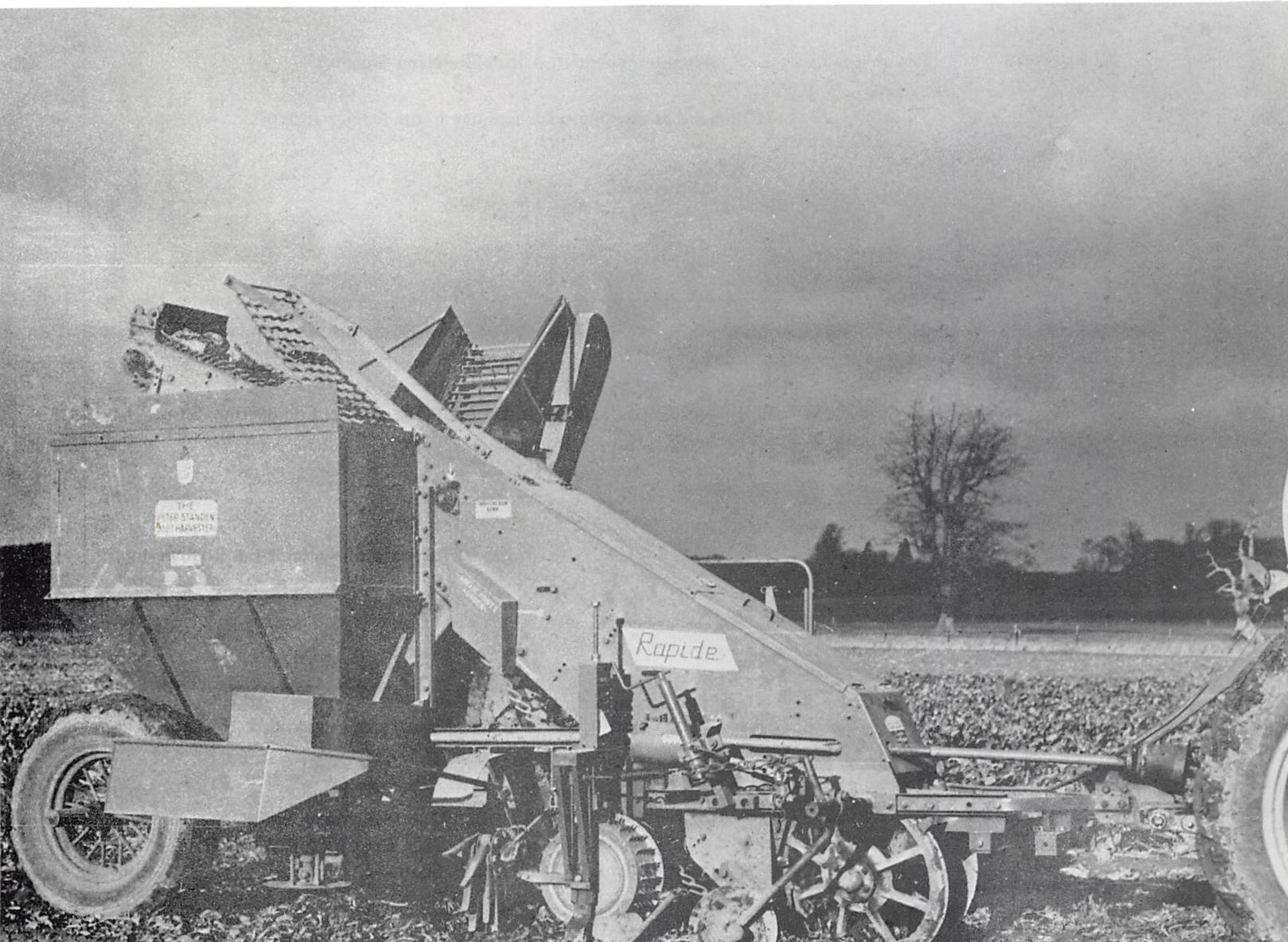
THE AGRICULTURAL ENGINEER

JOURNAL and Proceedings of the INSTITUTION of AGRICULTURAL ENGINEERS

Volume 31 Spring 1976 No 1



In this issue:

Conference on off-highway vehicles
Engineering research for sugar beet at NIAE
A sprayer for hedgerow apple orchards
Research and development at ESA

THE INSTITUTION OF AGRICULTURAL ENGINEERS

PRESIDENTIAL ADDRESS and ANNUAL CONFERENCE

Tuesday, 11 May 1976 at the Bloomsbury Centre Hotel, London.

10 20–11 00	Presidential Address – Research in Agricultural Engineering T C D Manby BSc MScEng CEng FI MechE FIAgrE

ANNUAL CONFERENCE Engineering Developments in Forage and Grain Conservation

11 00–11 25	Registration and coffee
11 30–11 35	C Culpin OBE MA DipAg (Cantab) FIAgrE Conference Chairman – Opens the Conference and Sets the Scene.
Morning Session	
11 35–11 40	Session Chairman, R W Waltham (President, British Grassland Society)*
11 40–12 15	Paper 1 Methods of harvesting and conserving silage and hay in the Netherlands. Ir G A Benders, Instituut voor Mechanisatie, Arbeid en Gebouwen, Netherlands.
12 15–12 30	Discussion on Paper 1.
12 30–14 15	Annual Luncheon.
Afternoon Session	
14 25–14 30	Session Chairman, C Culpin.
14 30–15 00	Paper 2 The field treatment of grass for conservation. W E Klinner FIAgrE Mem ASAE National Institute of Agricultural Engineering, Silsoe, Bedford.
15 00–15 10	Discussion on Paper 2.
15 10–15 40	Paper 3 Drying of hay and grain. M E Nellist PhD MSc (Agr Eng) MIAgrE, National Institute of Agricultural Engineering, Silsoe, Bedford.
15 40–15 50	Discussion on Paper 3.
15 50–16 10	Tea.
16 15–16 45	Paper 4 Conservation and feeding of forage crops. W F Raymond MA FRIC, Deputy Chief Scientist, Ministry of Agriculture, Fisheries and Food, London.
16 45–17 00	Discussion on Paper 4.
17 00–17 40	Open Forum – Conference Chairman, Morning Session Chairman and all Speakers. Discussion to be opened by: P H Bailey BSc (Eng) MSc (Agr Eng) AKC FIAgrE Scottish Institute of Agricultural Engineering, Penicuik, Scotland.
17 40–17 45	Summing-up and Closure by Conference Chairman.
Conference Convenor:	G Shepperson BSc (Agric) FIAgrE National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedford. Telephone: Silsoe (0525) 60000.
All enquiries to: Conference Secretary.	Mrs E Holden The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU. Telephone: Silsoe (0525) 61096.

**The Conference is being held in association with the British Greenland Society*

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CONTENTS

Cover: Sugar beet harvester fitted with NIAE lightweight topper. (Photograph by courtesy of NIAE)

A new honorary editor
by Brian May

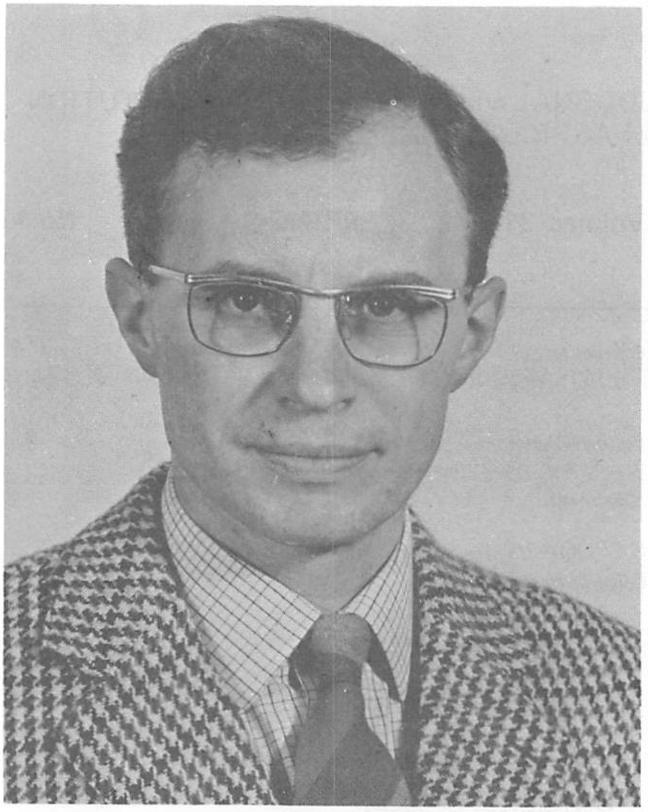
WHEN I was appointed Honorary Editor and Chairman of the Editorial Panel in May 1972 it was agreed that an appropriate period of office would be between three and five years. Council has agreed to my request to be relieved of these duties after a four year period and proposes that I should be succeeded by Brian Stenning with effect from 11 May 1976, the date of the Annual General Meeting.

Brian Stenning is well-known to those who are involved with aspects of glasshouse technology and instrumentation. Brian joined the NCAE staff in 1963 from the Rural Electrification section of the Electrical Research Association. He is currently a lecturer at the College and contributes to a number of courses and research programmes. For several years Brian has acted as College Audio Visual Aids Officer and has also accepted responsibility for aspects of College publicity and press liaison. In recent years he has edited the College Prospectus. Such experience suits him admirably for acceptance of Institution Editorial responsibilities.

Shortly after joining the Institution, Brian became a co-opted member of the Editorial Panel. He has actively contributed to the work of the Panel, introducing new thoughts and ideas, acting as referee for papers submitted for publication and assisting with the minuting of conference discussions. In recent months he has been helping the Secretary to select, edit and arrange material for the Institution Newsletter.

I am therefore confident that THE AGRICULTURAL ENGINEER will be in well-qualified and experienced hands during the next few years. The considerable interest shown by members in the form and content of the journal has always been a source of encouragement and stimulation for me. I very much hope that members will give Brian an equally generous measure of support and encouragement. Naturally, the most important form that this support can take is a plentiful supply of material for inclusion in the journal. The Honorary Editor and his Editorial Panel need a regular supply of papers of appropriate standard and content together with contributions from the branches giving news of activities and summaries of meetings held.

I should like to thank members of the Panel for their support and guidance during the past four years, particularly Norman Stuckey and Linda Palmer. Norman has been asked to work within the tightest of budgets which he has successfully achieved in co-operation with our printers who also deserve a vote of thanks for maintaining high standards of presentation. Linda has consistently made efforts to increase the amount of advertising in the journal, but in these difficult times has often found the task unrewarding. In thanking those organisations which have supported the journal in this way I add the hope that all affiliated organisations will consider the possibility of advertising in future issues of the journal.



Brian C Stenning BSc CIAgrE

I extend my best wishes to the Editorial Panel and to Brian Stenning in the future and look forward to serving on the Panel for a further year under his chairmanship.

Agricultural engineers in Australia – a recent conference

AS members are no doubt aware the presidents of a number of the larger professional engineering institutions have recently mooted the idea of forming an organisation which will be able to represent the interest of all professional engineers at the national level.

An organisation of this kind, The Institution of Engineers, Australia (IE Aust) has been performing this function for Australian professional engineers since 1938, when it was granted a Royal Charter, although it was formed much earlier, in 1919, by the amalgamation of various state engineering societies and associations. The IE Austs' membership of over 28 000 includes approximately 75% of all professional engineers practising in Australia.

Administration of the IE Aust is carried out at two levels:

(1) by the council and a national headquarters organisation and,
(2) by divisions on a local geographic basis.

At the Divisional level, the IE Aust is organised into technical branches which give engineers the opportunity of regularly participating in professional affairs relating to their own sub-discipline of the profession.

The Sydney Division is the only one with an agricultural engineering branch. It was formed in 1969 and now has approximately one hundred registered affiliates, including a number of members of the Institution of Agricultural Engineers (IAE).

In August 1974 this branch in association with the University of New South Wales, organised a three day agricultural engineering conference. One hundred and seventy delegates, from all States in Australia, and from New Zealand, attended the Conference. Ten of the Australian members of the IAE were present at the conference and seven of these ten delegates presented papers or informal reports.

The 96 papers read at the conference have been printed in two volumes under the following headings:

Volume I	–	Seeding and cultivation; soil and water; agricultural engineering education; wool; rural regulations; electricity and energy; grain handling and drying.
Volume II	–	Farm structures; fodder conservation; mechanisation; aerial agriculture; rheology.

Copies of the Agricultural Engineering Conference Proceedings are available from:

The Secretary, The Institution of Engineers, Australia, Sydney Division, Post Office Box 138, Milsons Point, Sydney, NSW, 2061, Australia, at a cost of $A 20.00, plus postage, (on the total weight of 3 kg, the current rate by sea is $A 5.15) per two volumes.

Conference on off-highway vehicles, tractors and equipment

A TWO day conference was organised by the Automobile Division of the Institution of Mechanical Engineers on 28 and 29 October to discuss problems of designing and operating off-highway vehicles, tractors and equipment. Jointly sponsored also by the Institution of Civil Engineers and Institution of Agricultural Engineers it was very well supported with many of the 200 participants and authors coming from countries as far afield as South East Asia, Scandinavia, North America as well as Europe. This was the fourth conference largely devoted to tractors which had been organised by the IMechE. In 1960 agricultural tractor problems and designs had been specially considered, in 1965 earth-moving machinery had received priority and in 1970 agricultural and allied industrial tractors had been featured. A major objective of the organising committee for the 1975 Conference was to bring together knowledge which is often acquired in some degree of isolation in the various disciplines concerned with the performance of off-the-road vehicles and to promote wider application through better appreciation. For example it was believed that research to improve operator safety, comfort and the efficiency of agricultural tractors could be helpful to designers of civil engineering equipment.

The Conference began with papers from a contractor, F C Ballard, of John Laing Construction; K Lawson, a consultant on construction plant selection, and J E Bywater, the chief executive of a multi-national holding group dealing with the experience of a distributor and user of equipment in widely dispersed territories in South East Asia. In excellent reviews of the problems, the need for reliability and the paramount importance of spares and service back-up was stressed by all, and the enormous variety in conditions under which equipment of this type must work was well illustrated in these papers and one given subsequently by the Chief Engineer of General Motors (Scotland) Ltd. He stressed the difficulty in optimising designs to meet the large variety of climates. tasks and working conditions to which any particular machine might be subjected. The range in climatic conditions and the materials which had to be handled and surfaces crossed, he believed provided such a variety of problems that inevitably manufacturers would only be able to aim at the best compromise.

In general, the users accepted the importance of providing operators with improved comfort, safety and controls. Track laying tractors were recognised as still having advantages on rough terrain, but their disadvantages had not yet been overcome. Low speed, high maintenance costs because of wear and vulnerability of track and drive components and operator discomfort were still the main problems.

The paper on equipment for South East Asian conditions was unusual; in addition to technical proposals aimed primarily at improving designs to obtain greater reliability and ease of servicing by using modular replacement arrangements, it presented forcefully argued suggestions as to the way engineers and senior management executives of manufacturing companies should tackle the job of designing and testing products for difficult and far distant market conditions, with South East Asia as an example of a large potential market. As the author (a past vice president of IAgE) has wide ranging interests in finance and food and equipment production and distribution, his views for improving communication and the relevance of design were interesting, well received and supported. He believed that if engineers were sent as a task force to areas where unusual conditions created difficult problems, then not only would considerable help be given to them by users and distributors of equipment, but their design solutions would be more appropriate. Bywater also suggested simplifications to increase reliability of instrumentation, perhaps by solid state circuitry, and stressed the need to increase the compatibility and engineering of equipment attached to tractors which was not provided by the tractor manufacturer.

Reference to the importance of simplifying the instruction and repair manuals and presenting them in the most appropriate form for the country of use also raised interesting points of discussion. For example the use of the "basic 800 technique" in preparing handbooks and service data so that a translation service from a computer is available was suggested. In anticipation of interest in reliability the conference programme included papers from military engineers, notably Millington and Thomas from REME who described the way the Army now records and analyses their vehicle failures and service problems. An additional bonus worth publicising was that Brigadier Hughes, Chairman of the Automobile Division, invited those keen to learn more about the Army procedures to make contact with him to plan visits to the units concerned. REME provides qualified engineering staff as a link between user and manufacturer which, unfortunately, does not usually exist commercially.

The problems for manufacturers which can arise from international legislation concerning noise and safety are uppermost in the minds of design engineers. The length of time now taken to create and manufacture new designs, and even make modifications, intensifies the need for harmonising regulations and give advance notice on impending legislation affecting crucial design issues – many involving enormous expense. Although details were not given at the conference it is interesting to hear that the overall cost of introducing new safety cabs for high volume production for a range of agricultural tractors, which must meet worldwide government and market acceptance can be about £20m. Papers on design and testing procedures were aimed at helping to improve safety cab design techniques and achieve more repeatable test results. Better understanding of the technical problems involved in the design, performance and use of construction machinery was helped by the paper from the Institute of Sound and Vibration Research, Southampton. Many current designs of earthmoving machines exceed the noise level limits required in some countries but it may be possible, in many cases, to reduce levels for operators and bystanders without major machine redesign.

Protecting drivers from a third hazard, ie vibration, is not generally being enforced, although on agricultural tractors it is known that present recommended ISO exposure levels are often exceeded. Hilton's research at NIAE on cab suspensions has shown that a passive suspension can reduce vertical vibration by 60-70% and roll and pitch vibrations by about 50%. Acceptable levels can thus be obtained for farm work at present operating speeds and the higher speeds envisaged for future development. Whether excessive stress is likely to be placed on equipment as a result of this further isolation of the driver from the 'feel' of his machine has yet to be determined. Another form of suspension, this time for the complete tracklaying vehicle, was a major feature of the high speed earthmoving tractor for military purposes. The paper by McLaurin and Elder, of MVEE, described design and development features of this unique machine, some aspects of which may be relevant in civil engineering applications. The compromise solution for the design of track, suspension and steering system was described and its performance illustrated. The authors estimate that the increased cost for a high speed suspension track and steering system may be 25%. Unfortunately, the problems with the Vickers tractors come to mind, and I suggest that more must be learned about probable costs, reliability and longevity in civil engineering use before this estimate is taken too seriously.

Other papers to help users obtain improved traction concentrated on the most recent tyre performance investigations from a new single wheel testing unit at NIAE and results were given for a wide range of conditions. From this work Dwyer was able to qualify more thoroughly than hitherto the traction advantages of using 4-wheel drive tractors for heavy draught operations. In a presentation updated from the written paper he quoted an optimum weight requirement, including mounted equipment, of 100 kg/kW on driving wheels which must be fitted with tyres large enough to carry the load at normal field inflation pressures. He believed that to obtain the maximum possible rate of work from a 2-wheel drive tractor approximately twice the expenditure on tyres or a 10% increase in the cost of an agricultural tractor was required. Reduction in slip, tyre wear and an increased work rate of 10-20% would, he suggested, quickly repay the extra cost. Therefore manufacturers should design to accommodate larger optional tyre sizes and operators interested in obtaining maximum

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This report is by T C D Manby, Chairman of the Organising Committee.

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rates of work on heavy draught operations should use them, ballast to permitted limits to keep slip down to 10% and choose equipment and gears to use the full power available.

Techniques were described in a paper from Rowland and Peel, of the Ministry of Defence, for predicting performance from wheeled and tracked vehicles. Crolla described research which had shown how to determine the influence of fluctuating load conditions, which prevent the predicted steady state values from being obtained.

A paper of a different type from those concerned primarily with vehicle design was presented, also from MVEE; it is relevant and helpful when planning large schemes which would benefit from the use of terrain evaluation techniques to minimise mobility problems.

In the final group of very interesting papers the latest and possibly little known developments to enable vehicles to be mobile in very difficult conditions ranging from underwater, sea shore and swamp forest to arctic snow conditions were described. Many were illustrated by films. Much of the information given related to overseas developments in Japan, Sweden and in Europe, and an interesting unprogrammed film was shown during the discussion of a multiwheeled vehicle for carrying loads across swamps; different vehicle configurations were available, all using very low pressure tyres. Hydrostatic wheel motor transmissions were vital to some of these vehicles from which the maximum ability to manoeuvre in confined spaces and on difficult terrain is a primary requisite. From the UK, an example noteworthy for its low cost development programme, was the Forestry Commission's tractor described by Ross and one on moving large loads. Use of the 'hover' principle for moving large loads has had much publicity in the past; a less well known application using water jets was disclosed in an interestingly presented paper.

Time did not permit full discussion on many aspects raised, and in closing the conference it was a pleasure to stress to authors that in addition to the brief discussions permitted during the two days, a major contribution would develop from their detailed papers which are to be made available as a bound volume of proceedings.

List of Papers

Some problems associated with the use of off-highway vehicles and equipment by F G Ballard, MIPlantE.

Users' requirements in off-highway equipment, by K Lawson CEng MIMechE.

Some problems relating to off-highway equipment in parts of South East Asia, by J E Bywater, CEng FIMechE.

Off-highway vehicles — a manufacturer's view of users' problems, by W Rankin CEng MIMechE.

Noise regulations and control on mobile construction equipment, by K Ratcliffe BSc CEng MIMechE and J E Ludlow BSc MSc.

Protecting the tractor driver from low-frequency ride vibration, by R M Stayner BSc MSc, D J Hilton PhD, CEng MIMechE DipMS and P Moran IINC(Mech).

Structural strength tests for protective cabs for agricultural tractors using static methods, by H D Sullivan MSc(Ag Eng).

Aspects of the design and testing of tractor safety frames, by J E Ashburner MA (Cantab) PhD(Reading) MIAgrE MSAE FRGS.

Reliability assessment techniques for military vehicles, by Maj A H Millington REME BSc(Eng) and M D Thomas PhD BSc MIQA.

Some aspects of tyre design and their effect on agricultural tractor performance, by M J Dwyer MSc PhD CEng MIMechE.

Soft ground performance prediction and assessment for wheeled and tracked vehicles, by D Rowland BSc(Eng)Hons and J W Peel HNC(MechEng) HNC(Prod Eng).

The performance of off-road vehicles under fluctuating road conditions, by D Crolla B Tech.

Terrain evaluation and off-highway mobility by G M M Neil MBE BSc CEng MICE and F W Gibbs.

Design of off-road vehicles for higher speeds, by E B Maclaurin BSc(Eng) CEng MIMechE and J W Elder BSc(Eng).

Designing an underwater tractor, by M Shimegi MEng.

The amphibious screw vehicle: a review of its development, by J Livesey BSc PhD and T J D Cunis BSc.

Specialised vehicles for forestry operations by R Ross.

New oversnow vehicle for arctic conditions, by B Andersson MMechEng and J Ljunggren, MMechEng.

The movement of heavy loads by L A Hopkins AMRAeS.

Engineering res at the National Engineering

by M J O'Dogherty BSc(Eng

1 Introduction

THE research described in this paper has been undertaken at NIAE during the last five years to obtain basic information to enable improvements to be effected in the design of machinery for the sugar beet crop. The paper is principally concerned with projects which have been undertaken by the Rowcrop Department but some other projects being conducted by the Institute are discussed in Section 6.

The object of the research conducted in the Rowcrop Department has been to study in detail the tasks undertaken by machines to provide data to enable a rational design procedure to be established. The long term aim is to provide the information required for optional designs to be achieved in the context of a defined crop production system. The resources of the Department have been such that only selected topics have been studied[1]. These are seed drilling, selective thinning of seedlings and sugar beet harvesting.

The programme of work on seed drilling has been broadly concerned with the control of seed placement in the row and the influence of drill design parameters. Attention is now being given to the influence which the drill can exert in preserving or enhancing the environment in which the seeds are placed so as to increase the probability of emergence and subsequent seedling survival. The work on selective thinning has been concerned with the factors which limit the rate of work of thinners and the uniformity of seedling spacing distribution. The programme on harvesting has been largely concerned with the factors which determine the ability of a topper to work accurately at higher working speeds and to accommodate the size and spacing variability in the crop.

2 Seed drilling

Establishment of the crop is of the highest importance in that it has a continuing influence on subsequent cultural and harvesting operations. It is important, therefore, that there is a good understanding of the correct principles of seed drill design. The objective of drilling can be considered as delivering and inserting seeds in the soil at discrete spacing intervals in an environment providing optimum conditions for germination and emergence, which can be maintained over a critical period independently of weather. The drill has to be able to meter seeds from bulk, without damage and be capable of high rates of work to achieve timeless of sowing.

The research programme has been principally concerned with the design of drills which handle dry seeds. This type of drill opens a furrow, meters and delivers seeds to it and then covers the seeds and firms the soil around them. It is known that the spacing distributions achieved by such drills show a considerable variance[2-4] and the object of the first phase of the work was to examine how the different phases of the drilling operation contributed to the total variability and, therefore, determine where the greatest improvements could be effected.

The basic components of a drill and their inter-relationships in producing the final seed spacing distribution are shown in fig 1. The design features of each component and the parameters relevant to their functioning are given in Appendix 1.

There are various ways in which seeds can be metered from bulk in a hopper, including cell wheels, cups, perforated belts and reduced pressure ("suction" or "vacuum" pick-ups). All such

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ɘarch for sugar beet
Institute of Agricultural

3Sc DipAM MIAgrE

methods have characteristics peculiar to the technique and to their design embodiment, but there is no body of knowledge concerning the effect of the various design parameters. Some laboratory and theoretical studies[5] were necessary for cell wheel and suction types of pick-up to obtain information on the limits of their ability to meter seeds efficiently with a minimum of misses and multiples. Supporting studies were made of the problems of seed transfer when using a two-stage mechanism, one stage of which meters seeds and the other delivers the seeds to the furrow.

Delivery of the seed to the furrow bottom may result in errors from incorrect seed release and from displacement by bouncing and rolling on impact with the soil surface. Theoretical studies were made of the effects of errors in seed release of different types of metering mechanism on the point of impact with the soil. Laboratory measurements were made of seed displacement following impact with different types of soil surface using a specially designed gantry and moving carriage over a soil trough fig 3 to obtain information on seed trajectories when released under dynamic conditions[6-8]. Photographs were used to record seed trajectories[7]. The critical parameters affecting displacement and its variance were the velocity and angle of impact, the nature of the soil surface and seed type. The results showed clearly the importance of achieving a correct seed trajectory to minimise bounce and roll.

The effects of covering and pressing may result in the disturbance of seeds which are accurately placed in the furrow. To measure the magnitude of the effect of these operations a radio-active tracer technique was developed to locate seed in a soil trough after passage of coverers and/or press wheels[9]. Cine photography was used to measure the velocity of soil particles entering the furrow to study methods by which their effect on seed position could be minimised. The effect of the passage of a press wheel at different depths of placement was studied photographically by measuring seed displacement by means of an open-sided box containing layers of fluorescent tracer.

The work on accuracy of seed placement is now at a stage where there is sufficient knowledge to enable placement accuracy to be improved and maintained over a wider range of operating speeds than in existing drills by the use of soundly designed components. A drill using a two-stage metering and delivery mechanism (fig 2) has been constructed and used in field experiments to establish the validity of the design in practice.

Much of the value of precision placement may be lost if a large proportion of seeds do not grow into plants. The coulter, coverer and press wheel do work on the soil and information is required on their effect on the soil environment in relation to seed germination and emergence. Work has recently been commenced, in collaboration with Broom's Barn Experimental Station, to study the design of soil working components[10]. This includes assessments of the benefits of removal of the dry soil at the surface, better control of depth of seed placement and amount of soil cover, improved coulter design, pressing the seeds into the furrow bottom and different techniques of soil firming.

3 Selective thinning

The objective of a thinning machine is to remove excess seedlings in the initially established stand so as to produce a final stand of seedlings at the required spacing in the row. The thinner should be capable of a high rate of work, be able to produce a uniformly spaced plant distribution and be capable of thinning seedlings over a wide range of stages of growth. It is known that selective thinners

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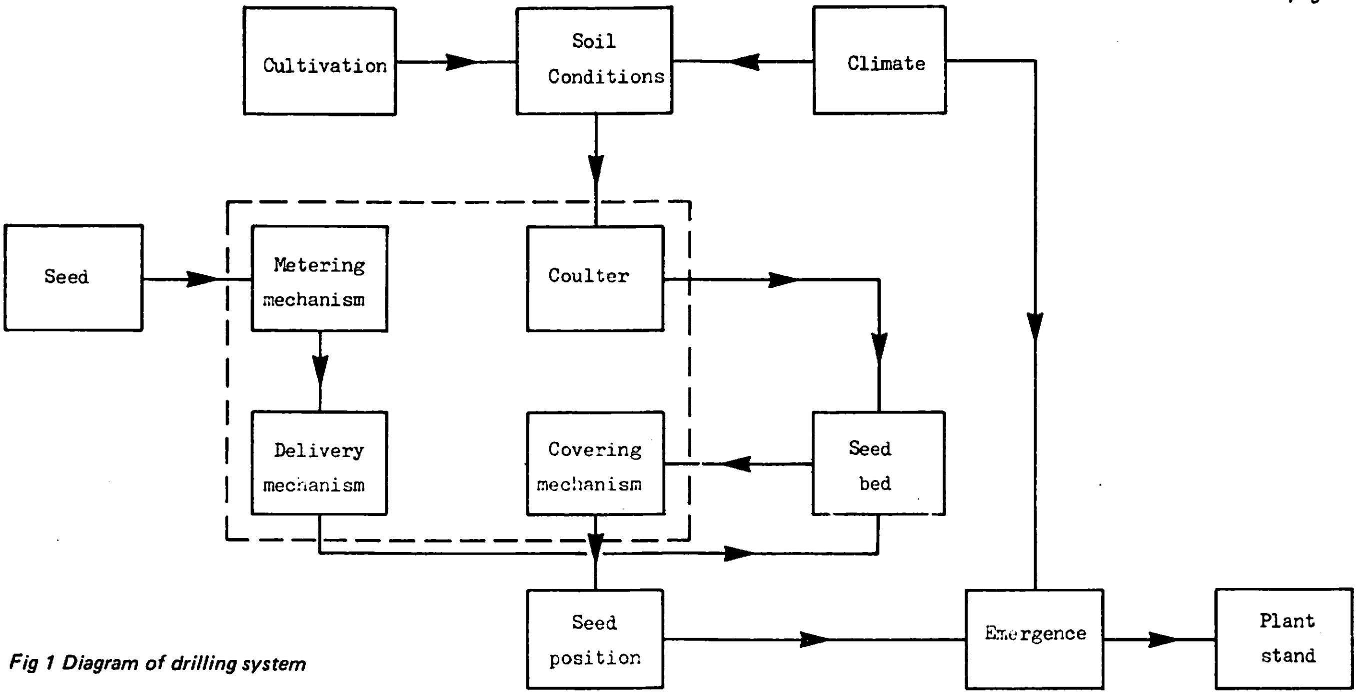


Fig 1 Diagram of drilling system

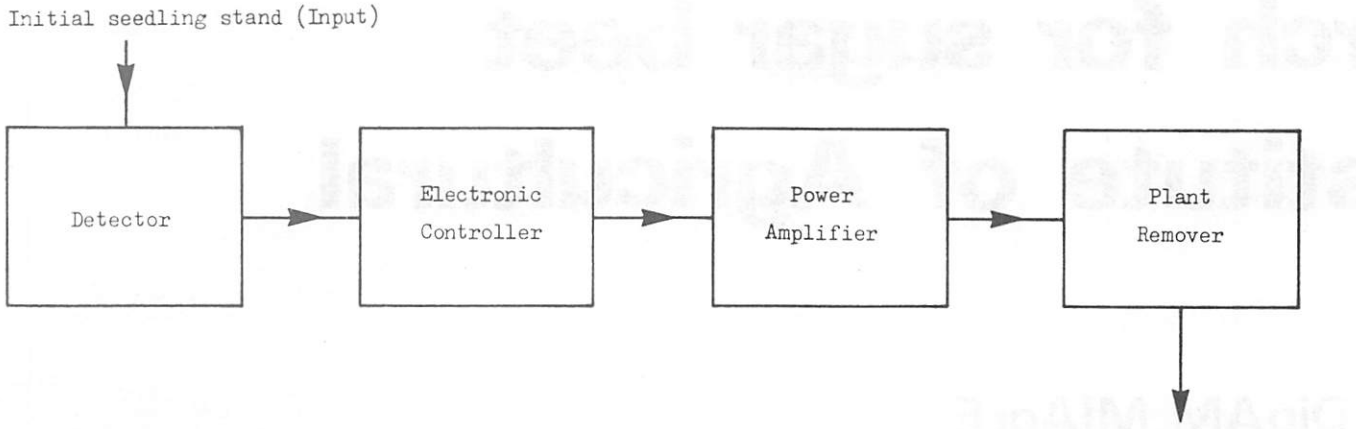
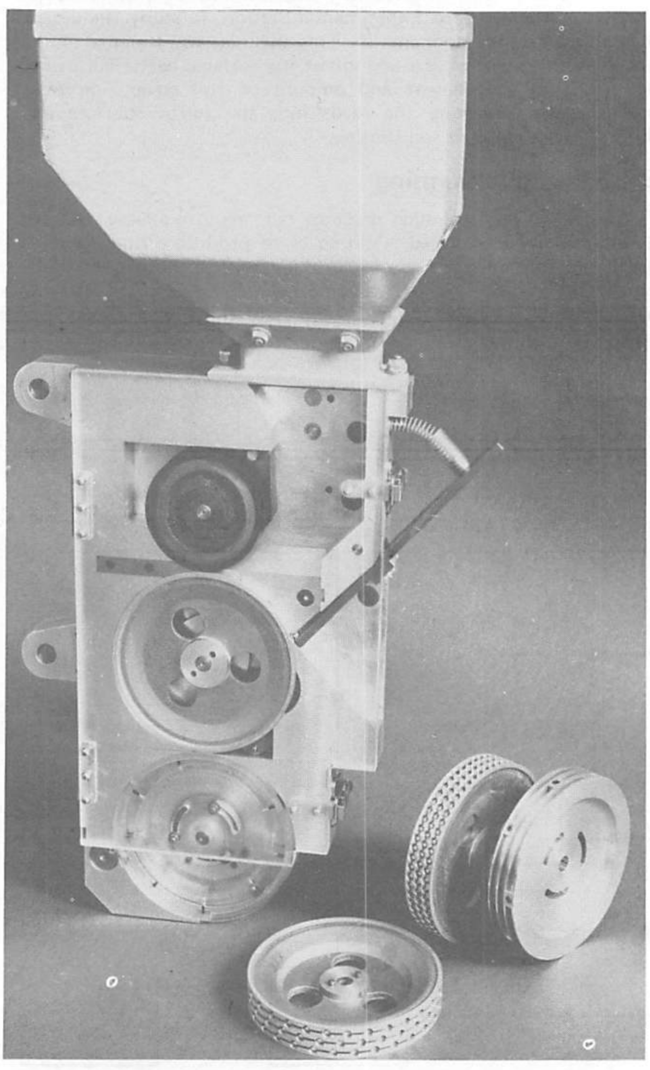


Fig 3 Basic elements of a selective thinning machine.

are restricted to relatively low operating speeds and produce seedling spacings which are less uniform than can be achieved by hand thinning[11,12]. The aims of the project are to determine the machine and crop parameters which are important in setting limits to speed and uniformity of spacing and define the practical limits of performance which are likely to be achievable.

A large number of trials, surveys and field experiments[12,13] has been made but the information available did not enable any clear understanding of the effect of design parameters on performance to be obtained. The forward speed of the machine was generally limited to 0.40 – 0.56 m/s (0.9–1.25 mile/h) in practice and the thinned seedling spacing distribution varied considerably in its characteristics. It was not possible to relate either aspect of performance to machine settings or to the spacing characteristics of the initial seedling stand.

Fig 2 Two-stage seed metering and delivery mechanism.



The main difficulty in understanding the design principles of thinners is the random nature of the problem, coupled with the large number of variables involved. The problem was approached by dividing it into two aspects: (a) the component parts of the machine and (b) the physical characteristics of the initial seedling stand. Essentially the machine effects a transformation of the "input", which is the initial seedling stand, to an "output" which is the thinned stand (see fig 3). The basic components of the machine are (i) the seedling detector, (ii) the electronic control system which provides the correct sequence of operation and (iii) the plant removal system (fig 3). The work of Rowcrop Department has concentrated on seedling detection and plant removal; the relevant design features and parameters for evaluating performance are given in Appendix 2. Design studies of control systems have been undertaken by the Control Department of the NIAE[14,15].

The problem of seedling detection is confounded by the fact that at any given time there is a statistical variation in seedling size and in the orientation of leaves to the row. In addition, the plant structure becomes more complex as it grows and acquires more leaves[16]. The machine can only respond to the information it receives from the detector and it is important, therefore, to relate this information to the physical configuration of seedlings within the stand. Measurements have been made using contact and optical detectors in the laboratory and in the field[17-19] in which the sequence of detector signals has been compared with the leaf and stem positions from sample lengths of row.

Work has been done to examine the response characteristics of different plant removal mechanisms, including continuous[20] and intermittent mechanical devices[21], herbicides spray systems and a high pressure water jet[22]. Particular attention has been given to examining a relatively simple intermittent system of minimum weight in order to achieve a sufficiently rapid speed of response with adequate strength for field duty[21].

Field experiments have been conducted in support of the design investigations to obtain qualitative information on the effect of increasing machine speed and of initial plant stand parameters. A laboratory analogue rig has been used to simulate machine performance in which artificial plants can be presented to a detector and the response of a seedling removal device recorded[21,22]. A computer simulation has been developed which can present various seedling stands to a thinner which incorporates some of the findings of the seed drill research[23]. The effect of detector and plant removal device characteristics together with different machine settings can be simulated. The thinned distributions are comparable with those obtained in the field and the simulation has proved of value in examining the benefits of improved design and the limits of performance likely to be achieved by the use of good design principles[24].

The work on this project has now been terminated. The information obtained is such that the principles of thinner design are better understood in relation to performance limitations, which are largely set by variability within the seedling stand and problems of accurate location of seedling position.

4 Sugar beet topping

The project concerned with the topping of beet differs from the work described above in that it is concerned with the design of a single mechanism with the task of removing the top of the beet crown below the lowest leaf bud. It has necessitated a detailed analysis of the physical nature of the topping operation to determine

Inputs		Mechanism Alternatives	Outputs	
Specification	*Environmental*		*Required*	*Undesired*
Driven feeler wheel. Adjustable static knife. Capable of sensing top of beet crowns over normal crop size range. Capable of working in crops produced by hand singling, machine thinning or drilled to a stand. Able to top beet accurately at speeds up to 5 mile/h. Able to withstand force loadings occurring in service. Use conventional materials components and construction techniques. Compatible with conventional harvesters. Reasonable cost.	Beet crown shape variation. Root spacing distribution. Crown height variation. Correct topping plane position variation. Beet diameter variation. Soil properties.		Minimum percentage undertopping. Minimum percentage overtopping. Minimum leaf and petiole tare. Simple to adjust and set in field. Low first cost, low maintenance costs, long life and easy servicing.	Crushing or excessive penetration of beet crowns by feeler wheel. Overturning or excessive displacement of beet. Breakage of beet crowns during cutting. Slip of feeler wheel on crown.

Fig 5 Input – output analysis for a sugar beet topping mechanism.

how errors arise and the design parameters of the topper influence its accuracy of operation.

In general, conventional feeler wheel toppers work satisfactorily at speeds up to about 0.9 – 1.3 m/s (2-3 mile/h), but at speeds in excess of 1.3 m/s errors in cutting increase rapidly[25]. Increasing irregularity of the crop spacing has also been found to lead to greater inaccuracies[26]. The object of the programme was to minimise uprooting and overtopping of roots, which represents a direct material loss and undertopping which may lead to processing problems at the factory[27]. In addition, the aim was to maintain the requisite accuracy over a greater speed range. Fig 5 gives an input-output analysis of the requirements of a topper in terms of performance required, together with the specification and environmental factors which must be taken into account.

Although many experiments have been conducted to study topping over the past 25 years, there was little basic information which could provide design principles leading to improved toppers. The problem was broken down, therefore, into its essential features. These were considered to be the dynamics of motion, problems of topper and beet crown geometry, and the constraints imposed by the strength of the beet. Appendix 3 shows these aspects of the problem with a summary of the laboratory and field experiments, and the theoretical analyses conducted.

The dynamics of topper motion was studied to obtain better following of beet crowns by the feeler wheel, so that contact was maintained and the topping knife cuts at the appropriate level. This included a study of the effects of speed, weight and its distribution, and of the benefits of restraining the mechanism by a compression spring and viscous damper. No information was available on the shape and variability of beet crowns, which is important in relation to feeler wheel motion, and measurements of beet geometry and of the correct topping plane position were therefore required[28]. Experiments were carried out on a laboratory rig, using simulated beet crowns to excite a topper into motion, together with similar experiments in the field[29-34]. Complementary theoretical studies of the dynamics of motion were conducted[35] and a computer simulation written[36]. These studies enabled a generalised understanding of the effects of the design variables to be obtained and also provided a basis for a design procedure for a specific problem.

As the topper moves along the row it has to cut each crown and accommodate a range of variation in beet size and spacing. Studies were made, therefore, of the effects of the topper parameters on the minimum spacing between beet which is necessary for correct topping[35]. The benefit of a compression spring was also studied[35] in relation to the greater acceleration it can provide towards the soil and so reduce the minimum spacing required between adjacent beet.

Improved following of the beet stand can be achieved by holding the topper down with sufficient restraining force. The obvious limitation to this is the force which beet can withstand. To enable the limits of restraint by a spring and/or damper to be determined it was necessary to measure both the crushing and overturning resistance of a range of beet sizes[37,38].

The body of knowledge obtained from this work has been used to develop a design procedure[35] to optimise trailing arm toppers and to design units of minimal-weight (fig 4). The basic principles are to use a drum feeler and frame of minimum weight restrained by an appropriate compression spring, possibly in association with a damper. Field trials with the British Sugar Corporation[39] and experiments at Wrest Park have shown that the re-designed topper has an improved performance compared with equivalent conventional units and that its standard of topping can be maintained up to at least 2.2 m/s (5 mile/h). A continuous liaison is being maintained with manufacturers of sugar beet harvesters and further trials are planned with the British Sugar Corporation for the 1975/76 season.

5 Crop production

The problems described above have been principally concerned with the mechanics of machines in relation to improved performance. The work is able to define the limits of performance set by the physical constraints of the problem and the design process will be able to relate the cost of producing a machine or a mechanism to achieving a defined level of performance. In selecting the optimal design for a machine, however, many other factors may have to be taken into account and the overall context of the crop production system taken into account. The inter-relation between different stages of mechanisation will need to be considered, eg the effect of the plant spacing achieved in establishment on the effectiveness of the harvester. The methods used to produce the crop may vary depending on its nature, on the soil type, condition and variability, and on weather conditions during the production cycle. The engineer must also be aware of the influence of economic factors such as the cost of seed, fertiliser, pest and disease control,

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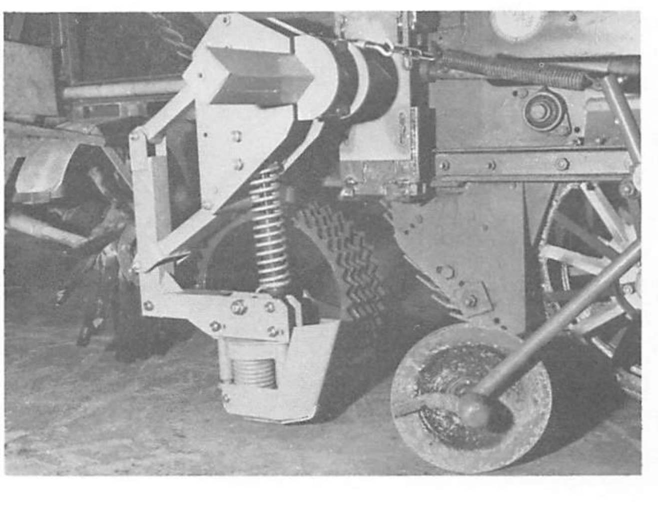
Fig 4 Lightweight topper mounted on a parallel linkage with spring and damper restraint.



the scale and nature of the farming enterprise, the availability of labour, equipment and capital, marketing considerations, and social and political factors. In addition, biological and agronomic developments must be appreciated in their possible influence on mechanisation requirements.

Some supporting studies of the technical research are necessary, both to enable the appropriate design optima to be appreciated against the complex background of the complete crop system, and also to enable the benefits of improved performance to be assessed. This approach is also of value in that it is able to indicate what changes in design are likely to be required in changing circumstances which may arise in future. Some preliminary work has been done to model a sugar beet production system using a computer simulation[40]. The crop establishment phase used variations in seed placement and emergence with different thinning methods. A crop growth model was then used to predict yield, together with a simulation of topper performance, to arrive at a final topped yield and a measure of topping inaccuracies. This programme has been limited to mechanisation effects but could easily be extended to take account of economic considerations. Other questions such as the value of increasing the speed of a single row machine, or alternatively, using a multi-row machine, could also be explored by such simulations.

6 Future programme

The work on seed placement by drills is now well advanced and there is a good understanding of the principles involved. It is proposed to carry the work into its second phase which is a study of the effect of drill design on seed germination and emergence. This work will be conducted in liaison with other Institutes concerned with biological aspects of the problem and will embrace both the optimisation of conventional methods of mechanical insertion of seed into the soil and developments in seed treatments which serve to produce more rapid and uniform germination[41,42]. Such methods may require new methods of metering and seed placement which would require more basic research on the problems of metering and placement of seeds, for example, in fluids or gels[43]. In addition, other possibilities of improving germination when using conventional drills should not be overlooked such as the addition of water in the vicinity of the seed and the use of artificial covering materials to conserve available moisture.

The work on harvesting of beet will be extended to cover other aspects of the operation in addition to topping. Some preliminary work has already been done in Machine Division to study problems of root lifting[44] and it is proposed to extend this work to look at the possibility of improving cleaning techniques. A programme is proposed by Rowcrop Department to examine the mechanics of

Appendix 1 Design features and variables of seed drill design

Component	*Design features*	*Problem variables*
Metering mechanism	*Seed hopper.* Geometry in relation to seed flow and presentation of seed. Fluidisation of seed bed or other means of improving seed presentation.	*Seed properties.* Size and weight distribution, shape, density, surface characteristics, flow properties, packing characteristics, moisture content, damage resistance, mechanical properties.
	Pick-up mechanism. Method of pick-up, eg belt, cell, cup, reduced pressure. Mechanics of pick-up process.	*Mechanism variables.* Velocity relative to seed bed, size and shape of transport hole or orifice, pressure differential.
Seed delivery mechanism	*Method of release.* Mechanical ejection, belt flexture, pressure equalisation valve, guidance tubes.	*Seed properties.* Aerodynamic characteristics, co-efficient of restitution with soil. *Soil properties.* Type, moisture content, physical nature of surface. *Seed trajectory.* Velocity components at release, height of drop (velocity and angle of impact at soil surface).
Coulter	*Furrow.* Shape of cross-section, depth. *Coulter geometry.* Form, size, angles of attack relative to soil, mechanism of furrow formation.	*Soil properties.* Type, structure, moisture content, mechanical and flow properties.
Seed covering and pressing mechanism	*Method of covering.* Angled scraper, split angled wheel, trailed bar, vibrating or powered mechanism.	*Soil properties.* As for coulter above. *Coverer and/or press wheel.* Geometry, critical angles, size and weight of press wheel. *Seed and soil properties.* Properties which determine displacement of seed in furrow bottom, eg momentum of soil particles along row, mass of seeds, roughness of furrow bottom.

Appendix 2 Design features and variables of selective thinner design

Component	*Design features*	*Problem variables*
Seedling detector	*Detection principle.* Light reflectance, light obscuration, electrically charged rod, contact switch.	*Seedlings.* Geometry and physical characteristics, eg size, number of leaves, orientation in row, stage of growth, reflectance characteristics, contact resistance, spacing distribution. *Environmental factors.* Vibration, moisture, dust, ambient temperature, solar radiation, clods and debris, weeds.
Thinning mechanism	*Method of seedling removal.* Mechanical, herbicide, high pressure water jet.	*Mechanical system.* Inertia, blade form, depth of soil engagement (speed of response and torque requirements.) *Fluid system.* Hydraulic circuit parameters, fluid properties, control valve design parameters, nozzle design (speed of establishment and cut-off of jet or spray), herbicide concentration. *Soil and plant.* Mechanical properties which affect the efficacy of seedling destruction.

Appendix 3 Outline of investigations on sugar beet topper design

		Laboratory experiments	*Theoretical analysis*	*Field experiments*	*Special apparatus and equipment*
(1)	Topper dynamics	Effect of speed and degree of restraint on topper motion. Impulsive forces on artificial beet crowns.	Kinetics and kinematics of topper. Effect of impulse on topper motion.. Prediction of impulse between feeler wheel and beet. Development of procedure for specifying restraint.	Studies of effect of speed and restraint on under- and overtopping	Lightweight topper with spring and damper restraint. Laboratory rig simulating topper motion over a beet stand. Artificial beet crowns. Beet crown force dynamometer.
(2)	Topper and beet stand geometry		Loci of topping knife in relation to topper and beet stand geometry. Effect of a spring on knife loci.	Measurement of beet crown shape and topping plane position. Studies of effect of knife setting.	
(3)	Physical restraints	Measurement of vertical load-penetration characteristics of beet crowns	Forces acting on beet crown during passage of topper wheel. Geometrical model defining limits of topping accuracy.	Measurement of horizontal forces to uproot beet. Measurement of impulse required to uproot beet. Measurement of forces due to knife.	Apparatus to apply horizontal force in field. Apparatus for vertical loading of crowns. Pendulum for applying impulse to beet in field. Dynamometer for measurement of knife cutting and vertical forces.

root lifting as part of a general programme aimed at alleviating the serious problem of root losses in the field. This work will cover the lifting of roots from the soil and consider the design problems of mechanisms to achieve a high degree of efficiency with optimal soil intake.

The basic research on topping mechanisms is now complete and the work has entered its development phase. It is proposed to conduct a further series of trials in a variety of crops to extend the range of conditions which will be met in practice. These studies will confirm whether the basic principles are generally applicable and whether particular modifications or extensions of the work are necessary in specific circumstances.

Some work has been carried out by Engineering Research Department on the specification of materials for topping knives in order to enhance the life of the cutting edge, together with complementary studies on knife design, including the possibility of using a tensioned wire[45]. This work will be continued and extended to topping studies in the field.

Further subjects for research and development projects are under active consideration by the Sugar Beet Study Group of the NIAE, which includes representatives of the Sugar Beet Research and Education Committee, Agricultural Development and Advisory Service, and the British Sugar Corporation, and will be considered for inclusion in the programme of work when its report is submitted.

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Design of a spra

apple orchards

by O D Hale Tech(CEI) MIAg

1 Introduction

BEFORE the 1939-45 war most commercial apple orchards were sprayed by hand-directed spray nozzles so that most of the foliage was wetted to the point of run-off. Between about 1950 and 1965 there were remarkable developments both of plant protection chemicals for use on applies and of "automatic" sprayers. These sprayers used a fan to blow the spray into the tree and were drawn continuously through the trees by a small tractor. The fans absorbed between about 15 and 60 hp (12 and 45 kW) and initially were driven by a separate petrol engine. Since popular small diesel-engined tractors of about 30 hp (23 kW) have been available most orchard sprayers have been driven by power from the tractor and have used about 20 hp (15 kW) to produce the airstream, thus allowing adequate power to drive the liquid pump and for traction. The sprayer fans have however used this power to give air pressures ranging from 3 to 30 in (75 to 750 mm) WG at a corresponding range of volumes.

Over the last few years a study has been made of the penetration of different air jets into apple trees[1], models being used to supplement limited full scale data. The results from the basic air jet studies had then to be reconciled with practical design limitations on fan selection and layout to arrive at the best arrangement for an orchard sprayer. Application of the work in the context of spraying intensive orchards of trees planted as hedgerows poses additional problems because of the restricted space in which the air jet has to be turned and spread. This paper describes work done to apply air jet studies to the design of a sprayer for such trees. It describes the development of the machine and field tests made of its performance.

A technique has been developed, in conjunction with this work, for the rapid assessment of spray deposits on large numbers (of the order of a thousand) of leaves. It depends on the addition of a fluorescent tracer to the spray liquid[2], and punching discs from leaves in the field into plastics holders. These are accumulated in special magazines in which they can if necessary be kept for short periods in a cool store before being fed into a fluorimeter with an attachment which allows the amount of deposit on each disc to be read automatically and the results printed out. The use of this system has enabled the wind tunnel indications to be taken through quickly to a practical design on the basis of rapid comparisons of spray distributions achieved in the orchard.

2 Indication of requirements from models

2.1 Scope of air jet studies

A study has been made of the penetration of an air jet into orchard trees. The performance, in terms of air velocities measured at points in and between trees, was measured[1], in a bush-tree orchard for three air jets at two travelling speeds. Each jet was of 10 air hp (7.46 kW) at the outlet and at 20, 11 and 4 in (508, 279 and 102 mm) WG respectively. Volumes of air, emitted over an arc normally of 90°, were 3240, 5220 and 13260 ft^3/min (92, 148 and 460 m^3/min). Travelling speeds were 2 and 4 mile/h (3.2 and 6.4 km/h). Because of variations due to changing leaf and wind conditions two seasons work was required to make these comparisons to the necessary limits of accuracy. A model technique, at 1/12 scale, which was established in a wind tunnel was shown to reproduce these field results[3], and has been used to extend them. It was first used to give intermediate points in the driving speed and air volume scales and then to determine the fan duty required for the best spray penetration at the fastest practicable forward speed.

yer for hedgerow

:, R B Sharp and J B Byass MA MemASAE

2.2 Outline of model results

The field work had already indicated that a high volume air jet was more efficient, so that the model of the high volume machine was used for further experiments. Four outlets were made, each round an arc of 90° on a 2¼ in (57 mm) radius. The outlet widths and the corresponding air volumes and velocities are given in table 1.

As in the initial field measurements these air jets have an equivalent full scale energy of 10 air hp at the outlet. The energy remaining at two points 10 and 20 in (254 and 508 mm) from the air centre, within the tree and between trees was recorded with the machine travelling through the model orchard at speeds of 2 to 5 mile/h (3.2 to 8.1 km/h). The measuring positions are identified as follows.

Position 1 10 inches (250 mm) from the air centre, within the tree canopy
Position 2 20 inches (500 mm) from the air centre, within the tree canopy
Position 3 10 inches (250 mm) from the air centre, between two trees
Position 4 20 inches (500 mm) from the air centre between two trees

Each point was along a line of about 35° above the horizontal. In some "windy" conditions a mid-point measurement was also taken.

This procedure was repeated with applied wind speeds of 5, 10 and 15 ft/s (5.6, 11.3 and 16.1 km/h) with the machine travelling into the wind, with the wind and across the wind.

To present the results in the simplest form the two variables of forward speed and machine air output have been combined to the single unit of air output per unit distance travelled forward. This unit is used as the base of the graph and the measured air horsepower is plotted against it.

The performance of the air jet in still air both between and written the tree and also the effect of travelling into an applied wind is shown in fig 1. The difference in recorded horse power resulting from travelling with the wind rather than against it is given in table 2. In all cases the results are expressed as the full size equivalents.

Measurements made with a cross wind of 5 ft/s (5.6 km/h) have shown that the measured power at positions 3 and 4 is almost the same as when the machine is moving directly into a wind of 10 ft/s (11.3 km/h).

3 Design of a spraying machine for hedgerow plantations

3.1 Design considerations

Using data already collected on air jet penetration into bush trees it was possible to apply the same principles to the hedgerow situation. As the trees in this type of plantation are planted in rows about 15 ft (4.5 m) apart, the distance from the machine air centre (the point from which the air jet may be deemed to radiate) to the rear of the tree would be about 10 to 12 ft (3.0 to 3.7 m). Therefore the positions that have been considered as the front of a bush tree may be considered as the rear of a hedgerow type of tree. Therefore, considering the graphs with this in mind it was apparent that a high volume air jet was required and that probably the optimum fan duty lay outside the region of practical dimensions.

High volumes of low pressure air are inherently prone to proportionally large energy losses. Axial flow fans are needed to generate this type of air movement but by using this type of fan for a spraying machine the air has then to be turned through 90° to be aimed at the tree, and this has to be done in a very short distance. Smooth turns and many guide vanes may be needed.

It was decided to use the largest diameter fan possible without producing a machine which was too large to travel between the rows. The overall width of the machine was fixed by the size of the bulk bins that are used at harvest, that is 48 in (1.2 m). But to allow for the air to be turned and distributed a fan diameter of 38 in (1 m) was selected. The high volume of low pressure air

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Table 1 Outlet dimensions

Model	*Air output ft^3/min*	*Equivalent full scale air output ft^3/min*	*Outlet air velocity ft/s*	*Outlet widths in (model) ft (full scale)*
A	35.3	5091	237	0.10
B	69.3	9979	168	0.28
C	111.1	15999	133	0.57
D	134.6	19385	120	0.80

Table 2 Comparisons of air horse power between the machine travelling with and against the wind. Model C 15000 ft^3/min per side

Measuring position	*1*	*2*	*3*	*4*	
Travelling into wind of 5 ft/s	2.33	0.44	2.50	160	Machine travelling at 2 mile/h
" with "	2.51	0.38	3.05	2.03	
Travelling into wind of 5 ft/s	1.66	0.06	1.50	0.50	Machine travelling at 4 mile/h
" with "	1.33	0.28	3.01	2.41	
Travelling into wind of 10 ft/s	2.05	0.13	2.00	1.60	Machine travelling at 2 mile/h
" with "	1.97	0.17	3.11	2.12	
Travelling into wind of 10 ft/s	1.70	0.00	1.30	0.10	Machine travelling at 4 mile/h
" with "	1.16	0.10	2.92	1.75	

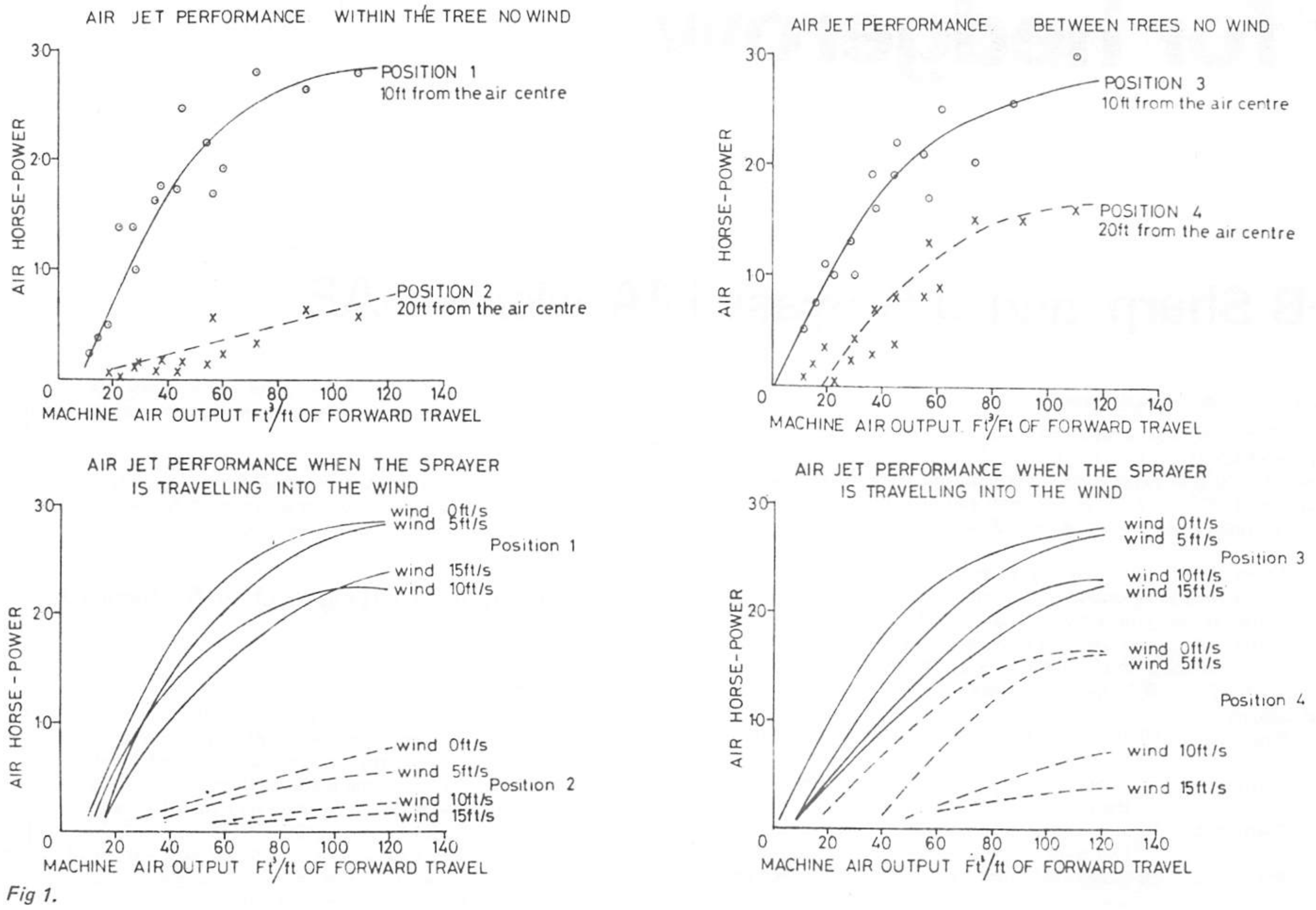


Fig 1.

required a large outlet area but because of the difficulty of ensuring that the duct was kept full the outlet could not be more than 9 inches (225 mm) wide. However, as hedgerow trees are much smaller than bush trees the outlet can be taken up to about three quarters of the tree height. This gives two advantages, firstly, the majority of the spray can be projected horizontally or at a low angle to the tree, thus avoiding the loss of fine spray above the orchard, and secondly, it avoids a high concentration of spray close to the outlet. One disadvantage is the close proximety of the foliage to the outlet. Because of this the spray booms were fitted well inside the outlet and carried a higher-than-usual number of nozzles. This ensured that the spray was well mixed with the airjet before reaching the tree, thus avoiding the production of a striped effect. It is important that as much as possible of the tractor power is put into the production of the air jet and not used to drive ancillary equipment. It is also advisable to use most of the power that is available at the pto of the normal orchard tractor.

3.2 First experimental machine

A first prototype machine was built on this basis in 1973. It used an axial flow fan of 38 in (1 m) diameter, which produced an air output of 32 000 ft^3/min (906 m^3/min) (16 000 ft^3/min each side) when running at a shaft speed of 1700 rev/min. The air was directed to the tree through two outlets 8 in wide and 42 in high (203 mm x 1.1 m). The spray booms were fitted within the outlet and carried nine conventional swirl nozzles each side. The fan was mounted at the rear of the machine with the outlets central and preceeded by a 200 gallon (900 litre) tank. The pump and gear box were at the front and the machine was trailed and driven from the tractor pto (fig 2). With this fan and outlet arrangement, it was found to be impossible to achieve an even distribution of air over the whole outlet area because of lower pressure in the section of the outlet above the fan. To obtain the advantages indicated by the basic air jet study it is essential to obtain an even distribution of pressure over the whole outlet area, as narrow areas of high velocity air will behave as a high velocity jet with the associated lack of efficiency. In the case of this machine the lack of air in the upper part of the outlet was reflected in the low spray deposit recorded at the top of the tree. However, the spray distribution patterns which were obtained were encouraging, even at forward speeds of 6½ mile/h (10.5 km/h). Another disadvantage with this fan and outlet arrangement was that with the large fan at the rear of the machine and close to the ground it sucked in dust and spray which built up on the guide vanes inside the casing.

3.3 Second experimental and production machines

Between the 1973 and 1974 spraying seasons, modifications were carried out to correct these design faults. The fan was repositioned at the front of the machine to reduce the intake of spray. It was also raised to a position mid-way up the outlet so that an equal amount of air was distributed above and below the fan axis. This produced a much more evenly distributed air jet.

This sprayer was constructed using components from the previous machine and many guide vanes and air deflectors were built into the outlet. This resulted in fan efficiency of about 16%, which was low. This meant that the air output had to be reduced to 26 000 ft^3/min (736 m^3/m) at 76 ft/s (23 m/s) in order to keep the power consumption within the capabilities of the smaller tractors. Although this was somewhat disappointing a series of trials carried out during the season showed that a reasonable spray distribution pattern was being achieved even at a forward speed of

Fig 2.

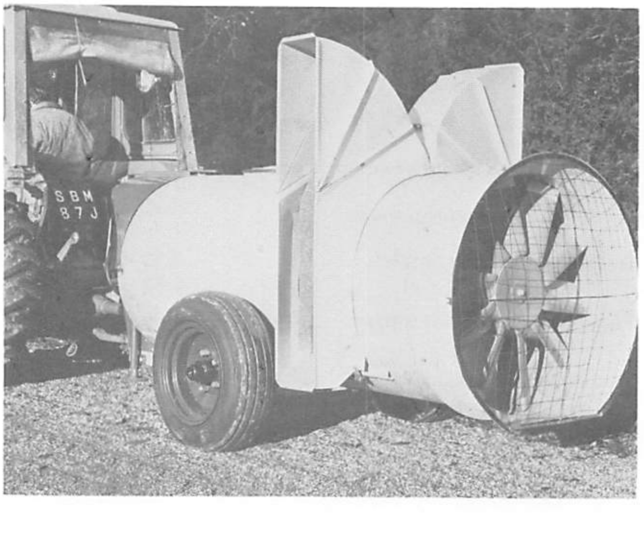


Table 3 **Machine specification**

Machine	Overall dimensions		Fan				Nozzles
	Length	Width	Type	Capacity ft^3/min	Total* pressure in WG	Dia in	
1973 Prototype	11ft 3in (3.4m)	4ft 0in (1.2m)	Axial	31'000 (878 m^3/min)	1.6	38 (0.97m)	Hydraulic pressure
1974 Prototype	10ft 6in (3.2m)	4ft 0in (1.2m)	Axial	25 800 (730m^3/min)	1.3	38 (0.97m)	Hydraulic pressure

**for equivalent air velocity, in ft/min, multiply square root by 4000.*

6 mile/h (9.7 km/h). The final production sprayer, made by Drake and Fletcher Ltd, (fig 3), working within the same dimensions, has a higher fan efficiency (about 28%) and produces 36 000 ft^3/min (1019 m^3/min), 18 000 ft^3/min each side, at an outlet velocity of 91.5 ft/sec (27.9 m/s).

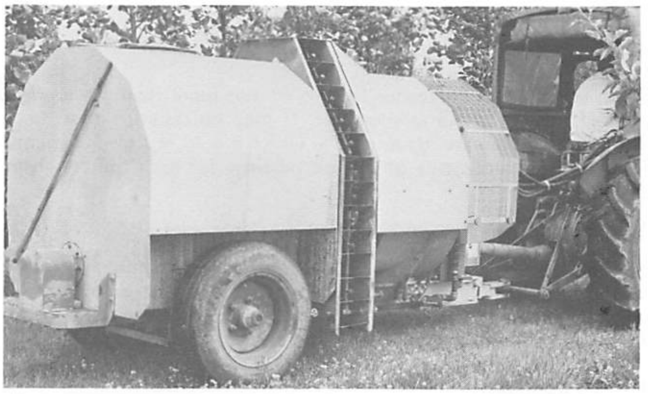


Fig 3.

4 Assessment of the sprayer performance

4.1 Method of assessment

A large number of leaf samples is required to compare different spraying treatments with a reasonable sensitivity. A statistical treatment of preliminary deposit measurements had shown that with 90 leaf samples the 95% confidence limits would be $\pm$20% of the mean value for the typical variations that occur during orchard spraying. Therefore it was decided to standardise on this number of samples from each tree region for the orchard deposit assessments associated with this sprayer development. This was the first large-scale use of the technique.

Six sampling regions were used in hedgerow trees to give a total number of 1080 samples when upper and under leaf deposits were measured separately. It was not possible to predetermine the sampling regions because of variations in tree shape from one orchard to another. The regions used were selected on site for the particular trees in use; the code that was used is shown in fig 4.

An important criterion of spraying machine performance is the extent of underdosed areas that remain in a crop after spraying because these areas will provide the centres for further infection or infestation. Apart from the waste of chemical, it is important from the ecological aspect that the elimination of underdosed areas is not achieved by overdosing other parts of the crop, with the risk of damaging fruit or foliage. The results are therefore presented in a form that enables the performance of the machine to be judged on these criteria, although more biological information is necessary to determine levels of active chemical needed for the control of different pests and diseases.

Results are expressed as:

(i) Mean spray deposits to give an indication of the deposits in each region of the tree.

(ii) Histograms to show the frequency of occurrence of each level of deposit.

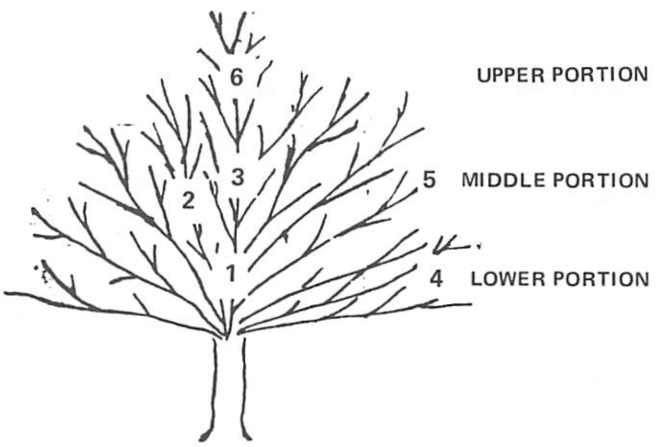
4.2 Experimental procedure

The trees were sprayed with a suspension of Saturn Yellow fluorochrome, this is a powder which requires to be mixed with a wetting agent before dispersal in water. With a density of 1.4 this material requires similar agitation to suspension formulations of pesticides. A 100 m row of trees was sprayed from both sides; when the spray deposit was dry, leaves were picked from a 60 m length of trees using six sampling regions in each tree as shown in fig 4, to provide samples for the leaf disc fluorimeter. The fluorimeter readings were expressed as the volume of spray deposited per unit area of leaf. These deposit readings were used to prepare distribution histograms of the frequency of occurrence of each level of deposit to illustrate the performance of the machine in each run. The mean levels of deposit on the upper and under surface of the leaves for each of the six sampling regions were evaluated from the deposit readings to indicate where an application weakness had occurred.

Samples which gave a fluorimeter reading indistinguishable from an unsprayed leaf were registered as "blank". Details are given of each run in table 4.

→*page 14*

Fig 4 Sampling regions used in each tree.



Each tree canopy was divided into three portions as indicated; the six sampling regions used were:

Region 1.	–	*foliage in the centre of the tree in the lower portion*
Region 2.	–	*outer foliage along the row in both sides of the tree in the middle portion*
Region 3.	–	*foliage in the centre of the tree in the middle portion*
Region 4.	–	*foliage in the lower portion where adjacent trees overlap*
Region 5.	–	*foliage in the middle portion where adjacent trees overlap*
Region 6.	–	*uppermost foliage in the centre of the tree in the upper portion*

Table 4 Details of runs

Run	Date	Gal/ acre	Forward speed mile/h	Wind speed mile/h
		Run conditions		
1973				
1	8.5.73 Pre-blossom	20	4	10
2	22.5.73 Post-blossom	20	4	3
3	8.6.73 Full leaf	40	4	3
5	19.6.73 Full leaf	28	6.4	7
6	19.6.73 Full leaf	40	4	7
7	19.6.73 Full leaf		Drift from run 6	
8	3.7.73 Full leaf	28	6.4	3
1974				
11 & 12	2.4.73 Pre-blossom	20	4 and 6.4	5½ to 6½
13 & 14	23.5.74 Post-blossom	50	4 and 6	5
15 & 16	25/26. 2.74 Full leaf	50	4 and 6	3 to 4

4.3 Results

4.3.1 Distribution between tree regions

The average deposits for the six sampling regions of the tree are given in table 5.

4.3.2 Occurrence of different deposit levels

The spray deposit pattern for each run is shown in histogram form in fig 5 using deposit increments of 0.1 1/cm^2.

Until more information on the lethal dose rate is available, it is impossible to determine the number of samples which were underdosed. However, it was possible to show the number of samples with a fluorescence reading of not more than the average fluorescence of an unsprayed leaf. It may be assumed that these leaves had a very low deposit level which would not give adequate control. The percentage of "blank readings for each run are given in table 6.

Table 6 Percentage of samples giving a blank reading

Run No	Speed mile/h	Upper surface	Under surface	Mean
		Blank reading %		
1973				
1	4	0.6	6.3	3.4
2	4	3.7	3.5	3.6
3	4	0.4	0.4	0.4
5	6.4	0.6	0.6	0.6
6	4	1.5	0.2	0.9
8	6.4	1.7	0.4	1.0
1974				
11	4	0.6	0.0	0.3
12	6.4	2.4	2.0	2.2
13	4	0.2	0.9	0.6
14	6	0.2	0.4	0.3
15	4	0.1	0.1	0.1
16	6	4.8	0.2	2.5

4.3.3 Spray drift on to the second row

On one occasion during the 1973 season an assessment was made of the amount of spray which was deposited on the second row of trees from the sprayer. The sample regions used were the same as for the other deposit runs and the results are given in table 6.

5 Discussion

This paper illustrates the problems involved in translating findings of a basic study of air jets in a wind tunnel model of an orchard into a practical spraying machine design. Much of the final design of air

Table 5 Mean spray deposit in each region (u1/cm^2)

Run No	Speed mile/h	1	2	3	4	5	6	1	2	3	4	5	6
		Upper leaf surface Region						*Under leaf surface* Region					
1973													
1	4	.22	.23	.31	.35	.34	.42	.88	.78	.86	.79	.88	.76
2	4	.14	.16	.13	.10	.14	.12	.50	.41	.39	.38	.38	.33
3	4	.32	.27	.25	.23	.28	.16	.58	.57	.55	.52	.64	.64
5	6.4	.27	.16	.17	.14	.18	.11	.60	.54	.61	.51	.57	.37
6	4	.24	.16	.21	.16	.15	.11	.51	.45	.37	.33	.43	.27
8	6.4	.38	.23	.26	.22	.28	.16	.66	.42	.44	.44	.50	.35
1974													
11	4	.52	.45	.59	.56	.64	.53	.59	.79	.62	.69	1.13	1.06
12	6.4	.37	.31	.34	.50	.47	.19	.39	.36	.47	.59	.64	.54
13	4	.49	.49	.44	.40	.35	.38	.32	.53	.38	.30	.43	.44
14	6	.55	.48	.50	.54	.54	.53	.64	.68	.56	.60	.74	.60
15	4	.54	.47	.53	.54	.49	.53	.45	.53	.77	.35	.78	.84
16	6	.45	.43	.45	.43	.40	.41	.52	.99	.53	.46	1.07	.95

Table 7 Drift deposit ul/cm^2

Run No	Speed mile/h	1	2	3	4	5	6	1	2	3	4	5	6
		Upper surface region						*Under surface region*					
6	4	.24	.16	.21	.16	.15	.11	.51	.45	.37	.33	.43	.27
7	Drift	.13	.13	.11	.11	.11	.09	.04	.09	.07	.03	.04	.05

Spray distributions over the tree canopy

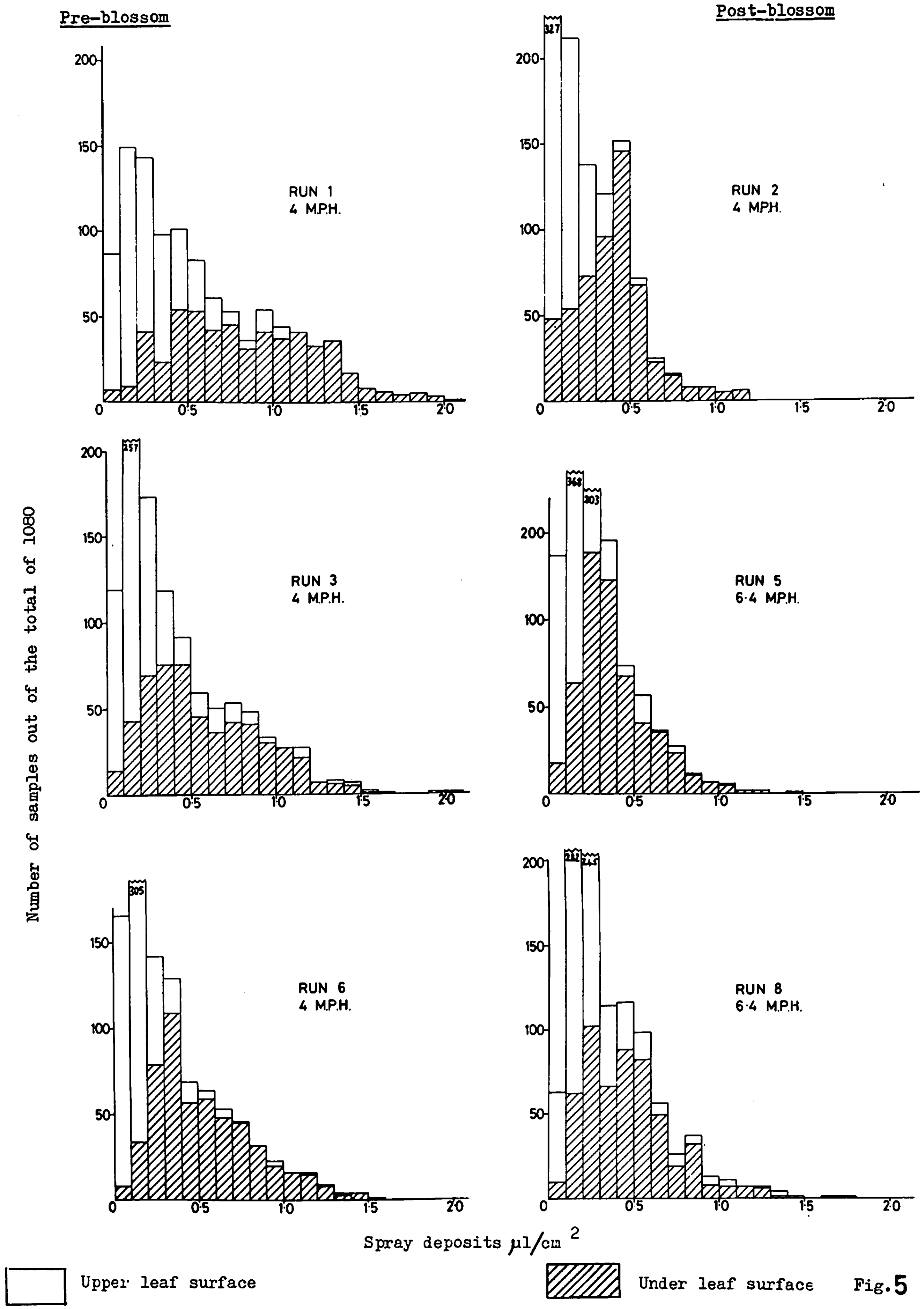


Fig. 5

Spray distribution over the tree canopy

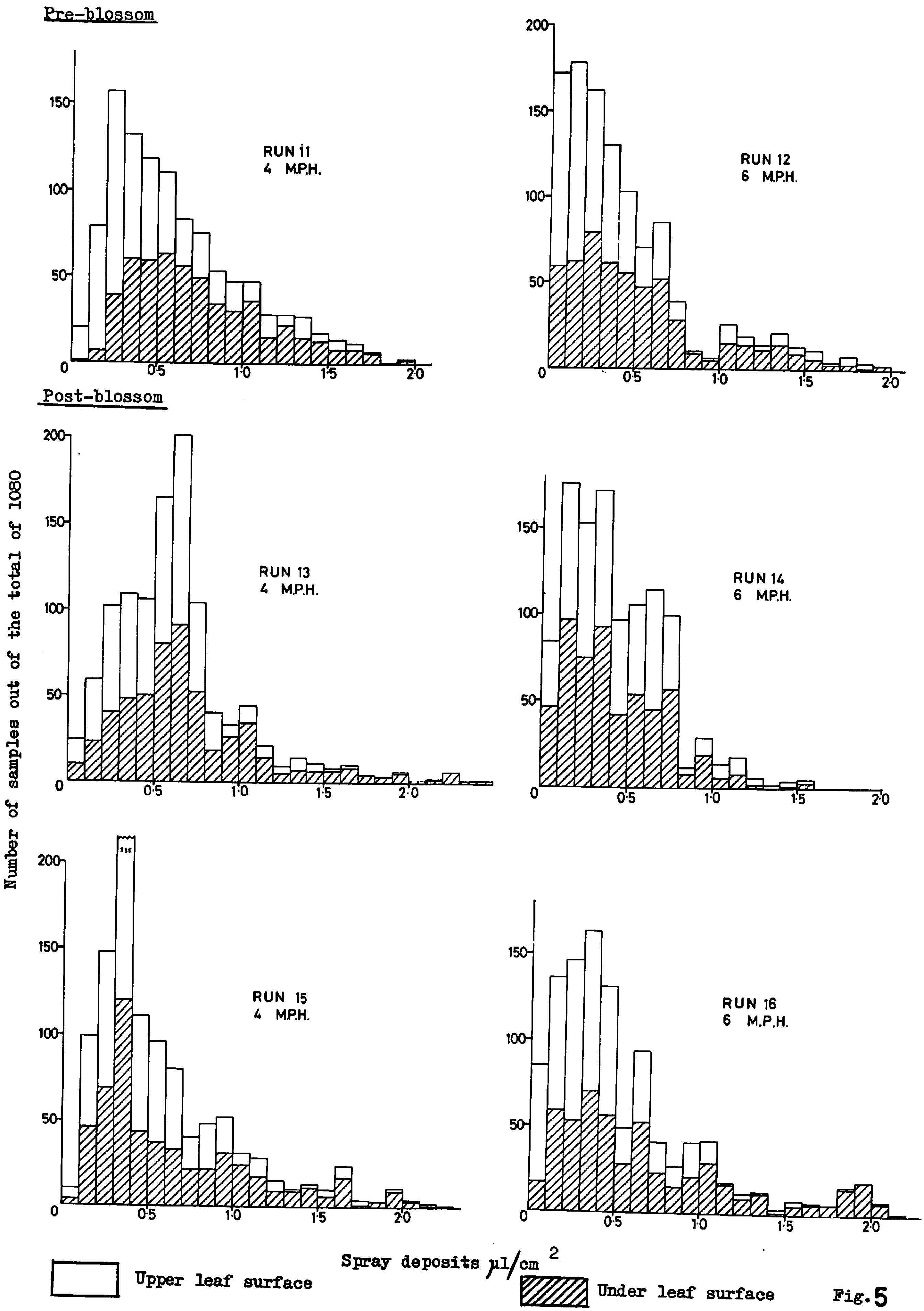


Fig. 5

outlets has been governed by practical considerations of fan size and duct losses. The work described has shown that the wind tunnel indications can be applied in a practical design.

The examples given of the use of the new method of measuring spray deposits on leaves have shown that the indications from the air measurements can be turned to practical effect in improving spray distribution even at higher work rates. Following the machine development, deposit distributions have been measured on the same basis for several sprayers in current use and these have generally shown a wider range of deposit levels about the mean.

The additional upper-surface deposit settling on the row beyond the sprayed one shows that this will affect the ratio of final upper-surface to under-surface cover, but this will also depend on the size of drops being applied. Different pests and diseases will have different requirements and the only assumption the engineer can make at present is that an even balance is needed between the two surfaces when good swirl nozzles are used at 10 to 20 atmospheres pressure. Further work is being done on the subject at East Malling Research Station[4]. The data presented illustrates not only how useful this facility for deposit measurement may be for interpreting dose: mortality data into sprayer requirements, but also how useful it could be for making general comparisons of sprayer settings.

6 Conclusions

The work has shown that the performance of the sprayer air jet improves as the air volume is increased and its velocity decreased to maintain a constant energy output. By using this type of air jet a spraying machine is able to travel faster and to operate in more windy conditions, whilst still maintaining an acceptable spray deposit distribution. Despite the reduction in fan efficiency which is inevitable when directing a large volume of slow moving air in the right direction for tree penetration, the model indications for the fan duty selected have been substantiated by the field performance. Some means of relating the spray liquid output to the machine's forward speed would allow an advantage to be obtained when travelling with the wind in one direction and against it in the other.

Acknowledgements

The authors wish to record their appreciation of the help of all who have made the work possible. Messrs Neame and Arnold, for the use of their orchards and for the co-operation of their staff, who have made every required facility available throughout the three years of field work. To Mr A P Smith and members of the staff of Drake and Fletcher Ltd for their co-operation and assistance and the Luddington Experimental Horticulture Station. Also to the staff of CID, Drawing Office and the workshops (NIAE) who built and serviced the equipment. R Andrews who devised the pneumatic leaf punches and J Pottage who has been the project technician throughout.

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Research and development at the Edinburgh School of Agriculture

Stone treatments for potato ground

THERE can be as many as four clods or stones lifted on to the harvester with every potato in some soil types. This situation creates a need for more pickers or more complex automatic sorting mechanisms for the potato harvester and causes additional damage to the tuber. An alternative to the improvement of harvester sorting mechanisms is to reduce the number of stones and clods lifted with the potatoes.

The methods of treating the stone fraction in the plough layer are to use:

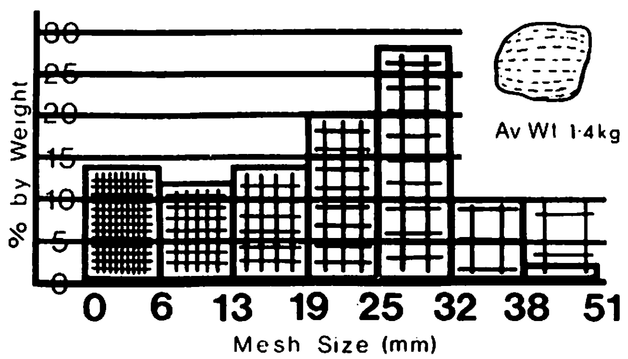
i) A stone picker to remove stones at harvest or in the spring.
ii) A stone crusher or land conditioner to reduce the size of the stones.
iii) A stone windrower to place the stones in the furrow of the stone-free ridge or bed.

The first two methods have a permanent impact on the soil, whereas the effect of windrowing is directed specifically at the potato crop.

With the exception of land conditioners which break up the stones with heavy rotary beaters operating within the soil itself, most other machines comprise a lifting share and a primary web which separates stones and clods from the soil. In stone picking machines care must be taken that the separation area and agitation is sufficient to ensure that clod is not transported off the field with the stones. This is of less significance where all the separated material is returned to the ground and an important feature of crushing and windrowing machines is their ability to deal with both stones and clods.

A stone crusher and three stone windrowers which are Scottish innovations have been used in prototype form and commercial production of the different models is in progress for the 1976 season.

On the stone picker, the separated material is elevated into a trailer running alongside or into a bunker (tank) for end-rigg unloading. On the crushing machine the separated material falls through two pairs of crushing rolls. One roll of each pair is driven and the other is spring loaded to provide an impacting action. This gives an impressive crushing performance for a surprisingly



STONE CRUSHING

low power requirement (fig 1). Windrowing involves a cross conveyor or chute to deflect the separated material into the furrow bottom of the drill or bed reformed by underslung or adjacent ridging bodies (fig 2). The rates of work vary from 2.5 to 3.5 ha/h which should not hinder the planter.

Potato harvester performance is significantly increased when field stoniness is reduced. Severe tuber damage is also decreased due partly to the reduced stoniness and partly to the increased harvester speed. The quantity of stones and clods separated on the harvester are similar after both stone picking and windrowing, rather greater after stone crushing, and are related to harvester performance (fig 3). During the second season of the three year research programme using some prototype equipment, a 25% increase in harvester forward speed was achieved after both stone picking and windrowing, that is changing from first to second gear

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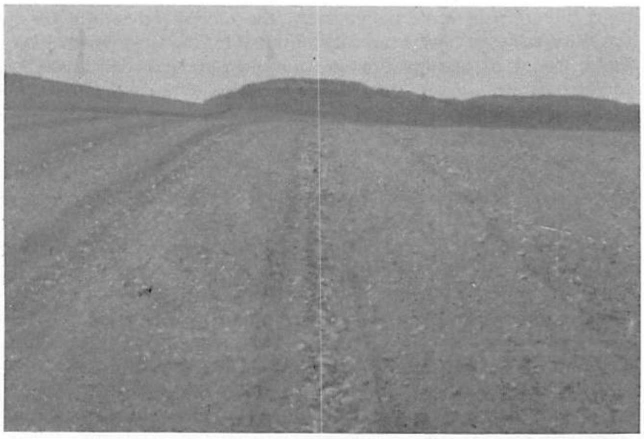

Fig 2.

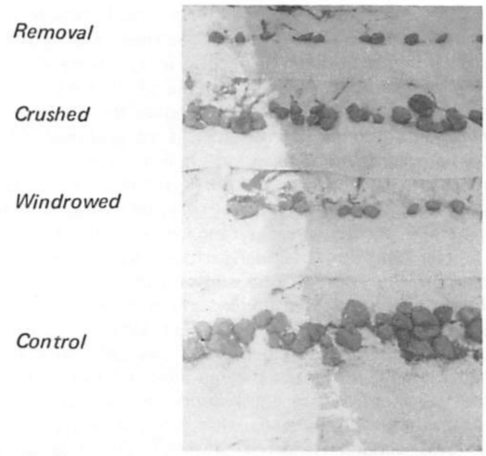

Fig 3.

at the same engine speed. A similar increase in forward speed was not feasible after the crushing treatment. There was a reduction in severe tuber damage of 15% after stone crushing and 40% after the other two treatments. As harvester forward speed is increased at the same engine speed web speed drops relative to forward speed reducing tuber rollback and agitation. Yield and tuber sizes do not appear to be significantly affected by any of the treatments.

The practical justification for stone treatment is fourfold. First, where damage is a problem, stone treatment can almost half severe tuber damage. Second, a 25% increase in harvester speed significantly reduces the harvest period and consequently increases the chance of obtaining the crop in good condition thus saving dressing costs. Third, where casual labour is scarce or expensive, stone treatment can save at least one person on the harvester. Finally, where hand picking only is feasible due to stony conditions, stone treatment makes mechanical harvesting possible.

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B D Withey and T S Wilson

Mechanical harvesting of raspberries

AT present about 12 000 t of Scottish raspberries must be harvested by hand in a four week period. The replacement of hand-pickers by machine is very attractive as a solution for personnel problems and picking in difficult conditions. The drawbacks of mechanical harvesting are loss of fruit quality, risk of mechanical failure and cost.

The Hally harvester, the only commercial harvester available in Britain, was tested over a complete season to compare its performance with commercial hand pickers. Whilst research into mechanical harvesting was in progress at the SIAE and SHRI, no data was available on commercial harvester performance over a season, and this trial provided that information.

The harvester, although trailed, is of the usual conformation, straddling the row and picking both sides in a single pass (fig 1). A self-levelling mechanism is fitted to aid working on slopes. Fruit is shaken from the truss and collected by side conveyors at the base of the shaking mechanism. These convey fruit through a pneumatic cleaner to collecting trays. All power is supplied hydraulically from a pto driven pump.

The trial was carried out in the variety Malling Jewel grown in 1.8 m rows for hand picking. It included three replicates of nine treatments randomly distributed within each replicate. The frequency and amplitude of shake were the variables. Records were kept of the total fruit harvested and its composition, fruit lost to the ground and rate of work. Commercial hand picking was used as a control in adjacent rows. The harvest was completed in five picks on the commercial rows and six picks in the machine harvested area, over a period of four weeks. The effect of variables on the yield and on loss of green fruit is shown in fig 2 and 3.

Fig 1.

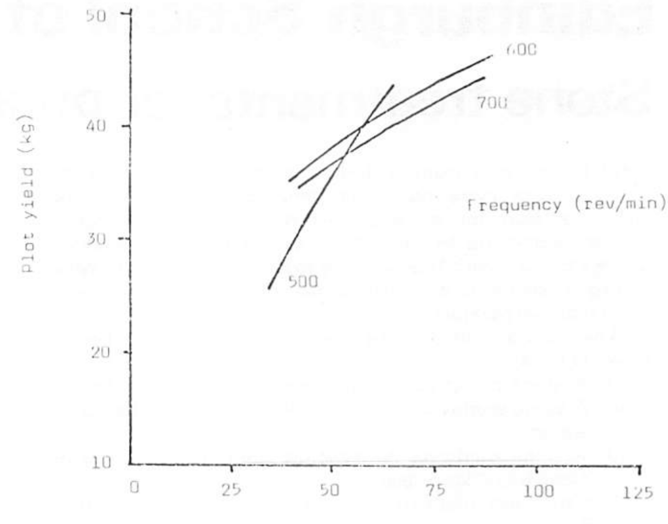


Fig 2 Effect of stroke length and frequency on loss of green fruit.

Hand picking yielded 7.70 t/ha: Machine harvesting yielded 4.65 t/ha in the better treatments ie 60% of the hand picked yield and, of this, 93.4% of the fruit was saleable. Thus, the saleable yield was 56.6% of the hand picked saleable yield. (In a commercial situation, less material would be unsaleable as operators would extract greens and plugs from the sample.) These results were obtained at an average speed 1.2 km/h and at an overall rate of work of 0.16 ha/h.

Of the fruit disturbed by the harvester, 87% was collected, the remaining 13% being lost to the ground. (Since the trial, modification to the harvester has been made to reduce this loss.)

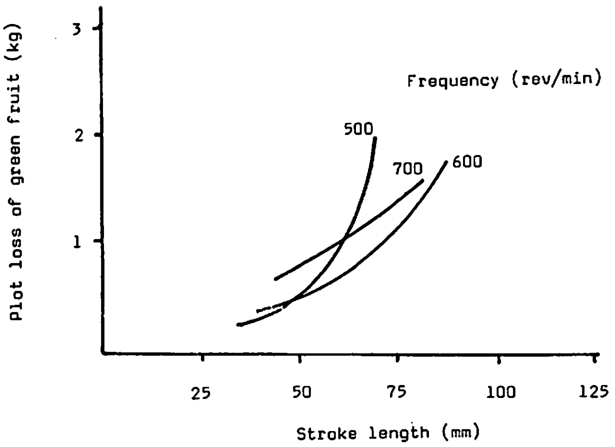


Fig 3 Effect of stroke length and frequency on loss of green fruit.

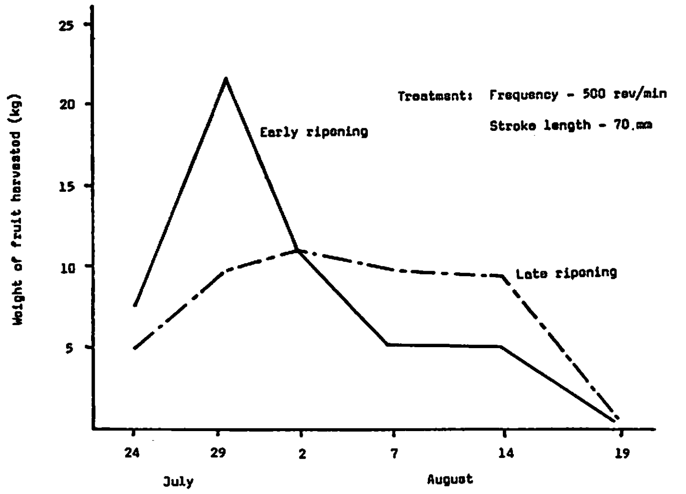


Fig 4 Distribution of harvested fruit over the season.

Variation in date of ripening occurred due to topography and its effect on harvest is indicated in fig 4.

The potential yield of fruit was reduced by machine harvesting. Only 70% of the hand picked yield was accounted for in terms of material mechanically harvested, loss of weight through harvesting green and fruit lost to the ground. This loss of yield was attributed to

(a) loss of berry weight from damage done to drupelets by both plant and machine.

(b) botrytis infection of damaged fruit causing them to dry on the truss.

(c) loosening of fruit which subsequently dropped off after the machine passed.

Development of varieties suitable for machines and further development of mechanical harvesters will improve the harvesting efficiency to a more viable level. A yield of 70% of the hand yield with an £8 000 machine would be viable on a minimum of 12 ha.

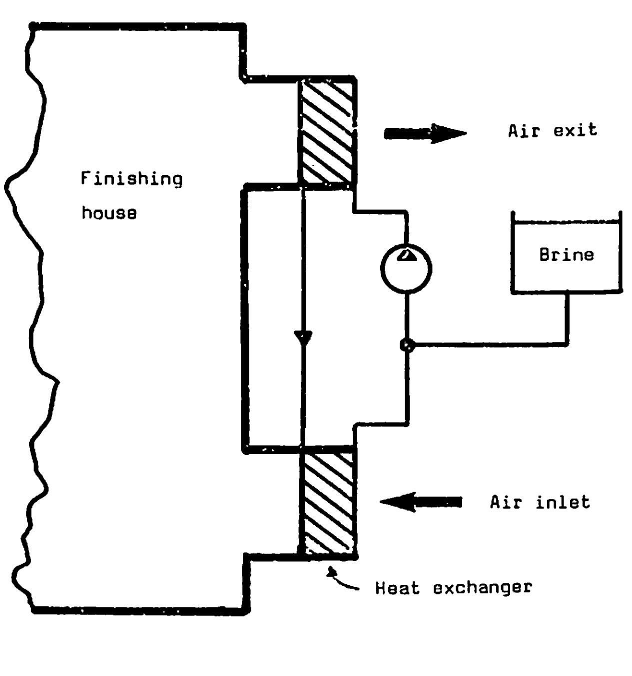
R R Morrison

Climatic conditions in pig housing

INVESTIGATIONS have been initiated over the past year into the climatic conditions that occur in commercial piggaries. A computer programme has been developed to enable the conditions of temperature and relative humidity within a finishing piggery to be rapidly predicted. This model is based on heat and mass balances and assumes steady state conditions. Heat loss to the ventilating air and through the various parts of the building structure are calculated and the heat loss due to clear night time radiation from the roof is included. Performance charts, which were published in THE AGRICULTURAL ENGINEER, Vol 30, No 2, were produced from this computer based model.

A study of the heat balance in a modern well insulated finishing piggery shows that nearly 90% of the total heat produced by the pigs is lost through the ventilating air when the ventilation system is set at the minimum recommended rate. Clearly to increase the insulating properties of the building structure will do little to alter the climatic conditions within the building. The possibility of recovering waste heat from the outgoing air and using it to heat the incoming air, has been investigated. For various reasons a simple heat exchange system using pumped liquid has been chosen for this initial study. A schematic of this system is shown in fig 1.

Fig 1 Schematic of simple heat recovery system.



The computer programme described above has been adapted to include the effects of the heat recovery system and the predicted performance of a typical finishing house is shown in fig 2. This house contains 400 pigs at an average weight of 60 kg. The stocking density is 1.2 pig/m^2 and the wind velocity is assumed to be 1 m/s

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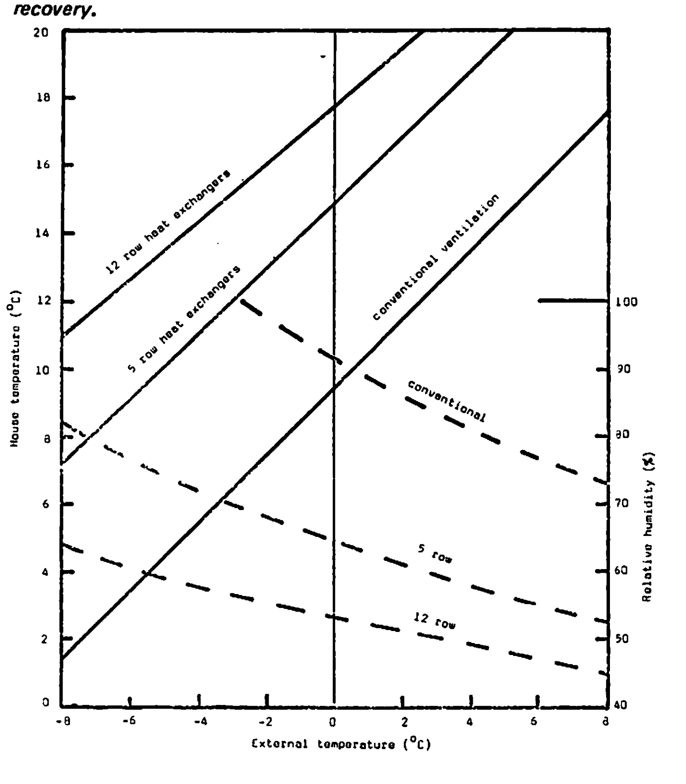
Fig 2 Performance curves for typical finishing piggery with heat recovery.



Mechanisation of Nigerian cassava production and processing: Research needs and interests

by Dr E U Odigboh MASAE MIAgrE

Introduction

THE FAO food balance sheets of 1964-1966 gave Nigerian total annual production of cassava at 7.5 million tons, 80% of which was consumed and 20% wasted. The same source estimates the present Nigerian cassava production at 10.0 million tons with an expected annual figure of 14.3 million tons by 1980. In terms of area, about 1.5 million hectares (3.5 million acres) is now devoted to cassava and expected to reach 2.1 million hectares (5 million acres) by 1980. Thus, Nigeria is the fourth largest producer of cassava in the world and the largest in Africa.

Cassava is a highly valued crop of the tropics and one of the highest yielding plants of the vegetable kingdom[1], next perhaps to sweet potatoes/yams. It is particularly valued because of its drought resistance, its ability to grow in poor soils, its relative resistance to weeds and insect pests[2] all resulting in its characteristically high biological efficiency. The present reported global average yield is 9.4 tons/ha even though Nigeria and the producing countries of Africa have yields of less than half that figure while other countries report averages in excess of 20 tons/ha. This indicates considerable potential for yield improvement in Africa. The fact that cassava productivity in terms of calories per unit land area per unit of time appears to be significantly higher than that of other staple food crops[3] should be of particular interest to the government economists concerned with resource development in the producing countries of tropical Africa.

Besides the traditional cassava meals such as garri which every Nigerian, rich or poor, likes to eat at least once a day, cassava in various forms is an excellent base for numerous nutritious foods[4]. A partial listing of the current and potential uses of cassava may be quite informative. In the food industry cassava starch or flour is preferred or is just as good as other starches[5] where it is used in party snacks, biscuits, bread, as a thickener in baby foods, soups, puddings, etc. The use of cassava in compound feeds for livestock has a vast potential. Feed industries in developing countries should therefore, invest in the development of new technologies of feed formulation which incorporate higher components of cassava.

Apart from the unchallenged position of cassava as the chief staple food in Nigeria, as in most of the tropical world, its industrial importance is also growing. Cassava starch is used in sandpaper, cardboard, charcoal briquettes, dolls, flashlight batteries, moulded plastic[3] toys, antihalation powder, photographic films, to name a few at random. Cassava starch represents the best material for the manufacture of adhesives[6]. It has a higher efficiency as a beater size in paper manufacture than starches from other sources[7].

The preference of cassava starch in laundry and textile industries is common knowledge to everybody in the business. The bland flavour of cassava starch, its non-retrogradation tendency and excellent freeze-thaw stability which make it the favourite of the food processor also recommend it as a diluent in chemical and drug manufactures or as carriers in cosmetics, pills and capsules[8]. The use of cassava starch in drilling muds, in the manufacture of explosives and such other unusual applications may not be common knowledge.

The uses are many and through modification and derivatisation the list can be further extended. Thus, besides providing a sure security against hunger for millions of humans, cassava has many non-food uses with potential for becoming an important foreign exchange earner for Nigeria and many other African countries. Many viable local industries can be developed with cassava as the major raw material. The awareness of the potentialities of cassava as food, feed and cash crop is already evident in Nigeria, with garri and cassava starch factories being set up in many parts of the country.

Research needs

The need to improve the yield of cassava in the countries of Africa has already been mentioned. This, of course, is an agronomic problem which is already receiving some attention at the International Institute for Tropical Agriculture (IITA) at Ibadan, in Nigeria as well as at the International Centre for Tropical Agriculture (CIAT) in Columbia.

Most aspects of cassava production and processing are very labour intensive. The planting of cassava as it is done in the producing countries of Africa is an arduous back-breaking manual operation. Various local attempts to design a cassava-cutting planter have not yielded a marketable machine. The author is currently designing a fully automatic cassava-cutting planter to plant inclined and on ridges. The development of an efficient cassava planter will mean considerable progress for the cassava industry in Nigeria.

Cassava harvesting also involves very difficult manual labour, and poses a problem which so far has defied all attempt at its mechanisation. The problem is complicated by the random growth pattern of the roots and the tremendous variability in size and shape of the tubers even in the same field of the same variety. It is hoped that the existing international institutes for tropical agriculture and the other agronomy research centres in the producing countries will give a high priority to the breeding of cassava cultivars which are amenable to mechanised harvesting. The fact

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cont from page 19

on a clear night. The major practical problem of keeping the heat exchangers free from dust is being tackled and the design for a heat recovery system suitable for a 280 pig unit has been completed. This system will be incorporated into an existing piggery in the near future so that practical trials can be conducted. At a later stage more sophisticated heat exchange systems may be tested if it appears that the benefits gained can justify the costs involved.

The prediction of piggery climatic performance described above is based on heat and moisture data obtained from animals kept under closely controlled conditions in small groups. There is a shortage of data from commercial piggeries and the acquisition of reliable information is considered important. In addition to data obtained from a multi-channel chart recorder, the Agricultural Engineering Department is developing a series of digital data-logging systems using tape cassettes which should enable large quantities of data to be analysed rapidly by computer. This data will be used to improve the predicted building performance model and provide more accurate analysis of existing systems.

A D TRAPP

that there is no specific harvesting season for cassava, while advantageous for obvious reasons, adds substantially to the problem. The cassava harvester needs to be designed to operate efficiently in the parched hard soils of the December – April period and in the water drenched muddy soils of the June – October period as well as in soils of consistency varying between these two extremes, during the other months of the year. Nevertheless, such a harvester will have to be designed and produced; it is a challenge which the indigenous agricultural engineers must face as a matter of urgency. This is particularly true in Nigeria where agricultural labour is getting very scarce and labour costs are rising rapidly[9]. Mechanisation is no longer considered to create unemployment. On the contrary, mechanisation is now recognised as a necessary part of the transformation is agricultural technology needed to increase agricultural production.

With the increasing awareness of the economic/industrial potential of cassava, there is pressing need for local research to determine those physical, mechanical, rheological and thermal properties which are important in various aspects of handling, storage and processing of cassava. Local engineering characterisation of cassava is essential for two reasons. Cassava is cultivated in almost every tropical climate of the world in one or more of the over two hundred varieties known[10]. With so many varieties grown there are wide variations in their composition and engineering properties as reported by Jones[11] and Lockwood[12]. Even the same variety will exhibit big differences in properties under different soil types, climatic conditions or cultural practices. The second reason arises from the fact that cassava is the crop of the developing countries of the tropical world. Consequently, very little research has been done or reported on the engineering properties of cassava. Most people in temperate regions are not familiar with the crop which, therefore, has been ignored by expatriate tropical agricultural research workers who, hitherto, have chosen to concentrate their activities on crops exportable in their primary forms. Hence, the few results of work in this area, such as those by the author[13] (presented in the appendix), do not have sources for comparison or collaboration.

The physical properties of shape, size, average straight length of roots, cortex thickness, etc are important in problems associated with the design of machines to peel, comminute or otherwise process the cassava roots. Such mechanical properties as modulus of deformability, resistance to cutting, impact or shearing of the root cortex and flesh are also essential engineering data needed to determine the best method to mechanise the peeling, grating or milling of the cassava. For example, it was found that the shear resistance of the cassava roots increased from the outer medullary zone to the central pith region, with sections containing the central chord being the most resistant parts during grating. It is not known, for instance, what are the effects of mechanical bruising on the storability of the roots or the quality of the cassava products. Little information exists on the thermal properties of cassava which are important for studying its storage requirements, hydrolysis for HCN removal and various other thermal treatments. The rheological properties dealing with the flow behaviour, cooling and extrusion characteristics of cassava starch pastes as affected by generic, varietal, climatic and cultural factors need to be studied to identify the varieties and local conditions that favour production of high quality cassava starch and other products.

Cassava processing is as labour intensive as its planting and harvesting. The peeling of the roots is particularly demanding in this respect and constitutes a major bottle-neck with a high nuisance value for the emergent cassava factories. Various local attempts at designing a cassava peeler have not been quite successful. The author has recently completed the design and construction of a continuous-process mechanical peeler that works satisfactorily. The design and performance tests will be reported shortly. Other areas of cassava processing requiring attention include commercial storage requirements, drying and frying for starch and garri production.

In considering the industrialisation of cassava processing, especially for food uses, it is important to realise that all varieties contain hydrocyanic acid in amounts that vary from harmless to lethal. Traditional methods of processing ensure the adequate removal of cassava toxicity. The literature contains discussions on numerous attempts at the classification of cassava into "sweet" or "bitter" depending on the HCN content[14]. But, the only point of complete agreement is that not enough is known regarding cassava toxicity.[15,16]

Many researchers think that the toxicity is associated primarily with the free HCN readily formed by the enzymatic hydrolysis of the toxines cynogenic glucosides or the so-called mainhotoxine whose occurrence is also generally established to be independent of the particular botanical taxa. The hydrolytic enzyme called linamarase or linase is heat sensitive. More study of cassava toxicity and chemistry is certainly called for. Meanwhile, any heat treatment involved in the mechanisation of the initial stages of cassava processing must ensure that the temperature employed is not high enough to destroy the enzyme before complete detoxication is achieved. In this respect, the knowledge of the thermal properties of the roots are of course essential. For a different reason, the processing temperature is also important in the drying of cassava starch. Apart from the importance of reaching the optimum moisture content of 12% it has been shown that the temperature of drying significantly affects the properties of the resultant starch.[17,18] Low – temperature or ambient – air-dried cassava starch tends to yield pastes with "long" cohesive textures which may be advantageous for use in high acid foods or in foods with added sugar. On the other hand, starch dried at 70°C or above has shorter textures which are preferred for pie fillings, in cream puddings and baby foods. Therefore the temperature of drying should be chosen in accordance with the intended use of the unmodified starch.

Summary

The size and uses of the cassava crop are received to justify the growing interest in the methods of production and processing. Some of the production and processing operations requiring research and mechanisation are discussed. In particular, emphasis is placed on the necessity to identify and quantify those mechanical properties of cassava which are needed in engineering design of machines, processes and handling systems, through local adaptive research which will lead to greater efficiency in the production and utilisation of cassava, with less waste and higher food quality at lower cost to the consuming millions, domestic and foreign.

→ *page 22*

Appendix :Some engineering properties of fresh cassava roots

Property	*Value**	*Method of determination*
Shape	Spindled-shaped, elongated ovoid, barrel shaped with rounded ends, conical with round heads, cylindrical. (Conical with rounded head)	Comparison with known shapes.
Roundness of transverse section	0.65 – 1.0 (0.85)	A_p/A_c = Actual area of section / Area of circumscribing circle.
Length	10 – 55 cm (25 cm)	Direct measurement
Average straight length	(10 cm)	Direct measurement
Maximum diameter	2.5 – 15 cm (6.3 cm)	Direct measurement
Weight	25 – 4000 gm (175 gm)	Direct measurement
Mean specific gravity	(1.025)	Water displacement
Moisture content (% wet basis)	85 – 93 tail and middle portion 78 – 86 head portion (88)	Aerated oven
Solid density (gm/cm^3)	1.9 – 2.3 (2.0)	Air comparison pycnometer using bone-dry roots ground to average particle size under 250
Thickness of outer periderm	0.25 – 0.3 mm	Instron universal testing machine time/ displacement recording
Thickness of Cortex	1.0 – 2.0 mm (1.5 mm)	Instron universal testing machine time/ displacement recording
Modulus of deformability (apparent modulus)	(3.45 E+06)– (4.82 E+06)pa @ Pa = 4.13 E+06	Tangent to stress – strain curve at designated stress (see fig 1)
Degree of elasticity	48 – 60% (50%)	$D_e/(D_e + D_p)$ From loading – unloading elastoplastic hysteris curve. (see fig 2)
Bioyield strength	((9.13 E+05)pa)	Force deformation curve
Shear Strength (i) Medullary zone	(i) ((6.76 E+05)Pa)	Double Shear Test
(ii) Central pith zone	(ii) ((9.96 E+05) Pa)**	represents main resistant part during grating of cassava root.
(iii) Section containing central chord	(iii) ((2.14 E+06) Pa)**	
Thermal conductivity	(0.285 W/m.K)	Modified Fitch apparatus
Specific heat	(0.94 J/kg.K)	Calorimeter – method of mixtures

*(mean value in bracket)

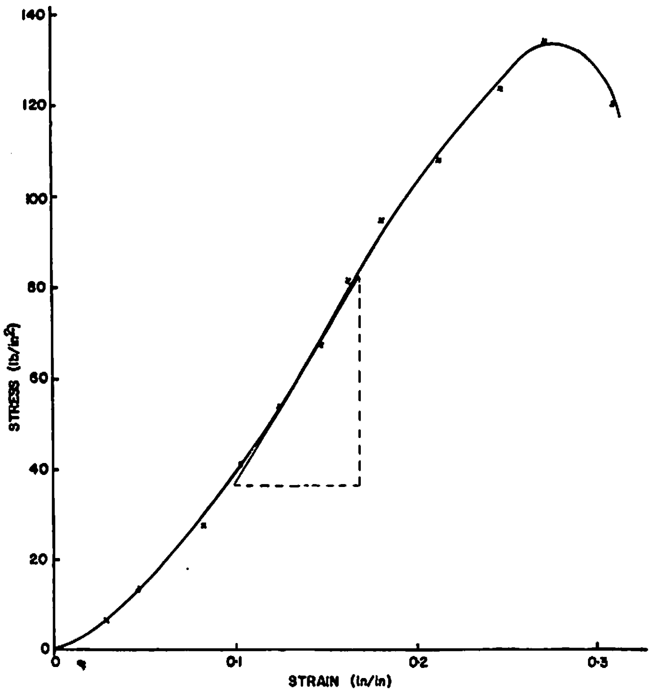
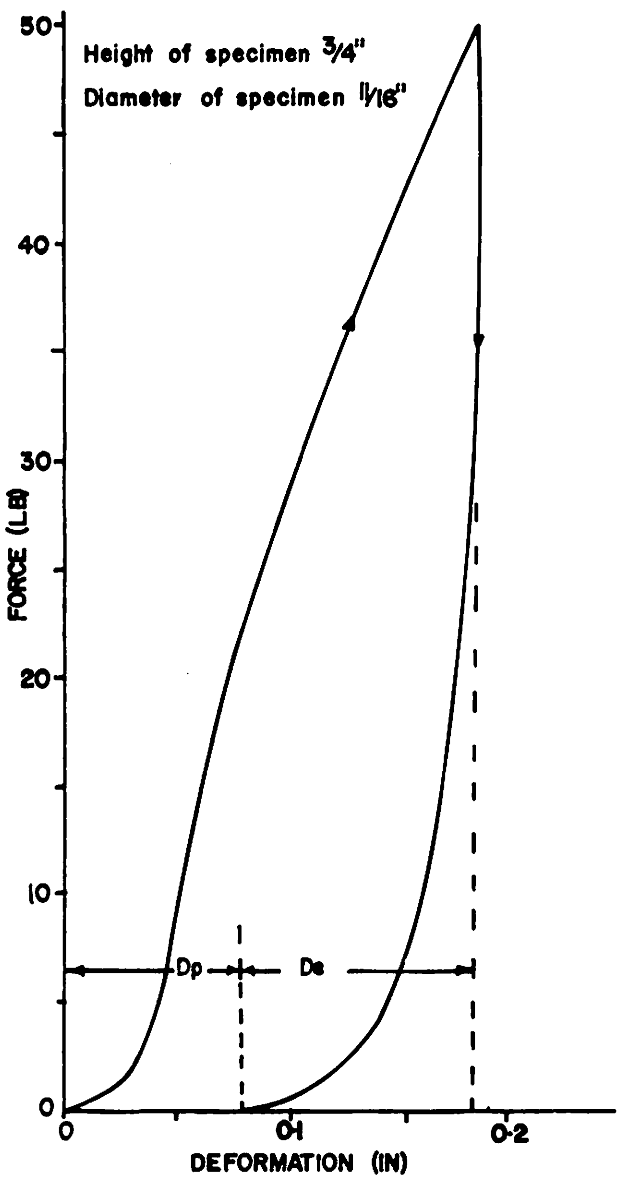


Fig 1 Compression test – stress/strain curve of a cylindrical specimen of a cassava root flesh.

Fig 2 Loading – unloading hysteresis curve of cassava root flesh.



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Secretary's notes

AROUND THE BRANCHES

Scottish

IT is with deep regret that the Scottish Branch records the death on 21 October 1975 of John Marshall, managing director of Cruikshank & Co, Denny Iron Works.

In addition to being one of the outstanding members of the Scottish foundry industry, he was also closely allied to agriculture through the ploughs made and marketed by his company.

He served as a member of the Scottish Branch committee of the Institution for a number of years and regularly attended the Branch annual supper.

South Eastern

A JOINT meeting of the South Eastern Branch and Chelmsford Farm Machinery Club was held on 8 October at Writtle Agricultural College.

Three speakers attended the meeting – Roger Reid, of Massey-Ferguson; David Pearson, of Ford Motor Company; and David Blenkiron, regional sales manager for Fiat. All three speakers suggested that in order to get most efficient use of the increased power which is becoming available, tractor drivers should ensure that they are fully conversant with the sophisticated features and controls available on these machines.

About 50 engineers, farmers and tractor drivers were at the meeting, which during question time and the discussion which followed, considered both, 2- and 4-wheel drive tractors. Some criticisms were also made about the suitability of manufacturers' instruction books.

Southern

THE committee of the Southern Branch of the Institution of Agricultural Engineers met recently to finalise its meetings for Spring of 1976 and to start planning for autumn meetings.

Since its formation only a year ago, this branch has held meetings at centres throughout the wide area it covers, which allows every member within the Branch an opportunity of attending at least one meeting close to home and this has proved to be a successful policy.

The October meeting on "Environment Control and Conservation of Energy in Glasshouses" was held at the Plumpton Agricultural College in Sussex, with speakers from the Glasshouse Crops Research Institute.

The November meeting moved to the Hampshire College of Agriculture at Sparsholt, nr Winchester, where Dick Cawshaw of CIBA – Geigy spoke on The Potential of Aerial Spraying and Bill Taylor of the Weed Research Organisation spoke on Low Volume Application.

On 19 March at Reading University, J O Cherrington (writer, broadcaster, journalist and farmer) will speak on "British Farming and the EEC". On 23 April at Merrist Wood Agricultural College, Worplesdon, nr Guildford, will be held the first annual general meeting of the Branch.

Sir Henry Plumb is Principal Guest

COUNCIL is pleased to announce that Sir Henry Plumb, President of the National Farmers' Union, has accepted an invitation to be the Principal Guest at the Annual Luncheon to be held on the occasion of the Annual General Meeting and Conference on 11 May 1976, at the Bloomsbury Centre Hotel, Coram Street, Russell Square, London.

Yorkshire

ALLINSON'S flour mill, Castleford, was visited by Yorkshire Branch members on 20 November. This mill produces 100% stone-ground flour. Dodging past bulk tankers delivering a new consignment of Canadian wheat, members entered the mill at the grain reception point and followed the route of the grain through all its stages right to being packed ready for retail sale. Whilst, obviously, few agricultural engineers are employed in flour mills, the more understanding we, as a profession, have of the technical requirements and problems of directly related industries such as milling, the better we can ensure that improvements and changes initiated by agricultural engineers do not unwittingly have adverse repercussions in other areas.

ADMISSIONS

The undermentioned have been admitted to the Institution, in the grades stated:—

Fellow (FIAgrE)

Ysselmuiden I L A	Herts	5	10 7 75	CS

Member (MIAgrE)

Frizelle D A	Gwent	7	22 1 75	DM/FM
Newman J R	Dorset	7	30 9 75	
Somasegaram K	Sri Lanka		23 1 74	
El Zubier E L	Sudan		7 5 75	

Companion (CIAgrE)

Norton H W	Salop	9	10 7 75	DM/RD

Technician Associate (AIAgrE)

Pereira P R	Malaysia		30 9 75	ED
Wilson D G	Oxon	13	23 10 75	ED

General Associate (AIAgrE)

Ajiboye E O	Nigeria		22 4 75	FE
Arnott J C	Norfolk	1	9 9 75	ED
Bound C L T	Lincs	2	9 9 75	ED
Brown J E	Lincs	2	23 10 75	ED
Davidson W	Glos	7	5 6 74	
Frost B J	Essex	12	8 11 75	FM
Gammage P L R	Essex	12	16 6 75	TS/DM
Guy J H	Oxford	13	26 9 75	BD/FE/TS
Kelly F	Eire		12 9 75	
Kotalawala D A	Sri Lanka		30 9 75	FE
Sanders J H	Norfolk	1	23 10 75	FM
Toulson B A	Hants	13	9 9 75	TS

Graduate

Akubuo C O	Nigeria		9 9 75	
Baker P C	Clwyd	9	8 11 75	AD/TS
Baxter G C	Cleveland	10	26 9 75	TS
Chambers J T	Co Down	NI	9 9 75	AD
Fashina A B	Nigeria		16 9 75	
Koroma A A	Sierra Leone		16 8 75	ED
Purton R G	Staffs	9	21 5 75	
Rowbottom R J	Netherlands		9 11 75	FE
Sanderson J J	Lancs	11	9 9 75	DM

Student

Darby E J	London		8 11 75	TS
Freeman R H	Cambs	5	8 11 75	ED
Loades B C W	Rhodesia		10 2 75	
Obaowo J A	London		8 11 75	AD
O'Keeffe P M	Eire		10 11 75	DM
Willcocks W J	Beds	5	8 11 75	FE

TRANSFERS

The undermentioned members have been transferred to the grades stated:—

Member (MIAgrE)

Apeaning J	Ghana		26 11 75	
Bradford S P J	Somerset	6	30 9 75	
Cox J P	Dumfries	4	26 11 75	AD/CS
Hale O D	Beds	5	16 11 75	RD
Hibbott R M	Wiltshire	7	23 10 75	ED
Hicks D M	Oxon	13	10 11 75	ED
Jones A R	Wilts	7	8 11 75	TS
Jones D M	Northants	2	10 11 75	DM

Technician Associate (AIAgrE)

Fenton S H	Cumbria	3	9 9 75	
Percival J H	Berkshire	13	22 4 75	FE

Graduate

Sheldon M C	Herts	5	10 3 75	
Sweetman J A	Swaziland		23 10 75	

Retired Rate

Drake R S	Warks	8	1 1 76	

REGRADING

The undermentioned has been regraded:—

Student

Copeland M J	Kent		1 1 76	

RE-INSTATEMENTS

The undermentioned have been re-instated:—

Technician Associate (AIAgrE)

Agundero S	Nigeria		16 9 75	

General Associate (AIAgrE)

Wharton F N	Co Down	NI	16 9 75	

Student

Amudipe S A	Nigeria		28 1 71	FE
Miller P C H	Bedford	5	16 1 69	

RE-ADMISSIONS

The undermentioned have been re-admitted to the Institution:—

Member (MIAgrE)

Waite J A	Staffs	9	9 9 75	CS/TS

Companion (CIAgrE)

Rainthorpe J J	Lincs	2	1 1 75	FM

RESIGNATIONS

The undermentioned have resigned from membership of the Institution:—

Bowditch H G	Australia		1 1 76
Brock W G	Hants	13	1 1 76
Desmond R A	Hants	13	19 11 75
Fearn J I	Yorks	10	9 10 75
Gilman J J	Dundee	4	1 1 76
Gunby R G	Belgium		1 1 76
Herman K M	Wilts	7	1 1 76
Higgins A E H	Berks	13	1 1 76
Jackson J A	Newcastle	3	1 1 76
Joscelyne N C	Essex	12	1 1 76
Kitchen A	Durham	3	16 10 75
Morgan W T	Warks	8	29 11 73
Morley E G	Glos	7	1 1 76
Murray G	Aberdeenshire	4	16 10 75
Percival W	Notts	2	25 11 75
Peters E W	London		1 1 76
Ramsey H S	Glamorgan	7	27 8 75
Shell O D	Newcastle	3	1 1 76
Tuck N G	Suffolk	1	25 10 75
Wallis T J R	Kent		29 9 75
Weldin F	Hants	13	27 11 75
Wilkinson G	Norfolk	1	1 1 76
Woodruff L J P	Wilts	7	1 1 76

DEATHS

We regret to announce the death of the undermentioned members:—

Ellson W G	Hereford	8	6 75
Marshall J	Stirlingshire	4	21 10 75

ENGINEERS REGISTRATION BOARD

The undermentioned have been placed on the ERB (CEI) Register:—

Technician Engineer (TEng [CEI])

Boyce B H	Wilts	7	9 10 75
Oduyemi I	Nigeria		10 9 75

Technician (Tech [CEI])

Bonner R H	Kent		9 10 75

"Shell" award to students

THE President and Members of Council of the Institution are pleased to announce that it is proposed to introduce a series of Awards for Papers and other activities during the forthcoming Session, 1976/77.

The first of these Awards applies specifically to Student members of the Institution; Shell UK Oil have kindly donated three prizes of £100, £75 and £50 which will be awarded for the best papers covering improvements for the handling and transportation of material and produce on the farm. A panel of adjudicators will be appointed by the Institution.

Any registered Student of the Institution is invited to apply to the Secretary for further details.

Closing date for any submissions will be 1 September 1976. The Awards will be presented to the winners at the Autumn Conference being held at Norwich on 9 November 1976.

Details of other Awards will be announced in the next issue of the Journal.

Thomas Hawksley lecture

THE interaction between the food producer and the engineer provided a very appropriate topic for Dr Ralph Lester, Head of Unilever's Colworth Laboratories, who gave this year's Thomas Hawksley lecture to the Institution of Mechanical Engineers, on 10 December.

After an entertaining and pictorial coverage of historical aspects of his subject from about 2000 BC up to the present day, Dr Lester summarised a number of modern examples of the co-operation and co-ordination between the plant breeder and the machine designer, for it was in mechanical handling that some of the most rewarding developments were likely to occur. Particular mention was made of the demands imposed by modern harvesting machinery and its influence on such matters as the straw length of cereals and the shape of tea bushes on large plantations. The Long Ashton meadow-orchard concept was cited as the possible precursor to a whole new era in the culture of tree crops.

In food processing, the modern emphasis was on fractionation; that is, the separation of the component parts of finely divided food raw material and their recombination in different proportions to make more palatable products. This process is well known in flour milling and bread making and in the manufacture of margarine, but is being extended to meat processing, to protein and fibre extraction from beans for purposes of meat simulation and to the ultra filtration of milk to enhance its protein concentration.

Dr Lester felt that perhaps the greatest unexplored field for food production lay in fish farming. The fish was now the only major food source which was hunted rather than farmed, and the potential available to us from selective breeding and from careful control of the environment should surely be exploited. *BCS*

Reprint Service

CHANGES have recently been introduced in the reprint service offered to members of the Institution. The Editorial Panel has now made arrangements with University Microfilms Limited, St. John's Road, Tylers Green, High Wycombe, Bucks., for *The AGRICULTURAL ENGINEER* to be placed on microfilm from which enlarged copies of articles or papers can be obtained. Those members wishing to obtain copies of articles should now address their requests direct to University Microfilms Limited who will make a charge for this service at the rate of $3 each for articles and 8c. per page for complete issues. Charges will of course be made in sterling, the equivalent being obtained by conversion at the rate current at the time of placing order.

University Microfilms Limited have now been supplied with earlier volumes of the journal and it is hoped that in future members' requirements can be met by this service.

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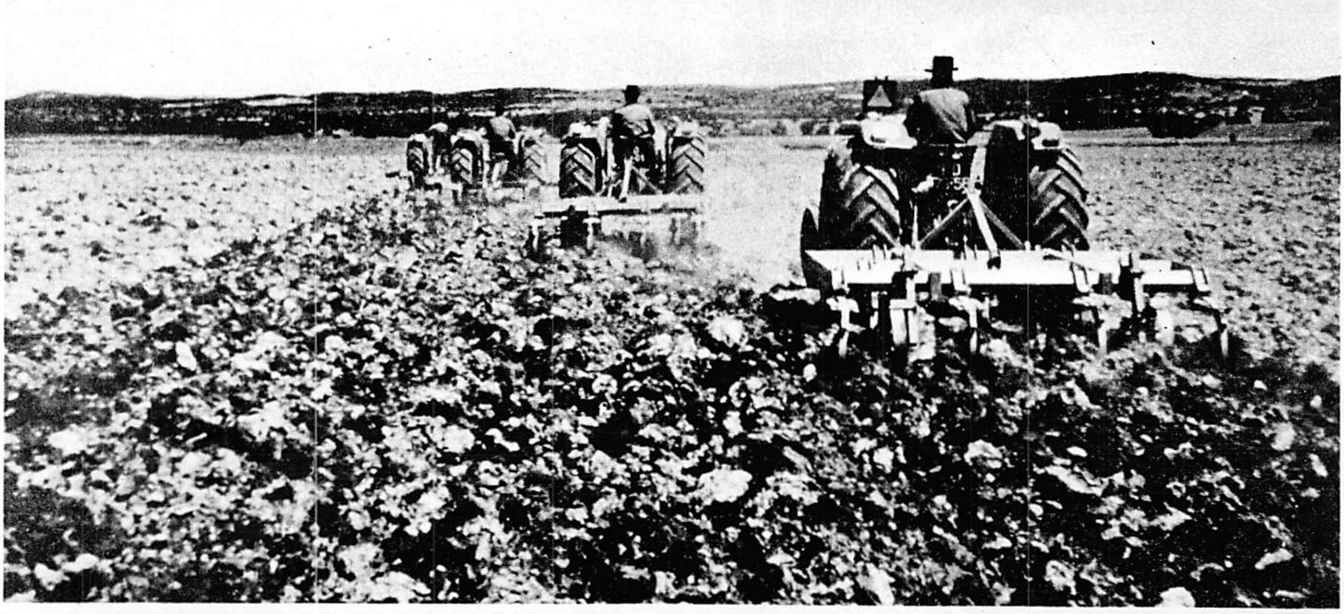

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