 25% of the most favourable marketing days. Methods where stripping does not take place in the field would have ensured that produce would be marketed every week although 15% of the best marketing days might have been lost when the price is likely to be between 5 and 20% higher than those for the rest of the week.[24 25 26]

Although at present it appears that multi-stage harvesting of Brussels sprouts offers advantages there can be little doubt that the present number of operations is high and some of them require too much labour. Costs would obviously be reduced if removing the leaves from the plants was mechanized or if plant breeders produced varieties where most of the leaves fell off when the crop matured.

Sprout stripping machines could also be improved by the incorporation of precleaning units which would speed up quality control and by the use of automatic feed mechanisms, which analysis of filmed records has shown to be capable of doubling the output without increasing the labour requirement[27].

6. CONCLUSIONS

The diversity of rowcrops, each with its own damage characteristics and marketing requirements, invalidates most general conclusions: there is no ideal harvesting system to suit all rowcrops. The range of conditions under which individual crops are grown even makes it impossible to specify any particular system for any individual crop. Probably the only valid general conclusions that can be drawn are:

(*a*) Systems in which harvesting and market preparation are separated by mechanized material handling stages allowing short term storage are more adaptable to adverse conditions than those in which any operation can dictate the speed of another previous operation.

(*b*) Complete harvesters for leaf vegetables which are harvested in wet field conditions are unlikely to be as successful as simple machines until methods of storing prepared produce for short periods are perfected.

(*c*) Harvesting machines carrying teams of operators are likely to give increases in productivity no greater than those from improved crop handling techniques.

REFERENCES

1. MAUGHAN, G. L., 'Harvesters and Harvesting Losses'. *Paper read to the Agricultural Development Association Conference on Sugar Beet* (28.1.69).
2. JACKSON, B. G., DAVIDSON, J. G., 'Sugar Beet Production and Harvesting: A report on surveys of the 1965 crop in the Eastern Counties'. *Farm Economic Branch School of Agriculture, Cambridge. Mimeographed Report No.* 63 (1966).
3. CHITTEY, E. T., MARCHANT, W. T. B., 'Automatic Steering of Lifting Wheels for Sugar Beet Harvesters'. *J. Agric. Engng Res.*, **9**, (3) 1964.
4. CHITTEY, E. T., MARCHANT, W. T. B., 'Automatic Control of Sugar Beet Harvester Shares'. *J. agric. Engng Res.*, **11**, (3) 1966.
5. Rep. natn. Sugar Beet Autumn Demonstrations, 1959, 1962.
6. WAYMAN, J. A., MAUGHAN, G. L., 'The Effects of Harvesting Speed on the Standard of Topping of Sugar Beet'. *N.I.A.E. unpublished report* DN/243/CD (1968).
7. CHITTEY, E. T., KEMP, I. F., N.I.A.E. report to be published.
8. WOOD, G. M., 'An Investigation into the Effect of Plant Spacing of Sugar Beet on the Problems of Mechanical Harvesting'. *N.I.A.E. unpublished report* DN/247/CD (1968).
9. BOA, W., 'A Universal Vegetable Harvester'. *J. and Proc. Inst. agric. Engrs*, **22**, (3) 1966.
10. DAVIES, A. C. W., WHEELER, J. A., 'Methods of Cauliflower Harvesting and Handling'. *J. agric. Engng Res.*, **13**, (2) 1968.
11. MACGILLIVRAY *et al:* 'Labour Requirement for Harvesting Lettuces in the Imperial Valley'. *Univ. of California Vegetable Crops Series No.* 98 (1960).
12. HAWKINS, J. C., 'The Mechanization of Vegetable Harvesting'. *J. and Proc Inst. agric. Engrs.*, **22**, (3) 1966.
13. WHEELER, J. A., DAVIES, A. C. W., 'Mechanised Harvesting of Brussels Sprouts'. (to be published).
14. GIBB, J. A. C., 'The Mechanical Handling of Farm Materials'. *J. and Proc Inst. agric. Engrs.*, **17**, (1) 1961.
15. HOLT, J. B., 'The Handling of Materials in Unit Loads in Agriculture and Horticulture'. *J. and Proc Inst. agric. Engrs.*, **21**, (1), 1965.
16. WATERFALL, J. H., Private communication, 1968.
17. Rep. 20th natn. Sugar Beet Autumn Demonstration, 1964.
18. Rep. 24th natn. Sugar Beet Autumn Demonstration, 1968.
19. SHARP, J. R., *et al:* 'A Mobile Packing Shed for Vegetables'. *N.I.A.E. unpublished report* DN/239/CD 1968.
20. DARBY BROTHERS. Private communications 1967 and 1968.
21. Horticulture in Britain, Part 1: *Vegetables*, H.M.S.O. 1967.
22. le MAY, G., 'Yield of Brussels Sprouts Trial at Blunham, 1968-69'.
23. Agro-met observations, *N.I.A.E., Wrest Park, Silsoe, Bedford.*
24. 'Domestic Food Consumption and Expenditure 1962'. *A rep. Nat. Survey Committee.*
25. BURRINGTON, G. G., Private communication 1969.
26. Bedfordshire Growers Ltd. Private communication 1969.
27. SHARP, J. R., BOA, W. *Unpublished N.I.A.E. report.*

Annual Conference 1969 – Discussion

MR W. J. WHITSED (Root Harvesters Limited) commented that he had found a great deal in Dr Bleasdale's paper that was most admirable and forward-looking. He was impressed with what the scientist could do in 'bending' nature towards the use of machinery. He was, however, disappointed that the paper did not reveal advances in developing crop varieties particularly suitable for high-speed, low-cost machanical harvesting. The rapidity and extent of the mechanization of the sugar beet crop owed much to the work of Mr Oswalt Rose's team in their endeavours to promote the most suitable plant varieties and methods that would favour the requirements of mechanization. Mr Whitsed said he greatly admired the manner in which Mr Rose had officiated in the marriage of nature and machinery. It was disturbing that there was apparently no such progress at the research stations with regard to other root crops. It appeared that no suggestion had ever been made to potato plant breeders that adaptability for mechanical harvesting and handling should be an important feature in new varieties; this was strange in a day and age when their opposite numbers in other lands had been doing this for years.

Discussing the problems of carrot harvesting, Mr Whitsed said that lifting carrots in 4 in. rows involved lifting 1000 ton/ac of soil. The acreage of carrots grown in this country was less than 30,000 per annum and harvesting extended over a period of seven months. Many harvesters made by his firm worked well over 100 acres per season and there were 250 in use. They had reduced the cost of carrot harvesting from £50 per acre to £10 per acre.

But further development was unlikely unless processors were prepared to finance the experimental work, as the potential of the market for special machines would be inadequate to attract the engineer. As the research institutions had already proved their ability to adapt crops to suit mechanization, this approach was the one most likely to prove fruitful. Mr Whitsed said that he could see Dr Bleasdale was doing this and hoped that he would continue to do so.

Dr Bleasdale replied that this was a fair statement of the conventional view, against which he had been battling for some considerable time. Only by thinking in terms of high-yielding systems and endeavouring to mechanize them would urgently needed progress be made. It was frightening to think that production had to be doubled in the next 30 years in order to meet future food requirements.

We could no longer afford to be frightened of mechanical difficulties such as moving a certain amount of earth, but even if we were, the standard by which to judge must be in terms of those high-yielding systems which were possible. Other systems must be judged in terms of yield and quality against the best. If one applied this to carrots a great deal was to be found wanting from the production point of view, particularly as regards the effect of conventional row-spacing on yield. The effect of conventional row spacing on quality and the inability to produce finger carrots in widely-spaced row, was well known. A few years ago, every finger carrot had been imported into this country and British growers could not grow them, although they had tried. The mistake they had made was in trying to grow them in normal wide rows, thereby leading to such considerable distortion of the roots that they could never get a good enough quality pack. The Dutch, who had learned how to handle them grew them in 7 in. rows. Quite a lot of the work was done by hand and one might have to do this in the interests of quality and yield, accepting that if it was difficult it would just take longer. Dr Bleasdale said that although one might hope for progress in the direction of 'bending' plants towards mechanization, one could not expect to go all the way. He was certain that there was a limit to how far one could go with wide spacing of rows. It was almost an immutable law of nature that if one expected to exploit the environment, one must have the crop uniformly distributed. Parallels with sugar beet were of no consequence. It was important to get away from conservative thinking and try to forget existing machinery and its exploitation for small markets in this country. One should think about world markets for carrot harvesters. There were plenty of carrots in the world and we could export plenty of machinery; it was therefore not necessary to argue that there were not enough carrots in this country—there were a great many around the world.

Mr Love said he wished to make a point about Dutch methods of lifting finger carrots, under very light, sandy soil conditions. In his tour of Holland the previous year, he had seen no hand lifting of carrots. They were all being lifted by machines, in some cases very simple, self-propelled machines, which lifted, say, a swathe of 3 rows about 12 in. in width, each row being some 4 in. apart or less. In larger operations, similar types of machine were lifting around 5 rows of some 30 in. width, going through the crop and elevating it up into boxes. The Dutch were mechanizing this crop on very light sandy soils, almost pure sand, and this was one aspect of mechanization which we probably would have to face.

Mr D. L. Maytom (National Research Development Corporation) said his job was looking at inventions in relevant situations to see whether they were good commercial investments. He agreed with Mr Whitsed in saying that many of these situations involved the development of specialized machinery, which may have a high user benefit but were not attractive to a Manufacturer. As for world markets, experience had shown that if a machine was not a commercial proposition in the home market alone development would rarely be justified on the basis that the additional export potential would make it worthwhile.

Mr Love said that during his travels abroad he had been amazed at how little penetration there had been by British machinery. In Cyprus, for example, tractors were running all over the Island being used more or less as bicycles by the growers. Yet, there were only two seed drills on the Island, both of which were operated by the research station; these were American old-style Planet drills. Surely there must be export opportunities. Mr Whitsed interjected that carrots were still broadcast in Cyprus, and Mr Love suggested that the harvester and drill manufacturers should collaborate in marketing their machines.

Mr J. C. Hawkins (National Institute of Agricultural Engineering) reminded the audience that work had been done by Dr Black at the NIAE Scottish Station on breeding potatoes for mechanical harvesting.

Mr H. J. M. Messer (National Institute of Agricultural Engineering) asked if Mr Love would say more about where he envisaged vegetables would be stored, whether they would be stored on farm or in special buildings put up by the large chain stores and also about the types of storage building he had in mind.

Mr Love said that he envisaged storage as being on the grower's or prepacker's farm. He would expect the central grading and packing station to be set up purely on economic grounds, as whole units embodying stores and grading and packing facilities all within one area. His own organization had facilities at their depot but this was only for overnight storage. There were two factors to consider—one was buffer storage which should be on the farm or at the central packing point, and the other factor was long-term storage which could be actually nearer the point of production.

Dr Arthey said he thought processors would generally take the same view of this situation. Quite a large amount of material was stored by processors in the units of cold storage companies in this country at the present time and he thought it would continue to be so.

Mr Love made the point that storage must be made relatively cheap and simple. Buffer storage, for example, should be able to cope with two to three days supply of carrots, or whatever might be needed to keep a packing shed going for the week. It was often impossible to meet the end-of-the-week demand—the Thursday/Friday demand in packing—by direct harvesting. One had to harvest on Monday, Tuesday and Wednesday, and then store in order to keep up with the demand on Thursday and Friday. Storage had therefore to be not necessarily large but fairly simple, cheap and efficient. Store temperature should be quickly pulled down and held, and this was why the ice bank theory looked very interesting.

Mr Maytom referred to a point in Mr Love's paper in which the author had said that the lack of labour had meant the virtual disappearance from the market of good quality green peas in pods and fresh dwarf french beans. He asked if there would be a demand for fresh peas and beans if a harvesting machine could be developed to overcome this labour shortage problem, bearing in mind the strong trend towards 'convenience foods'.

Mr Love said he had been looking at the question of the green pea crop and dwarf french beans for three or four years. In spite of discouragement from his Company's produce buying department, there was no doubt in his mind from the evidence so far available that there was a good customer demand provided growers did the job properly with successional sowings, using the right varieties and picking at the optimum periods to produce really good quality peas. The big problem was the cost of hand labour and if this crop could be mechanically harvested with the minimum of damage to the pods, there would be a good demand for the product. He had looked at dwarf french beans from the processors' harvesters but the amount of damage, debris and grit was currently far too high for a fresh prepacked article.

Mr A. J. Walters (Varley F.M.C. Ltd.) said that his Company's mobile pea viners were operating very successfully in Scotland. He was convinced that quality depended on rapid transit from field to store—not to exceed 90 min.

Dr Bleasdale said he would like to return to the point Mr Maytom had made about not being able to afford to develop machinery where it was mainly for export. Whilst one could accept that a machinery manufacturer must have a strong home-based market for his products as a whole, he did not think that this should preclude the development or manufacture of something that was largely for export. He recalled seeing at an NIAE Open Day a sprayer unit which had its own petrol engine and was intended for use with horses, to be used somewhere in the back-of-beyond. Presumably, this had been the result of expenditure of public money on a piece of machinery that could only ever be exported.

Mr Maytom said that N.R.D.C. tried to exploit many of these inventions, including ideas from N.I.A.E. such as the animal-drawn toolbar for developing countries, but if one studied the list of such products and the amount of money it costs to develop these, very few indeed were sound commercial propositions. The problem of getting a company to invest in the manufacture and marketing of these products was much bigger than that of development.

Dr Bleasdale retorted that there must be people here who were sufficiently interested in exports and who had sufficient experience of it, having been successful, to think that they might dare develop things marginally based on overseas markets.

Captain E. N. Griffith (Rotary Hoes Limited) said that in his view it was quite correct that more attention should be given to developments for the export market. Seen in proportion, the sale of agricultural machinery in this country was only about £38,000,000 plus £50,000,000 of tractors, whereas in Europe sales of agricultural machinery were of the order of £600,000,000, while machinery and tractors together totalled around £1,000,000,000. Europe was a great market. In this country and also in Europe, there was a dwindling labour force, with rising wages and getting older in years; therefore the demand in Europe was the thing the agricultural engineer should give particular attention to. Naturally, the market had to be carefully studied and one had to know the size of the farm one must be concerned with. If one took West Germany, 75% of the farms were under 9½ acres and consequently land values were enormously high. Sugar beet was only grown on land the most suitable for sugar beet, which was around Hanover where land was worth about £1,000 per acre. Likewise, potatoes were only grown in sandy soils, at less than half this value, thus avoiding the problems of mud and clods. There were different problems to which a lot of care and thought should be given, taking advantage also of the experimental stations on the Continent, which were excellent. One had to take the trouble to go and find out but Europe was where great prizes could be won and where great effort should be. England was a nice cosy market, but we had to go out out into the great world and there were over 150 countries in the world that used agricultural machinery.

Dr Bleasdale said that by and large, Britain, with its advances in mechanization, was ahead of a great deal of the world including America. He thought this country should stay ahead and educate the rest of the world to our way of thinking as far as possible. He said he firmly believed there was a large part of the world which need not endure the trouble this country had experienced as the result of Jethro Tull. Present methods of growing depended on broadcasting and even distribution of crops. Although broadcasting was inefficient, the distribution it produced was efficient and if the countries concerned could be allowed to stick to that, we would be there in due course. He felt it might take some time, in the light of today's discussions, but he felt sure this was the direction in which this country had the opportunity to lead the world.

Mr C. de B. Codrington (Agricultural Development Unit, Conrad Jameson Associates Ltd.) recalling what Mr Love and Dr Arthey had said about the requirements of the fresh and processed markets, expressed the view that as each market became more competitive, the quality requirements were going to increase. Unless the farmer could meet these requirements, his return would go down.

It had often been said that it was not the price the farmer obtained for his first quality produce that was significant, but that it was the return for his second quality produce that gave him profit. Mr Codrington thought there was a lot of truth in this. A great deal had been heard of the demand for continuity of supplies by both the retailer and the processor, and these could be met only by production programmes. Referring to a suggestion in Mr Boa's paper about a geographical separation of production programmes, Mr Codrington said he did not know if this was really feasible in view of the fact that the main sources of supply in the future would be from co-operatives i.e. groups of farmers combining together in one integrated production unit. This would be necessary in view of the acreages which were going to be needed to meet the requirements of these markets. Would not this change in concept of marketing and expansion of production groups affect our overall approach to mechanization? Whereas in the past one had thought of the individual farm, now one was thinking more of units of farms together. Probably as a result of the financing arrangements by which co-operatives were themselves established, more money might become available for machinery and one could then look for more sophisticated machines. Mr Codrington said that he was not advocating the use of more sophisticated machines as such but he believed that the finance would be there if they could be developed. With regard to the export potential, he believed that very valuable markets had already been identified for vegetable and root harvesting machinery but what would sell the machinery from this country would be not only the performance of the machines themselves but the overall production, harvesting, storage and marketing technology which we could offer.

With regard to packhouse operations, it looked as though these were going to be more sophisticated if Mr Love's and other companies requirements were to be met and as a result these would have to be carried out indoors. This would give rise to the problem of centralization as opposed to on-farm operations and high-lighted the problem of getting perishable products into a central packhouse at low cost and with no damage. One could see an interaction between farm transport and road transport on which, at the present time little research was being carried out. In the packhouse itself, where one was concerned with grading, selecting, preparing and packaging, there were also many research problems waiting to be investigated. Mr Codrington said he investigated the possibilities of weight grading some time ago and had found certain very useful advantages, one being that with potatoes the housewife saw the mass and not the size and yet it was the practice to go on grading them by size. Moreover, when selecting the smallest potatoes, or, in this case, the lightest potatoes, they were not so severely damaged and therefore one was getting some automatic selection of quality. Perhaps electronics could help to make weight-grading machines more accurate and compact. One might expect to see very shortly an electronic quality selection machine in certain fields. Subsequently, the development of automatic packing machinery to reduce the labour requirement within packhouses was important where crops had short seasons.

Research and development in grading and packaging did not appear to be covered by any particular research institute and this was an important gap in an area where a great deal of money was being spent at the present time.

Mr B. Burgess (Ben Burgess & Co.) said he had been interested in Mr Maughan's paper and was interested also in the delicate, complicated, expensive and ingenious machinery which had been developed to overcome a problem which he understood to be the lack of uniformity of germination of seed in soil. He would suggest that if this was the problem, it should be attacked from another angle, namely, that it was caused by the farmer's lack of ability to produce a uniform seed bed every year. This was partly the result of the farmer's mis-application of the use of power on the farm; power application started with ploughing. In recent weeks, he had been on a number of fields that were to be prepared for sugar beet. Some of these fields were on experimental farms in East Anglia where the application of power should have been thoroughly understood. The point of particular interest was the 'contour' of the ploughed land before it was touched. Mr Burgess said he had measured the contour in a number of fields on one experimental farm and had been horrified to find that it varied by 10 in. within a 12 in. depth in land that had been ploughed well before Christmas. Recently he had visited a quite normal farm where the contour varied by 12 in. within about 18 in. depth, and this went on all over the field. The weathering process had affected the surface band uniformly to the extent of 1½ in. When a primary cultivation implement first went through this in the springtime, it rubbed off the first inch and a half of this consolidated mud on the top of the heap and then dragged it down underlying these and deposited the mixture in the lower places. After this the farmer then started to produce what *he* called a tilth. This was not an easy matter for him. Engineers made a lot of machinery to aid the farmer to produce fields of ploughing which had the contours he had described and a lot more machinery which allowed them to produce fields full of consolidated mud, which, after an hour's drying, became lovely fields full of clods. Mr Burgess suggested that the correct approach was to pay more attention to the preparation of the seed bed, not merely at the time when the farmer went on to the land in the springtime, but in the period when he ploughed the land in the autumn. It could be done and was being done; the problem was not as Mr Maughan had put it. The answer was to avoid these unfavourable circumstances by means of the proper application of good tillage in the early stages. The problem in the springtime could then be reduced by quite 50%.

Mr Maughan said he entirely agreed with Mr Burgess that many people were mis-making their seedbeds one way or another, but nevertheless there were wide variations in the seed emergence qualities. Some of these were within the control of the grower and he would not disagree for one moment that seed bed preparation went right back to the initial ploughing in the autumn, or, in some cases, mid-winter, as it was the mid-winter cultivations that ironed out the gross irregularities to which Mr Burgess had referred. It was better not to create the conditions and he was sure there was a growing appreciation of this, especially amongst users of the reversible or one-way plough, and of the necessity to avoid ridges and open furrows. However, having done all this, and achieved a nice frost mulch on the top and kept it there, there were still differences in emergence across the field.

It was not often that the agricultural engineer rushed to the defence of the seed breeder; on the contrary, the seed breeder was usually blamed for all the faults that had arisen in the field. There was still scope for improving field emergence and if a means could be found of testing field emergence it would help. There did not appear to be much correlation between field emergence and laboratory germination in many of these seeds. Basically, the trouble was that there were variations within fields. One could go a long way towards alleviating them, but they could not be overcome altogether. Mr Maughan said this brought him to a point which he had thought Mr Burgess was going to advocate but had not gone quite so far as doing, namely, drilling to a stand, which was obviously the next step. It was a practice which had to be watched with great care, but people were both talking about this technique and using it. In the case of the beet crop, it was interesting to look overseas at Belgium where as much as 20% of the crop in 1967 was drilled to a stand. In 1968, the figure was again 20%, the only difference being that a number of people who tried the technique in 1967 had not used it in 1968, the balance being made up by newcomers. What the position would be in 1969 it was too early to say. Nevertheless, it was quite an appreciable proportion of the crop or the number of growers, and it was indicative of the number of people who had backed out.

Mr Burgess said that the point about the variation in condition of tilth from one end of the field to another, did not arise in practice until after the farmer had done his initial spring cultivation. If, from the time that he first went onto his field, the farmer could avoid scraping the mud up to the top, it was only at a later stage in his so-called seed bed preparation that the farmer produced variations in the surface soil texture, which affected germination by up to 50%, as Mr Maughan had shown.

Dr Bleasdale said he was in favour of drilling to a stand, although predators could present a problem with only a limited number of spaced plants to attack.

Mr T. Sherwen (Consultant) asked what percentage variation in seed size was normally encountered in a given batch and asked what it would cost to narrow the size range. As any seed cell mechanism released the seed at a variable point according to the size of the seed, this must affect the precision of placement of the seed and its consequent germination.

Mr Maughan replied that he could not give details of costs nor of percentages in relation to any one particular batch of seed. There was no doubt that seed producers could grade within very close limits. It depended somewhat on the shape and type of the seed, but certainly spherical seeds could be graded within 0.25 millimetres between maximum and minimum. The problem then became that of determining what the grower wanted. One could obtain a multiplicity of 0.25 millimetre grades out of any one batch; there was then the question of matching the seed-metering mechanism to the particular batch of seeds required. One might get a batch of seed that matched one's particular metering mechanism; on the other hand, one might be unlucky and get a batch of seed requiring a seed-metering unit of some other particular size—an ideal situation for the engineering industry since it would lead to more metering mechanisms being sold. However, it would create practical problems on the farm inasmuch that a multiplicity of metering mechanisms would be required to cater for a very wide range of seed-batch sizes. It would also create problems in the seed producing houses in the sense that they would have to get rid of the unwanted grades and where would they go? Mr Maughan said that he believed the practice of beet seed producers was to grade off anything over 14/64ths in. as surplus to their requirements, and they were attempting to grow seeds of smaller size. The alternative would be to find a market for the over-sized seed, but it was not likely to be very welcome on British farms.

Mr Sherwen suggested that if, for example, grades A, B and C were produced to give a batch, one would start off with grade A. The fact that they were closely graded would give a very even stand. Then by a small adjustment to the seeding mechanism, the next batch could contain grade B and at least there would be even spacing. Mr Sherwen suggested that one would not be faced with the problem of what to do with the grades which had been graded out. If they were put into a series of grades and then put into the seed box and sown in successive batches, much more accurate placement would be obtained.

Dr Bleasdale said it would take an Act of Parliament to bring this about. The trouble here was that whilst one could do this with seed potatoes, it was not possible with seed. Ordinary brassica seed would normally be split into three 0.25 millimetre classes; there might almost be equal weights in these, so it might cost three times the price if one only wanted to buy one grade. There would probably be a charge for grading. The real difficulty was that certainly the smallest seed and possibly the middle grade seed would sometimes have less than the statutory minimum germination. It was always the largest seed that had the highest percentage laboratory germination. It was no trade secret that a certain amount of blending took place from time to time in order to meet the requirements for the statutory minimum germination of the lot as a whole. It would need an Act of Parliament to ensure that seed was sold with declared germination.

Mr J. A. C. Gibb (University of Reading) asked Mr Maughan if in fact the vacuum seeder principle, which was one in which he was also interested, might not provide a means of dealing with varying sizes of seed.

Mr Maughan said that although he did not think he was competent to answer this, one thing that had impressed him about the work he had come across concerning vacuum seeders was that it was extremely difficult to match the venturi hole size to the type of the seed. Even with a very small venturi, no larger than a hypodermic needle, it was still possible to pick up two or three seeds. Another feature of some of the work that he had seen, although he claimed to know nothing about later work, was the extraordinary slow rate of working. He believed that 1 mile/h at 9 in. spacings was about the maximum that had been achieved with this type of equipment in New Zealand.

MR P. RICHARDSON (National Institute of Agricultural Engineering) said that he had been concerned with work at NIAE with seeds not graded for size and results had been obtained which, although not perfect, had been quite encouraging. Picking up several seeds at once was a problem to some extent but in their work with monogerm sugar beet seeds, for example, they had managed to pick up about 95% single seeds and the remainder were either missed or were doubles. With lettuce, 85% were singles. This was achieved by using a small vacuum operated pick-up device which had been developed purely as an experimental tool to help with a number of other problems of sowing, but it did appear to have a high potential. As regards speed of drilling, work at NIAE had so far entailed peripheral pick-up speeds of up to about 1 mile/h. If one dropped the seed at zero horizontal velocity this meant a speed of 1 mile/h, but many forward drills did not do this; some allowed a ratio between peripheral speed and forward speed, of up to 5, 6 or even 7 to 1.

Allowing a ratio of about 3 to 1 would provide a drilling speed of 3 mile/h which for precision drilling was probably acceptable; it was unlikely that one would wish to do more than that. Mr Richardson thought that realistic speeds could be attained with the vacuum operated pick-up device but it was not yet known what effect the differential speed would make to the precision of seed placement in the ground. This was part of the work now being done.

MR J. M. CHAMBERS asked if the reasons for the non-mergence of the plant from the seed were sufficiently understood. If one started off with a very high rate of germination of the seed, could it be assumed that failure to emerge was the result of capping-over of the soil? Could anything be done to assist the plant through the soil? Mr Chambers said he had noticed that with some crops, particularly cotton in some areas, if there was heavy rain after the seeds had been planted, the ground would cap-over and the young plant would be unable to push its way through. He understood that in Texas rolling was done to break the crust to allow the plant to get through. Had any work been done on this problem in relation to sugar beet and other plants?

Dr Bleasdale said his knowledge of work in this field concerned red beet which was very sensitive to capping; he would expect sugar beet to be similarly affected. This could be overcome either by some treatment that would prevent capping, such as bitumen mulches or by wetting the cap. The alternative was to crack the soil—actually to break it up. An interesting feature was that thin seeding increased the problem. If one was prepared to sow and chop out en masse, as it were, the seedlings would erupt and they would crack the soil right along the row. With single seedlings, widely spaced, this could not happen and one might lose very many more as a result. It was a real problem and the answer seemed to lie in irrigation at the time or some sort of light harrow treatment.

Mr Maughan agreed that the capping problem was extremely difficult. There were great variations in types of cap; different soils would cap in different ways. In the U.S.A. he had seen the cap broken up by using converging discs between the plants and just squeezing the soil sufficiently. But attempts to do it in this country would pull out the roots or pull the entire plant up by its roots and break everything asunder. The technique appeared to work in particular cases where the cap was a very thin one on the soil surface; most British soils, and especially the silts seemed to get deeper, thicker caps and of course the type of covering made by the drill could play a large part in this. Dr Bleasdale pointed out that only 60 yd^2/ac was required for a rowcrop seedbed. Why bother to break up the surface cap over the whole acre? It would be sufficient to apply the cap-preventative material only where it was needed.

A member of the audience said that some years ago one school of thought had suggested that the problems of precision sowing could possibly be overcome by placing the seeds out in pellets and these seeds could be provided with the various nutrients and fertilizers necessary to promote growth at the correct rate.

Dr Bleasdale replied that he thought the question of combination in pellets of protective devices was one of the great opportunities that had perhaps been missed. Answering a further question on seeds spaced out on paper tape, he said that essentially, the seed in paper was really only a substitute for seed metering and since, by and large, pelleting had brought about seed metering that would satisfy anybody, grading was often enough; it was doubtful nowadays whether there was any need to pellet any seeds in order to obtain effective seed metering. He thought the opportunity had been missed of creating a suitable environment in a big pill. One should be able to say to each seed 'There you are in a little plant pot. You really have your own environment there in a package; get on with it'. One could give the seed a squirt of nutrient as it was put in.

MR R. V. FALKINGHAM (NAAS, Somerset) took up a point mentioned by Dr Bleasdale about there being no longer any need to put plants in rows to meet weed control requirements because of advances in chemical weed control; consequently, a selection of row widths need no longer be for weed control purposes but rather for crop growth requirements and particularly for harvesting. Mr Falkingham said he was not necessarily recommending that carrots should be planted, for example, in twelve rows with 3.5 in. row spacings, but he wondered whether this was the trend that was likely to develop. What row widths would Dr Bleasdale recommend for a harvesting system for carrots?

Dr Bleasdale replied that he would not argue about 3.5, 4.5 or 5.5 in. spacing, but he stressed the need for effective covering of the ground from a fairly early stage. This was necessary in order to secure maximum yield per acre. One could argue perfectly correctly that the objective should not be maximum yield per acre; one should go for the cheapest cost per ton of produce and therefore it became a valid point that the row space should be convenient for harvesting. In order to know whether it was an economic thing to do, one had to know what one was missing—what the yield would have been if close rows had been used. One then had to say 'If I use wide rows, this represents a certain advantage in harvesting and I am prepared to lose so much yield to achieve it'. The loss in yield might be too great, particularly with the carrot crop. Beetroot was an example of the type of crop where row width was not so critical from the yield point of view and Dr Bleasdale thought that one might use row spacings of around 10 in. With rows wider than 10 in., even with the present fairly persistent herbicides, their effect would have worn off before the crop was harvested. In addition, the canopy would not be completely closed over and weeds could come in. The use of tolerably close rows ensured good crop cover and swamping of the weeds, which would make harvesting easier. Freedom from weeds was what people concerned with mechanized harvesting had always wanted and now that it was possible, they would say that you could not use the crop to help control the weeds, but one would have to do this if chemical residues in the crops were to be avoided. Dr Bleasdale said that for brassicas and so forth, row spacing was fairly wide and did not represent work restriction, but an interesting point emerged. Work on the spacing of Brussels sprouts had been conducted on the basis of the square because this gave reasonable reference for comparison. If, for the sake of argument, one said that 21 in. × 21 in. was probably the commercially correct spacing to aim at, then everybody would say 'We have a single-row harvester, so instead of 21 in. × 21 in., what about 30 in. × 18 in. so that there will be fewer rows per acre and less turn-round at the end?' Dr Bleasdale said it was not known at the moment just how far this reasoning could be taken with these once-harvested Brussels sprouts, but certainly with the picked-over crops, in cases where this sort of work had been done, one started to lose yield in the same way as with carrots. It was necessary to decide on the base from which to judge these things and everybody would then have to judge the matter on its merits.

Mr C. J. Moss (National Institute of Agricultural Engineering) said that reference was frequently made to the fact that for three-quarters of the world's population their main food was rice. How far was there likely to be, in the next twenty or thirty years, a marked increase in vegetable production in the more backward countries of the world?

Dr Bleasdale said he did not regard himself as competent to answer that question other than to say that where standards of living had been raised in underdeveloped countries, there had been an increase in the consumption of European types of vegetables.

Mr J. K. Grundey (N.A.A.S., Norfolk) said it seemed as though the carrot acreage was increasing, not by leaps and bounds, but sufficiently for the farmer, looking to the future, to ask himself whether he should be planting more carrots or not. Had the carrot crop a future? Dr Bleasdale's work might eventually result in considerably increased production of carrots. Would this increased production be absorbed in the next five years or so, allowing any adverse effect on prices to level out again?

Dr Arthey said that from 1966 to 1967 there had been a 60% increase in carrot production. Had this trend been maintained in 1968, production of carrots would, for the first time, have exceeded that of fresh garden peas. In fact, however, production of carrots had remained about the same as in 1967. The processors were anxious to obtain carrots for as many months of the year as possible, and some would can this particular crop from the end of the pea season until as far into the new year as they could obtain suitable raw material. There appeared to be an unsaturated market in which the processors could still can more and sell more. It was also interesting to note that diced and sliced carrots were becoming very much more popular than they had been in the past and an increase in this type of pack was also likely. The British consumer appeared to be able to absorb the increases in production quite readily.

Mr Love said that during a recent visit to Norfolk, this same question had been put to him by a big carrot grower. It was of concern also to growers of Brussels sprouts. The frightening aspect was that of the speculative grower who was going in just to get another crop for a year or two and had not arranged his market. Consequently, his produce would land in any old state and in any old market, thus depressing the price. The reputable growers did not like this because they wanted to be able to give a fair price to the regular suppliers, but obviously one had to think twice when one's competitors were buying up these cheap carrots in the market. It created a very unhappy situation.

Mr Love said that a grower who was going into carrots should ensure that they were aware of the type and quantity required and of what kind of price—or at least a basic minimum price—they would be likely to get. There was still room in this country for a little more carrot production, but spread over a longer period. It was sad to reflect that from the beginning of May until mid-June, carrots would be selling in Britain that had been imported from Israel, America and Cyprus. These were two months in the year when, if English production could be stored or otherwise dealt with in a way that was economic, the market would absorb quite an amount of the acreage being grown.

Mr V. Austin (National College of Agricultural Engineering) said there was one small point which he would like to add to Dr Bleasdale's reference to the consumption of vegetables in underdeveloped countries. Statistics would show that the highest consumption per head was in Mediterranean countries rather than Western Europe although this was often a substitute of vegetable protein for animal protein. He understood that in Europe, Portugal had the highest consumption per head.

Mr Austin said he had been interested in Mr Boa's reference to the advantages of cutting stalks and storing them so that one could put Brussels sprouts on the market on the days of the highest price. If this was correct, then obviously this was a tremendous advantage to the system of cutting stalks and then stripping them at the table. He wondered however whether the market really liked Brussels sprouts that had been cut on the stalk and stripped two or three days later and if there was in fact any deterioration in quality. If there was such deterioration it could mean that the engineer must still think about complete combine harvesters that would actually pick the sprouts in the field rather than cut the stalks—a rather fundamental aspect of design.

Mr Boa replied that obviously if one cut a crop and stored the stalks for some time without any special precautions, there could be some deterioration. However, there were growers selling in the quality market who maintained that, except at the beginning of the season when the weather could be mild, Brussels sprouts could be stored out of doors on the stalk for several days. The idea of cutting the stalk and stripping it separately was probably an interim stage. Sooner or later a combine must be developed, but not until mechanisms had been invented which had outputs about ten times greater than those of present stripping mechanisms.

Mr Love said his organization had not done any detailed work on this although it was an idea they had had for several years, having regard especially to the advent of sharp cold spells, severe frosts, and so forth. They had considered cutting the stems and storing them in a cool barn, to be stripped under cover. Not a great deal of work had been done on this, but they had been reasonably satisfied by the quality obtained, provided the storage conditions were reasonable. Obviously, one would not expect to do it in September or October when temperatures were high; the subsequent shelf-life would be very short. Provided storage facilities were adequate, and storage always seemed to be a dominant factor, the system would probably have to include a buffer supply of sprouts on the stalk.

Bringing the discussion to a close, the Session Chairman, Mr C. J. Moss, said that the output of the crops they had been talking about must amount to an annual total in the U.K. alone of the order of £200,000,000. This was an industry of quite gigantic size and he thought perhaps the discussion had not fully emphasized what a vast turnover was involved. In order to obtain this output economically, with falling manpower, there was a tremendous need for a much closer collaboration between the plant physiologists and the engineers, supported by the Agricultural Research Council, advisers of the Ministry of Agriculture, Fisheries and Food, manufacturers and marketing organizations. If one thing had come out of the day's proceedings it was the need to coordinate these efforts. Mr Moss said that at NIAE a very strong effort had been made in recent years to bring about this sort of collaboration and he had been encouraged by the day's discussions.

Mr Moss said that he had been impressed by the extent to which the first two speakers, Mr Love and Dr Arthey, knew what their customers wanted to buy. They had put forward the needs of the man or the woman in the street very confidently. He had not realized that such a weight of information on customer needs and on specification of product was available. Somehow or other, everybody concerned had to bend their joint efforts to meeting this market need. Mr Moss said that he often volunteered for work in the kitchen and he knew something about quality in relation to mechanical damage and other kinds of deterioration in vegetables! He believed that in an industry with a turnover of £200,000,000 per annum there was work to be done, not only in maintaining present quality, but in improving it. Housewives were going to become even more discriminating in future years. The industry had to do its job with diminishing manpower and Mr Moss suggested that the industry could do more to improve the working conditions of its manpower, such as had been shown during the discussion of packing sheds, with some protection being provided for the worker. The smaller number of men on whom the industry was going to depend in future would not be willing to work in the fields under the conditions even of the last ten years. Much remained to be done and a very important point for all at this Conference to bear in mind was that it might perhaps be the engineers who could help to improve the conditions of the remaining labour force in agriculture and horticulture.

RAW MATERIAL REQUIREMENTS OF THE VEGETABLE PROCESSOR
by V. D. Arthey

—from page 114

depends on effective quality control at many points.

With many of these defects a processor will stipulate in his specification the percentage of each that he will accept in material supplied to his factory. Thus a processor may not willingly accept carrots of which more than 7% are affected with shadow. In such cases the acceptance of such lots will depend on negotiation. The frequency of delivery of marginal samples to the factory will sometimes depend on the relationship between grower and processor, and the ability to obtain good quality material will always be easier for the processor whose relationship with his growers is good. It is important that the fallacy that grower and processor exploit each other unfairly is replaced by a more amiable and co-operative spirit of understanding, which can only lead to improvements in production of both raw material and final product.

ELECTIONS AND TRANSFERS

Approved by Council at its meeting on 24 July 1969

ADMISSIONS

Member	... ...	Merritt Webb, J.	Glos
	... ...	Peacock, J.	Co. Durham
	Overseas ...	Percy, M. J.	West Indies
	... ...	Seiler, K. D.	Sussex
Companion	*Overseas* ...	Caupin, J. H. G.	France
Associate	... ...	Ablett, D. A.	Sussex
	... ...	Atkinson, R.	Northumberland
	... ...	Brett, K. S.	Surrey
	... ...	Butcher, M.	Kent
	Overseas ...	Chadha, K. D.	India
	... ...	Christian, L. R.	Northumberland
	... ...	Coxshall, D. M.	Somerset
	... ...	Evans, W. H....	Yorks
	Overseas ...	Hales, D. W....	E. Africa
	... ...	Harris, C. H.	Warwicks
	... ...	Holden, R. G.	Warwicks
	... ...	Jones, B.	Yorks
	... ...	Keenlyside, J. F.	Yorks
	Overseas ...	Manaf, M. Z.	Malaysia
	... ...	Morris, B. P....	Sussex
	Overseas ...	Rathod, R. V.	E. Africa
	... ...	Rees, C. T. W. A.	Hants
	... ...	Sillito, J. W.	Scotland
	... ...	Spratt, C. D....	Lincs
	... ...	Spratt, U. G.	Lincs
	... ...	Turner, J.	N. Ireland
	... ...	Walker, P. H.	Surrey
Graduate	... ...	Bateson, K. G.	Lancs
	... ...	Booth, J. D.	Lancs
	... ...	Chambers, M. R.	Sussex
	... ...	Inverarity, B. R.	Yorks
	... ...	Knight, T. J. M.	Somerset
	... ...	Lockwood, G.	Warwicks
	... ...	Medd, M. W.	London
	... ...	Pollock, K. A.	Northumberland
Student	... ...	Andrews, D. T.	Cheshire
	... ...	Barrett, T.	Peterborough
	... ...	Bodger, R. W.	Cambs
	... ...	Chatting, T. J.	Norfolk
	... ...	Cherry, R. P.	Yorks
	... ...	Cutler, H. M.	Beds
	... ...	Davis, T. J.	Berks
	... ...	Foster, B. C.	Suffolk
	... ...	Gale, J. C.	Beds
	... ...	Hallett, N. M. J.	Beds
	... ...	Keeble, B. M.	London
	... ...	Kerbirou, Y. F.	Scotland
	... ...	Leeds-Harrison, P. B.	Beds
	... ...	Photiades, I. T.	Northumberland
	... ...	Roberts, J. H.	Beds

ELECTIONS AND TRANSFERS *(continued)*

	... ...	Rowe, E. P. H.	Warwicks
	... ...	Vaudin, M. B. A. J....	Scotland
	... ...	White, W.	Ireland
		TRANSFERS	
Fellow	... ...	Fox, J. V.	Warwicks
	... ...	Spofforth, B. C.	Hants
Member	*Overseas* ...	Adams, J.	Canada
	... ...	Moon, A. G.	Warwicks
	... ...	Reid, H. P.	Suffolk
Graduate	... ...	Fulton, R. N.	Scotland
	... ...	Garner, C. R.	Suffolk
	... ...	Gould, A. M.	Warwicks
	... ...	Hibbot, R. M.	Yorks
	Overseas ...	Meikle, G. J....	Rhodesia
	... ...	Sapsed, F. L.	Herts

OBITUARY—RAYMOND DOUGLAS BOMFORD

—from page 104

earth moving equipment, all of which are in use today. At the outbreak of World War II he was a persistently strong advocate of the purchase of a large number of American crawler tractors, which he saw as essential for increasing home food production and they were eventually purchased.

Douglas Bomford held many important appointments over a long period. He was a member of the Agricultural Machinery Development Board, the Tractor Users' Association, the N.F.U. Machinery Committee, a governor of Rycotewood College and later of the National College of Agricultural Engineering, but he prized most his membership of the Institution of Agricultural Engineers, of which he was President for two successive years. Honorary Fellowship of the Institution —its highest honour—was recently conferred upon him in recognition of his services to agriculture and the agricultural engineering industry.

Thus far is the record of Douglas Bomford's achievements over a working life which extended to only a few months before his death, aged 75. But no account could be complete without a tribute to his manifold contributions to the activities of the Institution of Agricultural Engineers, as a member of Council and various Committees for many years and of the Agricultural Engineering Examination Board and as President. In the face of the size of this contribution to the Institution's work, the amount of persuasion which it was necessary to exert before he would agree to accept Honorary Fellowship typified his modesty.

Above all, for those privileged to know him personally, was his kindness and the encouragement he gave to younger agricultural engineers. In his own companies he appointed a number of young men whom he judged to be promising, giving them real responsibility at an early age. Similarly, many of his friends who share his second great love—small boat sailing—will remember with deep appreciation Mr and Mrs Bomford's generosity in allowing them the unstinted use of their boat—the sloop 'Quest'—in the Fal estuary. Mrs Bomford, whom he married in 1923, survives him. The Institution expresses its deepest sympathy to her in her loss, which it is privileged to share.

OBITUARY

The Council of the Institution also records with deep regret the death of the following members:

ATKINSON, R. L.	Fellow
BYERLEY, W. A.	Associate
JENKINSON, R. A. C. ..	Associate
SMITH, F.	Associate

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING

Agricultural Approach Passes

		Subjects passed with Distinction	Subjects passed with Credit
Essex Institute of Agriculture	Adams, G.		EST, FMM
	Bailey, A. H.		EST, FMM, FE
	Dix, M. C.		BS
	Fraser, J. M.		EST, FMM, BS
	Griffin, A. G.		EST, BS
	Hull, P. J.		EST, FMM
	†March, J. H.	FME, EST, FE	FMM
	Robinson, D. L. ...		FME, EST, FE
	Shearing, J. D.		FME, EST, FMM, FE
	Stead, P. F.		FME, EST, FMM, BS
	Swallow, M. L. ...		EST
	Taylor, J.		FME, EST, FMM, BS
West of Scotland Agricultural College	Jones, T. C.		FME
	Oag, A. C.	FME, EST	FMM, BS
	Watson, E. C.	EST	FME, FMM

Engineering Approach Passes

		Subjects passed with Distinction	Subjects passed with Credit
Essex Institute of Agriculture	Brooks, C. P.		MCAP, BS
	Butler, S. W.		FBM
	Fuller, R. S.	AEPAE	MCAP, BS
	Hiscock, K. G.		MCAP, FMM, FBM
	Jackson, A. K.		AEPAE
	Moore, V. W.		AEPAE, FE
	Spyvee, P. W.		MCAP
	Wheelock, R. A. ...	AEPAE, MCAP, FE	FMM
	White, G. C.		MCAP, FMM, FBM
West of Scotland Agricultural College	Allan, A. M.		FE
	Baker, M. W.		AEPAE, FMM, FE
	Blackburn, R. F. ...		FMM, FE
	Blackford, R.	FE	AEPAE, MCAP
	Boys, P. D.	AEPAE, FE	MCAP, FMM
	Carruthers, J.		AEPAE
	Chambers, M. R. ...		FE
	Constantinesco, J. A. G.		AEPAE, MCAP, FMM, FE
	Cram, C. T.		FE
	Doncaster, D. W. ...		AEPAE

gricultural Engineering

1969 EXAMINATION RESULTS

	Subjects passed with Distinction	Subjects passed with Credit
Dowds, W.		AEPAE, FMM
Foreman, L. S.		AEPAE, MCAP
Graham, R. G.		FMM, FE
Hall, P. F.		MCAP, FMM, FE
Hancox, W.		MCAP, FMM, FE
Hilsdon, W. J. C. ...		AEPAE, MCAP, FE
†Holme, H. J.		FMM, FE
Jackson, R. G. B. ...		AEPAE, MCAP, FMM, FE
Junker, H. D.		AEPAE, FMM, FE
Kerbiriou, Y. F. ...		FE
Lattin, J. D.		MCAP
Lawrence, D. A. ...		AEPAE, FE
*Luke, A.		MCAP, FMM
McEwen, J. A.		AEPAE, MCAP, FMM, FE
Marks, D. H.		AEPAE, MCAP, FE
Peel-Yates, C. A. ...		
Scammell, T. J. ...		
Sims, B. A.	FE	AEPAE
Sterling, H. G.	FE	AEPAE, MCAP
Sunderland, R. F. J. ...	FE	AEPAE, MCAP, FMM
Swinstead, P. H. ...		AEPAE, FMM, FE
Thacker, J. R.		FE
Turyamureebba, S. ...		AEPAE, MCAP
Vaudin, M. B. A. J. ...		FE
Vellocott, W. J. ...		
Wain, R. H. R. ...		FE
Walker, C. C. B. ...		AEPAE, MCAP, FMM, FE
Ward, K. C.	AEPAE, MCAP, FMM, FE	
White, R. G.		AEPAE, MCAP, FE
Wyles, P. W.	FE	AEPAE, MCAP, FMM

† *Holding Shell-Mex & BP Bursary Award*

* *External Candidate*

Key to Subject Abbreviations

	Abbreviation
The Application of Engineering Principles to Agricultural Equipment	AEPAE
Mechanization of Crop and Animal Production	MCAP
Farm Mechanization Equipment	FME
Engineering Science and Technology	EST
Farm Mechanization and Management	FMM
Field Engineering	FE
Farm Buildings and Mechanization	FBM
Business Studies	BS

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