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ERGONOMIC ASPECTS OF HARVESTING APPLES BY HAND

by

ASTRID G DAVIS

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ABSTRACT

Following Parliamentary debates in 1980 on the quality of fresh market produce, in particular apples, a grant was awarded for research into the ergonomics of harvesting and marketing apples. The objectives were to study ways to improve the quality of English apples in the market place by examining the ergonomics and the cost effectiveness of methods of hand picking apples. This involved: participation observation studies, observation of professional pickers, surveys and questionnaires, in an effort to define problem areas and to prepare a criticism of present methods. Additional studies of potential fatigue and stress both in fieldwork and in simulation were intended as a preliminary investigation to devise a preferred picking method and to redesign picking and handling aids where appropriate.

The work was carried out over a period of two apple harvesting seasons, the first for exploratory studies and the second for evaluation of recommendations. The initial studies consisted of direct observations, subjective fatigue studies, questionnaires to farm owners and apple pickers and surveys of damage to apples by surface examination and peeling apples at various stages in handling. The damage surveys identified the importance of different degrees of bruise damage and its occurrence within the harvesting system with relation to various picking aids. Picker evaluation was developed from the damage surveys and used to establish guidelines for picker selection and training. During the harvesting operations video films were taken and later analysed to identify and quantify the activities involved in apple harvesting.

The analysis of data from the first season led to a number of possible solutions. During the second season a series of experiments were conducted to analyse the effects of different apple picking and apple transfer methods on the damage incurred by apples. To provide a basis for comparison to the previous season's data analytical methods remained unchanged.. The results confirm that selection of pickers and the supervision of apple transfer to storage containers is much more important than training with a particular method.

The results showed no significant effect on the quality of apples was produced by different picking methods. Overall it was noted that pickers employed methods dependent on the morphology of the tree. These methods were noted as being efficient and relieved fatigue imposed by repetitive work patterns. Improvements in apple quality occurred when apple transfer was replaced with a system of picking aids using disposable bags. This required redesign of the picking system and allowed for improved damages to be made in later stages of transport and storage.

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1.0 INTRODUCTION

Parliamentary debates on 24 January 1980 and 20 March 1980 revolved around the need for an improved standard in grading horticultural produce, with specific references being made to fresh market apples. However it must be noted that improved grading can only arise from a good quality product. This is partly a job for the horticulturist or pomologist but ergonomists can contribute by optimising fruit quality at the picking stage.

Within the Ministry of Agriculture, Fisheries and Food it was estimated that 20% of the crop is downgraded due to picking damage. Furthermore, 13% of this was thought to occur during the removal of the fruit from the tree. Work study data from the Ministry indicates that only about 80% of the picker's time is actually spent removing fruit from trees, the rest being taken up by non-productive work essential to the harvesting method. This project has been initiated to solve the ergonomic problems within the orchard, by reducing damage levels during harvesting and increasing the production rate of pickers.

1.1 Aims of the Project

The aim of this project was to carry out a systematic investigation and evaluation of the manual methods of detaching and conveying apples from the tree to typical orchard storage containers, currently employed in the British apple harvesting industry. The evaluation was to be based on the quantity and quality of apples according to EEC standards. Modifications to methods, equipment and organisational aspects that might lead to an improvement in the quantity and quality of apples were to be determined by investigation, then tested and evaluated for further recommendations. Overall it was aimed to improve the competitiveness of British apples with top class imported fruit in the retail market.

Of particular interest was the picker, the picker's task and picking aids. The project aims to identify any areas within the picker's job where insufficient optimisation of ergonomics has led to reduced standards in the quantity and quality of apples, so that alternative methods and aids to improve the quality of working life of the picker and thus improve the pickers output, with particular attention being paid to picking and handling of fruit, can be tested and evaluated.

1.2 Description of the Picking Subsystem

Picking apples involves removing the fruit from various cultivars, from a range of tree sizes (including height, span and shape) and from different areas on the tree. The actual tree shape is often dependent on the rootstock of the tree, soil type and harvesting method. Mechanical harvesters often demand a simpler shape of tree, i.e. a straight hedgerow or a single canopy tree of 'Y' or 'T' shape. Hand harvesting does not demand such specifically pruned trees, and may be employed in high density orchards, where trees are planted closer together. When hand harvesting, the picker may need to employ a ladder, steps or other means of elevation to reach some fruit. Semi-mechanised harvesting aids may be provided such as the orchard mobile discussed by Holt (1972). The fruit is normally removed from the tree either gently or with some force depending on the degree of fruit maturity and the cultivar. It is then moved either temporarily into a picking bag, to be transferred to a storage container, or directly into the storage container. Storage containers are either small, containing approximately 20 kg of fruit and are referred to as boxes, trays or crates, or are large containing approximately 320 kg and are called bulk bins. Storage containers are normally transferred from the orchard by forklifts or trailers to the packhouse for storage, grading and packing.

2.0 LITERATURE SEARCH

The literature relating to the problems of apple harvesting covers a wide and diverse area. It has been attempted to organise the research into logical groupings. As the project aims have already stated, the evaluation will be based on the quantity and quality of apples harvested. The initial references will be focused on apple quality and the deterioration of that quality. This will cover the physical causes of bruise damage and previous damage studies concerned with both hand harvesting and mechanical harvesting methods. Also considered is the use of storage containers and the filling of these containers which had been noted as an area of high damage potential. Consideration is given to alternative uses of picking bags in conjunction with storage containers with regard to damage reduction. The discussion then focuses on the tree and orchard layout.

Attention is then moved to the pickers task, the picker being centralised with regard to job demands. Much of the apple quality depends on the pickers handling of the fruit, so factors affecting the welfare of the picker are contemplated as are methods of measuring pickers welfare. The quantity of apples picked is dependent on the picker and is also affected by the pickers welfare. Work study measures are discussed to analyse the quantity of apples picked by the picker. Other work in relevant agricultural areas is discussed in relation to the apple picking task.

Of the work carried out on apple harvesting and picking aids, evaluation has been based on damage caused to apples and the picking rate. This is due to apple picking being a discrete task, the performance of which is reflected by the speed of the task, and the number of errors made. However the research has not been performed consistently, with varying time lapses between apple handling and damage assessment ranging from hours to days. The classifications of damage assessment have also been inconsistent (for example some disregard apple bruises and only record punctures and scratches). Furthermore the official standards in different nations are inconsistent, though since 1972 the UK has, because of EEC policy, become consistent with the rest of the EEC by adoption of EEC regulations. Much of the research in apple harvesting has taken place in America using the United States Department of Agriculture (USDA) apple damage classification and it is difficult to transfer conclusions from American work to cover the UK orchards. More importantly, it is difficult to compare research on the grounds of apple damage due to the differences in damage survey methods. Some damage studies have used commercial grading and packing lines to assess bruising, however concurrent studies have shown the inefficiency of commercial graders. Furthermore inconsistencies are noted with tree and apple types.

This study only considers bruise damage as it is thought that punctures and scratches are normally due to the cultivars stem length and stiffness, which varies between cultivars. EEC apple grading standards are used to assess the bruise damage to apples. These state that Class 1 fruit are allowed 100 sq.mm. of bruising only and Class 2 fruit allowance is 250 sq.mm. Anything over 250 sq.mm. is considered to be a reject apple and not suitable for sale. For fuller details of the EEC. standards refer to Appendix I.

This study has been based in orchards on commercial farms and semi-commercial (i.e. structured to be economically viable) government research stations. Consequently the research often encountered the day-to-day problems of varying apple harvests, yields and apple quality and the disruption of timetables due to seasonal fluctuations. Despite these difficulties, the nature of the research demands a study within the normal operational environment in order to claim relevance and to recognise such variables.

2.1 Biomechanical Aspects of Bruise Damage

As the project is assessing current apple harvesting practices on the basis of quality and quantity of apples it is necessary to consider research available in this field. Of particular relevance is the cause and evaluation of damage.

Holt and Schoorl (1977) formed a model of an apple consisting of spherical liquid filled cells, with interstitial spaces filled with air. Compression of the model apple led to ellipsoid shaped cells, further compression led to cell wall fracture. In other words the cell burst in regions of high shearing stress, the distortion and bursting of cells providing the energy dissipative mechanism. Ingle and Hyde (1968) showed that a bruise is distinguished by discolouration due to the oxidation of cell sap exposed to the air. The cells within a bruise have burst and have released sap into the air filled interstitial spaces thus causing discolouration or a bruise.

Holt and Schoorl (1977) demonstrated a strong correlation between bruise volume and energy absorbed for both impact and slow compression bruises in Granny Smith apples. Apple tissue was found to be more easily bruised by slow compression than impacts. The same amount of energy produced approximately 40% higher bruise volumes under slow compression. No correlation was found between stiffness (force over deflection) of apple flesh and bruise volume, implying that the elastic content of apples could not be used to describe bruising.

Work done by Fridley and Adams (1966) led to the conclusion that apples are highly subject to impact bruises at all maturities and that apples have the least potential for mechanical harvesting systems.

Green and Holt (1971) developed equipment to measure impacts of potential damage to fruit during harvesting and handling. They used the equipment in place of damage studies involving apple samples. The equipment simulated an apple and contained accelerometers in three mutually perpendicular planes. The simulated apple was subjected to impacts and vibrations, the accelerometers transmitting on three channels to a receiver. The relationship of the impacts to the simulated apple, to real damage to apples was determined by laboratory studies, subjecting real fruit to impacts of varying magnitude and measuring the damage. If a range of varieties could be tested to provide a data bank, the use of the simulated apple could predict probable damage.

The laboratory tasks included: dropping apples onto a solid wood surface, swinging ball collisions, puncture, shear strength and vibration. Of particular relevance to apple harvesting is the dropping of apples onto a wooden surface, reflecting the fall of apples into the storage containers. The results are given in Table 1. However, the authors did not consider the dropping of apples onto apples, which occurs more frequently in apple harvesting.

TABLE 1: Results of the Drop Test with Cox's Orange Pippin, Giving the Resulting Mean Bruise Volume (cubic mm)
(From Green and Holt (1971))

Mean Weight of Fruit (g)	Drop of 200 mm	Drop of 500 mm
145	1352	3335
140	1655	3156

Nelson and Mohsenin (1968) conducted static and dynamic loading experiments on apples at different temperatures to determine maximum allowable loads. The authors found that the most outstanding contrast between static and dynamic bruising characteristics was the difference in bruise volume associated with moderate impacts and dead loads. Even after

100 hours only small bruises occurred under dead loads as great as 3.2 kg whereas fairly large bruises resulted from drops at heights of 5 cm onto a rigid surface. The depth:diameter ratio tended to be smaller for dead load bruises than for impact bruises, deeper bruises being more significant commercially. This contradicts the studies by Holt and Schoorl (1977), though the experimental method and cultivars varied between the authors.

Nelson and Mohsenin (1968) concluded that bruises caused by "moderate" dynamic loads were considerably larger and deeper than those caused by similar static load. Warm apples were found to be more resistant to static bruising, whereas warm apples were less resistant to dynamic bruises. These temperature effects may also explain the conflicting results of Holt and Schoorl (1977). Dynamic yield pressure was found to be directly related to bruise resistance under dynamic loads; it was higher for cold apples. Quasi-static yield force under a 6 mm plunger was directly related to bruise resistance under static loads. Elastic modulus as determined from a quasi-static test with a 6 mm plunger, was higher for cold apples.

Brown (1967) conducted small experiments using bruise-free apples. The apples were either dropped or rolled onto a surface and checked for bruises. The results are given in Tables 2 and 3. Further experiments were performed dropping fruit 18 cm onto stationary fruit; 14 bruises were found on the 10 dropped apples, whereas 30 bruises were found on the 10 stationary apples. These tests were made to simulate the actions in harvesting and fruit handling on grading belts.

TABLE 2: The Size of Bruises on Sturmer Apples Produced by Tests (sq.mm) (From Brown (1967))

Test	Vertical Drop				Roll Down 15^{o} Inclines			
Distance (mm)	25	51	76	102	25	51	76	102
Hard base	19	21	21	27	13	22	21	24
6 mm foam lined	-	10	13	16	-	-	-	-
13 mm foam lined	-	-	-	-	-	-	-	-
25 mm foam lined	-	-	-	-	-	-	-	-

TABLE 3: The Number of Bruised Fruit Produced by Tests on Sturmer Apples and Type of Bruise
(From Brown (1967))

Test	Roll Down 15° Incline				Roll Down 30° Incline			
Distance (mm)	8	15	23	30	8	15	23	30
Hardbase:								
Clean	4	1	1	-	-	-	-	-
Slight	-	-	-	-	-	-	-	-
Moderate	6	4	6	5	8	-	-	-
Severe	-	5	3	5	2	10	10	10
6 mm Pads:								
Clean	10	8	9	5	8	5	-	-
Slight	-	1	-	-	1	-	1	-
Moderate	-	-	1	5	-	2	6	1
Severe	-	1	-	-	1	3	3	9

Bruises are seen to be due to discolouration after cell wall fractures, the volume of the damaged cells correlating with the amount of energy absorbed. Bruises are caused by both compression due to dead loads, and impacts to the fruit. Impact damage is noted as being more prominent in warm apples and this is a major problem in the orchard, where apples are warm and are moved separately and en masse from the tree to storage container. Cold apples are noted as being less resistant to static bruising, and it is when apples are in cold storage for long periods, stored in bulk containers, that they are more often vulnerable to this type of bruising. Of great importance is the fact that only small drops of the fruit causes notable bruises, whether the surface against which the fruit impacts is hard, soft or whether it is another apple as demonstrated by Nelson and Mohsenin (1968). Bruises result from drops of only 5 cm and fruit sorting machines often move fruit though drops of

7 cm to 10 cm, thus producing automatic bruises. Also of note is the lack of differences between apple varieties and maturities. Overall it can be noted that apples are generally very susceptible to bruising.

2.2 Assessments of Impact Damage

The laboratory studies of fruit damage display the varying susceptibility of apples at different temperatures to dynamic and static bruising. To understand the extent of this damage the fruit must be examined in normal situations, during harvesting, transport, grading and packing.

Ryall and Pentzer (1982) considered that the greatest quality losses to many fruit result from mechanical injuries, occurring at any point from harvest to final packing. Many injuries were noted to occur in the packhouse, particularly shallow bruises, due to impacts through 'human error' and machine design. Schomer (1957) reported that apples may receive many more small bruises during washing, sorting, sizing and packing than arise due to picking and hauling. The same study showed that bruises and punctures rank as first or second as a cause of packing house culls in certain varieties. Grading by machine was noted as causing more bruising, as seen in Table 4 for damage caused by harvesting and packing.

Brown also studied apple bruising within the orchard, and concluded that bruises, cuts, scratches and punctures were a commercial problem. Of particular significance were severe and slight bruises, however many of the slight bruises became less obvious on re-examination after a few weeks. The author carried out his investigations on a range of varieties, though the results given here only consider Cox's Orange Pippin which is the major British apple variety.

Random samples of 100 apples were taken from each of 13 stages of the harvesting process, from picker to the lidded case at the end of

TABLE 4: Damage to McIntosh Apples Resulting from Harvesting and Packing
(From Ryall and Pentzer (1982))

Sample Site		Number of Apples Sampled	Percentage of Apples Bruised
After harvesting	Stored four months	278	21.2
	Stored six months	284	38.3
After grading, sizing and bagging	1.8 kg bags	409	52.6
	1.4 kg bags	578	66.6

the grading and picking line. The samples were placed in strawboard lined cases and left as near the sample site as possible, to minimise further damage. Overall 80,000 apples were examined, though variables encountered by sampling caused some difficulties. The damage classification was as follows:

1. Slight bruise, up to 6 mm diameter
2. Moderate bruise, 6 mm to 13 mm diameter
3. Severe bruise, more than 13 mm diameter
4. Slightly bruised fruit, up to 5 slight bruises
5. Moderately bruised fruit, either: 1 moderate bruise
   or 1 moderate bruise, 4 slight bruises
   or 6 to 9 slight bruises
6. Severely bruised fruit, either: 1 or more severe bruises
   or 10 or more slight bruises
   or 2 or more moderate bruises
7. Slightly scratched, aggregate length up to 6 mm, light marking

8. Moderately scratched, aggregate length 6 mm to 13 mm, light marking
9. Severely scratched, deep marks or aggregate area greater than (7) and (8).

The pickers studied used three types of picking bag: a canvas apron, a canvas bag with a covered frame opening and a fully protected Canadian bucket. Picking damage refers to the damage found after the apples were picked and transferred to the bulk bin via the picking bag. The least bruising occurred with use of the Canadian bucket, followed by the apron then the bag, with the mean percentage of bruised apples for the bags being 14, 18.6 and 20.6% respectively. Pickers were generally more accustomed to the apron as opposed to the other two bags, so the bucket results were particularly notable. Further results are shown in Table 5.

TABLE 5: Damage to Cox Apples by Hand Harvesting Methods
(From Brown (1967))

Bag Type	Percentage of Bruised Fruit		Number of Bruises	
	Ladder Picking	Ground Picking	Ladder Picking N = 1600	Ground Picking N = 1700
Apron	19.4	19.8	458	477
Bag	21.0	21.2	531	538
Bucket	15.3	15.0	332	369
Mean:	18.6	18.7	82 bruises/ 100 apples	81 bruises/ 100 apples

The author noted that differences are not so pronounced when only considering severely and moderately bruised fruit. Slight or light bruises are often called "finger bruises" thought to result from the tight hand grip of the picker. That this caused all slight bruises could not be confirmed by observations during this investigation. It was observed that they may also be incurred by fruit bumping other fruit and hard surfaces. No overall increase in bruising was noted with ladder apple picking though this is not an indication of no differences between ground and ladder picking. It is possible that pickers were more careful when picking from ladders. Damage recorded in the bins indicated that extreme care is required in emptying picking bags into empty or partly filled bins. In particular, Cox apples were seen to be up to four times more susceptible to cuts and scratches compared to other varieties, i.e. Golden Delicious and Sturmer Pippin. This may be due to stem damage as Cox apples have stiffer stems. No significant differences for cuts and scratches resulted from the different bags used. Of importance, transport around the orchard did not appear to affect damage levels in the bins. Finally it was found difficult to assess the damage levels on the grading belts, due to human interference.

Eksteen (1983) conducted a damage study on Golden Delicious apples with reference to harvesting dates, times and conditions. He noted that bruising increased as the apples matured despite a decrease in soil moisture. Apples picked during the early morning were more susceptible to bruising, than apples picked later during the day. Apples cold stored for less than five days were more susceptible to bruising than those stored for longer periods. Bruise probability was not related to physical properties, e.g. turgor pressure, fruit firmness or cell elasticity. 70% of bruising was noted to occur on sorting and grading machines, but could be effectively reduced by padding contact points.

He also found in laboratory tests that the 6% tolerance of unacceptable bruising is reached when Golden Delicious apples are subjected to a vertical drop exceeding 33 mm, or when the vertical speed of the apple before contact with a solid object exceeds 0.56m per sec. These results were applied to a commercial packing house and reduced bruising ten fold, by the reduction of sorting and grading speed. The results of the initial damage study are shown in Table 6. The figures given do not agree with the figures produced by the present study, however full comparisons are not possible as the measurement of the bruises and the bruise classification scheme is unknown. Also of importance is the use of Golden Delicious in the study which were not considered in the present study.

TABLE 6: Percentage of Bruising Occurring to Golden Delicious Apples During Various Stages of Apple Harvesting and Packing (From Ecksteen (1983))

Locality	Percentage of Bruising
In the picking bag	0.3
After emptying the picking bag	3.0
At loading zone on farm	4.0
On arrival at the packshed	5.5
After emptying bulk bins into water	7.0
After undersize eliminator	10.0
After brushes and squeegies	35.0
After sorting	45.0
After singulator	60.0
After size grading	70.0
After packing	80.0

Eksteen (1983) noted that minor bruises became visible when underlying cortex tissue turned brown. If fruit temperatures were kept close to $0^{o}C$, browning was reduced considerably. It was also established that browning could be reduced by lowering the temperature of the fruit that had warmed up during the packing and handling process. This indicates that damage studies should be conducted at warm temperatures in order to identify all bruise damage.

It would appear that damage to apples is generally a result of the movement of fruit over a distance of several centimetres. Apple harvesting by traditional methods involves two points of movement; tree to picking bag and picking bag to storage container. With increased training and supervision to ensure that pickers are careful the movement of fruit from the tree to the bag can be controlled and free falling fruit can be eliminated. In contrast the passage of fruit from the bag to the storage container, even with due care, attention and training,allows a certain degree of free motion of fruit. Consequently the second stage of movement is a point of high damage potential, and its modification or elimination may be a significant factor in the improved quality of apples.

2.3 Impact Damage Occurring in the Bin

The design of the storage container must be taken into account and the rationality behind that design, in order to determine whether the use of storage containers and the resulting damage levels in fruit are acceptable.

Green (1966) concluded that opportunities for damage to apples are high when picking and filling bins in the orchards, where apples are being accelerated and moved rapidly on an individual basis. Little information on damage at this stage was available at the time, damage being dependent on the skill and care of the picker. Also thought to be of importance were the type of picking bag and the design of the bin. Green concluded that a 61 cm bin height is the limit for pickers to lift bags for emptying. Shocks and vibrations to the bin during transport were found not to cause much serious injury. However vibration could cause settling in the bin and loads on the apples during storage that could cause bruising by continued pressure. He also found that tongue and groove bin construction was preferable to plywood.

Bull and Holt (1968) investigated 12 designs of bulk bins on both a commercial and laboratory basis. At that time bulk bins were only just being introduced into commercial orchard work. The 12 designs included: well and pallet based bins, tongue and groove and plywood construction, various depths and different corner construction. The bins had diverse requirements, basically within the orchard they had to be suitable for filling by existing methods and be easy to handle and stack by fork lift equipment. In the packhouse they had to avoid waste of storage volume and be easy to empty by water flotation. Overall they had to have dimensional strength and inner characteristics to avoid excessive fruit damage whilst also being economical for harvesting, handling and storing fruit. Other important factors that were considered relevant included: orchard layout, roads and grades within the orchard, available handling equipment, storage facilities, bin emptying facilities, packhouse layout and grading system.

The bins were studied in the orchard with regard to damage to apples, by transport and storage of bins. Within the laboratory they were tested for strength with respect to: sag, bumps, racking, roll-over, corner-wise drop test and weathering.

The results showed that a 53 cm deep bin was low enough for adequate bag emptying. The picking rates increased with bins as compared to trays, however better bin and picker management is necessary for the best results. Well-based bins allowed a better storage of apples (kg per cubic metre) as opposed to pallet based bins or pallets of trays. Well-based bins occupied 47% of the space needed for pallets of trays. For pallet based bins this figure was 67%. Generally plywood bins were noted to collect more water, buckle and stain the apples.

Green and Rounthwaite (1966) calculated that 25% of apples in a bin were in contact with the sides (14%) and bottom (11%). The damage to apples increased with the depth of the bin and was more severe when fruit was in contact with bare timber. Damage was greatest at the bottom of the bin. They found that lining the bottom of the bin reduced the damage to a quarter of the fruit with a resulting damage level a third of that with bare timber. However not all bruises are commercially significant and bin lining was found not to be of commercial value.

A number of studies addressed themselves to mechanical means of reducing damage when filling bulk bins. Berlage (1981) stated that fruit damage should be reduced throughout all stages of mechanical fruit harvesting in both the orchard and the packhouse. The crucial stage was noted to be filling the bulk bins for which various mechanical aids existed. Berlage initially tested eight assorted mechanical bin fillers within an orchard, one discharging into a rotating container the rest rotating and emptying into a static container. All devices rose as the bin was filled.

Tests were made for fruit distribution through the bin, filling rate and bruising levels. The best filler was ideally pivoted, cantilevered or a swing conveyor which provided the least damage. He concluded that an effective filler should absorb the fruit energy at the lowest point of release, distribute the outgoing fruit and minimise fruit velocity and dropping height. The best filler discharged into a rotating container out of two exits.

O'Brien et al (1980) evaluated eight automatic bin fillers and noted that the use of fillers was highly significant in the reduction of bruises during filling. A swing conveyor filled with an electric eye height sensor and a bin moving mechanism performed best because it was self-cleaning, dispersed fruit, released fruit gently and could top off the load with minimum spillage.

The authors considered that hand labour picked and threw fruit into small containers or dumped containers into larger containers which resulted in high damage levels. Filling from mechanical harvester conveyors with or without fillers resulted in a similar loss of quality. This is due to the three stages of filling: initial fill with fruit falling onto hard surfaces, main fill with fruit falling onto fruit and topping off fill.

Hood et al (1981) showed that there is no significant differences in emptying hand harvested picking bags directly into a bin or onto a conveyor, that automatically fills the bin.

Diener et al (1983) discussed the harvesting of processing apples both manually and mechanically in conjunction with bulk bins. The bulk bin handling systems had to be compatible with existing harvesters, with at least as much capacity as the harvester and had to handle fruit gently. A bulk handling system for mechanically harvested apples was developed. Fruit was transported from the harvester to a trailer towed behind the harvester. The full trailer was then transported to a processing plant and the apples unloaded into a water handling system. According to them the new system simplified the handling of the fruit and eliminated the use of bins. As fruit was processed immediately bruising had not developed and apples did not require extra trimming. Damage assessment was compared for hand harvested and mechanically harvested apples, the results are given in Table 7. It should be noted, however, that this particular method could only be used with processing apples.

TABLE 7: Bruise Comparison of Bulk Handled Apples (Rome Beauty)
(From Diener et al (1981))

	1. Percentage fancy or better	2. Percentage bruised	Percentage of cuts or punctures
Mechanically harvested and bulk handled	29*	40	31
Mechanically harvested and handled into bins	52*	8	40
Hand harvested and handled into bins	64*	12	24

1. Total bruises $\leqslant$ 5.06 sq.cm.
2. Total bruises $\geqslant$ 5.06 sq.cm.
   No cuts or punctures.

The asterisks in the first column (Table 7) indicate a statistical difference at the 1% level between values.

From the studies it would appear that the use of bulk storage bins is preferable economically to the use of small boxes or trays, although damage to fruit when using bulk bins is high, this is due to the distances fruit moves to the bottom of the bulk bins. However the decrease in value of the bulk bin stored apples due to damage may balance with the savings in storage space and the possible quantity of apples harvested; however the data was not reported. This is particularly relevant to the harvest of apples by mechanical aids. It must also be noted that the use of mechanical fillers to load bins provides an advantage over hand filling bins in terms of damage to apples, but whether this provides an improvement in apple quality over hand harvested apples handled into boxes is questionable.

2.4 Mechanical Harvesting of Apples

Mechanisation of apple harvesting has been considered extensively from many perspectives, leading to the development of a variety of apple harvesters, some of which have been commercially developed. Many of these commercial harvesters are used in America where the sheer bulk of the harvest and various socioeconomic problems make manual picking less feasible, and consequently most of the papers discussed here refer to American conditions.

Tennes and Levin (1972) studied the apple harvesting problems of America from an economic standpoint where production costs were seen to be rising whereas the commodity prices were decreasing. This was said to be due to labour unionisation and immigration laws leading to labour forces being relatively expensive, unstable and sometimes unavailable. Taking into account the short harvest season it appeared that a back-up system to hand picking was required to harvest fruit crops.

Considering that in Michigan in 1969, 140 million kg of apples were produced and over 50% of these were processed, mechanisation of apple picking methods was seen to be viable. Tennes and Levin went on to examine the various mechanical harvesters and picking aids.

They found that picker positioners (i.e. picking platforms) did not reduce labour requirements but did increase a pickers productivity. To reduce labour requirements methods of mass removal were recommended (i.e. shake and catch, with padded catching frames). However they found that fruit harvested by the latter methods was suitable for short term storage or processing only, due to the damage incurred.

Brown et al (1983) surveyed farms in Berrien County, Michigan. Farm sizes ranged from 4 to 160 hectares, the average being 40 hectares as opposed to the national average of 70 hectares. 50% of the farms were found to be smaller than 20 hectares and 70% smaller than 40 hectares. The average fruit production area was 12 hectares with no crop specialisation.

Cooperative ownership was found in only one farm, although 50% of small and medium-sized farm owners said they would be interested in cooperative ownership. 70% of farms partook in the borrowing and lending of equipment.

All crops were found to be harvested mainly by hand and no detailed discussion was made of mechanical harvesters. The lack of equipment was not considered to be a problem. Consequently workers were hired on a seasonal basis; 0-20 workers on small farms, 0-60 on medium-sized farms, but only 0-10 on large farms. The large farms need fewer workers due to mechanisation, though all seasonal workers required some form of training. The respective average number of seasonal workers hired on the variously sized farms was 7, 15 and 5.

95% of the farms produced fruit and 45% produced vegetables. The smaller farms were seen to be increasing their production of fruit crops, whereas the medium-sized farms were reducing their fruit production. The variations in crops within a farm indicated the need for mechanisation to embrace several crops of similar growth patterns, i.e. all bush and tree crops as opposed to root crops.

Brown et al (1983) concluded that to control harvesting costs and increase income required the appropriate use of labour management, hand labour, simple picking aids, "pick your own", contract mechanical harvesting and operator owned mechanical harvesting. Additional mechanical harvesting technologies could be available through cooperative ownership of equipment.

Ryall and Pentzer (1983) in this study concluded that mechanical harvesting still had many unsolved problems; damage to fruit and trees, the separation of fruit from the plant and unwanted materials from the fruit, the selective harvesting of fruit and the transfer of fruit. In particular the susceptibility of apples to damage has limited the application of mechanical harvesters. Although numerous harvesters have been developed the best appear to be the "shake and catch" types. It must also be noted that the type of harvester used also depends on the tree type. Damage due to the harvester mostly occurs to the top growing fruit hitting lower limbs, so trees must be modified in shape and size to suit the harvester. However it is worth considering the type of harvesters designed to compare them with traditional or alternative apple harvesting methods.

Le Flufy (1981) divided harvesting into three stages: detachment, collection and transport. Apple ripening weakens the area of attachment between stalk and branch (the abscission layer) and the apple drops when overripe. The stalk detaches most easily by a "peeling" action, induced by bending. This is used when harvesting apples manually, the picker lifts and twists the fruit and is a difficult action to simulate with a machine.

Most mechanised harvesters use a shaking movement which vibrates the limbs of the tree and fruit is detached, or repeated oscillations are used. Otherwise a sharp upward acceleration of the limb results in high tensile loading and removal of fruit.

However fruit can be damaged by the oscillations created by a mechanical harvester prior to detachment. The damage by oscillations refers to the apples being shaken against branches and other apples, the impacts being of sufficient force to cause damage. Other damage by apple harvesters occurs during fruit collection, with fruit-to-fruit impacts, fruit-to-tree impacts and fruit-to-collection surface impacts. To counteract these effects thick padding must be used on the collection surfaces and deceleration strips or granules should be used to separate apples on the collection surface. Single canopy trees could be grown as in New Zealand and Australia, though this introduces the problems of tree training and delayed cropping. Where fruit damage is inconsequential whole tree shaking is an effective method of fruit removal. Otherwise mechanical harvesting requires the redesign of trees and orchards.

Even with successful detachment and collection, problems can arise due to the speed of mechanical harvesting and space restrictions within the orchard. The harvester must be designed to contain and handle several containers which increases the size of the harvester and creates manouevring problems at the ends of the rows. Filling containers also requires special equipment to reduce the heights through which apples drop from collection surfaces to bulk bins.

Berlage and Langmo (1976) studied mechanised harvesting in relation to fresh market apples during the 1971 apple harvesting season. They compared the performance and resulting fruit damage when using a commercial mechanised harvester as opposed to conventional hand harvesting. They used American grading standards where:

Extra fancy apples have no significant damage, with a maximum of two small bruises with a total bruise area less than 13 mm diameter.

Fancy apples have an allowance of three small bruises with a total bruise area of less than 19 mm diameter.

Culls contain a large bruise, puncture or both.

They found that Red Delicious apples harvested with a ladder and bag produced 77.5% of extra fancy and fancy grades compared to 47.7% for a mechanised harvester. On their selected performances a catching frame crew member is 5.6 times more productive than a picker with a ladder and bag and 4.4 times more effective than a man positioner.

With regards to their bruise study they sampled 100 fruit from each bin as it was discharged from the mechanical harvester, though the actual position in the bin was not stated. Similar samples were taken from 13 hand picked bins. Some damage evaluation occurred in the field and some apples were inspected 1-9 days after harvest, noting: pulled stems, puncture and bruises. Net weights were not noted consistently. The machine harvested fruit was inspected a second time after 27 days in cold stores. Previous studies had shown this was not necessary for hand harvested apples.. Fruit was then commercially graded and packed.

The results showed that machine filled bins contained 61 lb less fruit on average, compared to hand filled bins. This was noted as being an important waste of space if fruit is not graded and packed prior to storage. The resulting grades of the fruit are shown in Table 8.

Berlage and Langmo (1976) also conducted a time study using stop watches and films, the results are given in Table 9. Problems did arise because the orchards were not grown for use with mechanical harvesters, so the tree stakes and pruning methods increased the harvest time for the mechanical harvester.

TABLE 8: Apple Grades for Mechanically and Hand Harvested Fruit (From Berlage and Langmo (1976))

Harvesting Method	Hand		Machine	
Apple Variety	Red Delicious	Golden Delicious	Red Delicious	Golden Delicious
Percentage of extra fancy	99.8	99.3	65.4	26.5
Percentage of fancy	0	0	11.2	6.0
Percentage of culls	0.2	0.7	24.0	62.5
Percentage with pulled stems	1.2	0	73.7	47.0

TABLE 9: Harvesting Times by Mechanical and Hand Harvesting Delicious Apples (From Berlage and Langmo (1976))

Harvesting Method	Ladder and Bag	Man Positioner	Catching Frame Observed	Catching Frame Selected
Working time (man minutes/51 kg)	8.30	6.53	3.54	1.48
Savings over ladder (man minutes/51 kg)	-	1.77	4.76	6.82
Percentage saving in time	-	21.3	57.3	82.2
Harvest rate (kg/man minute)	5.5	7.0	12.8	29.8
Percentage increase in production	-	27.1	134.4	460.7

Millier, Werken and Throop (1983) studied a Recoil-Impact Shaker for semi-drawf trees using a pull-push movement of the trunk to remove apples from the tree. The tests used three impacts on each tree to harvest McIntosh and Golden Delicious from open centre trees and Red Delicious from 'Y' trellis trees. Two modes of catchment were used: under-tree and in-tree catching pads. The grade results are given in Table 10, though evaluation methods were not noted. The results show the benefits of tree training and pruning.

TABLE 10: Grades in Percentages of Apples, Harvested with a Recoil-Impact Shaker
(From Millier et al (1983))

Grade	Extra Fancy	Fancy	Utility	Cull
Under-tree catching pad:				
McIntosh) Open-	79.2	5.6	1.3	14.0
Golden Delicious) centre	60.5	6.8	4.0	29.0
Red Delicious, Y trellis	82.3	3.4	1.7	12.7
In-tree catching pad:				
McIntosh) Open-	81.2	3.2	0	15.5
Golden Delicious) Centre	71.2	3.2	1.1	25.0
Red Delicious, Y trellis	91.4	0.6	0.3	7.7

Pellerin et al (1979) compared a pendulum impulse trunk shaker with an inertial trunk shaker on semi-vigorous open centre and central leader McIntosh apple trees. Generally they found no significant difference in the amount of bruising using either mechanical harvester, though more stems were detached with the impulse trunk shaker. There was significantly less bruising with open centre trees. Overall 50% of the bruising and skin breakage occurred at detachment.

The catchment of apples under the tree was by expandable polystyrene quilted collection tray. The sequence of shakes reduced the number of apples caught at any one time. Samples of apples were then taken from various areas of the catching surface after each impulse and stored for two weeks in cold storage prior to damage assessment. The assessment was based on a template for bruises giving nine sizes of bruise. Skin breaks, cuts, splits and punctures due to stem or spur damage were also noted. The results are shown in Table 11.

TABLE 11: Percentages of Grades for Mechanical and Hand Harvested McIntosh Apples
(From Pellerin et al (1979))

Harvesting Method	Inertial Trunk Shaker		Impulse Trunk Shaker		Hand Picked	
Tree Type	Open-Centre	Centre Leader	Open-Centre	Centre Leader	Open-Centre	Centre Leader
Extra fancy	59.4	48.2	65.4	49.3	87.5	91.7
Fancy	15.9	14.4	12.1	16.0	8.3	3.3
Utility	4.4	5.7	3.1	4.0	0	0
Cull	20.2	31.6	19.4	30.7	4.2	5.0

Overall it was noted that fruit remaining in the tree was perpendicular to the direction of the shake. Apples in the centre of the centre leader type tree were detached first. Spur removal increased with the increase in energy level of the impulse shaker. Apple-to-apple impact was minimised by several shakes though occurred most in centre leader type trees. Open-centre trees distributed fruit well over the catching surface. Energy impact to the tree was found to be more easily controlled with the impulse shaker. Lower forces were found to reduce the damage to apples.

Le Flufy (1982) noted that shake and catch harvesters caused a high level of fruit damage. This was noted as being due to: the violent oscillation of fruit before detachment, the descent of fruit through the tree canopy, and the catchment of fruit. He noted that it is possible to redesign the tree, but preferable to limit the points of damage.

The detachment of short stemmed apples is often a simple case of lifting the apple away from the tree, whereas long stemmed apples with a more flexible stalk can require forces of up to 30N for removal. So Le Flufy designed a harvester using a set of combing fingers moving vertically up through the tree canopy, removing apples without violent oscillations and eliminating the free fall and catch aspects of previous harvesters.

The harvester was designed for slender, flexible trees with short branches, in a hedgerow style orchard. The harvester rig was built with comb-like fingers on a continuous straddle. The fingers were spaced 50 mm apart and were stiff enough to remove fruit though also flexible to avoid bruising. The rig was built to be adjustable for different width trees and the fingers sloped up to the trees, to enable apples to roll down the fingers to a conveyor belt and onto a commercial bin filler.

Problems arose with keeping fruit on the tips of the fingers when harvesting from the tree centre. With Cox fruit 70% of the fruit was successfully harvested by the machine, 20% of which was damaged. Of the remaining apples 20% dropped from the tree and 10% remained attached to the tree. Results were not so favourable with Golden Delicious apples. Hedgerow trees were found to perform better than other pruning styles, however older trees had stiffer branches and generally two branches per tree were damaged or distorted. The harvesting rate was 10 tonnes/hour or 1 km/hour.

Berlage and Langmo (1976) considered the problems of apple damage due to impacts as apples fall through the tree canopy and onto the catching surface. They experimented with a Trunk Shaker harvester with Red Delicious and Golden Delicious apples. To reduce impact damage they surrounded the individual trees with a box frame which was filled with blow moulded, low density, polyethylene spheres, prior to shaking. Evaluation of this harvesting method was by time elements and bruise damage assessments.

Samples of 100 apples were taken from the bulk bins 1-3 days after harvesting, comparing apples collected by a normal catching surface and those collected with the polyethylene spheres. Using the polyethylene spheres damage was reduced by 10 and 39% for Golden Delicious and Red Delicious apples respectively. However other damage was found to result from the pressure of the fruit against the tree limbs. Overall the use of the polyethylene spheres increased harvest time by a factor of 13.

Further research with mechanical harvesters has considered the positioning of the harvester around the tree. Parrish and Goskel (1977) looked at an experimental system, using cameras to position the harvester by pictorial recognition, whereas McMahon et al (1982) designed a non-contact sensing system and an automatic steering control system for an existing mechanical apple harvester. Their system was accurate within 4 cm so helping the over-the-row harvester drivers to steer accurately.

As a semi-automated method, Holt (1972) studied the use of mobile picking platforms in hedgerow orchards to improve the workrate of pickers. For the aids to be economically viable all apples must be hand picked, with the fruit being uniformly distributed and mostly above overhead reach when standing on the ground. Normally apples above overhead reach are picked with the aid of steps or ladders, but this decreases picking rates and some pickers prefer not to use them. Generally picking platforms relieve the pickers of carrying bags and moving ladders and therefore improve the picking rate by elimination of unproductive work.

Powered positioning of individual pickers was already in use, but was found not to be economic. It appeared reasonable to assume that modifying the aid for use by several workers would be more cost effective. Success was also deemed more likely in hedgerow type orchards, with a continuous wall of fruit, where space is limited and row length large. To save labour the machine was designed to be self propelled and steered.

Picking platforms were built on a rig. The pickers stood on the platforms, picking and placing apples directly onto conveyor belts. The apples were moved by the conveyor belts and placed into bins. The rig or orchard mobile also had bin changing facilities. The mobile was adaptable for 2.5m and 3.5m spaced tree rows. Two ground pickers picked between twin forward conveyors, whilst three pickers picked off platforms; two at 91 cm and one at 168 cm. Stop mechanisms were available for ground and lower platform pickers due to apple densities in these areas.

Early trials showed that in some circumstances a team of five pickers could pick significantly faster than an unaided control group. If this improvement could have been maintained it would have justified the equipment. However overall the improvement was inadequate and could not cover the investment. This was due to: the picking platforms not being at optimum heights to cover all yields and fruit distributions, the time lost changing bins, poor work sharing due to poor fruit distribution on the tree, excessive reach distances into the trees, variations in yield along the row, variations in vertical distribution pattern tree-to-tree and variation in yields of half facing rows. When using the picking platforms to harvest fruit it was found difficult to optimise each pickers performance. Freedom of movement for the pickers is an essential feature to counteract the effects of uneven fruit distribution. These problems led to the tree rig experiments.

Green and Holt (1972) used a tree rig simulator to examine fruit distribution problems. This particularly involved fruit clustering, where in hand picking the picker usually stands close to the cluster to pick fruit, moving from cluster to cluster and picking the occasional solitary fruit on passing. The picker tends to travel around the tree as demanded by fruit density as opposed to the rate determined by the mechanically driven picking platforms; showing the need for lateral freedom of movement.

The tree rig contained 798 apples; 33% placed singly, 40% grouped in doubles, 20% in triples and 7% in clusters of four. The experiments produced picking rates of 51-76 apples per minute with an average rate of 64 apples per minute. They also considered reach into trees and the natural tendency of pickers to step in towards the tree to pick fruit. It was then decided to use seven pickers on the orchard mobile, two on the ground, four on a split level low platform and one on a top platform. This led to a 67-81% productive workrate, though this was still considered a low and wasteful workrate. This was compared to hand harvesting and the results are given in Table 12.

TABLE 12: Comparing Harvesting Rates Using Picking Platforms and Hand Harvesting Methods for Cox Apples
(From Green and Holt (1972))

Yield (tonne/hectare)	Equipment	Number of Pickers	kg/minute	Fruit/minute
22.2	Ladder and bin	3	3.8	45
24.7	Picking platforms	7	3.4	42

It was noted that hand harvesting rates were reduced in light cropping orchards, due to the extra use of ladders. Picking rates of 60-100 apples per minute were noted in pickers who stand by a cluster and use both hands to detach two or three fruit at a time and release them into picking bags. The highest picking rates were noted with fruit at heart level. Any fruit slipping from the pickers grasp was considered to fall into the picking bag and at *"worse be only slightly bruised"*. It was also noted that mobile pickers had to contend with branches, bend double on conveyors, transfer fruit to conveyors. Any fruit that is mishandled falls to the ground and is lost.

Cottrell and Holt (1970) found that the picking platform rig speed was determined by the slowest picker or the picker picking in the area of highest fruit density. However it was found that when pickers increased their efforts by 11% (i.e. picking speed) to cope with high fruit density their output increased by 72%. Picking rates for the platform were found to be 82-178 kg/operator hour compared to normal hand picking at 58 kg/operator hour. A bonus incentive scheme increased standard hand picking rates dramatically, though these were not reported. However the picking rates on the platforms did not rise correspondingly. They also found that wet conditions, normal within the UK, made machine operation difficult, wasting time and therefore decreasing picking rates. Overall they found an 83% increase in picking rates using picking platforms as compared to conventional hand picking. They state that conventional hand picking accounts for 30-50% of unproductive operations, ignoring the fact that job variability relieves muscular loading and boredom. It must be recognised that the advantages of the picking platforms may be diminished in commercial orchards where bonus incentive schemes normally operate and conditions such as: weather, fruit distribution and yield and the conditions between tree rows, such as width and grades, are less susceptible to control.

Their discussion of fruit damage was based on punctures, cuts and stalk breakages only. References were made to scuffs which may have been bruises, though these were thought to be superficial and of minor consequence. Damage assessment was by commercial grading of fruit. Damage of fruit during picking was considered to be a consequence of human error, so that the elimination of human operations would reduce damage. They considered the increase in damage to fruit when using the picking platforms, not commercially significant.

During the trials with the picking platforms the fruit was not assessed for damage. Bins were stored in a barn and examined six weeks later. Fruit picked from platforms showed extensive rotting and signs of careless picking, more than in bins picked by conventional methods. This was thought to be due to the difficulty of selectivity when picking at arm's length from a moving platform. The fruit once placed on a conveyor is immediately removed from sight with no chance of further examination and removal in case of injury or rot. It was also found that more spurs were removed when picking from the platforms.

Green and Holt (1971) produced various recommendations concerning the design of the picking platforms covering platform heights, fruit disposal, freedom of movement for pickers, speed control, the requirements of ground pickers, bin handling and general manouevring of the picking platforms. They also concluded that the cost of the aids was excessive and their use not economically feasible. Further they identified the need to collect data on hand, arm, body and foot movements involved in picking fruit, in order to provide recommendations to the pomologist to improve orchard systems and for engineers to match the systems with machines.

Ryall and Pentzer (1982) concluded that apples sold on the fresh market must be free from severe bruises, cuts and punctures. Mechanically harvested fruit was not of a high enough quality, so the emphasis was transferred to aids for the picker to increase output. Aids range in sophistication, from long poles with pouches to pick high fruit, to individual hydraulic man-positioners. Output has been noted to increase by 30 to 50% by eliminating the use of ladders and fruit containers. However increases beyond this are unlikely due to restrictions with the pickers work rate.

Overall it is apparent that mechanical harvesters are not suitable for fresh market apples. They are more effective with regards to time but the disadvantages of apple damage outweigh the advantages. Furthermore mechanical harvesters currently preclude the use of selective picking on the grounds of colour, size, maturity and damage. The consequences of a rotten apple in a bulk bin are far reaching if the bin is stored over a long period. It is also worth considering that previous labour shortages have now disappeared and apple picking requirements can be easily fulfilled.

The economic handicaps must also be considered in particular the matching of the orchard to the machine. Due to the machine design features, including catching surfaces and bin handling equipment, harvesters tend to be large. Their size is disadvantageous when manouevring in the orchard, particularly when changing rows. They often require large headroom for turning and this reduces the available tree planting space. The actual layout of the trees is also constrained to the type of harvester, orchards often being of high density and therefore more expensive. The use of the harvester with a tree often leads to a specialisation in tree shape with the consequent cost of pruning the tree, training and maintaining its shape. It has already been noted that the degree of damage to fruit with mechanical harvesters is high, this limits their economic application to processing apples. A final problem is the short term use of the expensive machinery of the apple harvester. Within the UK the apple harvesting season is relatively short and the storage of the apple harvester would occupy expensive space, and the non-use of the harvester out of season would decrease its economic feasibility.

2.5 Picking Bags

Previous discussions have focused on the modifications in the transfer of apples to the bin with mechanical harvesters and automatic bin fillers. These alterations in some cases are attempting to eliminate apple damage, but any modification producing an extra point of free fall for apples causes damage. Another means of damage reduction is to use the picking bag or container as a means of storage. This was the principle with the 20 kg boxes utilised prior to bulk bins, as discussed earlier. Previous work in this area was not noted, though work of a comparable nature will be discussed.

Engels (1977) designed a bag for use in research orchards. The picker fills the bag with fruit then hangs the bag on the tree from which it has been filled, before picking up a new bag to fill. Therefore each tree can be picked clear of apples, and the fruit left safely in the bags on the tree for further data collection, i.e. weight, size and damage surveys. The bags are then emptied into bulk bins by opening an exit at the bottom of the bag. This reduces the movement of the fruit. As each bag contains 10-11 kg of fruit, each picker uses 150 bags a day, however this can be reduced if the bags are emptied and returned to the picker during the day.

Engels (1977) in his studies found that it was preferable in young orchards to empty bags onto a moving trailer containing the bins as there was greater access around the trees. With older orchards it was desirable to estimate the yield and position bins at relevant, regular intervals. In comparing the use of bags and bins to the previous system using crates, picking efficiency increased by 30 to 50%. However bag emptying was found to be more time consuming than loading the crates onto the trailers, so the overall saving was 15 to 25%. Due to careful picking regardless of the picking container, differences in fruit quality were found to be small and insignificant. The storage of bins as opposed to crates led to a space saving of 30%, showing the viability of large storage containers.

Although Engels (1977) developed the use of large numbers of picking bags, he did not extend the idea by using the bag for permanent storage purposes. Using bags within cold storage has been examined by Janick

(1979). He stated that using a sealed film liner within a 20 kg pallet box, it is possible to control the atmosphere within the box and create a micro-environment. Polyethylene film is five times more permeable to carbon dioxide than oxygen and this differential permeability is necessary when the fruit respires using oxygen and producing carbon dioxide. The final concentration of the gases within the bag is dependent on storage temperature and film thickness, the latter of which affects permeability. Film liners were found to improve the storage of Golden Delicious, though some cultivars were found not to benefit. It is said that this principle is particularly relevant with regard to packing and marketing fruit.

Ryall and Pentzer (1982) have elaborated on the use of sealed storage bags. The authors noted that post-harvest fruit continue most life processes; respiring as previously outlined, generating heat, changing colour and converting starches to sugar. Post-harvest fast cooling is generally desirable, reducing metabolic activity of the fruit and controlling rot. Mould, bacterial infections, bruises and mechanical injuries all increase respiration rates. Insufficient oxygen leads to incomplete respiration and the formation of aldehydes and alcohols, which impart an abnormal flavour to the fruit and can kill cells. Fruit must have enough oxygen for normal respiration. The amount is determined by the temperature of the fruit and its respiration rate. Fruit cannot be held in impermeable packages because of this danger. Such bags used for storage or as consumer packages must be perforated or left unsealed.

The authors discussed how modifications in the carbon dioxide and oxygen concentrations in the storage atmosphere would prolong the market quality of apples. This principle was applied toindividual containers by packing fruit in plastic film liners of limited permeability and sealing the liners to permit atmospheric modification by the normal respiratory processes of the fruit. Polyethylene film was shown to have variable permeability and was favoured, however imperfect seals or tears in the film added to the problems already found in modified atmospheres. Sacharow and Griffin (1970) noted that once sealed polyethylene bags are removed from storage they must be perforated to avoid decay and the development of alcohols, because of the increase in metabolic activity as the apples reach ambient temperatures.

When plastic film liners are used in commercial practices they include several small 3 to 6 mm perforations or 100 needle point perforations to ensure against harmfully low oxygen or high carbon dioxide concentrations. Often the liner is simply folded over at the top rather than sealed. Some systems include lime in the boxes containing the full liners as the lime absorbs excess carbon dioxide. Packing in unperforated polyethylene liners creates high humidities so it has often been found necessary to treat the fruit with a fungicide. Loss of moisture from fruit has been seen to reduce fruit weight with resultant financial losses. Polyethylene bin liners are beneficial in this respect in that they reduce water loss.

It was noted that if apples were packed directly from the tree into consumer packages and stored until sold, handling of the fruit was reduced and consequently so were the potential points of damage to apples. Further studies compared apples stored loose and those stored in bags, at a temperature of $0^{o}C$. After three months, weight loss for loosely stored apples was 3.5% against 1.6% loss for those stored in plastic bags. No serious decay was noted due to either storage method. However after seven days storage at $21^{o}C$ (to simulate marketing conditions) the bagged apples suffered more decay and internal breakdown. This indicated a necessity to repack the fruit after removal from storage. Further studies of apples stored in plastic bags at various commercial temperatures would be necessary to explore the economic viability of plastic storage bags.

It has been shown that points of apple transfer between containers are a source of damage to the fruit. The eradication of these points of damage would seem a sensible solution and a feasible method of reducing apple movement could be the use of plastic bags.

2.6 Tree Shape and Orchard Layout

With the introduction of mechanisation and modern farming methods, overall costs of old orchards were found to be too high to maintain. Preston (1974) experimented with new rootstocks to provide small trees from which most apples could be reached and picked from ground level, to supply fresh market apples. The trees needed to be vigorous, stable and precocious in bearing. He tested 11 rootstocks in their twelfth year, pruned by regulated methods. Many of the trials showed no advantages and were not considered further. The results are shown in Table 13.

TABLE 13: The Specification for Various Bramley Rootstocks in their 12th Year
(From Preston (1974))

Specification	MM106	M26	M9a	M27
Tree girth (cm)	19.8	15.2	10.5	9.4
Tree height (m)	3.0	2.5	2.0	1.9
Tree spread (m)	2.7	2.5	1.7	1.6
Total Crop per tree:	19	18	13	10

It was concluded that rootstocks MM106 and M26 provided a good choice for semi-vigorous and semi-dwarfing trees. Preston (1978) went on to consider the rootstock performance over a period of nine years and the results are given in Tables 14 and 15.

TABLE 14: Total Crop for Bramley Trees (kg) With Different Rootstocks in Different Areas
(From Preston (1978))

Rootstock	M27		M9		M26		MM106	
Age (years)	5	9	5	9	5	9	5	9
Canterbury	10.5	36.4	12.7	58.2	17.7	90.5	19.1	162.3
Wisbeach	-	-	12.3	110.5	12.7	119.5	6.8	179.5

TABLE 15: Proposed Tree Spacings
(From Preston (1978))

Rootstock	Spacing (m)	Trees per Hectare	Potential Tonne per Hectare
M27	0.9 x 3.0	3588	13.05
M9	2.4 x 4.6	902	5.25
M22	3.7 x 5.5	497	4.49
MM106	5.5 x 6.7	272	4.41
MM106	3.4 x 5.5	544	8.82

Other developments in tree design are being made, mostly considering tree pruning and shape. For example it has been possible to prune trees to a single canopy or "Y" shape, in order to avoid the hazards of fruit-to-tree impacts during mechanical harvesting. Godley (1983) provided data concerning "Y" trellis trees noting that they provided the advantages of early cropping, high yield, maximum land use, uniform fruit distribution and ease of harvesting both manually and mechanically. The trees are planted 1m apart and have only two limbs which are trained at an angle of 60^{o} from the horizontal towards the corresponding limbs in the next row. All the leaves and fruit are carried on a thin sloping wall, the walls being supported by a trellis of wire. Apple trees grown on this system generally do not crop in their second year and do not reach full production until they are five or six years old. It is thought that a production level two or three times higher than conventional low density plantings can be expected from this pruning system.

The cost of establishing this pruning system is high because of the extra costs for trees, trellis and labour. Trees can represent 50-60% of the total cost. It was noted that the soil had to be thoroughly prepared and appropriate irrigation provided. Further, depending on local conditions and outlay of the existing orchard, the application of this system can cost from $A10,000 to $A18,000 per hectare. Yet economic studies have shown that the initial higher costs are soon repaid by the "earlier and higher yields", and that the time spent in training the trees is repaid by their ease of management when mature. The system is now in wide use throughout Australia and in New Zealand, South Africa and America.

To ensure economical mechanical harvesting both the harvester and tree must be designed for optimum compatibility. These tree types must also be considered in the context of the present work. Generally trees must grow to provide the greatest exposure of sun to leaf area to ensure optimum fruit production, thus trees are grown as hedgerows or with one canopy, e.g. "Y" shape. Well spaced branches provide greater access to the tree and ease hand picking of fruit. Smaller trees come into bearing earlier and are planted more densely, further they eliminate the use of ladders increasing time spent picking apples, and reducing materials handling of ladders and the time spent climbing up and down ladders. Removal of ladders from the picking process also enhances safety for the pickers. Although they require greater attention during pruning the trees can be harvested quicker when time constraints apply, so making small tree orchards easier to manage.

2.7 Ergonomic Aspects

So far the peripheral requirements of apple harvesting with regard to bulk handling and mechanisation have been considered. The use of apple harvesters on the grounds of damage to apples and trees and overall on an economic basis, though the use of bulk storage and certain picking aids do look more favourable. Consequently it appears that manual labour is still a prerequisite for harvesting apples in the UK and the picker is the central pivot of the problems involved in apple harvesting, and therefore aspects of the pickers job fulfilment and welfare must be optimised to ensure successful task performance. It is important to determine whether the pickers task induces physiological fatigue within the picker and whether this is detrimental to the quantity and quality of apples harvested.

Murrell (1960) defined fatigue as the *"detrimental effect of work on the ability to continue work"* and noted that fatigue was due to physical activity, bad posture, poor working conditions, heat, etc. Physically hard work results in a fall off in work rate due to fatigue, though most work is not physically demanding in this sense, fatigue is an accepted cause of decreased productivity, though fatigue cannot be attributed to any one factor. It must be determined whether apple picking though classified as light physical work, causes fatigue.

However, overworking a small number of muscles can lead to localised muscular fatigue and decrease output, even though the overall physical effort required of the body is low. Murrell (1960) noted that light physical work which is normally found in industry cannot be estimated with any degree of accuracy by oxygen consumption or heart rate measures, due to the small number of muscles involved, and the low respiratory demand thus entailed. A convenient summary of fatigue is available in Grandjean (1980).

Localised fatigue is unlikely to occur if the load is spread over the body and any decrease in productivity or performance is likely to be a result of decreased motivation rather than ability. Decreased productivity is often caused by slow work cycles or pauses, poorly defined goals, lack of variation in the task, lack of job content, minimal knowledge of output, fear of rate cutting, too small a unit of work, bad organisation or supervision or boredom among other factors. These are separate from the effective skill or efficiency of the workforce and whether they have been trained or conditioned into the work cycle and shift duration.

The picker usually works an eight hour day at what is a physical job. Picking aids which have to be carried and moved include ladders and picking bags, the latter of which is on average half full and weighs 5 kg. Furthermore the picker is constantly moving around trees often in a partially stooped posture, up and down ladders, along rows, to and from bins etc. Partial body movements are typically: reach into the tree, grasp apples, move apples to picking bags and release the apples. The physical demands of any job may take their toll on the job, whether this is by decreased speed or increased errors. Measurement of these effects must take place in the orchard though pinpointing the cause may be more difficult. Objective measures are preferable, however subjective measures are advantageous in that the perceived fatigue of a picker is likely to have a direct effect on the picker's performance.

Woodrow (1982) performed a series of experiments to measure and quantify local physiological fatigue in those muscles used during the task of picking apples. The object was to examine the results in conjunction with the present study in the light of any changes in picking method and damage levels. Methods used were electromyography and "before and after work" tests of isotonic (dynamic) and isometric (static) contraction endurance time. The work task was a simulated apple picking task within a laboratory setting. The researcher, after limited tests were performed, concluded that electromyography and "before and after" isometric concentration endurance tests, appeared suitable to measure the fatigue of muscles involved in picking apples. However the application of these tests posed problems in an orchard setting and the results in trials carried out in orchards, appeared little different to random numbers.

Tomlinson and Cottrell (1970) also performed simulated apple picking experiments based on the apple harvester developed by Holt (1972). The experiments were performed on a simulated harvester and tree rig and studied the influence of front and rear conveyors systems on picking performance and physical effort. The distribution of fruit on the tree rig was also considered, to give an indication of picking rate, though it did not appear to be a major influence. Noticeable differences were found in the picking rate with different conveyor positions, though these were not statistically significant. Overall the front conveyor was superior to the rear conveyor and performance was improved when better access to the rear conveyor was provided.

This shows that shorter arm movements, reaching to apples and moving the apples to the conveyors improves the picking rate. This was verified when the picker was moved away from the fruit and the picking rate dropped significantly. During the experiments the heart rate of the pickers was monitored to give an indication of physical effort. It was found not to be significantly affected by any of the experimental variables, as indicated earlier.

A large percentage of apples on non-dwarfing rootstocks (i.e. in old orchards) grow above the average shoulder height. So much of apple picking involves the arms held in elevated positions. Several researchers have studied the problems of overhead work. Herbert et al (1980) studied the myoelectric activity in four different shoulder muscles in eight different arm positions. Localised muscle fatigue was found to be present in all muscles for the overhead and shoulder level work and some muscles with waist level work. This result may be of relevance to apple picking although the task performed in the study was static as opposed to the dynamic nature of apple picking.

Malmquist et al (1981) investigated dynamic tasks involving long periods during which one or both arms were elevated above shoulder level. The myoelectric signals from the four shoulder muscles as well as ECG were recorded at building sites, for workers, performing regular tasks. The authors found that significant localised fatigue occurred in one or more muscles during a period of work. The fatigue was particularly marked in the supraspinatus and trapezius muscles. It was particularly notable that fatigue was found in static work even if the force exerted was small. This indicated that uniform tasks are more likely to produce localised muscle fatigue than a varied one, even if the latter is heavier. It must be noted that traditional apple picking methods, i.e. with a picking bag, ladders and bulk bins, provides a more varied work schedule than mechanised or semi-mechanised apple harvesting with the orchard mobile (Holt, 1972). The researchers also concluded that methods of measuring oxygen consumption or heart rate were not sufficiently sensitive to monitoring the influence of localised loads.

In modern orchards almost universally planted with trees on dwarfing rootstocks apple picking involves much picking from below waist height. Apples growing along one branch can weigh down the branch till it reaches ground level. This is more often found with dwarfing rootstocks, because the trees are weaker. Vos (1973) compared the physical load of different work postures during light work at low working heights. The studies considered various frequencies of forward movement in conjunction with different work levels and postures. The postures studied were: bending, kneeling, squatting and sitting on a low stool.

Vos concluded that bending and kneeling are less strenuous when one hand or arm is used as a support to balance the trunk and a squatting posture is less strenuous than bending. Squatting is preferable for work below the foot level and can be alternated with another posture; putting one knee on the ground. Bending to below foot level increases the workload, though overall the work height did not influence workload greatly. With low forward movement frequencies squatting is preferable. With high forward movement frequencies of 4m per minute, or five moves a minute, bending is preferable to squatting and sitting, though it could overload the spinal area. Generally it was noted that work at low levels should be alternated frequently with other kinds of work or with rest pauses. With apple picking the varied nature of the task provides relief from the various work postures. For apple picking where both arms are involved in working it appears that squatting is a preferable posture to maintain when picking apples in the low regions of trees.

Morioka et al (1971) investigated the relationship between workload and maximum duration of exercise for: reciprocating flexion and extension of the forearm, cranking by both arms and bicycle pedalling. They concluded that arm work was more tiring than leg work, finding that mechanical efficiency and endured duration was higher with pedalling, than cranking, and lowest with flexion and extension of the forearm. They found that the workload and level of energy expenditure at which physiological burden can be assessed to be equivalent among different types of muscular work, are connected with the substantial mass of working muscle group. Apple picking using the arm and shoulder muscles is seen to use relatively small muscle masses which take most of the physiological strain.

Numajiri (1968) defined the fatigue allowance for muscular work as the ratio between work duration and recovery time to the resting level of oxygen uptake or heart rate after work. This ratio depends on the intensity of the work, the part of the body used in the work and the type of muscular exertion i.e. dynamic or static. The author studied leg and arm exertions in: the step test, work on the bicycle ergometer, cranking with both arms, arm extension, arm flexion and lifting a dumbell. The above order of exercise is the order of the longest to shortest duration and lowest to highest fatigue allowance. The bicycle ergometer involved the use of larger muscle masses than the arm exercises. The longer recovery time and shorter duration may be due, in the arm exercises, to small muscle masses or lack of muscle training. Thus it may be noted that the muscles used during apple picking may tire quickly and take longer to recover, though most apple pickers pace themselves and can take regular breaks to recover from the task and may develop specific fitness and adjust workrate to the load required.

It appears then that apple picking involving mainly arm work in relatively constrained postures may be fatiguing. However due to the nature of the work, i.e. light work and its intermittent nature, it is inappropriate to assess by simple metabolic measurements. Problems are also apparent regarding the use of electromyography measures, as an alternative, more direct method. However electromyography examines manipulative functions and is not relevant in energy assessment. Furthermore the use of electromyography is not suitable due to the outside nature of the work where weather affects the clothing worn by the pickers and can limit access to the body. Access is also limited by the use of picking bags worn on the body and attached by shoulder harness. The pickers are also highly mobile both horizontally and vertically and the work generally involves large changes in the working posture. Nevertheless even though such objective measures must be discarded consideration must be given to the effects of any muscular fatigue experienced by the pickers, on the quantity and quality of fruit picked.

Kao (1973) looked at the effect of exhaustive hand and finger exercise on the pace and accuracy of fine motor performance in a pattern tracing task. This may be of relevance to apple picking which involves the possible detriment of the task by lack of pace and damage to apples. Kao concluded that exhaustive hand and finger exercise did not appear to be detrimental to performance accuracy under normal conditions. However performance pace significantly accelerated under exercise conditions, possibly due to a training effect.

Ohtsuki (1981) measured voluntary maximum isometric grip strength for simultaneous bilateral and separate unilateral exertion in male and female subjects. The strengths of each finger and surface electromyograms of finger flexors in the forearm were recorded concurrently with grip strength recordings. Ohtsuki concluded that grip strengths and integrated EMG of both hands were significantly reduced by simultaneous bilateral exertion. The decrease in strength was 5-14%. The middle finger was found to hold the largest share of grip strength, followed by the ring, index and little finger in decreasing order. The proportional decrease in grip strength followed the above order. From this research it may be concluded that using both hands simultaneously to pick apples reduces the pressures exerted on the apples and may reduce bruising.

Jones and Hanson (1971) considered whole body movements as opposed to the five specific movements studied by Kao (1973). The movements in the study involved: the broad jump, running, moving from a standing to sitting posture and vice versa and climbing stairs. They used multiple image photography recording the movements before and after three kinds of fatigue inducing exercise. Individual differences in style were found for each movement and these persisted despite the effects of fatigue. This suggests that appropriate training for apple pickers will result in a definite apple picking style that will not erode due to fatigue.

Salvendy and Pilitis (1971) hypothesised that for various age groups a different freely chosen pace exists for which human energy expenditure per unit of external work performed is minimum. Working either above or below this freely chosen pace, the energy expenditure (measured by oxygen consumption) per unit of work, increases. The authors used an arm ergometer with male workers between 21 and 64 years old. They found that workers in the age range of 21 to 43 years supported this hypothesis, and experienced a greater psychological satisfaction working at a freely chosen pace, though this does not mean they were working at an optimal physiological pace. Conversely the higher age group exhibited the highest psycho-physiological efficiency during paced performance. Therefore younger workers can pace themselves as in the traditional methods of apple harvesting, whereas older workers have to be paced by external pressures around the freely chosen pace to maximise psycho-physiological efficiency.

Corlett and Mahadeva (1970) also used an arm ergometer to compare the physiological cost when a subject worked at a freely chosen pace, with that when he worked at a series of paces from 10 to 60 strokes per minute. When the energy cost per stroke (above resting level) was plotted against the workrate the graph suggested that there was a point of minimum energy per stroke. This point appeared to agree with the freely chosen work pace. Subjects performing repetitive sub-maximal physical tasks seem, when given the choice, to be able to choose the pace which involves the minimum physiological energy cost per cycle, as their working rhythm.

Snook (1975) performed psychophysical manual handling experiments on both male and female subjects. He established weight limits for a wide range of manual handling tasks based on the weights chosen by the subjects in the experiments, performing similar tasks. He applied these weight limits to industrial tasks and found that once jobs had been redesigned the incidence of lower back pain due to those jobs is reduced by a third.

Evans et al (1980) considered men and women subjects performing self paced hard work; walking over different terrains carrying loads of 0-20 kg. Each subject was timed and heart rate at completion was measured. The walking speed and energy expenditure of men was found to be significantly greater than women for all conditions. The relative energy expenditures for men and women for all conditions were very similar and constant at a value close to 45% $\dot{V}O_2$ max. Data indicated that voluntary hard work is dependent upon maximal aerobic power. The best predictor of speed for self-paced hard work of 1-2 hours duration appears to be based on 45% of maximal aerobic power.

Overall the studies indicated that working efficiency was improved when workers could choose their own working pace. In the orchard workers pick apples at a freely chosen pace, though often working with a payment scheme based on productivity. Often the incentives offered by the payment scheme encourage the pickers to work above their optimum pace and this may be over-fatiguing over the whole day. It can be seen that the opportunity exists for apple pickers to work efficiently when not moving with a mechanical harvester, and to pace themselves to avoid over-exertion and physical fatigue. In order to ensure that pickers are not over-exerting themselves causing physical fatigue, fatigue must be assessed either objectively or subjectively. The use of measures, such as heart rate and oxygen consumption have already been dismissed due to irrelevance with regard to light physical work. EMG measures have already been noted as difficult to administer under the conditions and questioned as to their meaning. This leaves subjective assessments of workload and fatigue.

Stamford (1976) studied the reliability of Borg's rating scale of perceived exertion. Women performed various work tasks involving: treadmill walking, jogging, cycling and stool stepping. During the work heart rate was recorded and at regular intervals and ratings of perceived exertion (RPE) were elicited at regular intervals or in the final minute of work. RPE responses were found to be highly reproducible, whether taken at intervals or at the end of the work task. High correlations were found between the two responses, i.e. interval and terminal responses. The RPE demonstrated a strong relationship with heart rate and work intensity. The author concluded that perceived exertion according to the Borg RPE scale offered a sensitive and reliable measure of stress encountered during locomotor work.

Hagberg (1981) studied women performing a series of concentric and eccentric flexions in the shoulder between 0-90^{o} with 0-3.1 kg weights held in a power grip, this was medium rated work. Measurements were made of heart rate, perceived exertion and the myoelectric activity from the trapezius, deltoid and biceps. The results suggest that the exertion of the descending part of the trapezius muscle in tasks involving repetitive shoulder flexion may promote discomfort and complaints referred to the neck. Static postures and repetitive arm movements have been suggested as factors in occupational shoulder and neck disorders. Work postures demanding elevated arms produce local loads on the shoulder muscles and lead to fatigue. By means of electromyographic analysis shoulder muscular fatigue has been found to be dependent on the working posture of the arm. The shoulder muscles in which electromyographic signs of fatigue develop rapidly in elevated arm positions, are the ones involved in occupational shoulder pain. Again, these are the muscles used during apple harvesting. Hagberg found that the time constants of EMG amplitude increase, were correlated with workload, endurance time and with slope coefficients of RPE-heart rate linear regression.

Gamberale (1972) also studied the relation between perceived exertion and physiological indicators of exertion during exercise. Subjects worked with wheelbarrows, weights and a bicycle ergometer. Measures were made of heart rate, oxygen uptake, blood lactate concentration and ratings of perceived exertion. RPE was shown to be related to heart rate in a fairly linear way regardless of the kind of work. Differences in the level of perceived exertion were found between the different kinds of work. To some extent these differences were related to the amount of oxygen uptake and blood lactate concentration. The general body RPE was found to be more relevant and indicative than localised RPE. Considering that apple picking mainly involves arm and shoulder muscle work, it is questionable that assessments of RPE can be adequately made.

The studies cited here concern simulated tasks which do not allow for skills and tend not to consider the developed "qualified worker". These types of tests do not utilise a sufficiently sensitive parameter to distinguish between skills, it would be preferable to consider productivity which is in effect retrospective whereas metabolic tests are anticipatory.

Corlett and Manenica (1980) stated that if a worker works too hard or too long it leads to exhaustion from hard physical activity or pain, and leads to a deterioration in the worker's performance. Furthermore "energy expenditure and postural pain represent in most cases independent criterion limits to performance". The authors went on to state that EMG is a useful laboratory tool, i.e. it is not significant for field studies and had yet to be related to the workers performance in the field, fatigue or pain. Perceptions of pain have not been found to correlate with EMG, therefore the worker's performance would suffer if EMG is considered alone. The authors used a body manikin (see Figure 1) to determine body discomfort. They noted that general discomfort was determined by several body parts being painful from a moderate to high degree. Localised discomfort was characterised by local pain even if other body parts suffered moderate to low levels of pain.

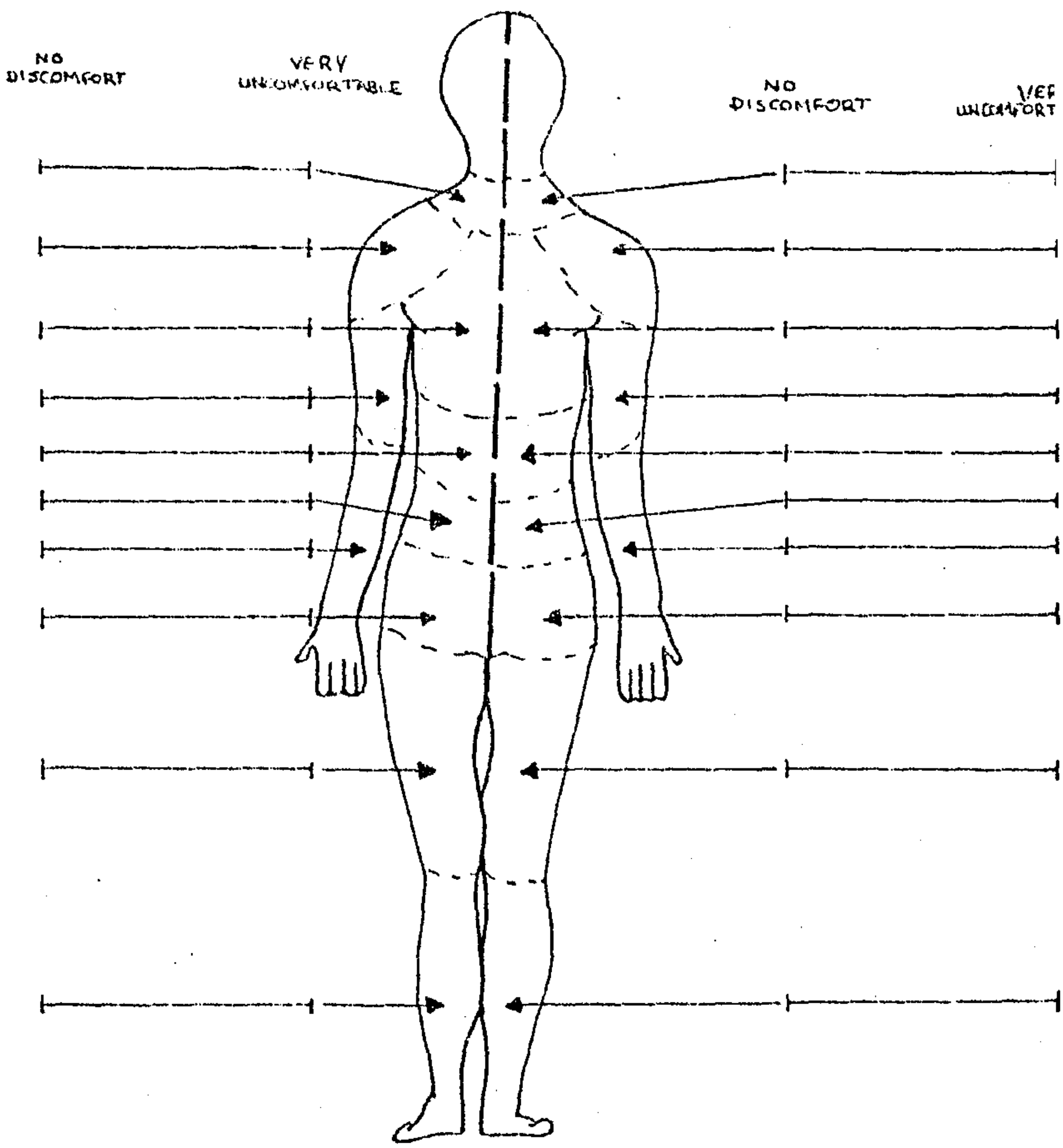

FIGURE 1: MANIKIN

Corlett and Bishop (1976) describe a technique for recording the distribution of discomfort in the body and its changes over a work period. They used the system to identify inadequate design features of a man-machine system and evaluate machine design. The system uses workers subjective judgement to explore the discomfort of work situations, as these had previously been successfully applied to assessments of noise, light and (as previously discussed) perceived exertion. The workers rate discomfort on a scale for 12 parts of the body. It would seem that this is an appropriate tool to use in assessing workers comfort and well being.

The Ministry of Agriculture,Fisheries and Food (MAFF) employ Method Time Measurement (MTM) to assess working practices in agriculture. It is a technique of work analysis, whereby human work can be divided into movements which are necessary for its execution. The movements have been given time values which are dependent on the nature of the movements and the circumstances under which they are performed.

A very detailed analysis of the movements of a process can be made with MTM-1 elements. The elements are differentiated by the kind of movement and variables such as distance, weight etc. Analysis is by direct observation or visualisation which when completed is used in conjunction with tabular charts to determine a time required for a process. This does not take into account rest periods, irregular movements, fatigue and postural allowances. MTM-1 recognises the basic movements of hands, fingers, eyes, body, legs and feet, all identified by code. Hand and finger motions are considered most important and their data has been further elaborated to include: reach, grasp, move and release motions. The units of time allocated to the movements are either seconds as designated by the International System or Time Measure Units (TMU) which is an hour divided by 100,000.

MTM-1 can be applied to study work methods prior to production, during product or tool development or to improve existing methods. It can also be used to lay down time standards or to produce time formulae and as a general tool of research and training. It is limited to physical, non-cognitive methods and should only be used by those trained in its methodologies.

Slater (1962) considered work measurement to be a technique for setting times that are standards from which the efficiency or performance of operators carrying out work are assessed. Work measurements or standards are only relevant to work carried out by a defined method. Work measurement is also a sampling technique, so a number of observations must be made to obtain confidence for mean time. Furthermore a number of operatives must be sampled by representative work study officers.

Good quality work measurement with synthesis of data leads to a consistent level of productivity for a given level of payment and a consistent workload on operatives. It facilitates the maintenance of incentive schemes with changes in work method and facilitates the evaluation of alternative methods without direct work measurement. It also enables more realistic pre-manning and planning.

Predetermined time motion systems such as MTM-1 can establish times of a work element far more economically than standard methods and with more confidence (±7% accuracy). Data can be more easily adjusted with changes in work methods. The amount of data required depends on the complexity and variability of the work. Slater (1962) concluded that work measurement should be a technique incorporating element times, method and motion studies. These are necessary to establish work content which is analysed into elements for which a combination of direct work measurement and data is used to establish the times.

Belshaw (1961) stated that data should be related to alternate methods at labour peaks. The data should be quickly available to avoid technical obsolescence and should avoid costly time consuming precision. Sufficient data is always required because of variability, particularly in agriculture, so that the pros of any particular method can be seen. The final data should be simple and easy to use, providing a range of times rather than a single figure.

Moores (1972) aimed to determine equitable workloads for operations of an arduous nature by classical work measurement and energy expenditure rates, finding that the two methods of work assessment differed considerably. During the course of the comparison it was found necessary to produce a film, so the author was also able to compare MEM assessments of operations with classical work measurement. This provided some confidence in the use of predetermined time motion systems.

Sury (1962) noted that time study was widely used as a work measurement technique and for setting "time standards" for manual operations which were sufficiently repetitive to have justified standardising the methods of working layout of equipment and training of workers.

Desmond (1950) noted that the concept of normal performance is entirely subjective and no absolute standard exists for comparison. The correct standard is an abstraction, defined as the means of the concepts of all qualified practitioners, under all conditions which can be applied to a job. The number of practitioners qualified to study a job is limited, and their average is accepted as standard for the operation. At any one time the observer's concept is subject to additional random errors of judgement which may mask differences between his concept at that time and the defined standard.

Overall it must be noted that the use of work study does not provide a measure comparative to that produced by energy expenditure measurements, so MTM will not measure workload in the way physical work measures can, and ignores local fatigue, and the cognitive elements of a task. It is also important that differences arise in work rating and these are found throughout work study practices, though familiarity with a task will improve concepts of work ratings. The application of work study to apple picking must also be questioned as the task is not wholly repetitive. Differences in apple yield, fruit distribution and tree type are apparent and differences in fruit picking methods and policies exist between farms and between pickers.

Work study has been successfully applied (Anon 1962) to the harvest of flower bulbs. The previous method consisted of collecting the bulbs and placing them into trays which were stacked and left for the wind to dry them. The bulbs were then packed in 50 kg bags and carried to the nursery and the trays moved elsewhere. Work study had shown the time consuming nature of the work and a new method was devised. The bulbs were packed in 13 kg string bags previously used for brussel sprouts, tied and left in position to dry, being transported in the same bag to the nursery later. The women collecting the bulbs were able to carry the spare bags with them as they worked.

Kellermann and Van Wely (1961) investigated the optimum size and shape of containers for transport and storage of bulbs in the Dutch flower bulb industry. They looked at the processes of bulb handling, noting 17 stages with numerous loading and unloading of bulbs into a variety of containers. The standard weight within the industry was noted as 35 kg, so a standard container had to weigh 35 kg or a division of that. It was also noted that work was carried out by temporary staff and that the containers could only have a maximum depth of 12 cm and be stackable. The research considered the movement of 210 kg of bulbs, either by six trips with 35 kg containers, 12 trips with 17.5 kg containers or 24 trips with 8.75 kg containers. Heart rate was measured to assess workload. It was found that the physiologically optimum weight was 17.5 kg carried in a long narrow container as opposed to a short narrow one.

When examining the problems of the bulb industry a few comparisons can be made with the apple harvesting industry. The use of boxes and their handling in apple harvesting have already been discussed due to the wastage of storage space. But it is worth noting that the weight of full boxes carried in apple harvesting is approximately 20 kg. This is not far from being the physiological optimum as defined by Kellermann and Van Wely's (1961) limited experiment. Of interest is the use of the brussel sprout bag carrying approximately 13 kg of bulbs. The use of this bag reduces the handling of the bulbs and is a specification applicable to apple harvesting as shown by Engels (1977). This idea is worth further investigation to examine all possibilities of its exploitation.

Carriage of apples during picking and prior to transferral to the bulk bin is also an important point to examine. Picking bags currently employed are carried in a variety of ways. A picking bucket simply made of a plastic bucket or moulded into a basket shape is carried by hand on a rigid handle, with the bag swinging on hinges underneath. A similar method of carrying is employed with the Clarke picking bag, though apples are emptied through the bottom of the bag as opposed to the top of the bucket. The Dutch nosebag is also emptied through the bottom of the bag, via a tube which is folded shut, and is worn in front of the chest, held in place by a shoulder harness. A canvas bag is worn by a shoulder and neck harness on the picker's back and is emptied through the entrance used for placing the apples in the bag. These methods will be elaborated later as they are the main picking methods found in the British apple harvesting industry. Each bag has its relevant merits and disadvantages with regard to access when placing the apple in the bag and exit when emptying the bag. A study of modes of carrying loads was carried out by Datta and Ramanathan (1971).

Datta and Ramanathan (1971) performed a comparative study of seven modes of carrying an identical load on level ground. They found significant differences between the modes of carrying with regard to energy cost, cardiac rate and pulmonary ventilation. They concluded that the best method involved a double pack, sharing the load on the chest and back. This was followed by carrying the load on the head. The worst method was to carry the load in two bags by the hands. Other modes included a rucksack, a sack carried on the back, sherpa style pack and yoke. The best mode however obviously depends on the terrain and other circumstances.

Consideration so far has been limited to alternative methods of apple transfer from tree to storage container. The present study is researching the use of manual labour in conjunction with available picking aids and possible improved picking aids. Thought has to be given to variables within that system. As far as possible control has been sought as to the use of cultivars within this study, however subject matter cannot always be controlled. It must be recognised that differences in pickers exist, apart from the obvious differences of sex and age a range of abilities are inevitable. The study aims to classify the range of ability and identify aspects of performance that can be improved. This may provide guidelines to employers as to the acceptable level of performance.

Sen et al (1981) evaluated tea leaf pluckers by measuring: energy expenditure, the average number of shoots plucked per minute, the total number of hand movements per minute and the average weight per shoot. This provided a ratio of the number of shoots plucked to the number of movements, and the energy expenditure per shoot plucked. This led to a point system: A - 14 points, B - 10 points, C - 9 points, D - 8 points or lower. Group A was found to be the fast pickers as defined by the company. Groups C and D overlapped the average and slow pickers. Group B were slow pickers but had some characteristics of Group A and were found to be trainees. This analysis could provide guidelines to employers as to whom to employ, train etc. It may also be possible to produce an equivalent system for apple pickers.

It is recognised that this study must provide an overview of the orchard aspects of apple harvesting. In order to do this opinions and facts must be gathered from all those who work in the orchards; pickers and supervisors. It is also necessary to identify the quantitative aspects, representative of farms, orchards, trees and apples. Consequently this study consists of damage and work studies considering the differences between picking aids, pickers, farms and the effects of the working day. Surveys were conducted on the pickers to provide an overview of the picker's population: age, sex, experience, training, normal occupations and subjective feelings of fatigue and discomfort.

The farm owners were also surveyed to determine: farm size, fruit crop size, methods of harvesting and management. The methods employed attempted to cover as much of the apple harvesting system as possible.

3.0 CONSTRAINTS ON RESEARCH

Due to the project being under the control of the MAFF certain limitations were placed on the research. Consequently most of the research was based on Cox and Bramley apples growing on rootstocks M9, M27 and MM106, as these were considered the most important apple trees due to widespread planting. Cox apples were noted to be the more important due to the direct competition of other eating apples within the EEC whereas English Bramleys have less competition as a cooking apple.

The use of automated or semi-automated apple harvesters was thought not to be within the confines of the project which was to concentrate on hand-picked apples. This was because most English apple farmers do not employ automated methods of apple harvesting. For the same reasons bin fillers were also eliminated from the study.

The research concentrated on the movement of apples from the tree to bulk bins. The transport of the apples from the orchard to the storage and packing areas was not taken into account as apples were moved by mechanical means and their treatment was subject to available equipment, road conditions and driving conditions.

Research concentrated on bruise damage to apples as scratches and punctures were noted to be due to natural damage i.e. insect damage and the movement of apples against trees. Although all bruise damage was recorded by the researchers only the obvious bruising was used in subsequent statistical analysis as this was more likely to affect eventual grading and buyers perceptions.

3.1 Bruise Damage Assessment

Research into the ergonomic problems of apple harvesting commenced in September 1982 with the development of a bruise classification scheme by the researchers in conjunction with Agricultural Development Advisory

Services (ADAS) personnel and with representatives of Her Majesty's Inspectorate (HMI). It was agreed that bruises should be classified by area (in square millimetres) and by bruise severity.

Three easily-defined levels of severity were fixed: pressure flats, identified as flat spots on the apple without discolouration; slight bruises, which were flat spots with discolouration; and concave bruises in which the surface was indented and discoloured. The range of bruise sizes ran from 4-26 mm diameter in steps of 1 mm. These diameters covered the range from the nearly imperceptible damage of pressure flats to the rotten apple, and the scale proved sufficient in practice.

To identify bruise sizes a set of sizing rings were developed. These were initially used fairly consistently but it became apparent that size judgements could be made with very little error, and the rings were subsequently used for comparison and calibration. Some difficulty was experienced with the assessment of elongated bruises. In such cases a "best guess" was made, with reference to the grading rings, (see Appendix 5).
Because of the problems found during the calibration of researchers a policy decision was taken that though data was collected on the incidence of pressure flats, these would not be included in the results. In consequence, a conservative picture is given of accrued damage to apples; there are more bruises present than stated, approximately 20%. Secondly, for the more important, easily visible bruises (slights and concaves) the data are accurate to +/- 5%. Since it is the visible bruises that affect the market value of apples this decision seems justifiable in practical terms.

3.2 Calibration of the Researchers

It is evident that the results of this study depend on the accuracy of the damage assessments made by the researchers. In view of this a brief training period was undertaken at the HMI training school in London, a further two day training period including training and experience in picking techniques was spent in the field, and at intervals not exceeding one week, calibration studies were made of the researchers, under field conditions.

The field training and calibration procedure were as follows. A random sample of at least 20 apples was collected. A researcher would then examine and mark all damage found on the surface, using the two classification variables of size and severity. This was performed in natural daylight under self-paced conditions, without consultation and at least two hours after the sample had been collected.

The apples were then peeled, by another researcher, comparing the marks on the surface with the extent of damage under the surface. These data were entered into "confusion" matrices, an example of which is shown in Figure 2. Analysis of these indicates that the researchers located approximately 95% of all bruises above 4 mm diameter, but performance was worse for smaller bruises. In the main, these smaller bruises were pressure flats; and as was noted earlier these had a tendency to 'disappear' after 24 hours or so, as the apple carried out its healing process. Consequently as a policy decision, it was decided that for the purpose of this study, bruising damage would be restricted to slight and concave bruises only.

3.3 The Development of Bruises

It is known that apple bruises develop with time, and that many pressure flats and some borderline small slight bruises can disappear with the passage of time. Consultation and some rudimentary experiments indicated that bruises were at their most visible in a period between 2 and 6 hours after the bruising impact. Accordingly, throughout the studies that are reported, all assessments made of bruise damage attributable to humans have been made in this time period. Where damage to apples on trees is assessed, the assessment was made immediately so that handling damage would not be included.

GRADER CALIBRATION

NAME:

DATE:

APPLE TYPE:

PERCEIVED DAMAGE

	SIZE	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	0														
	1														
	2														
URE	3														
	4														
TS	5														
	6														
	7														
	8														
	9														
	10														
	11														
	12														
	13														
	0														
	1														
	2														
HTS	3														
	4														
	5														
	6														
	7														
	8														
	9														
	10														
	11														
	12														
	13														
	0														
	1														
	2														
	3														
VES	4														
	5														
	6														
	7														
	8														
	9														
	10														
	11														
	12														
	13														

ACTUAL DAMAGE

FIGURE 2: CONFUSION MATRIX

4.0 DESCRIPTION OF HARVESTING SYSTEM, BASED ON 1982 DATA

4.1 Farmer's Survey and Conclusions

A survey of 20 farmers was conducted to establish current practices within orchards, general views on apple damage and preferences with regards to apple harvesting. The survey was based on a questionnaire (see Appendix II) on a face-to-face basis with farms sampled from Kent, Essex, Oxford, Cambridgeshire and Nottinghamshire. The general details of the farmers is given in Table 16.

TABLE 16: General Details of the Respondents

All farmers surveyed were male
Age range 27-67. Mean 47 years
Farming experience: range 5-36. Mean 24 years.
Twelve farmers had formal training, i.e. 60%

The farmers were asked about the area of their farm used for growing apples and how this was used with regards to apple variety and root-stock. This was of specific interest regarding Cox and Bramley apples on rootstocks M9 and MM106, see Table 17.

TABLE 17: Farm Orchard Area

Variety	Rootstock	Number of Farms	Range (ha)	Mean (ha)
All apples		20	15-347	100
Cox	M9	16	1- 40	8.0
Cox	MM106	17	1-121	26.5
Bramley	M9	11	1- 8	2.5
Bramley	MM106	16	1- 61	8.0

The farmers were questioned about the pickers they employed during the 1982 apple harvesting season to differentiate between full-time and seasonal workers and to determine the size of gangs deployed. Further questions were asked to establish how long a seasonal worker worked and how many years they returned, see Table 18.

TABLE 18: Picker Details

	Range	Mean	Mean Number Preferred by Farmer
Number of gangs employed per farm	1-16	5	9
Total number of pickers employed per farm	10-300	96	95
Total number of seasonal pickers employed per farm	6-270	82	
Number of years a seasonal picker returns	0- 15	8	
Number of weeks per year a seasonal picker works	3- 12	6	

The farmers were asked about the methods used on their farms to pick apples and the results are given in Table 19.

TABLE 19: Harvesting Methods Used by Farms

Picking Bag Used	Frequency of Use by Farms
Dutch-nosebag	14
Buckets	5 (usually on small farms)
Canvas sack	3 (used for harvesting tall trees)
Clarke bag	2

Note: Some farms use more than one method.

The survey covered areas of supervision, the results of which are given in Table 20.

TABLE 20: Supervision

Usual Supervision for Picking Gang	Frequency
Chargehand	11
Personal supervision	14
Tractor driver	11
Quality control personnel	4

The farmers were asked about the training they provided for all pickers regardless of whether they are full-time or seasonal workers. Questions concerned the type of training, the length of training sessions and their frequency, see Table 21.

TABLE 21: Training for all Pickers Each Year

Type of Training	Frequency
Demonstration	10
ATB Leaflets	5
None	5
Training length: Range 0-60 minutes. Mean 18 minutes. Normally one training session only.	

The farmers were questioned about their use of quality control, how they monitored quality and their use of quality control in reference to the employment of pickers. The results are discussed in Table 22.

TABLE 22: Quality Control

10 farms had formal quality control checks
Generally apple quality was checked in the bin in the orchard
16 farms had a monitoring system for pickers performance
16 farms recognised that pickers performance ranged from good to poor
4 farms issued warning to pickers identified as poor with regards to performance
Poor picking was assessed as causing damage to 10% or more apples
On average 7 pickers/year were dismissed from each farm

Table 23 shows the farmers figures for their production of apples in 1982 and the grades at which their apples were marketed.

TABLE 23: Production

Total Apple Crop (tonnes)		Range 102-5080	Mean 1703
Grades (%)		Range	Mean
Class I:	Cox	40-80	62.1
	Bramley	58-85	70.6
Class II:	Cox	15-99	58.8
	Bramley	15-99	65.0

Farmers discussed the methods they would prefer to use to harvest apples, see Table 24.

TABLE 24: Alternative Harvesting Methods

Farmers preferred to harvest apples by manual picking
12 farmers stated they would use direct grading and marketing
2 farmers stated they would use automated picking methods

Table 25 discusses the reasons why farmers use their current apple harvesting methods, most farmers having changed from a system of harvesting apples into boxes which were used as a storage medium.

TABLE 25: Reasons for Using the Present Harvesting Methods

Reason for Changing the System	Frequency
To ensure the optimum use of storage	10
Avoidance of damage to apples caused by picking into boxes	10
Easier management of resources i.e. setting out	10
Storage media, keeping tabs on pickers	
Reduction of time to move storage media around orchard and store rooms	5
Materials handling, moving boxes	5
Apple husbandry	5

The farmers were asked whether they were aware of any problems associated with the picking methods they were currently using. The results are given in Table 26.

TABLE 26: Problems Associated with Current Picking Methods

Problem	Frequency of Complaints
Picking damage to apples	15
Bin filling damage to apples	5
Pickers supervision and training	12
Bin use (transport, storage, etc)	11
Weather conditions	10
Piece-rate paying system	5
Lack of advice from ADAS/MAFF	2
Bag harness design	1

At the suggestion of MAFF, the questionnaire concentrated on the two varieties, Cox and Bramley, and on the two rootstocks, M9 and MM106.

Study of the data reveals that on average one picker is employed to pick one hectare of trees, though the range is 1-12 pickers/3 hectares. Using average figures one picker picks 17.7 tonnes of apples in a season.

It was noted that farmers do not generally wish to increase the number of pickers employed though do want to increase the number of gangs, i.e. to increase supervision. This would decrease the average gang size from 19 to 11, more in accord with ATB recommendations. The purpose appears to be to maintain a better control over picker performance in the orchard. From this point of view it is perhaps unfortunate, though understandable, that so much supervision is performed by tractor drivers.

Most apple pickers are employed on a seasonal basis (85%). The grower retains a pool of experienced pickers who will return for a number of apple picking seasons (on average a picker returns for 8 years), this provides some measure of continuity. The pickers are supposed to be trained in standard methods of picking as laid out in the ATB leaflets (see Appendix 3) to minimise time, effort and damage. However it appears that the training apple pickers receive is not always consistent with ATB recommendations. This may be due to the fact many of the pickers have previous experience but it neglects novice pickers. This indicates that training programmes should be developed for both experienced and inexperienced pickers.

Quality appeared to be a concern for all farmers, with a limit of 10% defective fruit being acceptable. It will be seen later that this figure is at some variance with the data from the damage studies. From the interviews it seems that farmers rely for their information on consensus, casual sampling and experience.

It was found that farmers relied heavily on picking by hand, using the Dutch picking bag as recommended by the ATB. The basis for this choice is overall economics. When this is matched with the data on current problems in Table 26 only one farmer links picking problems with bag design. Nor do farmers link bin-filling problems with bag design. Perhaps this is due to the widespread belief that most of the bruise damage to apples is due to the picker's fingers when the apple is plucked.

4.2 Pickers Survey

During the 1982 apple harvesting season 67 pickers from five picking gangs were interviewed. The interview was informal taking the form of a conversation whilst the picker was working. The questions asked were to establish a profile of the picking population, i.e. age, sex, normal occupation, experience and training. They were also asked whether they found any aspects of their job difficult. The results are shown in Tables 27 to 29.

TABLE 27: Number of Pickers Per Farm

Farm	Number	% of Whole Sample
1	15	22.3
2 (gang 1)	16	23.9
2 (gang 2)	21	31.3
3	9	13.4
6	6	8.9
TOTAL:	67	

TABLE 28: 'Normal' Occupation of Pickers

Occupation	Number	% of Whole Sample
Housewives	30	44.6
Farmworkers	15	22.3
Students	6	8.9
Unemployed	5	7.5
Others	11	16.4
TOTAL:	67	

TABLE 29: Description of Pickers

	Number	% of Whole Sample
Males	18	26.8
Females	49	73.2
Median age (years)	30	
Median experience (years)	4	

It should be noted that the (median) age and average experience of the pickers indicates that the work force is relatively stable and potentially reliable. The length of experience suggests that perhaps there is a need for retraining schemes to be developed, as well as initial training schemes.

The pickers commonly noted problems concerning reaching and stooping whilst picking apples; the problems being accentuated with full picking bags. Ladders were also a source of problem with respect to placement and movement but not to picking. It is suggested that bag design could be improved as well as management, i.e. improved orchard supervision and equipment. With respect to training a few pickers had received written instructions, others had received visual instructions whilst many had received no formal training whatsoever.

4.3 Subjective Feelings of Fatigue

As discussed earlier, fatigue is difficult to define and very difficult to measure. Apple picking is a self-paced, low-effort, psychomotor skill and fatigue is likely to be seen as a slowing down of performance rather than an increase in damage to apples. This slowing down can be disguised, subconsciously, by the sufferer, in that there are more pauses for discussion, or more queries, or more time is spent on inessentials. Consequently, it is not easy to find a physiological measure of fatigue. A number of experiments were conducted to try and find a suitable technique, without success, as discussed earlier.

An alternative approach was adopted, initially founded by Corlett and Bishop (1976). As outlined earlier, it elicits a response from potential sufferers as to whether or not they subjectively experience 'fatigue'. The rationale underlying this is that people are usually aware when they feel fatigue, and if they feel fatigue it is probable that their performance will be impaired some way.

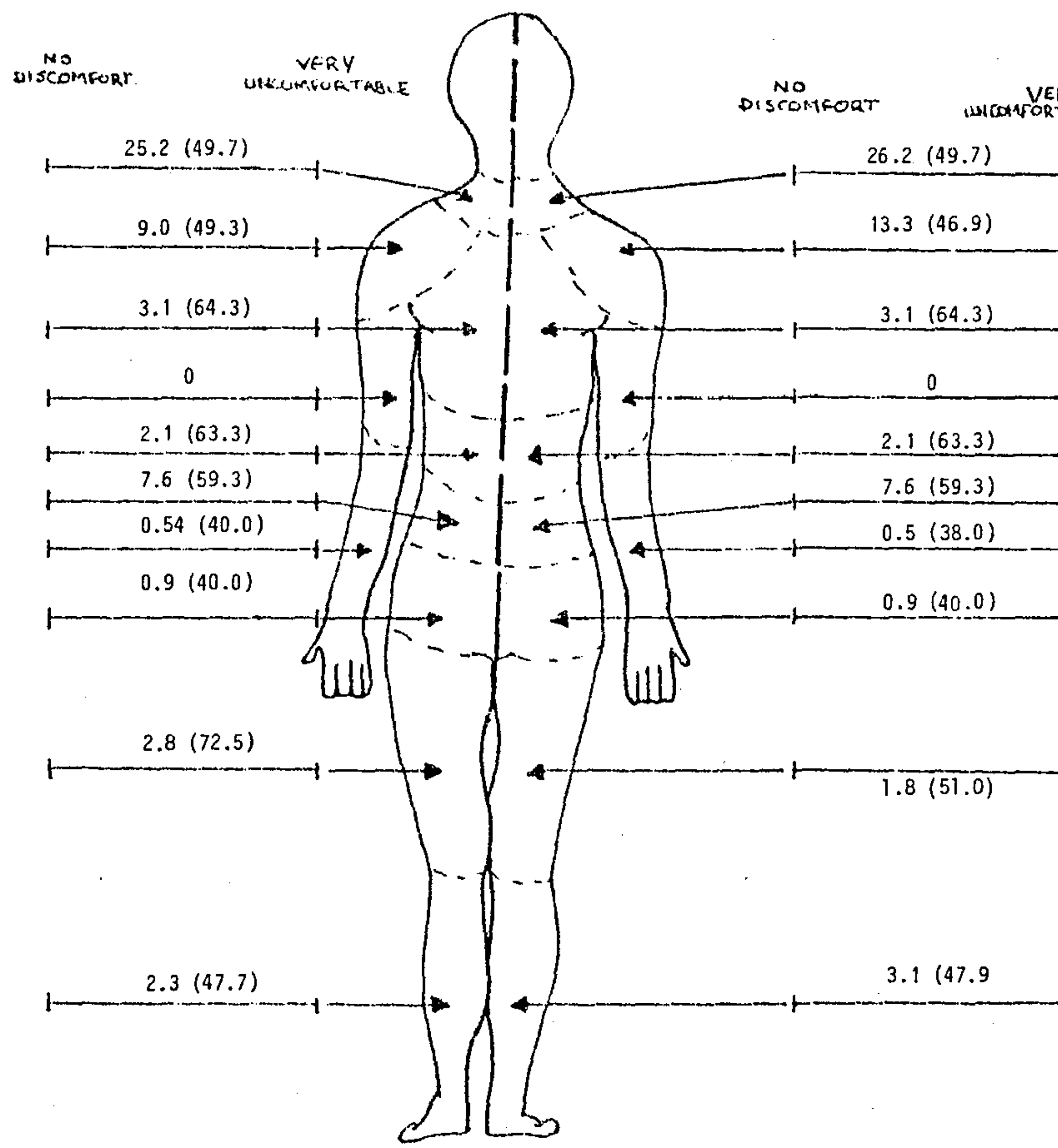

FIGURE 3: SUBJECTIVE DISCOMFORT

The % average pain for all pickers interviewed with % average pain by complainants only shown in brackets

Every picker interviewed was asked whether they felt discomfort on any specific areas of their body and how they graded this discomfort. Out of the total number of pickers the average discomfort was greatest in the neck region (26%), shoulders (left 9%, right 13%) and the lower back (8%). Taking only the responses of the pickers complaining of discomfort, responses were, the neck and shoulders 49% discomfort, the whole back 62%, the forearms 39% and the legs 55% (see Figure 3). For most areas, very few pickers experienced any real degree of discomfort. However, those that did report some discomfort noted a fairly high discomfort level. The major exception to this is the neck region, where about half of the pickers felt pain. Other areas that justify attention are the shoulders and lower back.

The pain and discomfort appear to be due to two factors; the straps supporting the picking bag (many pickers had produced makeshift padding for the straps), and the need to stoop to pick low branches. The latter factor was exaggerated when the picker was carrying a nearly full picking bag.

A question was also asked regarding the subjective tiredness of each picker at the end of the day. This was on a scale from 1 ("not tired") to 10 ("very tired"). The average scale rating was 6.6, irrespective of any perceived pain. It therefore seems probable that there will be some loss of performance among the pickers, affecting some people more than others, toward the end of the working day.

4.4 Summary of Pickers Survey

The survey reveals that the picker population is fairly young and therefore reasonably fit and healthy. Their 'alternative employment' fits the picture of fairly reliable workers, returning over a number of years to do the job of picking. This is not in disagreement with the results of the farm survey reported earlier. Their anthropometric information is given overleaf (MAFF-ADAS 1985 report CSA 660 p 119 is reproduced).

Their other comments point to some degree of physical discomfort occasioned by the task. As mentioned earlier, there is a tendency for people to optimise their pattern of work, usually with a view to reducing effort, in this case it could also reduce discomfort. This could show itself by increasing the number of rest pauses, less careful treatment of the fruit and slower working.

Further light can be cast upon this from the studies reported later, aimed at establishing whether there is a 'through-the-day' bruise damage pattern, and whether different picking containers have different damage rates associated with them.

5.0 QUANTIFICATION OF THE PICKERS TASK BY MTM-1

Orchard work was analysed from video-cassettes taken in the orchards in the 1982 apple harvesting season. The analysis was by MTM-1 and frame count.

MTM-1 analysis was undertaken as a means of quantifying the picking task. This method of analysis was selected owing to its ubiquity, and its role as a standard method within MAFF. The analysis was based on films showing the pickers working with a number of different picking bags, at various times during the day. The fruit variety was mainly Cox grown on either M9 or M106. Some instances of picking of Bramley and Gala apples were also recorded.

Having obtained MTM times for each element in each orchard, an average time was calculated for each element across all orchards (see Table 30). A synthesis of these times was then carried out to produce a standard time to pick a standardised crop of apples from a standardised centre-leader tree. The synthesis involved a standard picking method as advocated in the ATB training manuals, used in conjunction with four picking containers: Dutch-nosebag, Clarke-bag, canvas sack and box. Table 31 shows the same MTM analysis though relating to a range of picking abilities: poor, average, and good pickers (12.5, 50 and 87.5 percentiles) respectively.

A number of assumptions have been made in these calculations, as outlined below.

A standard orchard planting layout has been used as recommended in Bulletin 207 (HMSO, 1971), the data relating to this is outlined in Table 32.

The picker has been assumed to operate in one of four postures: stooped or bending to pick low fruit, standing to pick medium height fruit, reaching for high fruit and up ladders to pick fruit above overhead reach. The height boundaries between these posture levels have been obtained from Panero and Zelnick (1980), see Table 33.

The number of fruit in each posture level have been obtained from Green and Holt (1971), see Table 33.

Rest and personal allowances have been calculated using the guidelines in ILO literature (ILO, 1971), see Table 34.

Table 30 indicates that as far as picking time is concerned the differences between the Dutch-nosebag, and the Clarke-bag are so small that they can be discounted, whereas the canvas sack and the box are distinctly slower. The times given to strip a tree are slightly longer than the times commonly quoted by farmers of 15 minutes (or so). This difference is best considered in the discussion on picking method.

However, the canvas sack and box could still be in contention as picking aids if it could be shown that damaged apples were sufficiently less for those containers to outweigh the time advantage of the other methods. Results show later that the Dutch-nosebag and Clarke-bag produce the least damage by the time apples come to rest in the bin. This perhaps demonstrates the beneficial effects of short movement paths for the hands, coupled to purpose-designed containers. However, the results produced for the bucket, slung from a branch by a hook, indicate the advantages of clear access to the container (which with the Dutch-nosebag and Clarke-bag is not always the case when working in the central part of the tree) and also the disadvantages of a non-purpose-built container when transferring apples to storage containers.

Table 30 also shows that time spent picking apples accounts for 70% of the total time, and walking to and from the bin, emptying the bag and moving and climbing ladders account for the rest. Subsequent analysis of the video-cassettes indicates that social activities

TABLE 30: Synthesised Times Using MTM-1 for the Picking Task Using a Standardised Tree and Orchard, but Different Picking Bags (Units are seconds except where stated)

	Dutch Nosebag	Clarke Bag	Canvas Bag	Box
Picking	573.3	579.1	620.1	742.5
Emptying	16.8	15.2	25.2	17.4
Walking (see Table 32)	34.5	34.5	34.5	30.2
Ladder (see Table 32)	204.0	204.0	204.0	204.0
Total	828.6	832.7	883.8	994.1
Allowance of 28% (see Table 34)	232.0	233.2	247.5	278.3
Total plus allowance	1060.6	1065.9	1131.3	1272.4
Time to strip tree (minutes)	17.7	17.8	18.6	21.2
Time to strip tree (%)	100	100.5	106.7	120.0

TABLE 31: Range of Synthesised Times Using MTM for the Picking Task, Using a Standardised Tree and Orchard, but Different Picking Bags (Units are seconds except where stated)

Time	Dutch Nosebag			Clarke Bag			Canvas Sack			Box		
	12.5	50.0	87.5	12.5	50.0	87.5	12.5	50.0	87.5	12.5	50.0	87.5
Picking	466.3	568.3	644.9	416.1	561.2	683.2	357.4	628.7	795.7	513.9	721.8	835.4
Emptying	7.7	17.6	19.8	15.3	15.3	15.3	4.5	25	29.4	13.8	17.1	20.1
Walking (see Table 32)	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	30.2	30.2	30.2
Ladder (see Table 32)	204.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0	20.40
Total	712.5	824.4	903.2	669.9	815.0	937.0	600.4	892.2	1063.6	761.9	973.1	1089.7
Allowance of 28% (see Table 34)	199.5	230.8	252.9	187.6	228.2	262.4	168.1	249.8	297.8	213.1	272.5	305.1
Total plus allowance	912.0	1055.2	1156.1	857.5	1043.2	1199.4	768.5	1142.0	1361.4	975.2	1245.6	1394.8
Time to strip tree (minutes)	15.2	17.6	19.3	14.3	17.4	20.0	12.8	19.0	22.7	16.3	20.8	23.2
Time to strip tree (%)	118.8	137.5	150.8	111.7	135.9	156.3	100	148.4	177.3	127.3	162.5	181.3

TABLE 32: Calculation of Walking and Ladderwork Times

If 16 bushel bins are used:
there are 640 lbs per bin
Assume 4 bags of 30 lbs each are picked from one tree
One bin is filled by 5.5 trees
Assume tree layout as per Luddington minimum distances and ideal bin position.
The average distance to the bin is = 3.5m.
To empty four bags is 8 x 3.5 = 28m.
To move three boxes is = 6 x 3.5 = 21m.
The tree radius is 1.15m.
Therefore the circumference is = 7.2m → 7m.
Walking distance around tree and in and out 10 times is = 20m + 7m.
Total walking distance is = 27m.
Total walking distance using bags = 28 + 27 = 55m.
Total walking distance using boxes = 21 + 27 = 48m.
Time to walk 1 metre = 0.63 sec.
Time to walk 55 metres = 34.5 sec.
Time to walk 48 metres = 30.2 sec.
Time to move ladder 10 times = 10 x 9.2 = 92 sec.
(Moving and placing the ladder 10 times allows for arm reach across the tree and for obstruction by branches and foliage).
Time to climb up ladder 10 times = 10 x 6.9 = 69 sec.
Time to climb down ladder 10 times = 10 x 4.3 = 43 sec.
Total ladder time = 204 sec.

The apples per apple tree derived from data provided by E. Devine.

The apples per picking zone derived from 'Mechanically Assisted Hand Picking' by H.C. Green and J.B. Holt, National Institute of Agricultural Engineering, Silsoe, Bedfordshire, February 1971.

Waist, shoulder and overhead reach statistics from 'Human Dimensions and Interior Space' by J. Panero and M. Zelnick, 1980, The Architectural Press.

TABLE 33: Apples per Picking Zone

Height Above Ground (mm)	% of Apples per Zone	Number of Apples per Zone	Picking Zones	Number of Apples per Picking Zone
3048	2	11		Ladder zone out of reach from the ground 155 apples (28%)
2743	3	17		
2438	8	44		
2134	11	61	2060	
1829	16	88		High zone. Above shoulder but picking from ground 210 apples (38%)
1524	19	106	1400	
1219	17	94		Mid zone. Apples between waist height and shoulder height 106 apples (19%)
914	14	77	1020	
610	8	44		Low zone. Below waist height. 81 apples (15%)
305	2	11		
0	0	0	Ground level	
TOTAL:	100	552		

TABLE 34: Relaxation Allowance for the Picking Task, Obtained from 'Introduction to Work Study', 1977 (Geneva: International Labour Office)

Weight and pressure	3%
Standing posture	4%
Awkward posture	3%
Awkward posture overall	1%
Mental monotony	1%
Physical monotony	1%
15-60 min job duration	10%
Personal allowances	5%
Total:	28%

Note: These are recognised guidelines and widely used, the allowances above having been allocated after discussion with an experienced work study practitioner.

(chatting, etc) occupy only 0.3% of the time in the orchard. This figure does not compare well with the activity sampling exercise, however, the presence of a camera crew can have adverse effects.

Again, subsequent analysis of the videotapes indicate that of the time spent picking 19% was spent in heavily stooped postures and crouched postures, picking apples below waist height. 21% of the time was in more erect postures picking apples from waist height to shoulder height. 30% was spent picking above shoulder height from the ground, and 30% was ladder work. Table 30 illustrates this, and shows the mean time to pick an apple depends in which zone it hangs. The large amount of time spent on ladder work is explained by the placement of ladders around the tree. The apples are at various distances from the ladder and require a greater reach time to pick an apple. This is combined with problems of placement of the bag, search, balance and a reluctance to expend time and effort moving the ladder around the tree, leading to over-reaching.

Further analysis of the video-cassettes reveals that in no case did pickers use the recommended picking method for more than a small proportion of the picking time. Even after specific instructions to follow ATB recommended methods an experienced and trained operator (who trained other pickers) did so for only 13% of the time. There are a number of practical reasons why this should be so. Firstly, apples tend to grow in clusters on the branch and in these cases a picker will normally pick two or more apples at a time (multiple picking) using both hands, usually to prevent drops. Secondly, particularly on low branches, the picker will often use one hand to move the foliage to reveal the apples to the line of sight or to improve access. Thirdly, the bulk of the bag frequently reduces access to the apples between the branches unless it is moved from its normal position in front of the body. The picker usually moves the bag to hang over a shoulder and uses a picking method comprising of hand-to-hand, pick and transfer. Fourthly, where the picker is wearing many layers of clothing, and is particularly stooped in working posture, access to the top of the bag can be very restricted.

It seems therefore, to confirm that the ATB recommended picking method is not the ideal method, since it can so seldom be used. On the other hand, the methods actually used do not seem very efficient at first sight, except for the multiple-apple picking aspect, which is where the saving in time is believed to occur in relation to the MTM times given previously.

5.1 Activity Sampling

An activity sampling exercise undertaken at a farm produced the results shown in Figure 4. Picking at various levels on the tree accounts for 31.8% of observations. Ladder work accounts for 21.8% of observations in non-picking activities. Work involved in transferring apples from the picking bag to the bin occurred in 27.1% of observations. 10.9% of observations were for non-productive activities.

These results differ from observations from video, this is probably due to a subject camera interaction making the subject more work conscious. Whereas activity sampling occurring on an occasional basis has a lesser effect on the activities of the subject.

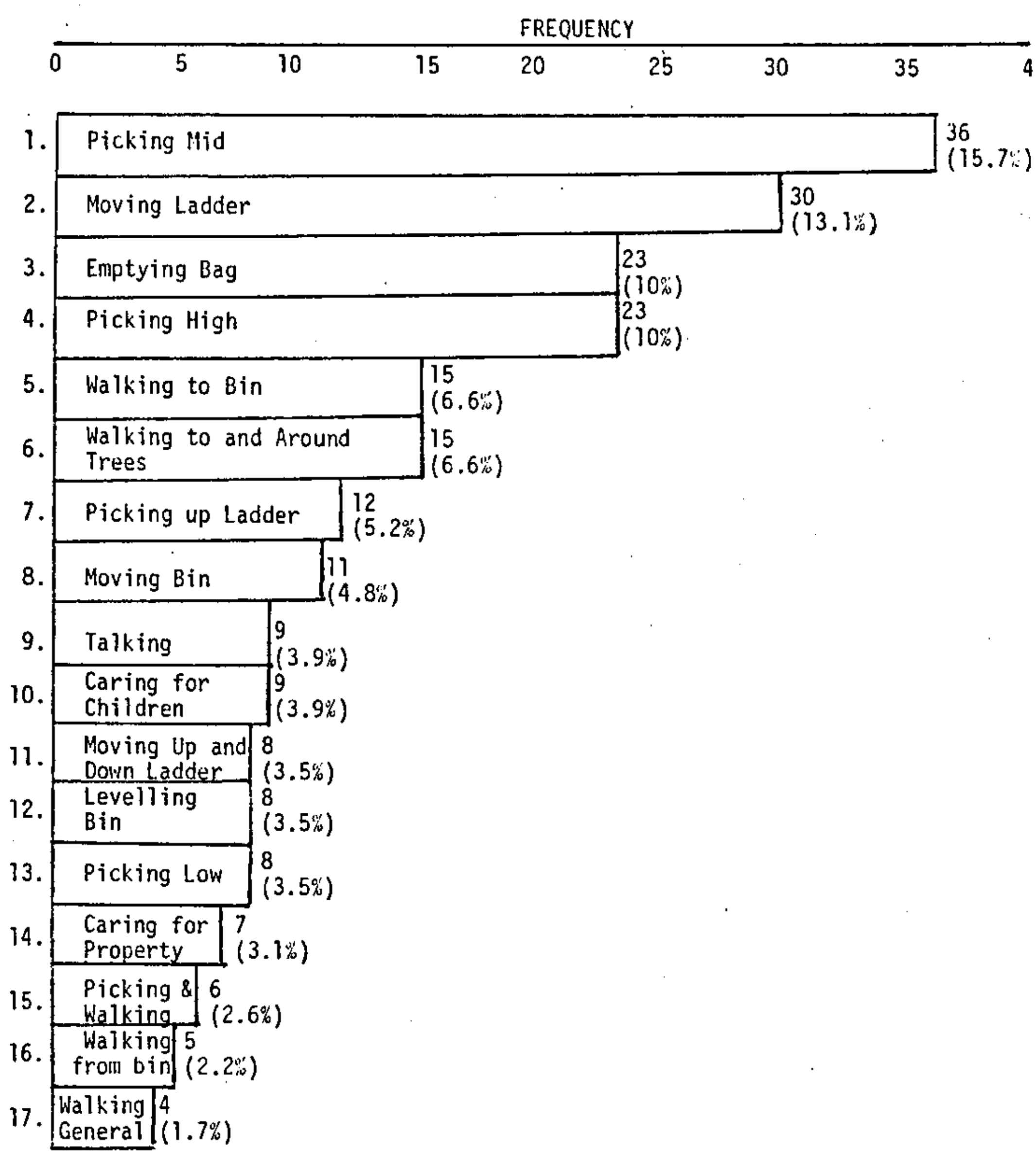

FIGURE 4: RESULTS OF ACTIVITY SAMPLING EXERCISE
(Shown as frequencies of activity occurrence)

6.0 BRUISE DAMAGE TO APPLES DURING HARVESTING AND CONCLUSIONS

Harvesting is taken to mean the process of detaching the apples from the tree and transferring them to an orchard box or bulk bin. It does not include the subsequent progress of the apples from the orchard.

In all six farms were studied and a government experimental horticultural station. These covered the geographical areas where apples are mainly grown.

At the farm sites bruise damage studies were completed. These involved sampling apples on the branch, in the picker's hand, in the picking bag or box, and in the orchard bin. The apples were then assessed for damage, following the procedure quoted in Section 3.2. Random sampling was used to avoid bias except that in the case of apples on the tree equal numbers were obtained from branches growing along and across the row.

The bruise damage studies were conducted to establish whether damage was incurred at any particular point in the harvesting system. Damage was assessed on apples on the tree to determine a baseline of damage. Samples taken from the picker's hand were studied for the purpose of resolving whether or not "finger bruising" occurs. The samples from the bag and bin studied the damage involved in transferring apples from hand to bag and bag to bin.

The damage studies also investigated how the time of day affected the pickers performance and consequently the damage to apples. This is in reference to the effects of fatigue and discomfort i.e. whether the picking task causes fatigue and discomfort and whether this in turn increases damage to apples.

It was important to determine how the various picking aids, i.e. picking bags and receptacles, related to damage to apples. Of specific importance are the differences between purpose built containers and general storage containers, e.g. the Dutch-nosebag and the bushel box. With regard to damage levels and movement of apples from tree to bin the following tables show the data from the various commercial farms. The data divides the damaged apples into classes as described by EEC regulations. For each class of apple, at each sample point and farm, the number of apples in that class is presented as a frequency and as a percentage of the total apples taken from the sample point. Also presented are the number of bruises noted in all the apples at a sample point, the collective area of those bruises and the percentage of apples damaged at that sample point.

The data from Tables 35 to 44 lead to a number of conclusions.

The improvement in apple grades from tree to hand is probably due to the rudimentary quality control applied by the pickers in dropping "poor" apples rather than transferring them to the picking bag and hence through the harvesting system. This explanation seems reasonable since it was observed on almost all the farms in the sample.

The data indicates some presence of finger-bruising, but its extent does not affect the grade of the apples. Bruised apples sampled from the hand include other sources of bruising that can occur when apples are being detached from the base, such as damage from branches or other apples which are in the path of the pickers hand.

From the results of the 1982 season it is apparent that the major sources of damage are in the transfer of apples into the bag and into the bin. As a general approximation in 1982 there is a loss of 10-20% of Class I fruit between tree and bin, the percentage of bruised apples doubles at each stage (5%:10%:20%:40%) and the percentage downgraded from Class I quadruples once the apples leave the hand (1%:1%:4%:16%).

The bruise damage was reduced in the 1983 season which may be due to various reasons, the fruit were much harder, all studies were conducted

TABLE 35: Farm 1, Damage Results, Bramley Applies Rootstock MM106, 1982 Season, Area of Bruises in in sq.mm.

	Sample Point							
	Tree		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%
1	295	98	278	99	255	94	253	88
2	3	1	4	1	11	4	26	9
3	2	1	-	-	4	2	8	2
Total:	300	100	282	100	270	100	287	99
Number of Bruises	16		35		61		160	
Area of Bruises	1247		2225		4971		10593	
% Apples Damaged	5		11		19		39	

TABLE 36: Farm 2, Gang 1, Damage Results, Cox Apples, Rootstock MM106, 1982 Season, Area of Bruises is in sq.mm.

	Sample Point							
	Tree		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%
1	120	100	80	100	73	91	62	78
2	-	-	-	-	6	8	11	14
3	-	-	-	-	1	1	7	9
Total:	120	100	80	100	80	100	80	101
Number of Bruises	4		4		14		69	
Area of Bruises	113		229		1860		5784	
% Apples damaged	3		5		18		46	

TABLE 37: Farm 2, Gang 2, Damage Results, Cox Apples, Rootstock MM106, 1982 Season, Area of Bruises is in sq.mm.

	Sample Point					
	Hand		Bag		Bin	
Grade	f	%	f	%	f	%
1	114	99	105	91	73	63
2	1	1	10	9	26	23
3	-	-	-	-	16	14
Total:	115	100	115	100	115	100
Number of Bruises	4		45		107	
Area of Bruises	261		2872		18903	
% Apples Damaged	3		31		55	

TABLE 38: Farm 3, Damage Results, Cox Apples, Rootstock Mixed, 1982 Season, Area of Bruises is in sq.mm.

	Sample Point							
	Tree		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%
1	120	100	180	100	174	97	163	91
2	-	-	-	-	5	3	11	6
3	-	-	-	-	1	-	6	3
Total:	120	100	180	100	180	100	180	100
Number of Bruises	5		14		33		97	
Area of Bruises	264		396		1873		6256	
% Apples Damaged	4		7		17		37	

TABLE 39: Farm 5, Damage Results, Cox Apples, Rootstock MM106, 1982 Season, Area of Bruises is in sq.mm.

	Sample Point					
	Tree		Hand		Box	
Grade	f	%	f	%	f	%
1	118	98	94	99	65	68
2	2	2	1	1	13	14
3	-	-	-	-	17	18
Total:	120	100	95	100	95	100
Number of Bruises	7		7		137	
Area of Bruises	542		459		14906	
% Apples Damaged	5		6		48	

TABLE 40: Farm 6, Damage Results, Bramley Apples, Rootstock M26 and MM106, 1982 Season, Area of Bruises in sq.mm.

	Sample Point					
	Hand		Bag		Bin	
Grade	f	%	f	%	f	%
1	90	100	82	91	80	89
2	-	-	7	8	8	9
3	-	-	1	1	2	2
Total:	90	100	90	100	90	100
Number of Bruises	3		21		42	
Area of Bruises	157		1998		2463	
% Apples Damaged	3		19		28	

TABLE 41: All Cox Apples, Damage Results, 1982 Season, Area of Bruises is in sq. mm.

	Sample Point									
	Tree		Hand		Bag		Bin		Box	
Grade	f	%	f	%	f	%	f	%	f	%
1	358	99	468	100	352	94	298	79	65	68
2	2	1	2	-	21	6	48	13	13	14
3	-	-	-	-	2	-	29	8	17	18
Total:	360	100	470	100	375	100	375	100	95	100
Number of Bruises	16		29		92		273		137	
Area of Bruises	919		1345		6605		30943		14906	
% Apples Damaged	4		6		21		44		48	

TABLE 42: All Bramley Apples, Damage Results, 1982 Season, Area of Bruises in in sq. mm.

	Sample Point							
	Tree		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%
1	295	98	368	99	337	94	333	88
2	3	1	4	1	18	5	34	9
3	2	1	-	-	5	1	10	3
Total:	300	100	372	100	360	100	377	100
Number of Bruises	16		38		82		202	
Area of Bruises	1247		2382		6969		13056	
% Apples Daamged	5		9		19		36	

TABLE 43: All Apples, Damage Results, 1982 Season, Area of Bruises is in sq. mm.

	Sample Point									
	Tree		Hand		Bag		Bin		Box	
Grade	f	%	f	%	f	%	f	%	f	%
1	653	99	836	99	689	94	631	84	65	67
2	5	1	6	1	39	5	82	11	13	14
3	2	-	-	-	7	1	39	5	17	18
Total:	660	100	842	100	735	100	752	100	95	100
Number of Bruises	32		67		174		475		137	
Area of Bruises	2166		3727		13574		43999		14906	
% Apples Damaged	5		7		20		40		48	

TABLE 44: Damage Results, Cox and Discovery Apples, Rootstock MM106, 1983 Season, from an Experimental Horticulture Station, Area of Bruises is in sq.mmm.

COX								
Grade	Tree	%	Hand	%	Bag	%	Bin	%
I	117	97	238	98	228	95	224	93
II	2	2	2	1	10	4	12	5
III	1	1	-	-	2	1	4	2
Total:	120	100	240	99	240	100	240	100
Number of Bruises	13		9		32		51	
Area of Bruises	943		575		2558		4487	
% Apples Bruised	9		4		13		21	
DISCOVERY								
I			418	100	409	98	395	95
II			1		10	2	22	4
III			1		1		3	1
Total:			420	100	420	100	420	100
Number of Bruises			9		33		46	
Area of Bruises			837		3016		5133	
% Apples Bruised			2		8		11	

at a government horticultural station, all the equipment used was ADAS recommended and the pickers were paid weekly rather than by piece rate. The percentage of bruised fruit is approximately (5%: 3%:9%:15%) and the percentage downgraded is (1%:1%:3%:6%). It is worth noting that the results of the studies at the government horticulture station for 1982 and 1983 are comparable with 1983 results (1%:1%:1%:8%) reflect better quality apples at the station than those found at commercial farms. It would seem that the 1982 data, based on commercial orchards and in a year when fruit was more susceptible to damage, is a better indicator of the problems involved in harvesting apples.

Referring back to the literature search Eksteen (1983) found 0.3% and 3.0% of apples bruised in the picking bag and storage container. Although these are not comparable to the present study due to the study taking place in South Africa with unknown procedures and bruise classifications, the results are similar in that downgrading occurs along the harvesting process.

6.1 'Through-the-Day' Bruise Damage Study and Conclusions

Bruise damage surveys were conducted sampling apples at various points during the apple harvesting system, as previously outlined, and continuing sampling at various times through the day. This was in order to establish whether picking apples throughout a working day affects the quality of the apples at any period during the day.

The studies were conducted at two commercial farms (see Tables 45 and 46) and at the government horticultural research station (see Table 47). The damage levels appear not to follow any evident trend, when the farms are considered together. It might be expected that fatigue in pickers would result in downgrading due to increased damage through the day but this does not seem to occur despite some small evidence of increased bruising. An analysis of variance was performed for the pickers for the time of day and the combined area of slight and

TABLE 45: Farm 3, 'Through-the-Day', Damage Results. Cox Apples, Rootstock MM106, 1982 Season. Area of Bruises is in sq.mm.

Time	0900						1100						1300						1500					
	Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	45	100	42	93	39	87	45	100	45	100	42	93	45	100	45	100	41	91	45	100	42	93	41	91
2	-	-	3	7	5	10	-	-	-	-	1	2	-	-	-	-	3	7	-	-	2	4	2	4
3	-	-	-	-	1	2	-	-	-	-	2	4	-	-	-	-	1	2	-	-	1	2	2	4
Total:	45	100	45	100	45	100	45	100	45	100	45	100	45	100	45	100	45	100	45	100	45	100	45	100
Number of Bruises	1		13		25		3		1		25		6		9		22		4		10		25	
Area of Bruises	28		801		1735		85		28		1738		170		276		1458		113		767		1577	
% Apples Bruised	2		24		33		7		2		42		11		20		40		9		20		56	

TABLE 46: Farm 6, 'Through-the-Day' Damage Results, Bramley Apples, Rootstocks MM106 and M26, 1982 Season. Area of Bruises in sq.mm.

Time	0930						1100						1300					
Sampling Point	Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	30	100	25	83	28	93	30	100	30	100	28	93	30	100	27	90	24	80
2	-	-	5	17	2	7	-	-	-	-	2	7	-	-	2	7	6	20
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-
Total:	30	100	30	100	30	100	30	100	30	100	30	100	30	100	30	100	30	100
Number of Bruises	0		11		7		3		2		16		0		9		19	
Area of Bruises	0		833		286		157		79		870		0		1087		1307	
% Apples Damaged	0		27		17		10		7		23		0		23		43	

TABLE 47: Experimental Horticulture Station, 'Through-the-Day' Damage Results, Discovery Apples, Rootstock MM106, 1983 Season, Area of Bruises in sq.mm

Time	0900			1200			1500		
	Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin
Grade									
I	30	25	28	30	30	28	30	27	24
II		5	2			2		2	7
III								1	
Total:	30	30	30	30	30	30	30	30	30
Number of bruises		11	7	3	2	16		9	19
Area of bruises		833	286	257	79	870		1027	1307
% apples bruised		27	17	10	7	23		23	43

TABLE 48: Analysis of Variance for 'Through-the-Day' Study, 1982 Season

Source	SSQ	df	MSQ	F	P
Between subjects	3880.3	14			
Farms (A)	24.7	1	24.7	0.08	NS
Subjects within groups	3855.6	13	296.6		
Within subjects	5522.9	30			
Times (B)	287.2	2	143.6	0.82	NS
AxB interaction	709.6	2	354.8	2.04	NS
Bx subject within groups	4526.1	26	174.1		
Total:	9403.2	44			

concave bruises on apples, for the two commercial orchards in 1982. The results show that there are no significant differences in the damage levels at the different times of the day. The implication of this is that if fatigue is affecting the pickers, it is affecting them in ways other than increasing damage.

6.2 Analysis of Picking Damage and Conclusions

An analysis of bruise damage was performed on all the apples sampled from the bulk bins, to measure the extent to which the least careful pickers were allowing the fruit to be damaged. The analysis covers all the pickers from all the farms in the 1982 picking season and the data is presented in Table 49. The data is based on a single sample of five apples per picker and is therefore susceptible to outlier bias. Furthermore data refers to apples picked in 1982 which as noted earlier were generally softer than usual and therefore more prone to damage. The figures in column 2 should thus be regarded with circumspection with respect to other years. However the other figures being relative rather than absolute, are probably applicable to other years.

It should be noted that the classes in column 1 have been created with regards to the EEC standards, the limit for Class I is 100 sq.mm. and for Class II is 250 sq.mm. Hence, for 1982, while recognising that outlier bias may exist, the implication is that at least 50% of the fruit picked by the last four pickers is of reject quality before it leaves the orchard.

Perhaps of more significance for other years are the last two columns in the table. These indicate that the worst 1.5% of pickers do 20% of all bruise damage during picking and the worst 4% of the pickers produce 37%, over one third of bruise damage. Since most of this damage occurs in transferring the apples from one container to another, it points to the importance of close supervision around the bins,

TABLE 49: Analysis of Bruise Damage in Orchard Bins, 1982 Season, for all Farms in Study, Area of Bruises in sq.mm

Damage Group	Mean Bruise area/apple	Number of People	% of People	% Bruise Area	Cumulative % of people	Cumulative % bruise area	Cumulative % of people	Cumulative % bruise area
I	0	85	31.8	0	31.8	0.0	99.9	100
II	1-29	106	39.7	14.2	71.5	14.2	68.1	100
III	30-49	32	12.0	14.9	83.5	29.1	28.4	85.8
IV	50-99	22	8.2	18.4	91.7	47.5	16.4	70.9
V	100-149	11	4.1	15.3	95.8	62.8	8.2	52.5
VI	150-249	7	2.6	16.9	98.4	79.7	4.1	37.2
VII	250+	4	1.5	20.3	99.9	100.0	1.5	20.3

and suitable training. It indicates that the desire of farmers to improve their supervision ratios, as mentioned earlier, is well-founded.

6.3 Picking Bag Comparison Study and Conclusions

It was apparent that the type of picking bag used during harvesting varied between and sometimes within farms. To identify differences between the picking bags, a comparative study of the bags was effected at a government horticultural research station. The study aimed to establish whether the picking bag affected the damage levels found on fruit and which was subjectively most acceptable.

Due to time constraints imposed by the shortened picking season in 1982, an exhaustive study of all picking containers was not feasible. However, the four techniques found most frequently during the farm visits discussed earlier were investigated (see Table 50). These represent the main classes of picking containers used, in commercial orchards.

TABLE 50: Bags Studied

Bag	Farms where used Commercially	Weight (kg)	
		Empty	Full
Plastic Bucket	Farm 5	0.35	4.8
Clarke-bag	Farm 1	1.5	9.3
Dutch-nosebag	Farms 1,3,4,6	2.0	10.6
Canvas sack	Farm 2	-	-

Notes:

The plastic bucket was used commercially with wooden crates. However to standardise the study bins were substituted.

Harnesses for the Clarke-bag were not available so it was used in conjunction with a stand, to provide comparison and equal freedom for pickers hands.
The study involved eight pickers working in pairs over two days. Each pair used one type of picking container on the first day and changed bags on the second day. The study was to continue over four days, however, the apple crop was smaller than expected and the study was curtailed.

Samples of 10 apples were taken from the hand, bag and bin of each picker at three times during the day: 0900, 1200 and 1500 hours. Subjective fatigue of the pickers was measured at the end of each day. At the end of the study the pickers ranked the four picking bags in order of subjective performance.

The results are shown in Tables 51 and 52 and are accumulated over the times of the day. This accumulation was carried out because there was no significant difference between times of day as reported earlier. The results of this study are comparable to performance in commercial orchards (though commercial orchards show more downgrading) thus suggesting that differences found are genuine and not localised. No differences were found in the amount of downgrading for fruit in the picking container using Meddis' OMNIBUS test (1981). However, there were significant differences between the containers for fruit in the bin ($H = 14.181, p < 0.03$). The sack bag was significantly worse than the Dutch nosebag when just the two were compared. In the commercial orchards, there were differences in the bag between the canvas sack, the nosebag and the bucket, which were present in the bin as well. However, because of the different farms involved, these results are not as reliable.

This analysis indicates that it is not the filling of the picking bags where the main problems lie, but in the transfer of apples from the vicinity of the tree into the orchard bin, and most probably at the point of emptying into the bin. This analysis points clearly to the need to consider improved methods for bin filling.

TABLE 51: Picking Bag Comparison Study. Damage Results, Cox Apples, Rootstock MM106, at an Experimental Horticulture Station, Area of Bruises is in sq.mm.

Bag	Canvas Sack						Dutch-Nosebag						Plastic Bucket						Clarke-Bag					
Sample Point	Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin	
Grade	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	119	99	115	96	97	81	120	100	119	99	110	92	119	99	116	97	106	88	119	99	117	98	114	95
2	1	1	5	4	16	13	-	-	1	1	9	8	1	1	3	3	13	11	1	1	3	3	6	5
3	-	-	-	-	7	6	-	-	-	-	1	1	-	-	1	1	1	1	-	-	-	-	-	-
Total:	120	100	120	100	120	100	120	100	120	100	120	101	120	100	120	101	120	100	120	100	120	101	120	100
Number of Bruises	8		41		113		7		18		75		7		18		67		6		18		50	
Area of Bruises	522		2209		6888		226		823		3849		424		1360		3704		468		1027		2505	
% Apples Damaged	4		24		48		6		14		44		3		11		40		5		13		32	

TABLE 52: Picking Bag Comparison Study. Commercial and Government Orchards Damage Results, Percentages Downgraded Apples (Clarke Bag omitted due to lack of data in commercial situation).

Bag	Canvas Sack						Dutch-Nosebag						Plastic Bucket/Box			
Farm	Commercial			Government			Commercial			Government			Commercial		Government	
Grade	Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin	Hand	Box	Hand	Bin
1	100	91	71	99	96	81	100	94	90	100	99	92	99	68	99	88
2	-	9	19	1	4	13	-	6	8	-	1	8	1	14	1	11
3	-	-	10	-	-	6	-	-	2	-	-	1	-	18	-	1
Total:	100	100	100	100	100	100	100	100	100	100	100	101	100	100	100	100

The pickers expressed a subjective preference for the Dutch-nosebag.

The study by Brown (1967) comparing the canvas apron, nosebag and Dutch-nosebag also shows the better performance of the Dutch-nosebag; results are shown in the literature study.

7.0 GENERAL CONCLUSIONS ARISING FROM THE SURVEYS, THE DAMAGE STUDIES AND MTM-1 ANALYSIS FOR PICKING AND EXPERIMENTS SUGGESTED BY THESE

It is evident that much more damage occurs to the apples than is expected, before they have left the orchard (some 16% of fruit were of Class II standard or worse in 1982). Most of this damage is seen to occur when the apples have left the tree and are being transferred to containers (damage ratios were 5%: 10%: 20%: 40% for tree:hand:bag: bin in 1982), and reveals a scope for improvement in materials handling. This suggests changes to the current picking bag to orchard bin method.

Further it takes some 17 man-minutes to strip the apples from a standardised tree (Cox MM106), where previous studies suggest that mechanical methods might be able to achieve two minutes per tree, though with more damage. It is also noted that pickers seem unable to use the recommended method consistently, and suffer some discomfort when picking. This suggests an investigation of the current picking method, with a view to finding an improvement. However, since picking costs are only 10% of the total harvesting and marketing costs (MAFF data), financial benefits are likely to be marginal.

A number of different approaches are suggested by the conclusions above, and are outlined below.

7.1 Improve Hand Picking

Since so little time can be spent using the recommended picking method given in the ATB leaflets, other picking methods must be considered. The other methods used by the pickers are in principle slower than the ideal, but because the pickers tend to pick several apples at once (multiple-picking) and transfer them together to the picking bag, overall there is an equivalence of time taken.

The consequence of picking several apples at once needs to be explored. There seems to be a firm belief among farmers that most of the damage done to apples during picking occurs when detaching the apple from the tree, and that picking several apples at once compounds the problem. However, damage study results given earlier indicate that hand damage to apples (1% downgraded to Class II) is fairly marginal compared to damage caused at other stages (e.g. 5% bruising, but only 1% downgraded). It should be noted that this 1% of damage included apples that have been multiple-picked. It may become apparent that with suitable training programmes multiple-picking can become cost effective, by reducing both time taken and damage incurred. Four options must be further explored, these were all observed to be in use in commercial orchards:

a) ATB method as described in the training leaflets, for comparison purposes;

b) Single picking with both hands working in phase because it is likely to be less costly in physiological terms to the pickers, to be known as 1/hand method;

c) Multiple picking with both hands, as discussed above, the 2/hand method;

d) Freestyle, in which the pickers use any of the methods above as dictated by the access to the fruit at the time.

An initial analysis of these methods was carried out to assess the possible contribution that might accrue, by synthesising the methods using MTM-1 from video films of picking taken during the 1982 season. This analysis is given in Appendix 4 and the results summarised in Table 53.

Table 53 indicates that there was potentially a significant saving in time to be made by the 2/hand method, and that none of the methods was

TABLE 53: Standard Picking Times Synthesised From Video Data from the 1982 Picking Season for Three Rootstocks, for Three Yields. Times are in Centiminutes

Rootstock	106			9			27
Yield	Low	Medium	High	Low	Medium	High	Medium
ATB Method	13.35	15.54	17.72	4.28	6.10	7.85	3.07
1/hand Method	14.17	16.56	18.95	4.72	6.79	8.90	3.54
2/hand Method	10.00	11.35	12.70	3.09	4.21	5.43	2.23
Freestyle	13.38	15.58	17.77	4.62	6.62	8.82	3.23

significantly worse than the ATB method. Clearly nothing could be said regarding likely bruise damage; this could only be investigated during the 1983 season.

7.2 Eliminate Bag-to-Bin Damage

A solution may be found either by eliminating the picking bag and transferring the apple directly to the bin from the tree, or by eliminating the bin and using the bag (or some alternative container) as the storage medium.

The former approach is typically what is used in attempts to mechanise picking, as currently manifested in the 'pluck-a-truck' which may be considered to be a sophisticated bin-filler, requiring a gang of pickers to feed it, or in a more advanced form in the combing method suggested by Le Flufy (1981). Evaluation of this is not considered to be within the scope of the brief of this project. Further, due to the nature of the machine it demands a level terrain and a certain style of apple management which is not possible on all farms. Due to these reasons many farmers have expressed their lack of faith in mechanised methods of apple harvesting. So far no feasible suggestions have appeared for manually filling bins without the use of a picking bag, and therefore this method is not considered further.

The latter approach represents a return to the classical methods before bins came into use. In principle, this approach should obviate all the damage caused by emptying bags into bins, i.e. it should prevent damage to 23% of the apples and the downgrading of 15% of the apples (by subtraction of bag data from bin data in Table 41). However the same table indicates that in practice this is not so; the damage is in fact worse. From observations in the field, one reason for this is that pickers do not work with the box always at optimal height; frequently it is placed either on the ground, or on another upended box. The pickers initially work within arm's length of the box, and then slightly beyond; the result is that fruit are tossed into the box. Redesign of the box so that it may be carried by the picker, as is the case with the Clarke bag should produce the expected savings.

However, it must be recognised that there are severe space penalties when it comes to handling and storage. Assuming 1980 costs to be representative of future costs, and using data from the ADAS publication 'Fruit Quality - Tree to Market', data on costs from ADAS personnel, and data on storage space from Bull and Holt (1968), it is possible to calculate the increase in profit from improved quality to be 8p per kilo, and the additional cost of handling and storage to 4.7p per kilo, excluding capital costs. This indicates that by returning to boxes an increase in return of 3.3p per kilo is theoretically achievable; however, it also indicates that if bin-filling damage can be reduced sufficiently, even larger returns are possible by retaining bins instead. Thus it is recognised that redesigning bin filling methods to reduce apple damage would eliminate most harvesting problems.

7.3 Keep the Intermediate Storage but Reduce Transfer Damage to the Apples

The salient point here is that one poorly-emptied bag cascading apples onto other stationary apples can damage far more than the original bagful, and with a group of pickers emptying bags the worst pickers will undoubtedly do more than their fair share of damage. This may be obviated either by using mechanical bin loaders, examples of which are given in Berlage (1981), or by improved training and closer supervision, or by removing the need for bag emptying. The latter could be achieved by using plastic disposable bags fitted as a liner into the picking bag. These can be stored as units within the bulk bin. There are immediate problems with this idea, for example the reduced picking density of apples in a bin, microclimate problems in the bag, and problems of emptying apples for grading purposes.

Alternatively the picker does not transfer apples to the bin. This approach requires the use of detachable bags and a special bag emptying crew. From Tables 30 and 31 it is apparent that 3% of a pickers time is spent emptying bags, and 3% is spent walking to and from the bin, indicating that in terms of wages and time the ratio of pickers to emptiers should be 16:1. However, decoupling picking from emptying allows each part of the process to be optimised, and should enable a significant reduction in damage, particularly during emptying, to be achieved. The very process of task specialisation creates problems at the interface of the tasks. For instance, the placement of full bags must be supervised to ensure the bag emptier does not neglect any of the output. Bag marking must be optimised to retain current pay-schemes. Any transport of bins in the orchard must be monitored to keep pace with the picking. This could be solved by filling bins after the pickers have finished work for the day. This may also enhance safety by the removal of excess personnel and baggage from the orchard and allow the supervisor, who often doubles as the tractor driver (55 of cases, from the farmer questionnaire, see Section 4.2) to do the job of supervision of picking. However this task specialisation may lead to increased boredom in the pickers.

8.0 EXPERIMENTS IN 1983 ARISING FROM THE 1982 FINDINGS

Two series of experiments were devised to explore the implications of the earlier studies. The first series investigated picking methods and the second concentrated on transfer problems from bag to bin. Both series of experiments were carried out at an experimental horticultural station, who made their facilities available for field work. This provided a degree of continuity through the experiments and as the pickers are paid weekly did not interrupt their work as it would on a commercial basis.

8.1 Calibration of the Researchers

As a year had passed since the original series of studies it was apparent that the researchers should undertake calibration exercises to ensure that standards of accuracy in the previous studies could be maintained and checked. The same process, as outlined earlier, was followed and it was established that there was no change in standards in the experiments that follow. Before the commencement of each day of study, a calibration exercise was carried out on each researcher working in the field.

8.2 Experiments to Compare Picking Methods

The reference to 'picking' concerns only the process of apple detachment from the tree by hand, and the release of the fruit into the picking bag. Four methods of picking were evaluated and to ensure the greatest degree of uniformity all the methods were used in conjunction with a Dutch nosebag, worn by the pickers. The methods are briefly described below. In the previous studies it was obvious that pickers encountered difficulties in employing a set style of picking, therefore close supervision was used to try and ensure there was a minimum number of departures from the required method of fruit picking. Thus, apart from the freestyle method described below it could not be stated with certainty that the pickers only used the desired method.

a) *ATB Method:*

This is the method described in leaflet APG1 and pamphlet FR2A8, published by the Agricultural Training Board. This is the 'baseline' method against which other methods could be compared.

b) *'One/hand' Method:*

Here the hands move in phase to pick single apples, in opposition to the ATB method which uses the hands in opposing phases. Possible benefits are a reduction in postural fatigue, more natural hand-eye coordination and greater flexibility in dealing with apple clusters.

c) *'Two/hand' Method:*

This method is basically the same as the 1/hand method, except that the picker, as circumstances dictate, either picks one apple into each hand simultaneously, followed by a second apple into each hand simultaneously or picks two apples into each hand simultaneously. Since this method requires much greater hand-eye coordination and some cooperation between the hands on occasions, possible benefits are a considerable reduction in picking time, though possibly some increase in damage.

d) *Freestyle Method:*

The above methods are based on the specific placement and spacing of apples on the tree. Observational studies indicate that this is not the case; a trained picker using the recommended ATB method had been observed using the required method for only 10-20% of the time. For the rest of the time different methods are used as determined by the clustering of apples on a branch, camouflage and other natural obstacles and also postural difficulties for the picker. The freestyle method requires that pickers pick apples as circumstances dictate, using the guidelines given in Appendix 4.

8.2.1 Evaluation of the Methods

Two main evaluation methods were bruise damage assessment and MTM-1 analysis, following the procedures used in the 1982 studies. In addition subjective measures of fatigue were obtained. Attempts were made to measure productivity and to assess objectively physiological fatigue. These were abandoned when it became obvious that they were difficult to administer in the orchard.

As stated previously a series of experiments were carried out. This became necessary due to the vagaries of nature and unforeseen hitches in field experimentation that necessitated departures from the planned programme.

8.2.2 Experiment I, Discovery Apples, Rootstock MM106

Eight pickers participated, working in pairs, all using Dutch-nose-bags, which were emptied into bulk bins. Each pair adopted a different picking method, for which they were given verbal instructions, and used throughout the day. The pickers experience of apple picking varied from picker to picker, see Table 54.

Samples of apples were taken from: the tree, and the picker's hand, bag and bin as previously outlined, the latter three samples being taken three times during the day.

A total of 840 apples being sampled and examined for bruises.

This study was planned to continue over four days which would have allowed each picker to attempt each method in turn. However, the crop of Discovery apples was small and in the event only resulted in one and a half days of harvesting. On the second day the pickers were filmed.

TABLE 55: Damage Results, Picking Study, Discovery Apples (22.8.83) Apple Grades

Picking Method		ATB						1/Hand						2/Hand						Freestyle					
Sample Point		Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin	
Time Class		f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
0900	1	20	100	19	95	19	95	20	100	19	95	18	90	20	100	17	85	18	90	20	100	19	95	20	100
	2	-	-	1	5	1	5	-	-	1	5	2	10	-	-	3	15	1	5	-	-	1	5	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-
1200	1	20	100	20	100	17	85	20	100	18	90	19	95	19	95	19	95	19	95	20	100	19	95	18	90
	2	-	-	-	-	2	10	-	-	1	5	-	-	1	5	-	-	-	-	-	-	1	5	2	10
	3	-	-	-	-	1	5	-	-	1	5	1	5	-	-	1	5	1	5	-	-	-	-	-	-
1500	1	20	100	19	95	19	95	20	100	19	95	19	95	20	100	20	100	19	95	19	95	20	100	19	95
	2	-	-	1	5	1	5	-	-	1	5	1	5	-	-	-	-	1	5	1	5	-	-	1	5
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OVER-ALL TIMES	1	60	100	58	97	55	92	60	100	56	93	56	93	59	99	56	93	56	93	59	99	58	97	57	95
	2	-	-	2	3	4	7	-	-	3	6	3	6	1	1	3	6	2	3	1	1	2	3	3	6
	3	-	-	-	-	1	1	-	-	1	1	1	1	-	-	1	1	2	3	-	-	-	-	-	-

TABLE 56: Damage Results Picking Study, Discovery Apples (22.8.83), Bruise Data

Picking Method		ATB			1/Hand			2/Hand			Freestyle		
Sample Point		Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin
Time	Bruises per Sample												
0900	Number	0	5	6	1	5	5	0	4	6	1	3	2
	Area	0	239	212	28	243	315	0	247	532	50	281	100
	% Apples damaged	0	20	20	5	20	20	0	15	15	5	15	10
1200	Number	1	1	5	0	3	6	1	2	5	3	1	6
	Area	50	50	582	0	419	661	201	306	837	90	153	482
	% Apples damaged	5	5	15	0	10	10	5	5	15	10	5	30
1500	Number	0	2	1	0	2	1	0	1	2	2	3	6
	Area	0	279	113	0	163	201	0	50	106	156	128	346
	% Apples damaged	0	10	5	0	10	5	0	5	10	5	15	25
Overall Time	Number	1	8	12	1	10	12	1	7	13	6	7	14
	Area	50	368	907	28	825	1177	201	603	1475	296	562	928
	% Apples Damages	2	12	13	2	12	13	2	8	13	7	12	22
Total Number of Apples Sampled		60	60	60	60	60	60	60	60	60	60	60	60

TABLE 54: Pickers Experience

Picker	Previous Experience (years)	Picking Method Used
1	2	ATB
2	0	ATB
3	3	1/hand
4	0	1/hand
5	1	2/hand
6	1	2/hand
7	0	Freestyle
8	0	Freestyle

Appropriate statistical analyses, using Meddis OMNIBUS test (Meddis, 1981) indicated that there was no significant difference between the methods, with respect to the EEC grading standards (Table 55) ($H = 1.1$, $P < 0.05$), and no significant difference for bruise areas ($H = 2.4$, $P < 0.05$), despite the high total bruise area for 2/hand in Table 56. There were significant differences between the sample points ($H = 16.1$, $P < 0.001$), where the damage is in the approximate ratio (3%:9%:15%) for bruise areas in the (hand:bag:bin) and (1%:3%:6%) for downgrades from Class I. There is also significantly less damage to the fruit in the mid-morning, though this may be due to a training effect, as it was the first apple picking day of the season.

8.2.3 Experiment II, Discovery Apples, Rootstock MM106

This was a one-subject experiment, using an individual widely regarded as an expert picker of considerable experience. All four methods were evaluated as shown in Table 57, the damage results are shown in Tables 58 and 59.

TABLE 58: Damage Results, Picking Study, Discovery Apples, Expert Picker, Tree and Bin Data (23.8.83) Apple Grades

Picking Method/Sample Point	Tree		ATB		1/Hand		2/Hand		Freestyle	
Class	f	%	f	%	f	%	f	%	f	%
1	117	98	73	99	45	83	47	98	77	99
2	2	1	-	-	5	9	1	2	1	1
3	1	1	1	1	4	7	-	-	-	-
Total:	120	100	74	100	54	99	48	100	78	100

TABLE 59: Damage Results, Picking Study, Discovery Apples, Chargehand and Tree, and Bin Data (23.8.83), Bruise Data

Picking Method/Sample Point	Tree	ATB	1/Hand	2/Hand	Freestyle
Bruises per Sample					
Number	13	10	28	5	3
Area	943	596	2883	387	175
% Apples Damaged	9	12	30	10	4
Total Number of Apples	120	74	54	48	78

TABLE 57: Chargehand Study

Tree	Picking Method Used	Number of Apples/Tree
1	ATB	74
2	1/hand	54
3	2/hand	48
4	Freestyle	78

Analysis of the results using Meddis' OMNIBUS test shows that the 1/hand method was significantly worse than the other methods with respect to the EEC standards ($H = 56.4$, $P > 0.001$); there was no difference between the other three. With respect to bruise areas, the 1/hand was again worse than the average of the other three. The freestyle method was better than the average of the other three, though it was not significantly better than the 2/hand method in a paired comparison.

Overall the results of this experiment concludes that the 1/hand method is unsatisfactory.

8.2.4 Experiment III, Worcester Apples, Rootstock MM106

Five subjects were used in a full randomised block experiment, for the four picking methods, at one time of day and with apples sampled only from the orchard bin. The five subjects were 1,2,3,5 and 6 as described in Table 54. The results are shown in Tables 60 and 61.

The statistical analysis using Meddis' OMNIBUS test (1981) indicates that the 2/hand method is significantly worse than the other three with respect to the EEC grades ($H = 1977.41$, $P < 001$), but not with respect to bruise damage area. There are no significant differences between the other three methods. This experiment concludes that the 2/hand method is producing slightly more damage than the others.

TABLE 60: Damage Results, Picking Study, Worcester Apples (9.9.83), Apple Grades

Picking Method	ATB		1/Hand		2/Hand		Freestyle	
Class	f	%	f	%	f	%	f	%
1	475	99	397	99	491	98	467	98
2	4	1	2	1	5	1	7	1
3	1	-	1	-	3	1	1	-
Total:	480	100	400	100	499	100	475	99

TABLE 61: Damage Results, Picking Study Worcester Apples (9.9.83), Bruise Data

Picking Method	ATB	1/Hand	2/Hand	Freestyle
Bruises per Sample				
Number	40	24	68	30
Area	2593	1490	4018	2473
% Apples Damaged	8	6	11	6
Total Number of Apples	480	400	499	475

TABLE 62: Damage Results, Picking and Bag Study, Cox Apples (28.9.83 and 29.9.83), Apple Grades

Picking Method		ATB						2/Hand						Freestyle					
Sample Point		Hand		Bag		Bin		Hand		Bag		Bin		Hand		Bag		Bin	
Bag	Class	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Nosebag	1	29	97	29	97	23	77	60	100	55	92	58	97	30	100	30	100	29	97
	2	-	-	1	3	7	23	-	-	4	6	2	3	-	-	-	-	1	3
	3	1	3	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
	Total:	30	100	30	100	30	100	60	100	60	100	60	100	30	100	30	100	30	100
Nosebag plus Liner	1	30	100	30	100	30	100	60	100	59	98	60	100	30	100	30	100	30	100
	2	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	30	100	30	100	30	100	60	100	60	100	60	100	30	100	30	100	30	100
Both Bags	1	59	98	59	98	53	88	120	100	114	95	118	98	60	100	60	100	59	98
	2	-	-	1	2	7	12	-	-	5	4	2	2	-	-	-	-	1	2
	3	1	2	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	Total:	60	100	60	100	60	100	120	100	120	100	120	100	60	100	60	100	60	100

TABLE 63: Damage Results, Picking and Bag Study, Cox Apples (28.9.83 and 29.9.83), Bruise Data, Area is in sq. mm

Picking Method		ATB			2/Hand			Freestyle		
Sample Point		Hand	Bag	Bin	Hand	Bag	Bin	Hand	Bag	Bin
Bag	Bruises per Sample									
Nosebag	Number	1	6	15	2	14	6	0	0	4
	Area	314	397	1314	78	1197	535	0	0	291
	% Apples damaged	3	20	50	3	23	10	0	0	13
Nosebag plus Liner	Number	0	1	1	0	6	0	0	0	0
	Area	0	78	50	0	447	0	0	0	0
	% Apples Damaged	0	3	3	0	10	0	0	0	0
Both Bags	Number	1	7	16	2	20	6	0	0	4
	Area	314	475	1364	78	1644	535	0	0	291
	% Apples Damaged	2	12	27	2	17	5	0	0	7
Total Number of Apples Damaged		60	60	60	120	120	120	0	60	60

8.2.5 Experiment IV, Cox Apples, Rootstock MM106

Each of six pickers used three of the four methods (ATB, 2/hand and freestyle) for four work periods over three days. In addition a second factor was introduced in that the pickers were divided into two groups of three, one group of which used plastic liner bags in the Dutch nosebag and the other group did not. The first work period was used to give the pickers some experience in the use of the liner bags. The subjects used were 3, 5 and 6 also three pickers who had not picked during previous years though had been picking apples for some weeks, these were numbers 9, 10, 11. The results of the study are given in Tables 62 and 63.

The analysis using Meddis' OMNIBUS test (1981) shows no significant differences between the methods with respect to the EEC standards. However the freestyle method produced significantly the least number of bruises, and the least bruise area, with the 2/hand method producing slightly more than the ATB method.

8.2.6 Conclusions Arising from Experiments I to IV

Considering the bruise damage data from the experiment, two conclusions are apparent. Significantly more damage is found on the apples as they progress through the harvesting process, from tree to bulk bin.

With the possible exception of the 1/hand method (see Experiment II) there is no statistically significant differences between the four picking methods, with respect to the EEC grading standards. However, using the bruise damage measures, the 1/hand method does appear to offer little future, and could be discarded without further consideration. The 2/hand method also appears to cause more damage but may be cost-effective when picking time is taken into account (see later).

8.3 Experiments to Assess Liner Bags

A series of experiments were conducted to assess the feasibility of the concept of using a bag to transfer apples from the picking bag to the bulk bin. If this proved an acceptable solution to the damage problem, it would then be reasonable to explore the consequences for storage and grading.

From surveys conducted in commercial orchards in 1982 it was apparent that out of the four picking systems examined: nosebag, Clarke-bag, sack and box, the nosebag and Clarke-bag were preferable with respect to damage to apples and time to pick a tree. The sack had been rejected on terms of damage by some picking cooperatives and the box was rejected on the basis of wasted space (30%) in stores.

The Clarke-bag, although performing well, was very dependent on tree type and apple size. As it was hung by a hook from the waist it hung lower than the nosebag increasing the reach and move times of apple picking with apples above shoulder height. When ladder work was required for the 10% of apples on rootstocks 106 Clarke-bag obstructed movement up and down ladders. This was because it either hung against the legs or had to be carried in one hand so interfering with balance and stability. In comparison the nosebag was adjusted to hang either side of the body out of way, leaving two free hands to grasp the ladder and to pick apples.

Generally the harness of the Clarke-bag was inconvenient and potentially more dangerous. It consisted of a waist strap and hook which rested and therefore exerted all pressure, on the lower lumbar region of the back, the area in which back pain is more prevalent, whereas the nosebag harness distributed weight over both shoulders.

With regard to apple size the Clarke-bag, under observation from a farmer who uses it commercially, was found to damage more apples, when the apples were larger. It was thought this occurred because of the size of the exit trap which was blocked when emptying larger apples. As the general move in pomology is towards larger fruit because of commercial pressure this problem will increase.

The Clarke-bag, because of its structure and opening mechanism, was found to be less durable than the nosebag whereas the nosebag (Dutch-style) is most widely used and recommended by the ATB. Its aluminium frame was found to be protective to fruit, when a picker moves around a tree and durable. For these reasons, the Dutch-style nosebag will be recommended for use and adapted to harvesting methods suggested and used in the following experiments.

The liner-bag used in these studies was a standard supermarket plastic shopping bag. It was found that this size fitted conveniently into the Dutch-nosebag, with its handles protruding. One of these could be looped over the catch at the front of the nosebag, and the other could be tucked between the nosebag and the picker to prevent the liner-bag from slipping down into the nosebag as it was filled. The handles could then be used to remove the full bag. Spare liner-bags were kept folded at the bottom of the nosebag. Pilot experiments indicated that the liner-bag should be removed when it was about two-thirds full. At this level it weighed about 7 kg, compared to a normal nosebag, filled weight of about 10 kg. This lighter load should be more acceptable to the pickers. A two-thirds full liner-bag could also be packed fairly efficiently in the bulk bin; this is discussed later. Liner-bags were removed by the pickers and were placed by the tree. The liner-bags were moved at the end of the day and packed in bulk bins.

Half of the liner-bags used in the studies were ventilated, by means of 40 holes cut into the bag sides. The rest were termed unventilated.

8.3.1 Experiment V, Cox Apples, Rootstock MM106, Picked With and Without Liner-Bags

As previously mentioned in Experiment IV, three pickers used liner bags and three worked normally with Dutch-nosebags only. Each of the pickers used three picking methods: 2/hand, ATB and freestyle. Samples were taken from the hand, liner-bag in the nosebag and liner-bag on the ground for the liner bag group, and from the hand, nosebag and bin for the normal group. The data can be found in Tables 62 and 63. It should be noted that this experiment was unbalanced and that the equivalence of the conditions in this analysis relies upon the non-significant grade out differences between picking method found in the earlier experiments.

Analysis of the data using Meddis' OMNIBUS test (1981) indicate that there is no significant differences at the first sampling point. However there are significant differences at the second and third sampling points ($Z = 2.1$, $p < 0.02$ and $Z = 3.42$, $p < 0.01$ respectively); there is significantly less damage associated with the liner-bags. This is especially so at the third sampling point; it appears to be possible to obtain 100% Class I apples just prior to loading the apples to the bin.

The significant difference at the nosebag stage is probably due to the increase in care required to ensure that the top of the liner-bag is not caught by the hands or clothing to obscure the bag opening. The consequence was that the apples were placed in the liner-bag rather than being dropped the last few centimetres.

The significant difference at the third point could be eradicated by the packing of the liner-bags into the bulk bin. This is discussed next.

Four bulk bins were marked and set aside for this study. Two of the bins were filled with liner-bags, one with ventilated bags, the other with unventilated bags. The two other bins were filled normally, with apples from the other group of pickers.

Some brief experimentation took place to optimise the packing of liner-bags in the bin to reduce the 'dead space' between the bags. It was found that if the liner-bags were more than two-thirds full then 35 bags could be packed in the bin. If the bags were two-thirds full or less, 45 bags could be packed. Data is given in Tables 64 and 65.

For the ventilated bags no special precautions were taken in packing. However in the case of the unventilated bags it was thought to be of interest to discover the effect of enclosing the apples in their own microclimate. Accordingly the bags were packed on their sides with the open end tucked underneath the bag. It proved possible to pack the bags in five layers of three x three liner-bags as shown in Figure 7. The bins were sent to cold store (29.9.83). Two months later (22.11.83) they were removed for analysis.

TABLE 64: Bin Loads in Liner-Bag Experiment

Bin 1 -	45 plastic bags of apples
Bin 2 -	35 plastic bags (with ventilation holes) of apples
Bins 1 and 2	contained apples picked by the freestyle methods
Bin 3 -	apples picked by the 2/hand method
Bin 4 -	apples picked by the ATB method

TABLE 65: Weights of Bins

Bin Description	Total Weight (kg)	Weight/Bin (kg)
Bin 1 (average bag weight = 7.1 kg)	318	318
Bin 2 (average bag weight = 8.9 kg)	311	311
Bin 3 and Bin 4	693	346
12 Freepack Bins	4091	341
8 Freepack Bins	2640	330
4 Freepack Bins	1371	343

Average weight of freepack bin = 338 kg.
Average weight of bin with plastic bags of apples = 315 kg.
This gives a 93% packing of bins when using plastic bags, which is reasonable, and if damage is reduced sufficiently by using plastic bags, will be cost effective.

A damage study was performed on Bins 1, 3 and 4, the bins being divided as dictated by the plastic bags, see Figure 5. The 45 bags were packed in five layers of nine bags to produce a three-dimensional grid in Bin 1. Five bags were sampled, 50 apples being taken out of the bags and assessed for damage.

The bags were removed from the following points in the bin:

1AX
2BY
3CZ
4CY
5AY

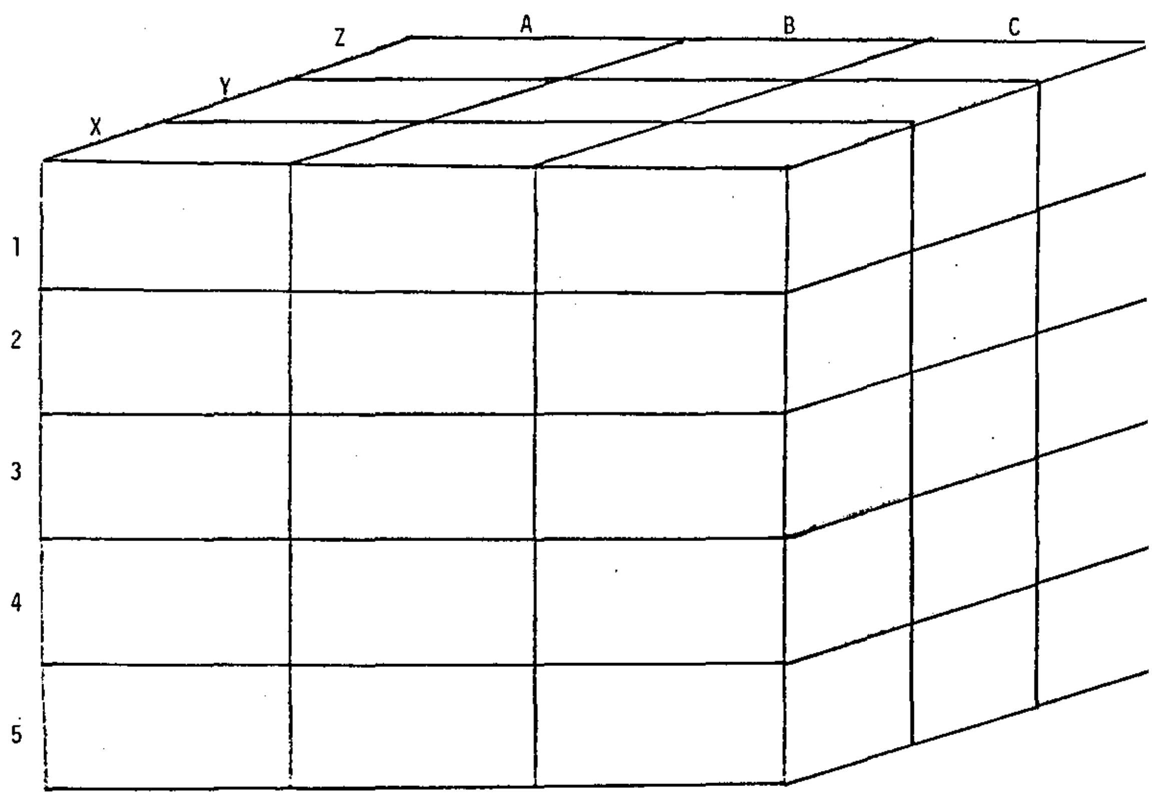

FIGURE 5: SAMPLING POINTS IN THE BIN

TABLE 66: Damage Results from Bin Study (22.11.83) Apple Grades

Sampling Point	Class	Bin 1		Bin 3		Bin 4	
		f	%	f	%	f	%
1AX	1 2 3	49 1 -	98 2 -	46 4 -	92 8 -	50 - -	100 - -
2BY	1 2 3	44 5 1	88 10 2	46 4 -	92 8 -	49 1 -	98 2 -
3CZ	1 2 3	49 1 -	98 2 -	49 1 -	98 2 -	45 3 2	90 6 4
4CY	1 2 3	49 1 -	98 2 -	45 4 1	90 8 2	49 - 1	98 - 2
5AY	1 2 3	47 2 1	94 4 2	45 4 1	90 8 2	41 7 2	82 14 4
Overall Results	1 2 3	238 10 2	95 4 1	231 17 2	92 7 1	234 11 5	94 4 2

TABLE 67: Damage Results from Bin Study (22.11.83) Bruise Data

Sampling Point	Bruises per Sample	Bin 1	Bin 2	Bin 3
1AX	Number	11	21	17
	Area	567	1048	610
	% apples damaged	22	34	30
2BY	Number	13	35	24
	Area	1562	1506	824
	% apples damaged	24	50	42
3CZ	Number	13	32	36
	Area	620	1247	1829
	% apples damaged	20	58	56
4CY	Number	13	35	37
	Area	675	1948	1728
	% apples damaged	26	46	60
5AY	Number	22	35	42
	Area	1302	1778	3090
	% apples damaged	34	52	56
Overall Results	Number	72	158	156
	Area	4726	7527	8081
	% apples damaged	25	48	49
Total Number of Apples Sampled:		250	250	250

In Bins 3 and 4, 50 apples were sampled from similar positions. The results are given in Tables 66 and 67.

With respect to the EEC grading standards, there was no statistically significant differences between the bins overall, using Meddis' OMNIBUS test (1981). However there were differences between individual sampling points, though these were not consistent and therefore do not present a cohesive picture. These results are therefore disregarded.

However there were marked differences between the bins with respect to bruise areas, and to the number of bruised apples. Bin 1 was consistently better than the other two.

The amount of bruising also differed between layers in the bins. The top level was relatively undamaged, the three middle layers were about equal in damage, and the bottom layer was the worst affected. This reflects a well-known finding. It was also found that the apples towards the middle of the bin were more bruised in the loose-packed bins. It is thought that this reflects the fact that pickers emptying nosebags cannot reach the centre of the bin to release the apples gently from the nosebag.

Apples that had rotted were counted in bins 1, 2 and 3. Bins 1 and 2 had 255 (approximately 11% of the bin) and 333 (approximately 15%) rots respectively, and there was no correlation between rots and number of apples per bag. 385 (approximately 17%) rots were found in bin 3. It appears that the microclimate in the unventilated bags in bin 1 reduced the spread of rots fairly successfully.

8.3.2 Experiment VI, Cox Apples, Rootstock MM10, Picked With and Without Liner Bags

A final corroborative study was made to assess the effect of using liner bags, in view of the problems mentioned in Experiment V. Two blocks of three subjects were used, each block with and without the

TABLE 68: Damage Results, Bag Study, Cox Apples, 12.10.83 and 13.10.83, Apple Grades

Bag		Nosebag						Nosebag Plus Liner					
Sample Point		Hand		Bag		Bin		Hand		Bag		Bin	
Time	Class	f	%	f	%	f	%	f	%	f	%	f	%
0930	1	60	100	59	98	57	95	60	100	58	97	56	93
	2	-	-	1	2	3	5	-	-	1	2	4	7
	3	-	-	-	-	-	-	-	-	1	2	-	-
1130	1	60	100	59	98	56	93	60	100	58	97	58	97
	2	-	-	1	2	3	5	-	-	2	4	2	4
	3	-	-	-	-	1	2	-	-	-	-	-	-
1330	1	29	97	29	97	25	83	28	93	27	90	30	100
	2	1	3	1	3	3	10	2	7	2	7	-	-
	3	-	-	-	-	2	7	-	-	1	3	-	-
1530	1	30	100	29	97	27	90	29	97	30	100	28	93
	2	-	-	1	3	3	10	1	3	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	2	7
Overall Times	1	179	99	176	98	165	92	177	98	173	96	172	96
	2	1	1	4	2	12	7	3	2	5	3	6	3
	3	-	-	-	-	3	2	-	-	2	1	2	1
Total:		180	100	180	100	180	101	180	100	180	100	180	100

N.B. All apples sampled from the tree were found to be grade I.

TABLE 69: Damage Results, Bag Study, Cox Apples, 12.10.83 and 13.10.83
Bruise Data.
Area of Bruises is in sq.mm.

Bag		Nosebag			Nosebag Plus Liner		
Sample Point		Hand	Bag	Bin	Hand	Bag	Bin
Time	Bruises per Sample						
0930	Number	3	2	3	0	3	8
	Area	191	191	379	0	457	887
	% Apples Damaged	5	3	5	0	5	13
1130	Number	2	1	5	1	3	4
	Area	141	201	1020	50	344	394
	% Apples Damaged	3	2	8	2	5	7
1330	Number	1	2	6	3	3	0
	Area	113	251	997	480	593	0
	% Apples Damaged	3	7	20	10	10	0
1530	Number	0	1	6	1	0	2
	Area	0	254	547	201	0	508
	% Apples Damaged	0	3	20	3	0	7
Over-all Times	Number	6	6	20	5	9	14
	Area	445	897	2943	731	1394	1779
	% Apples Damaged	3	3	11	3	5	8
Total Number of Apples Sampled:		180	180	180	180	180	180

TABLE 70: Subjective Discomfort Experienced by Pickers in Experiment 1, Results are Percentage Discomfort

Subject	Neck		Shoulders		Thorax Region		Lumbar Region	
	Left	Right	Left	Right	Left	Right	Left	Right
1	1	3	-	-	-	-	-	-
2	4	4	-	-	-	-	-	-
3	6	1	3	-	-	-	-	-
4	57	59	-	-	20	21	-	-
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
7	12	29	6	21	-	-	-	-
8	24	32	10	2	-	-	-	4

liner-bags in turn, and the freestyle picking method, subjectively preferred by the pickers, was used. The study extended over two days, and damage assessments were made at four times during the day. The results are given in Tables 68 and 69.

Analysis of the results using Meddis' OMNIBUS test (1981) indicated that with respect to the EEC grading standards, there was no statistically significant benefit from using liner-bags ($Z = -1.07$, $p = 0.14$). Neither was there a significant benefit with regard to bruise areas, nor the number of bruises.

Since Experiment V indicates that liner-bags are of benefit and this experiment is equivocal, it must be concluded that the benefits of liner-bags remain unproven, but that further research is indicated.

8.4 Subjective Discomfort of the Pickers

The subjective discomfort of the pickers was noted in order to determine whether any of the particular picking methods, or the new method of transferring apples to bins caused any more or less discomfort. The measures of discomfort were made hourly. The measures of discomfort were noted as a percentage along a scale marked 'no discomfort' to 'very uncomfortable', see Figure 1.

The problems that were noted involved the bag design and bag use. Problems were specifically attributed to the pressure exerted by the bag harness and the strain of emptying the bag into an empty bin.

During Experiment I, subjects 5 and 6 did not note any discomfort. The discomfort noted by the subjects is given in Table 70, as an average score throughout the day.

It should be noted that the pickers with the least experience (see Table 54) experienced the greatest discomfort, and this follows throughout the studies. However, pickers 7 and 8, employing the freestyle method noted less discomfort than picker 4 using the 1/hand method. Pickers 1, 2, 5 and 6 are males and generally appeared to suffer less than the female pickers. The greatest area of discomfort is the neck region where the bag harness hung.

In Experiment IV three new pickers who had been picking apples for several weeks took part in the experiment. Pickers 3, 5 and 6 were also included. After picking by each of the methods over several hours each picker rated their subjective discomfort. Pickers 3, 5 and 6 experienced no discomfort for any of the picking methods. Pickers 9 and 10 noted 25% discomfort on average in both shoulders whilst using the freestyle picking method. Pickers 9, 10 and 11 experienced on average 50% discomfort in their arms whilst using the ATB picking method and pickers 10 and 11 experienced 20% discomfort when using the 2/hand picking method.

Again these problems were attribured to the bag harness design, no specific discomfort being attributed to the picking methods or bag emptying when using the Dutch-nosebag plus liner.

With Experiment VI pickers 3, 5 and 6 again noted no discomfort. Three new pickers were introduced to the study: 12, 13 and 14. Picker 13 was a male and noted no discomfort. Consistently throughout the study picker 13 noted about 50% discomfort where the straps of the bag harness crossed over on her back, whereas picker 14 noted an average discomfort of 50% on her shoulders where the straps hung. This indicates that the bag and bag harness should be redesigned and this is discussed in Appendix 6.

8.5 MTM Analysis

During the experiments video films were taken of the pickers employing the various methods, whilst using the Dutch nosebag with and without a plastic lining bag. These have been analysed to produce MTM times for picking a single apple, by each of three methods.

1. The ATM recommended method
2. The 1/hand method
3. The 2/hand method.
4. A fourth method 'freestyle' was utilised in the field, which consisted of letting the pickers pick as they felt comfortable. This consisted of the above three formal methods being used as required by the tree formation and apple distributions. Another three methods were adopted by the pickers using freestyle and these are described in Table 71.

To produce MTM times for the freestyle method it was necessary to establish the frequency by which each of the six picking methods was used. The use of the methods is determined by the apple distribution over a tree, in particular how apples are clustered: single apples growing over a branch are picked by the ATB method, whereas apples growing in pairs are picked by the 1/hand method. Apples growing in clusters of four are picked by the 2/hand method, those in clusters of three by the 1 and 2/hand methods (for the latter method and other cluster work see Table 71).

Using the MTM times produced it has been possible to derive a time to strip a tree for each of the four methods of picking studied during the 1983 harvest. It is possible to compare these with MTM times, synthesized from data of the 1982 harvest (see Appendix 2), based on the first three formal methods. This produces an indication of the extent to which the method is maintained and whether it can be trained.

Table 71 gives the MTM times (seconds) for each of the picking methods and a description of some picking methods used when pickers pick free-style. The times produced are for picking at various heights and these are used in calculations involving the first three formal methods. However, calculations involving the freestyle method of picking are based on the frequency at which each method is employed to strip the apples from a tree. This is determined by photographic analysis to establish the frequency of various apple distributions, the heights at which the individual apple distributions occur cannot be derived from photographs, so an average apple picking time over all heights is used for MTM analysis of the freestyle method.

The initial MTM times include a proportion of occasions when more than one apple was picked in a cycle. This is occasioned by the clustering of apples and the integrated nature of the picking method.

The data has been applied to apple trees on three rootstocks (see Table 72) as suggested by ADAS personnel (private communication - 4.5.83). The distribution of apples over the trees is based on work by Holt and Green (1971) on Cox 106. The percentages of fruit over the tree have been transferred to rootstocks 9 and 27 on the assumption that tree pruning is duplicated on each tree, which is standard procedure. The picking zones (i.e. overhead reach, shoulder height, waist height) were determined from anthropometric tables (Panero and Zelnick, 1980), they amalgamate male and female data, as pickers are of both sexes.

Table 73 considers the three rootstocks: 106, 9 and 27. Rootstocks 106 and 9 have been planted extensively and data on yields for Cox apples are well documented (Preston, 1967; Anon, 1982; Andrews, 1983; Anon 1978). The data from various reports has been considered and has been used to provide three yields for each tree: low, medium, high. Rootstock 27 has not been planted extensively for dessert apples, though some orchards have been planted with culinary varieties. ADAS personnel (private communication - 20.7.83) suggest that rootstock 27 would yield approximately 14 kg of dessert apples and this has been taken as an average yield. The yield (kg) of apples for each tree has been multiplied by 100 to obtain the number of apples per tree. This is derived from the average Cox weight of 100g (data supplied by personnel at East Malling Research Centre). The yield for each tree has been divided into the number of apples per picking zone (based on data in Table 72) for each tree type and yield.

Table 74 combines the data from Table 71 on single apple picking times with the apple distributions in Table 73. The time to pick a single apple in a zone, by each of the methods, is multiplied by the number of apples in that zone. The time to pick all the apples in each zone is summed for each of the methods. This produces total apple picking times, for the three formal picking methods, on the varying yields of the three rootstocks, for the average picker.

Table 75 calculates the times (seconds) required for the freestyle picking method, by combining the data in Table 71 on single apple picking times with the photographic analysis of apple distribution. From the photographic analysis the percentages by which the various picking methods are used can be determined. These percentages are multiplied by the yields for the tree to produce the number of apples picked by each method. These are multiplied by the figures from Table 71 on single apple picking times. The total apple picking times for each method are summed to give total apple picking times for a free-lance method, for an average picker.

Table 76 calculates the times (seconds) taken for average pickers to perform the non-picking aspects of the picking task, from three types of tree of varying yields. The time accounts for the use of a Dutch nosebag with and without a plastic lining bag. The Dutch nosebag is emptied directly into a bin whereas the lining bag is lifted by the picker out of the Dutch nosebag and placed on the ground by the tree. The bag is then placed carefully into a bin by a different person, and assumes that the bins are moved along the rows by the tractor. This obviates the need to place bins in the orchard rows prior to picking.

Walking distance to and from the bin for pickers using the Dutch nosebag without a lining bag is estimated from the bin distribution in orchards at a government research station. Walking around the tree is estimated as:

3 x 'the tree spread circumference'

This allows pickers to walk once around the tree and at each metre move in towards the tree centre one metre, and out again. This enables pickers to pick the apples in the centre of the tree and at the perimeter.

The ladder work is calculated for rootstocks 106 and 9 only, as rootstock 27 does not grow above overhead reach. On rootstock 9 the maximum number of apples in the ladder zone is four. It is estimated that with careful ladder positioning the ladder need only be moved and climbed once. With rootstock 106 the number of apples in the ladder zone ranges from 112 to 168. As the distribution of apples over the ladder zone is unknown, it is assumed to be uniform. With consideration of horizontal arm reach it seems reasonable to suggest that the ladder be positioned at equal intervals around the tree of approximately one metre. This leads to 10 ladder moves and climbs.

The non-picking orchard time for a picker using a Dutch nosebag emptied into a bulk bin is equivalent to the time it takes a picker to empty the bags filled plus walking time to and from the bin and around the tree plus ladder work time.

The total non-picking orchard time for a picker using a Dutch nosebag in conjunction with a plastic lining bag is the sum of bag movement time (from nosebag to ground to bin) plus walking time around the tree plus ladder work time. Replacing the lining bag was seen to occur as the picker walked to a new picking position, and has been discounted.

Table 77 gives the total times (seconds) for a picker to pick all the apples from the three types of trees of different yields and transfer them to bulk bins. The figures represent the picking time plus bin filling time plus walking plus ladder work time. The times cover the four picking methods used in conjunction with a Dutch nosebag with and without a plastic lining bag.

Table 78 adds a 28% fatigue allowance to the data in Table 77, based on weight and pressure, working posture, job duration, personal allowance, mental and physical monotony (Anon 1977). The data is converted to minutes. It is apparent that using the Dutch nosebag with or without plastic lining bags has no significant effect on the time taken to strip a tree. However, the time is noticeably faster for a picker using the 2/hand method. This is followed by the ATB method, freestyle method and lastly the 1/hand method.

Table 79 is an extension of the MTM analysis taking into consideration the performance of good and poor pickers. By plotting the pickers performances on cumulative percentage graphs it is possible to determine a range of pickers abilities. The good picker is defined as the median picker in the lower quartile of the picking times range and the poor picker as the median of the upper quartile, the 12.5th and 87.5th percentiles respectively. As with Table 71, ladder height picking was not observed with the 1/hand and 2/hand methods, so the values determined in the high region have been substituted. The freestyle methods have again been extrapolated from the three formal methods. Differences in pickers abilities with regards to non-picking activities have only been noted in the emptying of the Dutch nosebag into the bin, the results are shown in Table 79 (seconds).

Table 80 expands upon the data in Table 79 to give total picking times (seconds) for each of the methods and total non-picking times using a Dutch nosebag with and without a plastic lining bag. The times cover the three rootstocks and the different tree yields. The figures again cover the range of pickers abilities: the poor picker (87.5th percentile) and the good picker (12.5th percentile).

In Table 81 a 28% fatigue allowance as previously outlined, is added to the total times to strip a tree. The figures have been converted to minutes and cover the pickers abilities whilst using the four picking methods on the three rootstocks of varying yields. The data shows that the difference in time between the methods generally follow the patterns of the data in Table 78.

Tables 82 and 83 compare the actual and synthesized (see Appendix 2) times to strip a tree, in minutes, and as a percentage of the most time absorbing method, respectively. Overall the ATB, 1/hand and freestyle methods were overestimated and the 2/hand method underestimated, so revealing less time differences between the methods than expected. Generally this shows that fewer differences exist between methods.

TABLE 71: MTM-1 Times (Seconds) to Pick an Apple Using the Various Styles Noted in the Orchard

		ATB Method (Hands moving alternatively to pick single apples)		1/hand Method (Hands moving simultaneously to pick single apples)		2/Hand Method (Hands moving simultaneously to pick two apples)	
		Number of Apples Picked	Time	Number of Apples Picked	Time	Number of Apples Picked	Time
Low Apples	Sub-total	34	30.18	10	10.94	20	12.2
	Mean		0.89		1.09		0.61
Mid Apples	Sub-total	36	24.70	10	7.21	20	7.41
	Mean		0.69		0.72		0.37
High Apples	Sub-total	14	14.09	10	11.12	20	11.69
	Mean		1.01		1.11		0.58
Ladder Height Apples	Sub-total	20	20.58		Missing Data		Missing Data
	Mean		1.03				
All Apples	Total	104	89.55	30	29.27	60	31.3
	Mean		0.86		0.98		0.52
1+2/Hand Method (Hands moving simultaneously to pick three apples; one in one hand, two in other hand)						$\frac{(0.98 + 0.52)}{2} = 0.75$	
1 from Cluster Method (Holding cluster of apples in one hand, picking a single apple with the other hand)						2 x 0.98 = 1.96	
2 from Cluster Method (Holding cluster of apples in one hand, picking two apples with the other hand)						2 x 0.52 = 1.04	

Note: Where data is missing for picking 'ladder height apples' the data from 'high apples' will be substituted.

TABLE 72: Fruit Distribution on Three Types of Tree

	Tree	Centre Leader	Dwarf	Very Dwarf
	Height	4m	2.5 - 3m	1.5 - 2m
	Spread	3 - 3.5m	2m	1 - 1.5m
4M	Rootstock	106	9	27
		No Fruit		
3M		28% Fruit		
	(Ladder Work)	28% Fruit	No Fruit	
2M	206 cm Overhead Reach	28% Fruit	1% Fruit	
	(High Work) 140 cm Shoulder Height	38% Fruit	23% Fruit	No Fruit
1M	(Middle Work) 102cm Waist Height	19% Fruit	33% Fruit	4% Fruit
	(Low Work) Ground	15% Fruit	43% Fruit	96% Fruit

TABLE 73: Fruit Distribution and Yield on Cox, Rootstock MM106, 9 and 27

Rootstock	106			9			27
Yield	Low	Medium	High	Low	Medium	High	Medium
kg apples/tree	40	50	60	17	27	37	14
Number of apples/tree	400	500	600	170	270	370	140
% of apples at ladder height	28	28	28	1	1	1	0
% of apples in high region	38	38	38	23	23	23	0
% of apples in mid region	19	19	19	33	33	33	4
% of apples in low region	15	15	15	43	43	43	96
Number of apples at ladder height	112	140	168	2	3	4	0
Number of apples in high region	152	190	228	39	62	85	0
Number of apples in mid region	76	95	114	56	89	112	6
Number of apples in low region	60	75	90	73	116	159	134

TABLE 74: Total Apple Picking Time (seconds) for the Average Picker, Using Three Picking Methods on Various Trees

Rootstock		106			9			27
Yield		Low	Medium	High	Low	Medium	High	Medium
Time to pick all the apples from each region using the ATB method	Ladder height region	115.4	144.2	173.0	2.06	3.09	4.12	-
	High region	153.5	191.9	230.3	39.4	62.6	8.59	-
	Mid region	52.4	65.6	78.7	38.6	61.4	72.3	4.1
	Low region	53.4	66.8	80.1	65.0	103.2	141.5	119.3
	Total apple picking time	374.7	468.5	562.1	145.1	230.3	303.8	123.4
Time to pick all the apples from each region using the 1 apple/hand method	Ladder height region	124.3	155.4	186.5	2.2	3.33	4.44	-
	High region	168.7	210.9	253.1	43.3	68.8	96.4	-
	Mid region	54.7	68.4	82.1	40.3	64.1	80.6	4.3
	Low region	65.4	81.8	98.1	79.6	126.4	173.3	146.1
	Total apple picking time	413.1	516.5	619.8	165.4	262.6	352.7	150.4
Time to pick all the apples from each region using the 2 apples/hand method	Ladder height region	65.0	81.2	97.4	1.16	1.74	2.32	-
	High region	88.2	110.2	132.2	22.6	36.0	49.3	-
	Mid region	28.1	35.2	42.2	20.7	32.9	41.4	2.2
	Low region	36.6	45.8	54.9	44.5	70.8	97.0	81.7
	Total apple picking time	217.9	272.4	326.7	89.0	141.4	190.0	83.9

TABLE 75: Total Apple Percentages, Numbers, and Picking Times (Seconds) for the Average Picker Using a Freestyle Picking Method on Various Trees

Rootstock		106			9			27
Yield		Low	Medium	High	Low	Medium	High	Medium
Number of Apples per Tree		400	500	600	170	270	370	140
% picked by each of the methods	ATB	22	22	22	22	22	22	22
	1/hand	31	31	31	31	31	31	31
	1+2/hand	27	27	27	27	27	27	27
	2/hand	5	5	5	5	5	5	5
	1 from cluster	8	8	8	8	8	8	8
	2 from cluster	6	6	6	6	6	6	6
Number picked by each of the methods	ATB	88	110	132	37	59	81	31
	1/hand	124	155	186	53	84	115	43
	1+2/hand	108	135	162	46	73	100	38
	2/hand	20	25	30	9	14	19	7
	1 from cluster	32	40	48	14	22	30	11
	2 from cluster	24	30	36	10	16	22	8
Time for picking by each of the methods	ATB	75.7	94.6	113.5	31.8	50.7	69.7	26.7
	1/hand	121.5	151.9	182.3	51.9	82.3	112.7	42.1
	1+2/hand	81.0	101.3	121.5	34.5	54.8	75.0	28.5
	2/hand	10.4	13.0	15.6	4.7	7.3	9.9	3.6
	1 from cluster	62.7	78.4	94.1	27.4	43.1	58.8	21.6
	2 from cluster	25.0	31.2	37.4	10.4	16.6	22.9	8.3
Total picking time for freestyle method		376.3	470.4	564.4	160.7	254.8	349.0	130.8

TABLE 76: MTM Times (Seconds) for Non-Picking Activities Whilst Stripping Three Types of Tree of Varying Yields Using a Dutch-nosebag With and Without a Liner Bag

Rootstock	106			9			27
Yield	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
kg of apples per tree	40	50	60	17	27	37	14
Number of bags filled by one tree	3	4	5	2	2	3	1
Time to empty nosebags into bin	13.2	17.6	22.0	8.8	8.8	13.2	4.4
Time to transfer lining bag to ground then to bulk bin	17.4	23.2	29.0	11.6	11.6	17.4	5.8
Time to walk to and from bin to empty bag	13.0	17.4	21.7	8.7	8.7	13.0	4.3
Time to walk around tree	20.8	20.8	20.8	17.8	17.8	17.8	11.9
Number of ladder moves and climbs, up and down	10	10	10	1	1	1	0
Time taken for ladder work	204.0	204.0	204.0	20.4	20.4	20.4	0
Total time for non-picking activities with nosebag	251.0	259.8	268.5	55.7	55.7	64.4	20.7
Total time for non-picking activities with nosebag +liner	242.2	248.0	253.8	49.8	49.8	55.6	17.7

Notes: Non-picking time with nosebag = Time to empty bags + time to walk to and from bin + time to walk around tree + ladder work time

Non-picking time with liner = Time to transfer liner to ground + bulk bin + time to walk around tree + ladder work time

TABLE 77: Total Time to Strip a Tree (Seconds) Using the Four Picking Methods on the Three Trees of Varying Yields

Rootstock		106			9			27
Yield		Low	Medium	High	Low	Medium	High	Medium
Total time for non-picking activities with a nosebag		251.0	259.8	268.5	55.7	55.7	64.4	20.7
Total time for non-picking activities with a nosebag+liner		242.2	248.0	253.8	49.8	49.8	55.6	17.7
Total picking time ATB method		374.7	468.5	562.1	145.1	230.3	303.8	123.4
Total picking time 1/hand method		413.1	516.5	619.8	165.4	262.6	352.7	150.4
Total picking time 2/hand method		217.9	272.4	326.7	89.0	141.4	190.0	83.9
Total picking time freestyle method		376.3	470.4	564.4	160.7	254.8	349.0	130.8
Total Time Using a Nosebag	ATB Method	625.7	728.3	830.6	200.8	286.0	368.2	144.1
	1/Hand Method	664.1	776.3	888.3	221.1	318.3	417.1	171.1
	2/Hand Method	468.9	532.2	595.2	144.7	197.1	254.4	164.6
	Freestyle Method	627.3	730.2	832.9	216.4	310.5	413.4	151.1
Total Time Using a Nosebag + Liner	ATB Method	616.9	716.5	815.9	194.9	280.1	359.4	141.1
	1/Hand Method	655.3	754.5	873.6	215.2	312.4	408.3	168.1
	2/Hand Method	460.1	520.4	580.5	138.8	191.2	245.6	101.6
	Freestyle Method	618.5	718.4	818.2	210.5	304.6	404.6	148.5

TABLE 78: Time to Strip a Tree Using the Four Picking Methods on the Three Trees of Varying Yields with a 28% Fatigue Allowance

Rootstock			106			9			27
Yield			Low	Medium	High	Low	Medium	High	Medium
Time to strip a tree using a nosebag with 28% fatigue allowance	ATB Method	seconds minutes	800.9 13.35	932.2 15.54	1063.2 17.72	257.0 4.28	366.1 6.10	471.3 7.85	184.4 3.07
	1/Hand Method	seconds minutes	850.0 14.17	993.7 16.56	1137.0 18.95	283.0 4.72	407.4 6.79	533.9 8.90	219.0 3.65
	2/Hand Method	seconds minutes	600.2 10.00	681.2 11.35	781.9 12.70	185.2 3.09	252.3 4.21	325.6 5.43	133.9 2.23
	Freestyle	seconds minutes	802.9 13.38	943.7 15.58	1066.1 17.77	277.0 4.62	397.4 6.62	529.2 8.82	193.9 3.23
Time to strip a tree using a nosebag with liner with 28% fatigue allowance	ATB Method	seconds minutes	789.6 13.16	917.1 15.29	1044.4 17.41	249.5 4.16	358.5 5.98	460.0 7.67	180.6 3.01
	1/Hand Method	seconds minutes	838.8 13.98	978.6 16.31	1118.2 18.64	275.5 4.59	399.9 6.66	522.6 8.71	215.2 3.59
	2/Hand Method	seconds minutes	588.9 9.82	666.1 11.10	743.0 12.38	177.7 2.96	244.7 4.08	314.4 5.24	130.0 2.17
	Freestyle	seconds minutes	791.7 13.9	919.6 15.33	1047.3 17.45	269.4 4.49	389.9 6.50	517.9 8.63	190.1 3.17

TABLE 79: MTM-1 Times (Seconds) to Pick an Apple by the Various Methods and to Empty a Dutch-Nosebag Considering Pickers of Different Capabilities i.e. Poor and Good Pickers

		Good Picker (12.5th Percentile)	Poor Picker (87.5th Percentile)
ATB METHOD	Ladder height region	0.7	1.16
	High region	0.67	1.0
	Mid region	0.59	0.71
	Low region	0.54	1.02
1/HAND METHOD	Ladder height region	0.9	1.2
	High region	0.9	1.2
	Mid region	0.47	0.8
	Low region	0.79	1.3
2/HAND METHOD	Ladder height region	0.45	0.58
	High region	0.45	0.58
	Mid region	0.24	0.44
	Low region	0.47	0.74
1 + 2/hand method		0.56	0.85
1 from cluster method		1.44	2.2
2 from cluster method		0.77	1.17
Emptying nosebag into bin		1.92	5.0

Note: The picking methods: 1+2/hand, 1 from cluster and 2 from cluster were calculated as shown in Table 1 though based on the mean times produced for each of the formal methods for each of the picker's capabilities.

TABLE 80: Total MTM-1 Times (Seconds) for Picking and Non-Picking Activities for the Four Picking Methods and Two Picking Bags for a Range of Pickers Abilities

Rootstock		106			9			27
Yield		Low	Medium	High	Low	Medium	High	Medium
Time taken to pick all the apples from a tree using the ATM method	Poor picker	379.1	496.4	595.6	155.6	247.0	331.3	140.9
	Good picker	257.4	321.9	386.3	99.9	158.7	211.8	75.9
Time taken to pick all the apples from a tree using the 1/hand method	Poor picker	455.6	570.0	633.4	188.9	300.0	403.1	179.0
	Good picker	320.7	401.0	481.1	120.9	191.1	258.3	108.7
Time taken to pick all the apples from a tree using the 2/hand method	Poor picjer	230.9	288.7	346.5	102.4	162.7	218.6	101.1
	Good picker	165.2	206.6	247.9	66.21	105.2	141.7	64.4
Time taken to pick all the apples from a tree using the freestyle method	Poor picker	423.8	529.8	635.8	181.1	287.1	393.0	147.4
	Good picker	277.6	347.0	416.3	118.6	188.0	257.4	96.5
Time taken for non-picking activities using a nosebag	Poor picker	252.8	262.2	271.5	56.9	56.9	66.2	21.3
	Good picker	243.6	249.9	256.1	50.7	50.7	57.0	18.2
Time taken for non-picking activities using a nosebag with liner	Average Picker	242.2	248.0	253.8	49.8	49.8	55.6	17.7

TABLE 81: Total MTM-1 Times (Minutes) for Stripping a Tree Using the Four Picking Methods With a Dutch-Nosebag With and Without a Liner Bag, with a 28% Fatigue Allowance

Rootstock			106			9			27
Yield			Low	Medium	High	Low	Medium	High	Medium
Using Nosebag	ATB Method	Poor Picker	13.48	16.18	18.50	4.50	6.48	8.48	3.46
		Good Picker	10.69	12.20	13.70	3.21	4.48	5.73	2.01
	1/Hand Method	Poor Picker	15.11	17.75	19.30	5.24	7.61	10.01	4.27
		Good Picker	12.04	13.89	15.73	3.66	5.18	6.73	2.71
	2/Hand Method	Poor Picker	10.32	11.75	13.18	3.40	4.68	6.08	2.63
		Good Picker	8.72	9.74	10.75	2.49	3.33	4.24	1.76
	Free-style Method	Poor Picker	14.43	16.90	19.36	5.08	7.34	9.80	3.60
		Good Picker	11.12	12.73	14.34	3.61	5.09	6.71	2.45
Using Nosebag with Liner	ATB Method	Poor Picker	13.25	15.88	18.12	4.38	6.33	8.25	3.38
		Good Picker	10.66	12.16	13.66	3.19	4.45	5.70	2.00
	1/Hand Method	Poor Picker	14.89	17.45	18.93	5.09	7.46	9.79	4.20
		Good Picker	12.01	13.85	15.68	3.64	5.16	6.70	2.70
	2/Hand Method	Poor Picker	10.09	11.45	12.81	3.25	4.53	5.85	2.55
		Good Picker	8.69	9.70	10.70	2.47	3.31	4.21	1.75
	Free-style Method	Poor Picker	14.21	16.59	18.98	4.93	7.19	9.57	3.52
		Good Picker	11.09	12.69	14.30	3.59	5.07	6.68	2.44

TABLE 82: Actual and Synthesized MTM-1 Times (Minutes) for the Different Picking Methods, Different Picking Bags, Different Tree Types, for Average Pickers

Rootstock			106			9			27
Yield			Low	Medium	High	Low	Medium	High	Medium
Using Nosebag	ATB Method	Actual	13.35	15.54	17.72	4.28	6.10	7.85	3.07
		Synthesized	15.3	18.0	20.7	5.0	7.2	9.6	3.6
	1/Hand Method	Actual	14.17	16.56	18.95	4.72	6.79	8.90	3.54
		Synthesized	14.2	16.6	19.0	4.5	6.4	8.6	3.2
	2/Hand Method	Actual	10.00	11.35	12.70	3.09	4.21	5.43	2.23
		Synthesized	9.8	11.1	12.4	2.8	3.8	5.0	1.8
	Freestyle Method	Actual	13.38	15.58	17.77	4.62	6.62	8.82	3.23
		Synthesized	14.21	16.62	19.02	4.97	7.19	9.59	3.52
Using Nosebag with Liner	ATB Method	Actual	13.6	15.29	17.41	4.16	5.98	7.67	3.01
		Synthesized	15.1	17.8	20.4	4.8	7.1	9.4	3.5
	1/Hand Method	Actual	13.98	16.31	18.64	4.59	6.66	8.71	3.59
		Synthesized	14.0	16.4	18.7	4.4	6.3	8.4	3.2
	2/Hand Method	Actual	9.82	11.10	12.38	2.96	4.08	5.24	2.17
		Synthesized	9.6	10.8	12.1	2.7	3.7	4.8	1.8
	Freestyle Method	Actual	13.19	15.33	17.45	4.49	6.50	8.63	3.17
		Synthesized	14.03	16.37	18.71	4.84	7.06	9.40	3.46

TABLE 83: A Comparison of MTM-1 Data for Different Picking Methods and Bags, by Percentages of the Longest Time to Strip Each Tree, Considering Actual and Synthesized Data Separately

Rootstock			106			9			27	Average %
Yield			Low	Medium	High	Low	Medium	High	Medium	Average
Actual Data	Using Nosebag	ATB Method	95.3	93.8	93.5	90.7	89.8	88.2	84.1	90.8
		1/Hand Method	100	100	100	100	100	100	100	100
		2/Hand Method	70.6	68.5	67.0	65.5	62.0	61.0	61.1	65.1
		Freestyle Method	94.4	94.1	93.8	97.9	97.5	99.1	88.5	95.0
	Using Nosebag With Liner	ATB Method	92.9	92.3	91.9	88.1	88.1	86.2	82.5	88.9
		1/Hand Method	98.7	98.5	98.4	97.2	98.1	97.9	98.4	98.2
		2/Hand Method	69.3	67.0	65.3	62.7	60.1	58.9	59.5	63.3
		Freestyle Method	93.1	92.6	92.1	95.1	95.7	97.0	86.8	93.2
Synthesized Data	Using Nosebag	ATB Method	106.5	108.4	108.9	111.1	112.5	111,6	112.5	110.2
		1/Hand Method	100	100	100	100	100	100	100	100
		2/Hand Method	69.0	66.9	65.3	62.2	59.4	58.1	56.3	62.5
		Freestyle Method	100.1	100.1	100.1	110.4	112.3	111.5	110.0	106.4
	Using Nosebag With Liner	ATB Method	106.3	107.2	107.4	106.7	110.9	109.3	112.5	108.6
		1/Hand Method	98.6	98.8	98.4	97.8	98.4	97.7	100	98.5
		2/Hand Method	67.6	65.1	63.7	60.0	51.8	55.8	56.3	60.9
		Freestyle Method	100.2	99.8	100.1	110.0	112.1	111.9	108.1	106.0

9.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR PICKING METHODS AND BAGS

From the work conducted in the orchard during the 1982 and 1983 apple harvesting seasons it is apparent that it is not possible to enforce a formalised picking method on pickers. Each apple tree is different and each apple grows in an original position. Allowing pickers to pick a tree as they felt comfortable did reduce damage levels considerably though this did not always reflect the eventual grade of the apple. It was possible to note how the pickers approached certain situations to establish the best picking methods for apple growth distribution and clustering on the tree. Freestyle methods of apple picking may not be the quickest way of removing apples from the tree as shown by the MTM-1 analysis, though statistically they are the preferred methods. However, the annual variations in apple crops, i.e. apple size, susceptibility to damage and weather conditions, may result in the necessity of repeating comparison studies of picking methods to ensure that freestyle methods of picking remain preferable to other methods.

From observations of pickers it was possible to produce the following recommendations showing how a picker should approach a tree to harvest apples by freestyle methods.

Recommendations for stripping a tree:

1. Pick the apples from above shoulder height first though well within overhead reach. Start with a branch that allows easy access. As apples are picked from the upper branches these branches will tend to spring up to their original position so providing better access to lower branches.

2. Work from the inner part of the branch to the distal end. The apples at the outer tips of the branch will pull the branch down to provide better visual and physical access to the apples on the inner parts of the branch.

3. To pick an apple, the apple must be held within the palm of the hand as far as possible, without applying pressure.

4. To separate the apple from the branch the apple should be lifted up and over the branch. If the stalk is not detached from the branch in this process, the apple must be moved in a direction at 90^o to the left. This move must be repeated, gently, and the apple will easily be removed if moved in an appropriate direction.

5. After stripping a branch follow the same procedure with the branches below the one cleared. Finish with the lowest branch otherwise this branch will spring up and hamper access to the rest of the tree.

6. Return to the starting point and the next branch at above shoulder height (see point 1) either on the left or right. Work around the tree systematically either clockwise or anti-clockwise.

7. When apples grow singly they should be picked separately as indicated in points 3 and 4. However, if apples have grown closely together it is possible to use both hands simultaneously to reach for the apples, pick and place them in the picking bag. This method does not tend to be suitable for apples growing more than 5 cm apart.

8. For apples growing singly and more than 5 cm apart it is preferable to reach and pick apples one at a time, the other hand working in opposition moving and placing apples in the picking bag. The two hands work alternatively and continuously to pick and place apples into the picking bag.

9. When apples grow in pairs they can be picked singly as mentioned in points 7 and 8, conversely one hand can be used to pick both apples. When picking two apples in one hand, care must be taken to keep them separate, particularly when placing the apples into

the picking bag. Alternatively the hand picks one apple, then move the same hand to pick a second apple.

10. When apples have grown in a group of three it is preferable to pick them simultaneously to prevent drops, two in one hand, one in the other.

11. Four apples growing together can be picked two per hand both hands working simultaneously, or as a cluster (see below).

12. To pick clusters of apples, four apples or more, one hand should be used to support the cluster whilst the other hand picks the apples, singly or as doubles, and places them into the picking bag.

13. When picking clusters, pick the perimeter apples that do not touch other apples first, then pick the apples growing on top of the cluster that provide the greatest access. Finish picking the cluster with the lowest apples.

14. When picking apples from low branches it is preferable not to bend over, particularly when the picking bag is over half full. It is suggested that the picker squats or crouches with knees bend and back as upright as possible. Alternatively lift the branch and continue picking as for a cluster of apples (see point 12) and thus maintain a more upright posture while picking and place the apples into the picking bag with the other hand.

15. When visual access is reduced it is suggested that the picker uses one hand to move foliage and branches, whilst the other hand is used for picking and placing apples into the picking bag.

16. If access to the apples in the centre part of the tree is hampered by branches and or the picking bag, it is suggested that the picking bag be slung from the shoulder that is away from the tree centre and the picker stands sideway in to the tree.

17. When standing sideways in to the tree it is suggested that the hand nearest to the tree centre be used for picking apples which are then transferred to the other hand. The other hand transfers the apples singly or in multiples to the picking bag allowing the first hand to continue picking.

18. Apples that are only just within overhead reach and above require picking from a ladder. Ladder work should only be started after the ground hand picking is completed. Pulling branches towards the picker for easier access to fruit can lead to damage to both tree and fruit, it can also unbalance the position of the ladder.

19. It is important while picking from the ladder not to overreach for apples. This could lead to instability as well as the picker exerting greater gripping forces on the apple.

20. When using ladders or tripod steps the picking bag should be worn slung on one side of the body or on the back. If the picker feels unstable it is possible to hang the bag on the tripod steps.

21. When picking from the ladder apple removal is identical to picking from the ground. However it is preferable from a stability point of view to use one hand to pick and place apples into the picking bag, whilst using the other hand to hold the ladder.

22. Generally, picking cannot follow a prescribed pattern as all trees and crops vary, it is best to allow the picker to pick as they feel comfortable.

Using the methods described in points 1 to 22 would result in pickers harvesting apples to the optimum of their capabilities. Random checks on the quality of apples produced by each picker would identify whether specific pickers needed further training and supervision to improve their performance. However, this study has shown that damage to apples during picking is negligible compared to that caused during apple transfer processes.

The damage studies conducted in the 1982 apple harvesting season displayed the problems of damage to apples during transfer from picking bag to bin in the orchard and bin to grading belt in the packhouse. This is due to the force exerted on the apple when it is dropped, a drop of 5 cm (effectively the diameter of an apple) of one apple onto another apple is sufficient to bruise both apples. Using a liner bag within the picking bag was found to significantly reduce damage to apples during the 1983 apple harvesting season. As mentioned previously it may be necessary to repeat studies using the liner bag in following years, to check that the performance of the liner bags is comparable for various apple crops.

Considering that little time appears to be saved by pickers lifting the liner bags out of their picking bags and placing them on the ground, for later transferral to the bin, it would seem preferable for pickers to transfer and pack liner bags directly into bins. This will decrease handling damage induced by lifting and placing the bag in several positions. It is also better ergonomic sense to reduce materials handling and therefore reduce potential lower back pain problems, in the workers handling the bags. Further including the walking 'to and from the bin' tasks aspects increases the job variability and reduces boredom.

With regards to bin filling it is apparent that a bin can be efficiently filled with 45 bags, measuring 45 cm by 50 cm and holding approximately 7 kg of apples each. These can be packed into a 16 bushel bin by laying them in five layers, each layer holding nine bags in a 3 x 3 bag square (see Figure 7). The bags should be fitted into the bin in an orderly fashion to ensure that each layer lies flat in the bin. Each time a new layer is fitted into the bin it should be started in a different corner, as the last bag into a layer will be slightly proud. This may require extra supervision, but this appears to be a general necessity.

A problem arises when it comes to removing the bags from the bin. If polyethylene bags are used to store the apples, they will produce a micro-climate within each bag. This will control the transfer of oxygen and carbon dioxide within the bag and improve storage condition for some apples. However, the bags will not allow the circulation of fungicidal dips, so apples will have to be sprayed prior to picking rather than being dipped prior to storing. They will then have to be individually emptied which is not feasible if the grading process relies on flotation bin emptying. If the bin is dry tipped the resultant damage is often severe, so individually emptying the liner bags, with the aid of the hydraulic bin tipper reducing the bending and lifting of the workers may be beneficial.

Studies have been completed looking into the possibility of soluble polymers. If the liner bags could be made of soluble polymers, which dissolved within a few minutes to produce non-toxic by-products this would solve the bag emptying problems, by bag elimination.

The liner bags were used in recent studies in conjunction with a Dutch nosebag, this is of benefit to the farmers as they would not be required to replace expensive equipment. However, the picking bag could be redesigned to produce a lighter weight version, with an improved padded harness and storage facilities for the liner bag. It could also incorporate a telescopic leg which could provide extra support for the picker when carrying a full or partially full bag. This could be adjusted to the required height as the picker stands upright, stoops or bends, and can be folded away as necessary.

Recommendations have been compiled for the design of a new picking bag for harvesting apples and these are as follows:

Bag recommendations:

1. The liner bag should be easily fitted and removed from the picking bag and held firmly in place to allow easy placement of apples into the bag.

2. A specification for a water soluble polymer was provided by Syntana Handelsgesellschaft, E. Harke GmbH and Co., Postfach 101753, 4330 Mulheim/Rhur, W. Germany. The bag being 44 by 56 cm, unventilated and 25 microns thick. The plastic commences to dissolve at 50 degrees Centigrade and is completely soluble at 60 degrees Centigrade. However, heating apples to these temperatures may cause damage to the fruit and must be considered further.

3. The container of the liner bag should be as small as possible and as close to the pickers body as feasible. Containers could be moulded to fit general body curves, this would ensure that the weight of the bag is close to the body and may prevent bad postures being adopted to compensate for bulky bags and balance.

4. The bag should be rigid to protect the apples, but lightweight to ease the pickers job.

5. The weight of the full bag should not be greater than 10 kg. Recommendations for carrying tasks are limited (Snook 1978), however the closest approximation to the apple picking task is an 8 in carry every 18s. Apple pickers often carry full bags for greater distances, however once apples are transferred to storage containers the weight of the bag increases gradually according to the speed of the picker.

6. The weight of the bag should be distributed over a harness allowing the pickers to dress as they wish, facilitating free movement of hands and arms and enabling pickers to carry the bag either to the front or side of the body. The harness straps should be 40 mm wide, flexible and fit over both shoulders, padding being provided and adjustable. A third strap may be provided to link around the picker's waist so that when the picker bends forward the weight is distributed as far as possible over the picker's back. All the harness straps should be adjustable. Figure 6 provides an overview of the bag and harness.

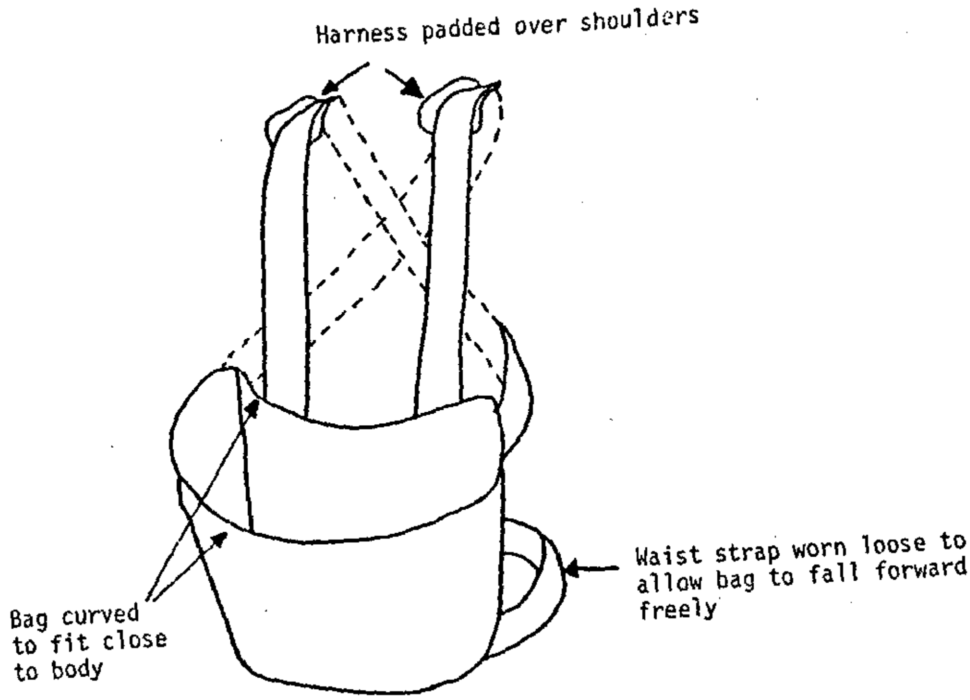

FIGURE 6: BAG AND HARNESS

7. If possible a folding or telescopic rod should be built onto the picking container to fold downwards and provide extra support for the bag when the picker is stationary and picking large clusters of apples.

Liner bags should be beneficial to apple harvesting with regards to efficiency and economy. Further improvements in apple harvesting should arise with improved selection, training and supervision of pickers particularly at points of potential apple damage. This refers to points of mass transfer of apples, i.e. from picking bag to bulk bin.

As previously discussed only a small percentage of pickers (4%) produced 37% of all the bruises found on apples sampled from the bin. It is suggested that apples are sampled from the bin to check on an individual pickers performance. From Table 49 it is apparent that pickers who cause on average more than 150 mm^2 of bruise area per apple require more training and greater supervision or selection away from picking tasks. Apple sampling techniques must obviously be random, extensive and fairly regular, e.g. 20 random apples taken at any one time once a week.

Training should ensure that pickers realise that greater care and attention must be paid to prevent as much free fall of apples as possible. This should be helped by greater supervision, preferably using one supervisor for each 12 pickers and concentrating on the transfer of apples to bulk bin.

Overall it must be noted that more damage is caused in the apple handling processes than in picking. Therefore more effort must be made with regard to selection, training and supervision of the personnel who load and unload apple storage containers. This should reduce bruising by restricting the tree movement of apples either individually or en masse by the use of liner bags.

There is no need to train pickers extensively to a certain method as they generally adopt good freestyle methods; however pickers do require monitoring as a small percentage of pickers cause a large proportion of damage to apples.

There is scope for improved design of harvesting aids with regard to the picking bag and liner bag. Though financially this may cause problems to the farmers, and existing equipment could be modified and used.

APPENDIX 1

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
(Publications), Tolcarne Drive, Pinner, Middlesex HA5 2DT

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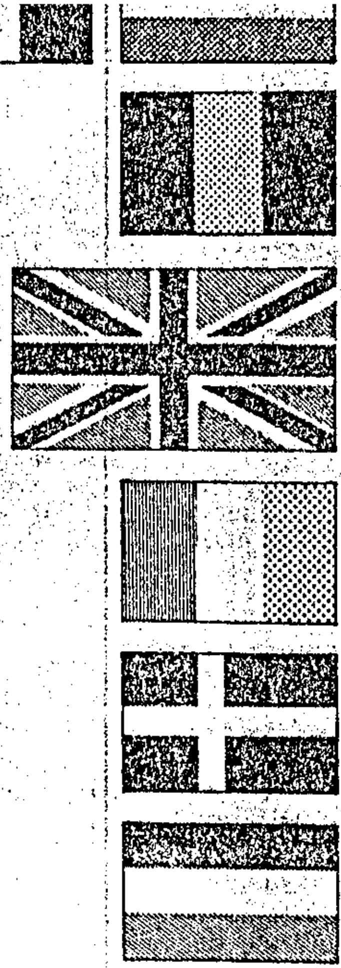

E.E.C. Standards for Fresh Apples and Pears

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MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DEPARTMENT OF AGRICULTURE AND FISHERIES FOR SCOTLAND
MINISTRY OF AGRICULTURE FOR NORTHERN IRELAND

INTRODUCTION

This leaflet has been prepared by the Agricultural Departments to give general guidance on the EEC grading requirements for apples and pears which came into effect on the domestic market on 1 February 1973. It does not purport to be a comprehensive statement of the legal requirements and does not cover the requirements of any other legislation.

It supplements the more general information of interest to growers given in the leaflet 'Horticulture and the EEC'. Enquiries should be directed to the Regional Horticultural Marketing Inspectors or local Horticultural Advisory Officers in England and Wales or to the Headquarters Office in Scotland or Northern Ireland.

CONTENTS

COMMON STANDARDS OF QUALITY FOR APPLES AND PEARS

1. APPLICATION

The apple and pear standards are laid down in EEC Regulation 1641/71.* The standards apply to dessert and culinary apples and pears grown from varieties of *Pyrus Malus* L. and *Pyrus Communis* L. All varieties of dessert and culinary apples and pears grown in the U.K. or imported fresh are covered by this definition. Cider apples and perry pears are excluded.

The standards define requirements for apples and pears at the dispatching stage after preparation and packaging. Only apples and pears meeting these requirements may be displayed or offered for sale, sold, delivered or marketed in any other manner within the Community (subject to the exemptions indicated in Section 7).

There are three main classes for apples and pears—Extra Class for fruit of top quality, Class I for fruit of good commercial quality and Class II for fruit of marketable quality which does not meet the requirements of the higher classes. An additional class, Class III, may be brought into operation on a Community wide basis if it is decided by the Community that supplies of fruit in the higher classes are inadequate to meet consumer requirements. A Class III standard has not been in operation in the Community since 1970.

* *Note:*—Regulation 1641/71 which came into effect on 1 October 1971 replaced the earlier standards for apples and pears laid down in Regulations 23/62 Annex II/3 and 211/66 Annex III.

CLASSES			
Extra	I	II	III (when applicable)
Minimum requirements for all classes The fruit must be: – whole – sound (subject to the special provisions for each class and the permitted tolerances) – clean (in particular free from visible foreign matter) – free from excess external moisture – free from any foreign smell or taste The fruit must be sufficiently mature and capable of withstanding the hazards of transport and handling without damage.			
Additional requirements			

Fruit in this class must:
– be of superior quality
– be typical of the variety in:
  – shape
  – development
  – colouring
– have stalks intact
– be free from defects except for very slight skin blemishes, provided that the quality of the fruit and the general appearance of the package are not impaired.
Gritty pears are not permitted.
	Fruit in this class must:
	– be of good quality
	– possess characteristics typical of the variety.
	However, the following defects may be allowed:
	– slight deformation
	– marginally faulty development
	– small defects in colouring
	– slightly damaged stalk
	– the Granny Smith variety may be without stalk provided that the skin in the stalk cavity is undamaged.
		Fruit in these classes must retain characteristics typical of the variety but may have defects of:
		– shape
		– development
		– colouring
		The stalk may be missing provided the skin is undamaged.	

CLASSES			
Extra	I	II	III (when applicable)
Additional requirements—*continued*			
	The flesh must be free from any deterioration, but skin blemishes which do not impair the general appearance or keeping qualities are permitted for each fruit within the following limits: – elongated blemishes—maximum length 2 cm – other blemishes—maximum area 1 sq. cm with the exception of speckles (e.g., scab) which must not cover more than ¼ sq. cm. Gritty pears are not permitted.	The flesh must be free from major defects but skin blemishes are allowed for each fruit within the following limits: – elongated blemishes—maximum length: 4 cm | 6 cm – other blemishes—maximum area: 2·5 sq. cm | 5 sq. cm with the exception of speckles (e.g., scab) which must not cover more than: 1 sq. cm | 2·5 sq. cm	
Colouring and russeting criteria for apples are set out in Appendices 1 and 2			

3. SIZE REQUIREMENTS

CLASSES			
Extra	I	II	III (when applicable)

Minimum permitted sizes
Size is measured by the diameter at the widest part of the fruit. The following are the minimum permitted sizes in each class:

	Extra	I	II	III
APPLES				
Large fruited varieties*	65 mm	60 mm	55 mm	50 mm
Others	60 mm	55 mm	50 mm	50 mm
PEARS				
Large fruited varieties*	60 mm	55 mm	50 mm	45 mm
Others	55 mm	50 mm	45 mm	45 mm

Size Uniformity
Fruit in any one package must be packed to the following range limits:
Apples (except Bramley's Seedling) and Pears:

Extra	I	II	III
5 mm (must be packed in layers)	5 mm when packed in layers 10 mm when packed in bulk	5 mm when packed in layers. No limit when packed in bulk.	No limit

Bramley's Seedling variety (to be reviewed at the end of the 1974/75 season):

Extra	I	II	III
5 mm (must be packed in layers)	10 mm when packed in layers 20 mm when packed in bulk	10 mm when packed in layers. No limit when packed in bulk.	No limit

* Large fruited varieties are listed in Appendix 3.

CLASSES			
Extra	I	II	III (when applicable)

In any one package quality and size tolerances are allowed as follows:

Quality

Extra	I	II and III
5% by number or by weight of fruit not meeting the requirements of the class but meeting those of Class I or, in exceptional cases, those of fruit allowed within the tolerances of that class.	10% by number or by weight of fruit not meeting the requirements of the class, but meeting those in Class II or, in exceptional cases, those of fruit allowed within the tolerances of that class. 25% by number or by weight of fruit without stalks, provided that the skin in the stalk cavity has not deteriorated (except for Granny Smith where fruit without a stalk may be allowed without restriction, provided that the skin in the stalk cavity has not deteriorated).	10% by number or by weight of fruit not meeting the requirements of the class nor the minimum requirements, excluding fruit visibly attacked by rot, heavily bruised fruit or fruit with unhealed cracks. Within the above tolerance 2% at most by number or by weight of fruit may: – have internal defects by pests (e.g., codling, saw fly, etc.). – serious presence of cork or vitreous disease (bitter pit or water core). – minor damage or unhealed cracks – a very slight trace of rot or decay.

Extra	I	II	III (when applicable)
Size			
A size tolerance of 1 mm above or below the range packed is allowed for any fruit packaged to a 5 mm range provided that the deviation is due only to the normal use of machinery, affects only a limited number of fruit in any package and is not likely to affect the overall appearance of the contents of the package.			
Any package of fruit graded by size may in addition to the above allowance contain 10% by number or weight of fruit corresponding to the size immediately above or below the range packed, subject to a minimum size limit of 5 mm below the permitted size for the class and variety.			
		Fruit not graded by size may contain by number or weight of fruit below the permitted minimum size as follows: 10%	15% subject to a limit of 5 mm below the permitted minimum size for the class and variety.

5. PACKAGING AND PRESENTATION

Extra	I	II	III (when applicable)
Uniformity			
The contents of each package must contain only fruit uniform in:			
– origin – variety – quality – ripeness – colouring	– origin – variety – quality – ripeness	– origin – variety – quality – ripeness	need be uniform only in origin and variety but the visible content of a container must be repres-entative of the whole.
Packaging			
Packaging must be such as to give the produce adequate protection. Any paper or other material used inside the package must be new, clean and harmless to human food. The use of paper, stamps or other material bearing trade information is permitted provided that non-toxic ink or glue is used. Packed containers must be free from leaves, twigs or other extraneous matter.			
Fruit in this class must be packed in layers.			

6. LABELLING

Each package must bear the following particulars legibly and indelibly marked on the outside of the container on one side or end:

A. Identification
   Packer and/or Dispatcher } Name and Address or identifying mark.

B. Nature of produce
   - 'Apples' or 'Pears' (on closed packages)
   - Name of the variety, compulsory for Extra Class and Class I, optional for Classes II and III.
     (N.B.—Apples and pears presented in Classes II and III without any indication of variety will be considered to be large fruited varieties).

C. Origin of produce
   –District of origin or national, regional or local trade name (e.g., British, English, Kent, East Anglian).

D. Commercial specifications
   - Class
   - Size, or for fruit packed in layers, number of apples or pears.
     The size shall be shown:
     a. For fruit graded by size, by specifying the largest and smallest diameters of the fruit in the package;
     b. For fruit not graded by size, by specifying the diameter of the smallest fruit in the package followed by the diameter of the largest fruit in the package or by the words 'and +'.

The information required as to marking may be given by means of:

i. A label firmly fixed to the container;
ii. An ink stamp or printing on to the container; or
iii. A combination of the above methods.

Suggested forms of label with dimensions are shown in Appendix 4.

Marking for retail sale

At the retail stage, where the produce is presented in its original packaging, the label must be clearly displayed. Where the produce is presented in any other way the retailer must display with the goods as offered for sale a durable label or display card(s) giving the following information:

- variety (for Extra Class and Class I)
- the origin of the produce
- the quality class.

7. EXEMPTIONS

The following transactions are exempt from the grading and labelling requirements:

1. Sales or deliveries by growers, or from growers' holdings, to packers or to storage; and deliveries from storage to packers.
2. Offers and sales by growers on minor local markets and deliveries from such markets to packing stations or storage, within the same area. However, on secondary sale or sale by retail other than sales on growers' holdings as below, the produce must be properly graded and labelled.
3. Sales to manufacturers for processing.
4. Sales on growers' holdings to consumers for their personal use.

8. EXPORTS

Only apples and pears meeting the requirements of Classes Extra, I or II may be exported outside the Community.

These must be accompanied by a certificate indicating that the produce complies with the appropriate standard. Certificates are issued in England and Wales by the Horticultural Marketing Inspectorate of the Ministry of Agriculture, Fisheries and Food, in Scotland by the Department of Agriculture and Fisheries for Scotland and in Northern Ireland by the Ministry of Agriculture for Northern Ireland.

Consignments of apples and pears sent to other Member States must also in most cases be accompanied by a certificate issued by the Agricultural Departments as shown above.

Exporters can obtain full information and application forms from the Horticultural Marketing Inspectorate at their nearest regional office of the Ministry of Agriculture, Fisheries and Food, or from the Department of Agriculture and Fisheries for Scotland or the Ministry of Agriculture for Northern Ireland. Full details of the consignment and its destination will be required, and exporters should normally give at least three clear working days' notice, so that arrangements for inspection can be made.

A list of addresses of Regional Horticultural Marketing Inspectors in England and Wales is shown in Appendix 5.

The three Agricultural Departments also arrange for the issue of the necessary certificates of health which may be required by overseas governments to accompany consignments exported. Particulars and advice about overseas countries' plant health regulations may be obtained from the Plant Health Branch of the Ministry of Agriculture, Fisheries and Food, Great Westminster House, Horseferry Road, London SW1P 2AE, the Department of Agriculture and Fisheries for Scotland, Chesser House, 500 Gorgie Road, Edinburgh EH11 3AW or the Ministry of Agriculture for Northern Ireland, Dundonald House, Stormont, Belfast BT4 3SB.

9. METRIC MEASUREMENTS WITH IMPERIAL EQUIVALENTS

65 mm = $2\frac{9}{16}$ in.	20 mm = $\frac{13}{16}$ in.
60 mm = $2\frac{3}{8}$ in.	10 mm = $\frac{3}{8}$ in.
55 mm = $2\frac{3}{16}$ in.	5 mm = $\frac{3}{16}$ in.
50 mm = $1\frac{15}{16}$ in.	1 mm = $\frac{1}{32}$ in.
45 mm = $1\frac{3}{4}$ in.	5 sq cm = $\frac{3}{4}$ sq in.
40 mm = $1\frac{9}{16}$ in.	2·5 sq cm = $\frac{3}{8}$ sq in.
35 mm = $1\frac{3}{8}$ in.	1 sq cm = $\frac{1}{8}$ sq in.
30 mm = $1\frac{3}{16}$ in.	$\frac{1}{4}$ sq cm = $\frac{1}{32}$ sq in.
25 mm = 1 in.	

10. REFERENCES

As indicated in Section 1 the apples and pears standards are laid down in EEC Regulation 1641/71.

Regulations dealing with the general application of quality standards are as follows:

R80/63 (quality control of imports into the Community)

R93/67 (quality control within the Community)

R2638/69 (quality control within the Community)

R496/70 (quality control of exports)

R1035/72 (common organization of the market in fruit and vegetables).

Pre-accession translations of these regulations from which most of the information in this leaflet is taken were published by HMSO in Part 28 of EEC Secondary Legislation. Official authentic texts have been published in the Special Editions (English) of the Official Journal of the European Communities obtainable from HMSO.

APPENDICES

APPLES: COLOURING CRITERIA

Varieties of apples are classified in four groups A to D according to their colouring as follows:

GROUP	CLASSES		
	Extra	I	II and III
Group A – Red Varieties: Black Ben Davis Democrat King David Red Delicious Red Rome Red Stayman (Staymanred) Red York Richared and Mutations Stark Delicious Starking Winesap (Winter Winesap) Spartan Rose of Berne Cherry Cox Reinette étoilée	at least $\frac{3}{4}$ of surface of fruit must be red.	at least $\frac{1}{2}$ of surface of fruit must be red.	at least $\frac{1}{4}$ of surface of fruit must be red.
Group B – Varieties of mixed red colouring (bright colouring of the red part): Belfort (Pella) Red Boskoop Cortland Delicious Ingrid Marie Jonathan McIntosh Morgenduft (Rome Beauty) Stayman Winesap Tydeman's Early Wealthy York	at least $\frac{1}{2}$ of surface of fruit must be red.	at least $\frac{1}{3}$ of surface of fruit must be red.	at least $\frac{1}{10}$ of surface of fruit must be red.

GROUP	CLASSES		
	Extra	I	II and III
(Group B—continued) Red Gravenstein Red James Grieve (Rosamund) Ontario French Rambour Wagener Worcester Pearmain			
Group C—Striped varieties, slightly coloured: Cox's Orange Pippin Imperatore (Emperor Alexander) Reine des Reinettes (King of the pippins) Rose de Caldaro (Kalterer) Laxton's Superb Stark's Earliest Berlepsch Commercio Ellison's Orange Oldenburg Pomme raisin Abbondanza	at least $\frac{1}{3}$ of surface of fruit streaked with red.	at least $\frac{1}{10}$ of surface of fruit streaked with red.	no provision.
Group D—Other varieties	no provision.	no provision.	no provision.

APPLES: RUSSETING CRITERIA

1. Russeting is not considered to be a defect in the following varieties of apple in which it is a characteristic of the variety so long as the extent of the russeting is typical of the variety:

Boskoop group	Grey Reinette
Cox's Orange group	Golden Russet (Egremont Russet)
Ingrid Marie	Yellow Newtown (Albermarle Pippin)
Laxton's Superb	Sturmer Pippin
Canadian Reinette	Dunn's Seedling

2. For varieties other than those listed above, russeting is permitted within the following limits:

	CLASSES		
Extra	I	II and III	Tolerance of Classes II and III
I. Brown patches			
– not outside the stalk cavity;	– extending a little way beyond the stalk or eye cavities;	– extending beyond the stalk or eye cavities;	– fruit not detracting from the appearance and condition of the package.
– not rough.	– not rough.	– slightly wrinkled.	
II. Russetting			
Maximum permitted on the surface of the fruit:			
(a) Fine net-like (not contrasting strongly with the general colouring of the fruit)			
– slight and isolated traces of russeting not altering the general appearance of the individual fruit or of the contents of the package as a whole.	1/5	1/2	– fruit not seriously harmed in appearance or likely to affect the overall appearance of the package.
(b) Dense			
– none.	1/20	1/3	– as for (a).
(c) Combined allowance—Fine net-like russeting and dense russeting together must not exceed:			
– slight and isolated traces of fine net-like russeting as for (a).	1/5	1/2	– as for (a).

APPLES AND PEARS: LARGE FRUITED VARIETIES*

1. Apples

Belle de Boskoop and mutations
Blenheim
Bramley's Seedling (Bramley, Triomphe de Kiel)
Charles Ross
Crimson Bramley
Ellison's Orange (Ellison)
Golden Delicious
James Grieve and mutations
Lane's Prince Albert
Melrose
Red Delicious and mutations
Tydeman's Early

Altländer
Bismarck
Black Ben Davis
Black Stayman
Brettacher
Calville Group
Cox pomona
Democrat
Double Bellefleur
Finkenwerder
French Reinette
Gelber Edel
Glory of Holland
Graham (Graham Royal Jubilé)
Grand Duke Frederick of Baden
Gravenstein (Gravensteiner)
Horneburger
Imperatore (Emperor Alexander)
Jacob Fisher
Jacques Lebel (Lebel, Jacob Lebel)
Königin (The Queen)
Lemon Pippin
Luxemburg Triumph
Morgenduft (Rome Beauty)
Musch (Musk)

* Apples and pears presented in Class II without any indication as to their variety shall also be considered to fall under this heading.

Notarapfel (Notaris, Notarisappel)
Ontario
Orleans Reinette
Pater v.d. Elsen
Reinette blanche et Reinette grise du Canada (Kanada Renette, Renetta del Canada, Reinette van Canada)
Reinette de Landsberg (Landsberger, Landsberger Reinette)
Signe Tillisch
Sour Gamerse
Stark Crimson (Starkrimson)
Staymanred
Stayman Winesap
Transparente de Croncels (Croncels)
Winter Banana (Winter Bananenapfel)
Winter Rambour
Zabergäu
Zigeunerin

2. Pears

Beurre Hardy, Hardy Butter-pear (Gellerts, Butirra Hardy)
Catillac (Pondspeer, Ronde Gratio, Grand Monarque, Chartreuse)
Doyenné du Comice (Vereinsdechant, Decana del Comizio)
Marguerite Marillat (Margherita Marillat)
Packham's Triumph (William d'Automne)
Passe Crassane (Passa Crassana)
William's Duchess (Pitmaston)

Abbot Fetel (Abbé Fétel, Abato Fetel)
Alexander Lucas Butter-pear
Clairgeau Butter-pear (Beurre Clairgeau, Clairgeaus Butterbirne, Butirra Clairgeau)
Congress (Souvenir du Congres, Kongress)
Diel Butter-pear (Beurre Diel, Diels Butterbirne, Butirra Diel)
Doyenné d'hiver (Decana d'inverno)
Duchess of Angoulême (Duchesse d'Angoulême, Herzogin von Angoulême, Duchessa d'Angoulême)
Emperor Alexander (Empereur Alexandre, Beurre Bosc, Beurre d'Apremont, Imperatore Alessandro, Calebasse Bosc, Kaiser Alexander, Bosc)
Jeanne d'Arc
Lebrun Butter-pear (Beurre Lebrun, Butirra Lebrun)
Triomphe de Vienne (Triumph von Vienne, Trionfo di Vienna)
Vicar of Winkfield (Curé, Curato, Pastoren)

APPENDIX 4

SUGGESTED FORMS OF LABEL

Packers may well find it possible to adapt their existing labels to comply with the marking requirements for apples and pears (see Section 6). When labels are being reprinted the following forms are suggested:

(a)	Name and address of packer and/or dispatcher (or identifying mark) Origin: (Country or Region)		25 mm
	Nature of produce (i.e., apples or pears) where contents not clearly visible Variety, or commercial type		35 mm
	Class	Size, count or other details as necessary	35 mm
	55 mm	35 mm	

OR

50 mm	50 mm	30 mm	30mm	
Name and address of packer and/or dispatcher (or identifying mark) Origin: (Country or Region)	Nature of produce (i.e., apples or pears): where contents not clearly visible Variety, or commercial type	Class	Size, count or other details as necessary	50 mm
(a)				

All entries should be clear.
The class should be in Roman figures not less than 7 mm in height.
Other letters should be not less than 3 mm in height.
The section (a) may be divorced from but should be adjacent to the remainder.

ADDRESSES OF REGIONAL HORTICULTURAL MARKETING INSPECTORS

Region	Address	Counties covered
Eastern	Room F. 12, Block B, Govt. Buildings, Brooklands Avenue, Cambridge CB2 2DR Tel: 58911 (STD Code 0223)	Bedford, Cambridgeshire, Essex, Hertfordshire, Huntingdon, Lincs. (Holland), Norfolk, Suffolk (excluding the Greater London area)
East Midland	Shardlow Hall, Shardlow, Derby DE7 2GN Tel: 313 (STD Code 033 128)	Derbyshire, Leicestershire, Lincs. (Kesteven and Lindsey), Northamptonshire, Nottinghamshire, Rutland
Northern	Govt. Buildings, Kenton Bar, Newcastle upon Tyne NE1 2YA Tel: 86-9811 (STD Code 0632)	Co. Durham, Cumberland, Yorkshire—North Riding, Northumberland, Westmorland
South Eastern	Room 221, Block A, Govt. Offices, Coley Park, Reading RG1 6DT Tel: 581222 (STD Code 0734)	Berkshire, Buckinghamshire, Hampshire (and Isle of Wight), Kent, Oxfordshire, Surrey, (except Greater London area), Sussex
	Room 143, Great Westminster House, Horseferry Road, London SW1P 2AE Tel: 834 8511 (STD Code 01)	Greater London area
South Western	Room G66, Block III, Govt. Buildings, Burghill Road, Westbury on Trym, Bristol BS10 6NJ Tel: 62 2851 (STD Code 0272)	Cornwall (and Isles of Scilly), Devon, Dorset, Gloucestershire, Somerset, Wiltshire
West Midland	Room 118, Woodthorne, Wolverhampton WV6 8TQ Tel: 754 190 (STD Code 0902)	Cheshire, Hereford, Shropshire, Staffordshire, Warwickshire, Worcestershire
Yorks and Lancs	Room 10, Wing 1, Block 2, Govt. Buildings, Lawnswood, Leeds LS16 5PX Tel: 67-4411 (STD Code 0532)	Lancashire, Yorkshire—East and West Riding
Wales	Room 144, Block 2, Govt. Buildings, Gabalfa, Cardiff CF4 4YH Tel: 62111 (STD Code 0222)	Anglesey, Brecon, Caernarvon, Cardigan, Carmarthen, Denbigh, Flint, Glamorgan, Merioneth, Monmouth, Montgomery, Pembroke, Radnor

Headquarters

England and Wales	Horticultural Marketing Inspectorate, Ministry of Agriculture, Fisheries and Food, Great Westminster House, Horseferry Road, London SW1P 2AE (Room 138) Tel: 834 8511 (STD Code 01) (Ext. 563 or 303)
Scotland	Department of Agriculture and Fisheries for Scotland, Chesser House, 500 Gorgie Road, Edinburgh EH11 3AW Tel: 443 4020 (STD Code 031)
Northern Ireland	Horticultural Marketing Division, Ministry of Agriculture for Northern Ireland, Dundonald House, Stormont, Belfast BT4 3SB Tel: 650111 (STD Code 0232)

APPENDIX 2

Farmers Survey Questionnaire

1. Name?
2. Farm?
3. Age?
4. Sex?
5. What is the size of your farm in hectares?
6. What is the area of these crops on your farm?
   - All apples
   - Cox M9
   - Cox MM106
   - Bramley M9
   - Bramley MM106
7. How many years have you been farming fruit?
8. Do you have any formal training?
9. How many gangs did you employ to pick apples in 1982?
10. How many would you ideally employ?
11. What was the maximum number of pickers you employed at any one time in 1982?
12. How many would you ideally employ?
13. Which picking method(s) do you use?
    - Nosebag-bin
    - Clarke-bag bin
    - Sack-bin
    - Nosebag-box
    - Bucket-bin
    - Bucket-box
    - Box
    - Other
14. Why do you use these methods?
    - Economics
    - Damage reduction
    - Management

Q14 (continued)

Time constraints

Health and safety

General wear and tear

Apple husbandry techniques

Other

15. Who supervises the pickers?

    Chargehand

    Tractor driver

    Personal

    Other

16. How many of your pickers are seasonal workers?
17. On average how many weeks do the seasonal workers pick out of the total season?
18. On average how many years does a seasonal worker return?
19. Are pickers formally trained?
20. What training is given to the pickers?

    None

    Lecture

    Demonstration

    Documentation

    Other

21. How often during the apple picking season is training given to the pickers?
22. What is the length of training (minutes)?
23. Do you have any preference for male or female pickers?
24. Are the people who train the pickers formally trained?
25. Who trains your trainers?
26. Who is responsible for quality control of apples in the orchard during the day?

    Chargehand

    Tractor driver

    Personal

    Other

27. At what point is damage to apples assessed?

    Picker

    Bag

    Box

    Bin

    Storehouse

    Grader

    Continuously

    Other

28. How do you identify different pickers performance for future reference?

    No records

    Bulk bin record card

    Pay system

    Other

29. Is action taken against pickers who consistently bruise fruit?
30. What action is taken against pickers who bruise fruit?
31. What percentage of damage must occur before action is taken?
32. How many times did you take such action in 1982?
33. Which pay scheme do you use?

    Day rate

    Piece rate

    Bonus incentive

    Other

Of the following methods:

34. Which are you familiar with?
35. How do you rate them?
36. Which would you not use?

    Hand picking from ground

    Hand picking from ladder

    Semi-automated

    Picking platforms

    Shake and catch

    Comb

    Direct grading

    Other

37. Is your picking method dictated by the need to use ladders?

38. What percentage of your crop is hand picked from ladders?

    Cox M9

    Cox MM106

    Bramley M9

    Bramley MM106

39. What was your total apple crop in 1982 (tonnes)?

40. What percentage of your crop was marketed at grades 1, 2 and 3 in 1982?

    Cox M9

    Cox MM106

    Bramley M9

    Bramley MM106

41. How many years have you used your current harvesting system?

42. Which harvesting system did you use previously?

43. Why did you change your apple harvesting system?

44. Do you have any major problems with apple harvesting in the orchard?

45. Do you have any major problems with apple grading?

APPENDIX 3

ltural Training Board
Beckenham Road, Beckenham, Kent, BR3 4PB

consent of the Agricultural Training Board is necessary
reproduction of this work or any part thereof.

/78 APG1

APPLE PICKERS' GUIDE

AGRICULTURAL TRAINING BOARD

APG 1

Introduction

This guide has been produced to help you pick fruit more effectively.

Following the recommendations shown in this guide will enable you to pick more fruit.

MORE FRUIT PICKED CORRECTLY MEANS MORE MONEY FOR YOU IF YOU ARE EARNING BONUS.

Note: △ = important safety point

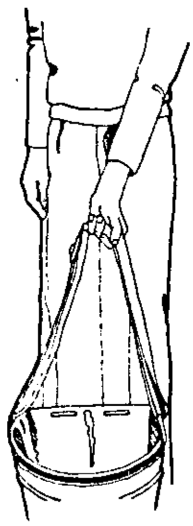
1. The picking bag

The bag must be adjusted correctly as shown below.

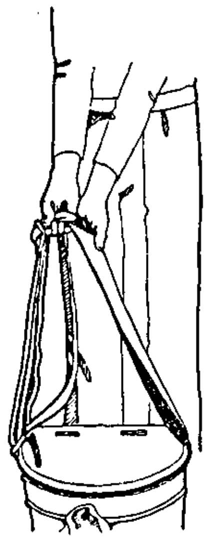
Putting on the bag

① Make sure that straps are not twisted before you start to put on bag.

①



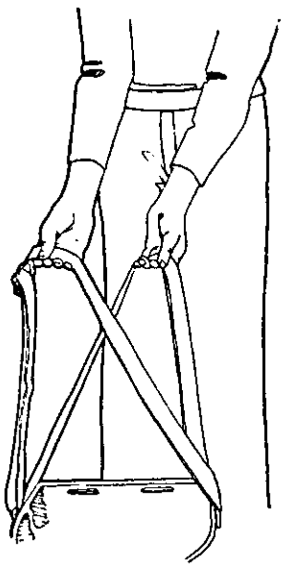
② Right hand pulls out bottom strap so that it is in position shown in ③.



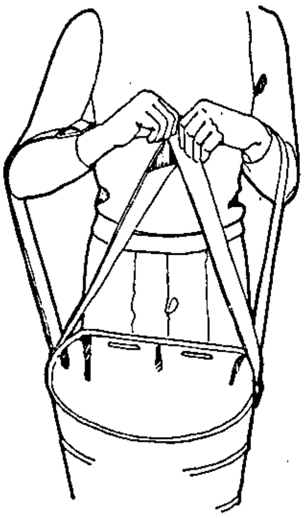
②

Take hold of lower strap

③

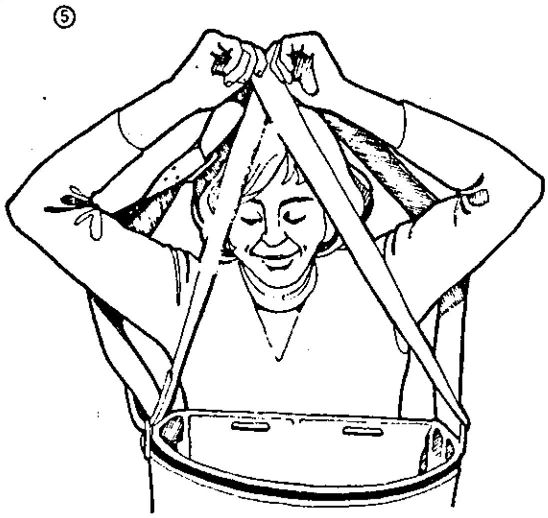


④



④ Lift up straps over forearms, placing them over head as shown in ⑤.

⑤

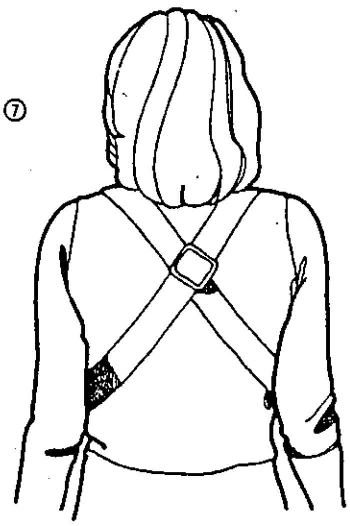


⑥ Bag should end up like this

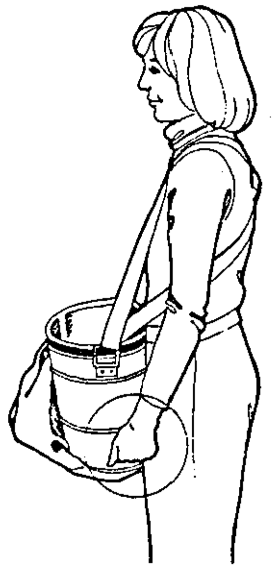
⑥

⑦ Back view. Note: straps are not twisted

⑦



Adjust straps so that you can touch bottom of the bag with your clenched fist.



2. Picking

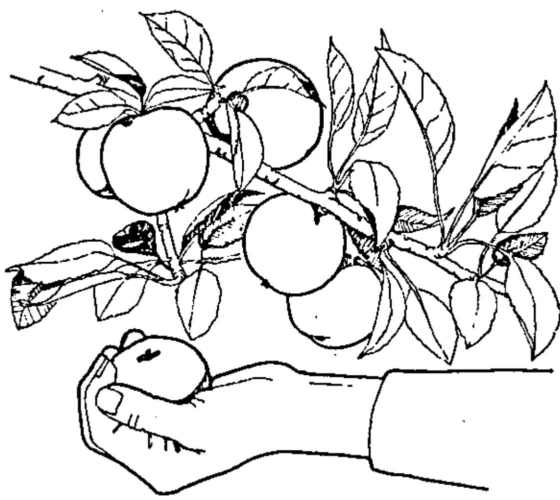
Fruit near to ground should be picked when bag is empty.

△ Never bend down to pick fruit near to the ground when the bag is more than ¼ full otherwise you may injure yourself.

Pick apples correctly.

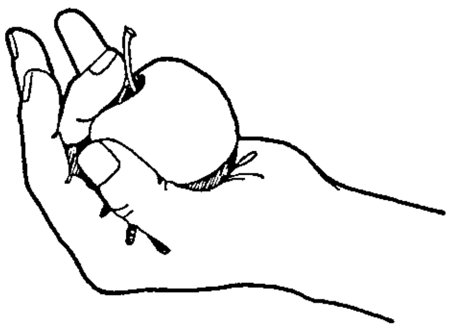
Lift and twist

Note: stalk is intact.



Note: apple is in palm of hand.

Golden Delicious and some other varieties have long stalks which can easily be torn off, so remove them using the method shown below.



Pick with both hands alternately, as shown below.

One hand picks apple; the other hand places apple into bag.

Apples in clusters of two or three should be picked by the methods shown below.

Doubles

Trebles

Place fruit carefully into picking bag.

Do not overfill picking bag. Fruit should be level with top of the bag.

Reject apples which have

- skin punctures (e.g. bird peck, wasp bites)
- bruises or signs of rot
- large cracks
- large insect marks.

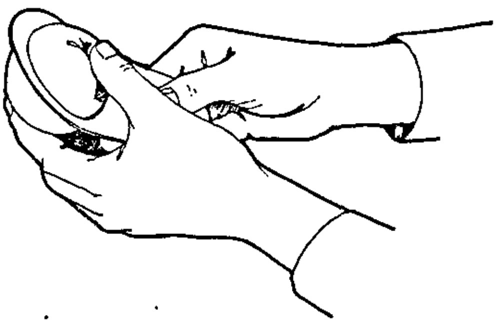
Check with your supervisor where to put these rejected apples. (Usually, they are dropped on the ground below the trees, but not near to the trunks).

3. Size of apples to be picked

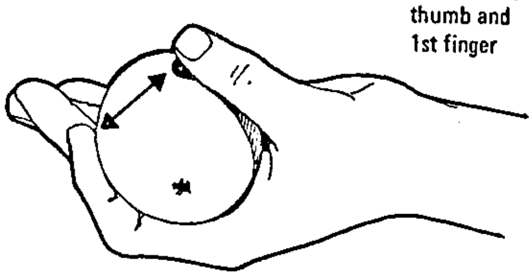
Do not pick apples which are too small.

Following the method below will help you remember the size of apple you must not pick.

Check size of apple in sizing ring.

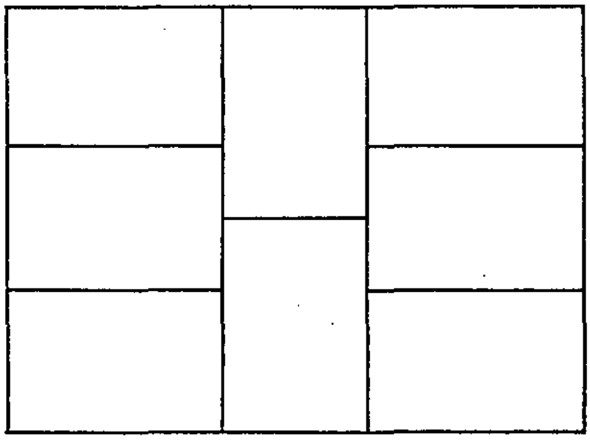


Then place apple between thumb and first finger.



4. Emptying picking bag into boxes

Arrange boxes on pallet as shown below.

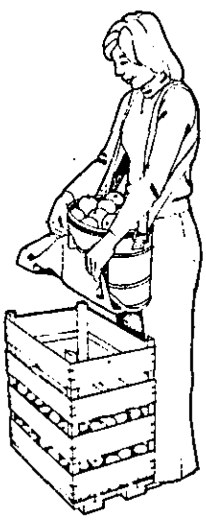


To avoid damage to the fruit or injury to yourself make sure the box being filled is stacked at a convenient height.

Carefully place picking bag on top of box and remove apples in three stages as shown.

Step 1

Note: apples are level with top of bag.



Step 2

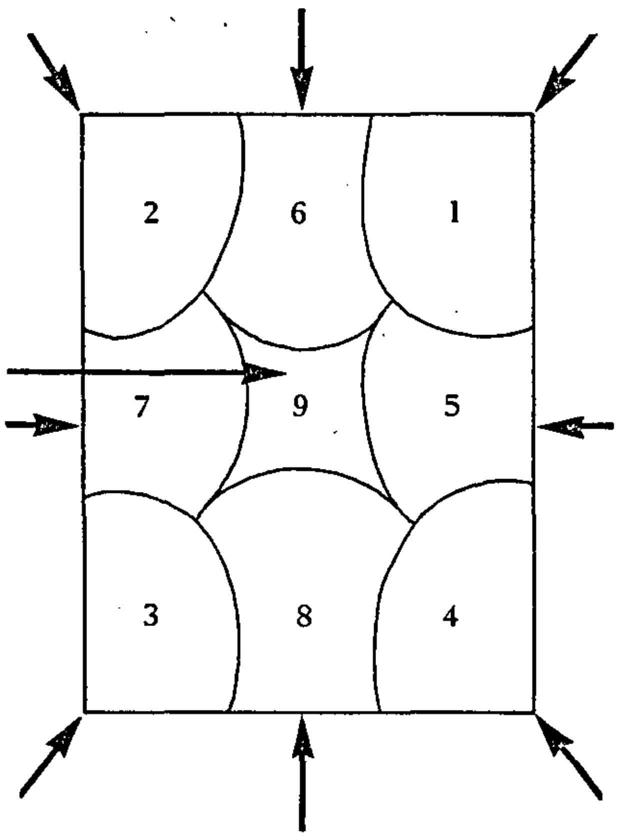
Step 3

Release the canvas and gently withdraw bag upwards

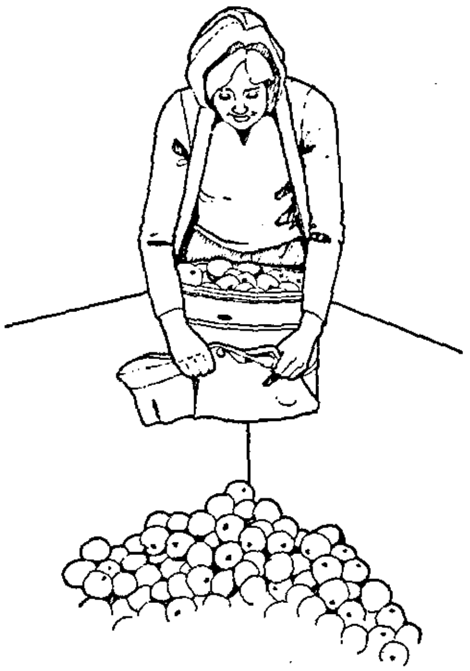
Do not overfill boxes

5. Emptying picking bag into bulk bins

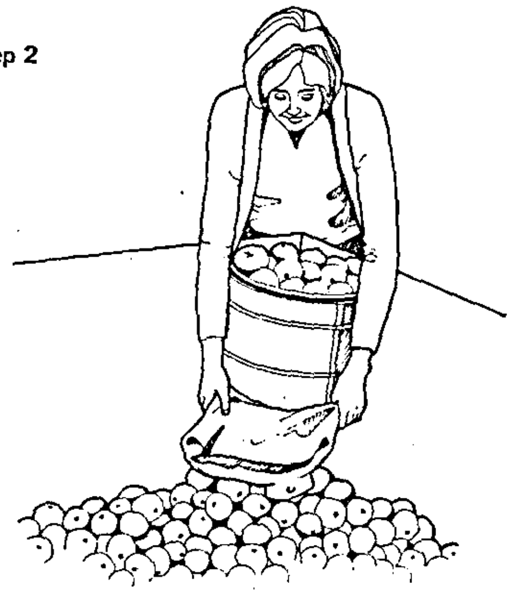
Apples placed in a bulk bin will roll. To minimize damage, fill the bin in the sequence shown below.



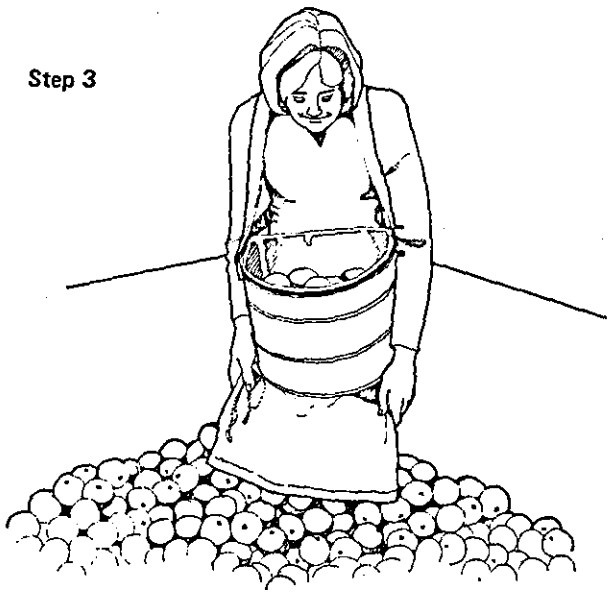
Step 1



Step 2



Step 3



Step 4

Note: hands guiding apples from base of bag.

6. Using steps and ladders

Position bag to side or back of body.

△ Do not over reach or you may injure yourself.

△ *Remember, it is your responsibility to make sure that the steps/ladder is:*

- complete, no rungs are missing or broken
- firmly placed on the ground
- placed in the tree so that no apples are knocked off.

△ Always position the ladder so that it is pointing towards the centre of the tree.

If the branch breaks, the ladder will fall into the centre of the tree, which will reduce the possibility of injuring yourself.

△ Do not jump off ladders

REMEMBER, APPLES BRUISE MORE EASILY THAN EGGS BREAK.

Use the next three pages for recording the bins and boxes of fruit you have picked.

Record below the bin/boxes of fruit you have picked. Then check what you have recorded against your record.

	Week 1	Week 2	Week 3
Sunday			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			

Record below the bin/boxes of fruit you have picked. Then check what you have recorded against your record.

	Week 4	Week 5	Week 6
Sunday			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			

Record below the bin/boxes of fruit you have picked. Then check what you have recorded against your record.

	Week 7	Week 8	Week 9
Sunday			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			

APPENDIX 4

Synthesized MTM Times

MTM times have been synthesized using films of apple picking taken during the 1982 apple harvesting season to produce times to strip a tree. The data is based on several assumptions as with the MTM analysis outlined previously, including apple distribution over the tree, apple clustering and branch placement. MTM times have been synthesized for the three formal picking methods, and the freestyle method again considering the three rootstocks of varying yields and the pickers abilities.

Tables 1, 2 and 3 consider rootstocks 106, 9 and 27 respectively. The data is based on Table 4 considering the distribution of fruit over each of the rootstocks. Each tree has been divided into the number of apples per picking zone for each type of tree. The time (seconds) has been given for picking a single apple in each picking zone considering different pickers abilities. The median picker (50th percentile) has also been considered and falls midway between the poor and good picker. However, the average (arithmetic mean) picker is slightly faster. This is because the distribution of picker's speeds is skewed towards the slower picker i.e. there are fewer fast pickers than slow pickers, or apples are more frequently picked slowly, as opposed to quickly.

The zonal picking times (seconds) for each picker are multiplied by the number of apples in that zone. This gives apple picking time per zone. The total picking time for each picker is the sum of the time spent picking in each zone. It represents the time taken to pick each apple individually and place it in the Dutch nosebag.

Table 5 converts the total picking times from Tables 1, 2 and 3 for the different tree yields and picking abilities into picking times (seconds) using the three formal picking methods.

The ATB is calculated by:

$$\frac{\text{Total Time}}{2} + \text{Number of apples per tree} \times 0.13 \text{ (the MTM rotation time)}$$

The rotation time is used to multiply the number of apples per tree as it is the ATM recommended movement to detach the apple from the tree. This movement occurs as well as the normal reach, grasp, move and release movement already noted and accounted for in the data from Tables 1, 2 and 3. However, in the MTM analysis from the 1983 harvesting season the apples were detached during the move from the tree to the pickers bag.

The 1/hand method is calculated by:

$$\frac{\text{Total Time}}{2}$$

The 2/hand method is calculated by:

$$\frac{\text{Total Time}}{4}$$

The last calculation is based on the assumption that the picker reaches and grasps two apples in each hand, then moves and releases them together into the Dutch nosebag. The actual movement noted in the films of the 1983 harvesting season involves the two hands working simultaneously though reaching for individual apples, moving and releasing four apples into the picking bag.

Table 6 calculates the total time (seconds) to pick all the apples off a tree and place them into a bulk bin. The figures are based on the data in Tables 7, 8 and 5. The non-picking time (Tables 7 and 8), when using a Dutch nosebag with and without a plastic lining bag, is added to the total picking time (Table 5), for each of the three formal picking methods. The figures take into account: the pickers ability, the tree types and yields, the picking method and picking bag. Table 9 calculates the synthesized MTM times for the various pickers to pick the different trees with the two types of bag, using the freestyle picking method, which combines the three formal methods plus other methods observed in the field, these are described overleaf by MTM-1 notation.

Tables 10 and 11 present the same data but with a 28% fatigue allowance added as previously outlined, and the data has been converted to minutes. It is apparent that using the Dutch nosebag with or without a plastic lining bag has no significant effect on the time to strip a tree. However, the time is noticeably faster if a picker uses the 2/hand method, followed by the 1/hand method, then the freestyle method, then the ATB method.

Overleaf the notation is given for MTM-1 analysis of the synthesized picking methods.

MTM Notation

1. ATB Method:

	Left Hand	Right Hand	
Reach for apple on tree	R70B		
Grasp apple	G1A		
Move apple from tree to bag (apple detaches with motion)	m M70B	R70B	Reach for apple on tree
		G1A	Grasp apple
Release apple into bag	RL1	m M70B	Move apple from tree to bag
Reach for apple in tree	m R70B	RL1	Release apple into bag
Grasp apple	G1A		
Move apple from tree to bag	m M70B		
Release apple into bag	RL1		

2. 1/hand Method:

Left Hand	Right Hand	
R70B	R70B	Both hands reach for apples on tree, moving in unison
G1A	G1A	Hands grasp apples one per hand
m M70B	m M70B	Both hands move apples from tree to bag
RL1	RL1	Both hands release apples into the bag

3. 2/hand Method:

Left Hand	Right Hand	
R70B	R70B	Both hands reach for apples on tree
G1A	G1A	Hands grasp apples, one per hand
m R10B	m R10B	Hands move to next apples
G1A	G1A	Hands grasp second apples
m M70B	m M70B	Hands move apples from tree to bag
RL1	RL1	Hands release four apples into the bag

4. <u>1+2/hand Method</u>:

	Left Hand	Right Hand	
	R70B	R70B	Both hands reach to cluster of three apples
	G1A	G1A	Hands grasp apples one in one hand, two in other
	m M70B	m M70B	Hands move apples from tree to bag
	RL1	RL1	Hands release apples into bag

5. <u>1 from Cluster Method</u>:

	Left Hand	Right Hand	
Hand reaches for cluster of apples	R70B	R70B	Hand reaches for apple
Hand grasps cluster of apples	G1A	G1A	Hand grasps apple
		m M70B	Hand moves apple from tree to bag
		RL1	Hand releases apple into bag

6. <u>2 from Cluster Method</u>:

	Left Hand	Right Hand	
Hand reaches for cluster of apples	R70B	R70B	Hand reaches for apple
Hand grasps cluster of apples	G1A	G1A	Hand grasps apple
		m R10B	Hand reaches to second apple
		G1A	Hand grasps second apple
		m M70B	Hand moves two apples from tree to bag
		RL1	Hand release apple into bgg

TABLE 1: Synthesized MTM Picking Times (Seconds) for a Centre Leader Tree, Cox 106, (Height 4m, Spread 3.5m)

Yield	LOW				MEDIUM				HIGH			
kg of apples per tree	40				50				60			
Number of apples per tree	400				500				600			
Picking region of the tree	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low
% of apples per region	28	38	19	15	28	38	19	15	28	38	19	15
Number of apples per region	112	152	76	60	140	190	95	75	168	228	114	90
Time for a poor picker to pick one apple in region	3.36	1.76	2.17	1.77	3.36	1.76	2.17	1.77	3.36	1.76	2.17	1.77
Time for a poor picker to pick all apples in a region	376.3	267.5	164.9	125.4	470.4	334.4	206.2	156.8	564.5	401.3	247.4	188.1
Total picking time for a poor picker	934.1				1167.8				1401.3			
Time for a median picker to pick one apple in the region	2.77	1.76	1.77	1.85	2.77	1.76	1.77	1.85	2.77	1.76	1.77	1.85
Time for a median picker to pick all apples in a region	310.2	267.5	134.5	111.0	387.8	334.4	168.2	138.8	465.4	401.3	201.8	166.5
Total picking time for a median picker	823.2				1029.2				1235.0			

/Continued...

TABLE 1 - continued...

Yield	LOW				MEDIUM				HIGH			
kg of apples per tree	40				50				60			
Number of apples per tree	400				500				600			
Picking region of tree	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low
Time for a good picker to pick one apple in the region	2.05	1.61	1.38	1.61	2.06	1.61	1.38	1.61	2.05	1.61	1.38	1.61
Time for a good picker to pick all apples in the region	229.6	244.7	104.9	96.6	287.0	305.9	131.1	120.8	344.4	367.1	157.3	144.9
Total picking time for a good picker	675.8				844.8				1013.7			
Time for an average picker to pick one apple in the region	2.82	1.76	1.77	1.88	2.82	1.76	1.77	1.88	2.82	1.76	1.77	1.88
Time for an average picker to pick all apples in the region	315.8	267.5	134.5	112.8	394.8	334.4	168.2	141.0	473.8	401.3	201.8	169.2
Total picking time for an average picker	830.6				1038.4				1246.1			

TABLE 2: Synthesized MTM Picking Times (Seconds) for a Dwarf Tree, Cox 9, (Height 3m, Spread 2m)

Yield	LOW				MEDIUM				HIGH			
kg of apples per tree	17				27				37			
Number of apples per tree	170				270				370			
Picking region of tree	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low
% of apples per region	1	23	33	43	1	23	33	43	1	23	33	43
Number of apples per region	2	39	56	73	3	62	89	116	4	85	112	159
Time for a poor picker to pick one apple in region	3.36	1.76	2.17	1.77	3.36	1.76	2.17	1.77	3.36	1.76	2.17	1.77
Time for a poor picker to pick all apples in a region	6.7	68.6	121.5	152.6	10.1	109.1	193.1	242.4	13.4	149.6	264.7	323.3
Total picking time for a poor picker	349.4				554.7				760.0			
Time for a median picker to pick one apple in a region	2.77	1.76	1.77	1.85	2.77	1.76	1.77	1.85	2.77	1.76	1.77	1.85
Time for a median picker to pick all apples in a region	5.5	68.6	99.1	135.1	8.3	109.1	157.5	214.6	11.1	149.6	215.9	294.2
Total picking time for a median picker	308.3				489.5				670.8			

/Continued...

TABLE 2 - continued ..

Yield	LOW				MEDIUM				HIGH			
kg of apples per tree	17				27				37			
Number of apples per tree	170				270				370			
Picking region of tree	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low	Ladder	Over-Shoulder	Mid	Low
Time for a good picker to pick one apple in a region	2.05	1.61	1.38	1.61	2.05	1.61	1.38	1.61	2.05	1.61	2.05	1.61
Time for a good picker to pick all apples in a region	4.1	62.8	77.3	117.5	6.2	99.8	122.8	186.8	8.2	136.9	168.4	256.0
Total picking time for a good picker	261.7				415.6				569.5			
Time for an average picker to pick one apple in a region	2.82	1.76	1.77	1.88	2.82	1.76	1.77	1.88	2.82	1.76	1.77	1.88
Time for an average picker to pick all apples in a region	5.6	68.6	99.1	137.2	8.5	109.1	157.5	218.1	11.3	149.6	215.9	298.9
Total picking time for an average picker	310.5				493.3				675.7			

TABLE 3: Synthesized MTM Picking Times (Seconds) for a Very Dwarf Tree, Vox 27 (Height 2m Spread 1.5m)

Note: This rootstock is not normally used for growing dessert apples so yield has been estimated by J. Partis, 20.7.1983

Yield (kg)	14			
Number of apples per tree	140			
Picking region of tree	Ladder	Over-Shoulder	Mid	Low
% of apples per region	0	0	4	96
Number of apples per region	0	0	6	134
Time for a poor picker to pick one appled per region	3.36	1.76	2.17	1.77
Time for a poor picker to pick all apples per region	-	-	13.0	280.1
Total picking time for a poor picker	293.1			
Time for a median picker to pick one apple per region	2.77	1.76	1.77	1.85
Time for a median picker to pick all apples per region	-	-	10.6	247.9
Total picking time for a median picker	258.5			
Time for a good picker to pick one apple per region	2.05	1.61	1.38	1.61
Time for a good picker to pick all apples per region	-	-	8.3	215.7
Total picking time for a good picker	224.0			
Time for an average picker to pick one apple per region	2.82	1.76	1.77	1.85
Time for an average picker to pick all apples per region	-	-	10.6	251.9
Total picking time for an average picker	262.5			

TABLE 4: Fruit Distribution on Three Types of Tree

	Tree Height Spread Rootstock	Centre Leader 4m 3 - 3.5m 106	Dwarf 2.5 - 3m 2m 9	Very Dwarf 1.5 - 2m 1 - 1.5m 27
4M				
		NO FRUIT		
3M		28% FRUIT		
	(LADDER WORK)		NO FRUIT	
2M	206 cm Overhead Reach		1% FRUIT	
	(HIGH WORK)	38% FRUIT	23% FRUIT	
	140 cm Shoulder Height			NO FRUIT
	(MIDDLE WORK)			
1M	102 cm Waist Height	19% FRUIT	33% FRUIT	4% FRUIT
	(LOW WORK)	15% FRUIT	43% FRUIT	96% FRUIT
	Ground			

TABLE 5: Synthesized MTM Picking Times (Seconds) to Pick a Tree Using Different Picking Styles on Three Types of Tree With Varying Yields

*Based on picking times from tables

Rootstock		106			9			27
Yield		LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
kg of apples per tree		40	50	60	17	27	37	14
Number of apples per tree		400	500	600	170	270	370	140
Picking Style	Picker Type							
ATB Picking Method	Poor	519.1	648.9	778.7	196.8	312.5	428.1	164.8
	Median	463.6	579.6	695.5	176.3	279.9	383.5	147.5
	Good	389.9	487.4	584.9	153.0	242.9	332.9	130.2
	Average	467.3	584.2	701.1	177.4	281.7	386.0	149.5
Both hands picking simultaneously one apple per hand	Poor	467.1	583.9	700.7	174.7	277.4	380.0	146.6
	Median	411.6	514.6	617.5	154.2	244.8	335.4	129.3
	Good	337.9	422.4	506.9	130.9	207.8	284.8	112.0
	Average	415.3	519.2	623.1	155.3	246.6	337.9	131.3
Both hands picking simultaneously two apples per hand	Poor	233.5	292.0	350.3	87.4	138.7	190.0	73.3
	Median	205.8	257.3	308.8	77.1	122.4	167.7	64.7
	Good	169.0	211.2	253.4	65.4	103.9	142.6	56.0
	Average	207.7	259.6	311.5	77.6	123.3	168.9	65.6

TABLE 6: Synthesized MTM Picking Times (Seconds) to Strip a Tree Using a Nosebag With or Without a Lining and Three Picking Styles on Three Types of Tree with Varying Yields

Rootstock			106			9			27
Yield			LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
		Pickers							
Using a nosebag which is emptied into a bulk bin	Using ATB recommended picking methods	Poor	771.9	911.1	1050.2	253.7	369.4	494.3	186.1
		Median	714.6	839.4	964.0	232.0	335.6	447.9	168.2
		Good	633.5	737.3	841.0	203.7	293.6	389.9	148.4
		Average	718.3	844.0	969.6	233.1	337.4	450.4	170.2
	Using both hands together picking one apple per hand	Poor	719.9	846.1	972.2	231.6	334.3	446.2	167.9
		Median	662.6	774.4	886.0	209.9	300.5	399.8	150.0
		Good	581.5	672.3	736.0	181.6	258.5	341.8	130.2
		Average	666.3	779.0	891.6	209.0	302.3	402.3	152.0
	Using both hands together picking two apples per hand	Poor	486.3	554.2	621.8	144.3	195.6	256.2	94.6
		Median	456.8	517.1	577.3	132.8	178.1	232.1	85.4
		Good	412.6	461.1	509.5	116.1	154.6	199.4	74.2
		Average	458.7	519.4	580.0	133.3	179.0	233.3	86.3

/Table 6 .. continued

TABLE 6 ... continued

Rootstock			106			9			27
Yield			LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
		Pickers							
Using nosebag with a plastic lining bag which is placed into a bulk bin	Using ATB recommended picking methods	Poor	761.3	896.9	1032.2	246.6	362.3	483.7	182.5
		Median	705.8	827.6	949.3	226.1	329.7	439.1	165.2
		Good	632.1	735.4	838.7	202.8	292.7	388.5	147.9
		Average	709.5	832.2	954.9	227.2	331.5	441.6	167.2
	Using both hands together picking one apple per hand	Poor	709.3	831.9	954.5	224.5	327.2	435.6	164.3
		Median	653.8	762.6	871.3	204.0	294.6	391.0	147.0
		Good	580.1	670.4	760.7	180.7	257.6	340.4	129.7
		Average	657.5	767.2	876.9	205.1	296.4	393.5	149.0
	Using both hands together picking two apples per hand	Poor	475.7	540.0	604.1	137.2	188.5	245.6	91.0
		Median	448.0	505.3	562.6	126.9	172.2	223.3	82.4
		Good	411.2	459.2	507.2	115.2	153.7	198.0	73.7
		Average	449.9	507.6	565.3	127.4	173.1	224.5	83.3

TABLE 7: MTM Times (Seconds) for Non-Picking Activities Whilst Stripping Three Types of Tree of Varying Yields Using a Dutch-Nosebag With and Without a Liner

Rootstock	106			9			27
Yield	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
kg of apples per tree	40	50	60	17	27	37	14
Number of bags filled by one tree	3	4	5	2	2	3	1
Time to empty nosebags into bin	13.2	17.6	22.0	8.8	8.8	13.2	4.4
Time to transfer lining bag to ground then to bulk bin	17.4	23.2	29.0	11.6	11.6	17.4	5.8
Time to walk to and from bin to empty bag	13.0	17.4	21.7	8.7	8.7	13.0	4.3
Time to walk around tree	20.8	20.8	20.8	17.8	17.8	17.8	11.9
Number of ladder moves and climbs, up and down	10	10	10	1	1	1	0
Time taken for ladder work	204.0	204.0	204.0	20.4	20.4	20.4	0
Total time for non-picking activities with nosebag	251.0	259.8	268.5	55.7	55.7	64.4	20.7
Total time for non-picking activities with nosebag + liner	242.2	248.0	253.8	49.8	49.8	55.6	17.7

Notes: Non-picking time with nosebag = time to empty bags + time to walk to and from bin + time to walk around tree + ladder work time
Non-picking time with liner = time to transfer liner to ground + bulk bin + time to walk around tree + ladder work

TABLE 8: Total MTM Times (Seconds) for Picking and Non-Picking Activities for a Range of Pickers Abilities

Rootstock		106			9			27
Yield		LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
Time taken for non-picking activities using a nosebag	Poor Picker	252.8	262.2	271.5	56.9	56.9	66.2	21.3
	Good Picker	243.6	249.9	256.1	50.7	50.7	57.0	18.2
Time taken for non-picking activities using a nosebag with liner	Average Picker	242.2	248.0	253.8	49.8	49.8	55.6	17.7

TABLE 9: Synthesized MTM Picking Times (Seconds) to Strip a Tree Picking Freestyle Using a Nosebag With or Without a Lining on Three Types of Tree With Varying Yields

Roostock		106			9			27
Yield		LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
Using Nosebag	Poor Picker	710.2	834.0	957.6	252.2	366.5	490.2	180.5
	Medium Picker	661.8	773.3	884.7	231.1	333.8	445.2	163.6
	Good Picker	580.7	671.3	761.8	194.6	278.9	369.5	135.5
	Average Picker	666.3	779.0	891.5	233.0	336.8	449.4	165.2
Using Nosebag with Liner	Poor Picker	699.6	819.8	939.9	245.1	359.4	479.6	176.9
	Median Picker	653.0	761.5	870.0	225.2	327.9	436.4	160.6
	Good Picker	557.3	669.4	758.5	193.7	278.0	368.1	135.0
	Average Picker	657.5	767.2	876.8	227.1	330.9	440.6	162.2

TABLE 10: Synthesized MTM Times (Minutes) to Strip a Tree, plus 28% Fatigue Allowance, Using a Nosebag With or Without a Lining and Three Picking Styles on Three Types of Tree with Varying Yields

Rootstock			106			9			27
Yield			LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
		Pickers							
Using a nosebag which is emp-tied into a bulk bin	Using ATB recommended picking methods	Poor	16.5	19.4	22.4	5.4	7.9	10.5	4.0
		Median	15.2	17.9	20.6	4.9	7.2	9.6	3.6
		Good	13.6	15.7	17.9	4.3	6.3	8.3	3.2
		Average	15.3	18.0	20.7	5.0	7.2	9.6	3.6
	Using both hands toge-ther pick-ing one apple per hand	Poor	15.4	18.1	20.7	4.9	7.1	9.5	3.6
		Median	14.1	16.5	18.9	4.5	6.4	8.5	3.2
		Good	12.4	14.3	16.3	3.0	5.5	7.3	2.8
		Average	14.2	16.6	19.0	4.5	6.4	8.6	3.2
	Using both hands toge-ther pick-ing two apples per hand	Poor	10.4	11.8	13.3	3.1	4.2	5.5	2.0
		Median	9.7	11.0	12.3	2.8	3.8	5.0	1.8
		Good	8.8	9.8	10.9	2.5	3.3	4.3	1.6
		Average	9.8	11.1	12.4	2.8	3.8	5.0	1.8

/Continued..

TABLE 10: continued...

Rootstock			106			9			27
Yield			LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
Using a nosebag with a plastic lining bag which is placed into a bulk bin	Using ATB recommended picking methods	Pickers							
		Poor	16.2	19.1	22.0	5.2	7.7	10.3	3.9
		Median	15.1	17.7	20.3	4.8	7.0	9.4	3.5
		Good	13.5	15.7	17.9	4.3	6.2	8.3	3.2
		Average	15.1	17.8	20.4	4.8	7.1	9.4	3.6
	Using both hands together picking one apple per hand	Poor	15.1	17.7	20.4	4.8	7.0	9.3	3.5
		Median	13.9	16.3	18.6	4.4	6.3	8.3	3.1
		Good	12.4	14.3	16.2	3.9	5.5	7.3	2.8
		Average	14.0	16.4	18.7	4.4	6.3	8.4	3.2
	Using both hands together picking two apples per hand	Poor	10.1	11.5	12.9	2.9	4.0	5.2	1.9
		Median	9.6	10.8	12.0	2.7	3.7	4.8	1.8
		Good	8.8	9.8	10.8	2.5	3.3	4.2	1.6
		Average	9.6	10.8	12.1	2.7	4.7	4.8	1.8

TABLE 11: Synthesized MTM Picking Times (Minutes) to Strip a Tree, Plus 28% Fatigue Allowance, Picking Freestyle Using a Nosebag With or Without a Lining on Three Types of Tree with Varying Yields

Rootstock		106			9			27
Yield		LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
Using Nosebag	Poor Picker	15.15	17.79	20.43	5.38	7.82	10.46	3.85
	Median Picker	14.12	16.50	18.87	4.93	7.12	9.50	3.49
	Good Picker	12.39	14.32	16.25	4.15	5.95	7.88	2.89
	Average Picker	14.21	16.62	19.02	4.97	7.19	9.59	3.52
Using Nosebag with Liner	Poor Picker	14.92	17.49	20.05	5.23	7.67	10.23	3.77
	Median Picker	13.93	16.25	18.56	4.80	7.00	9.31	3.43
	Good Picker	11.89	14.28	16.18	4.13	5.93	7.85	2.88
	Average Picker	14.03	16.37	18.17	4.84	7.06	9.40	3.46

APPENDIX 5

APPENDIX 5

GRADING RINGS

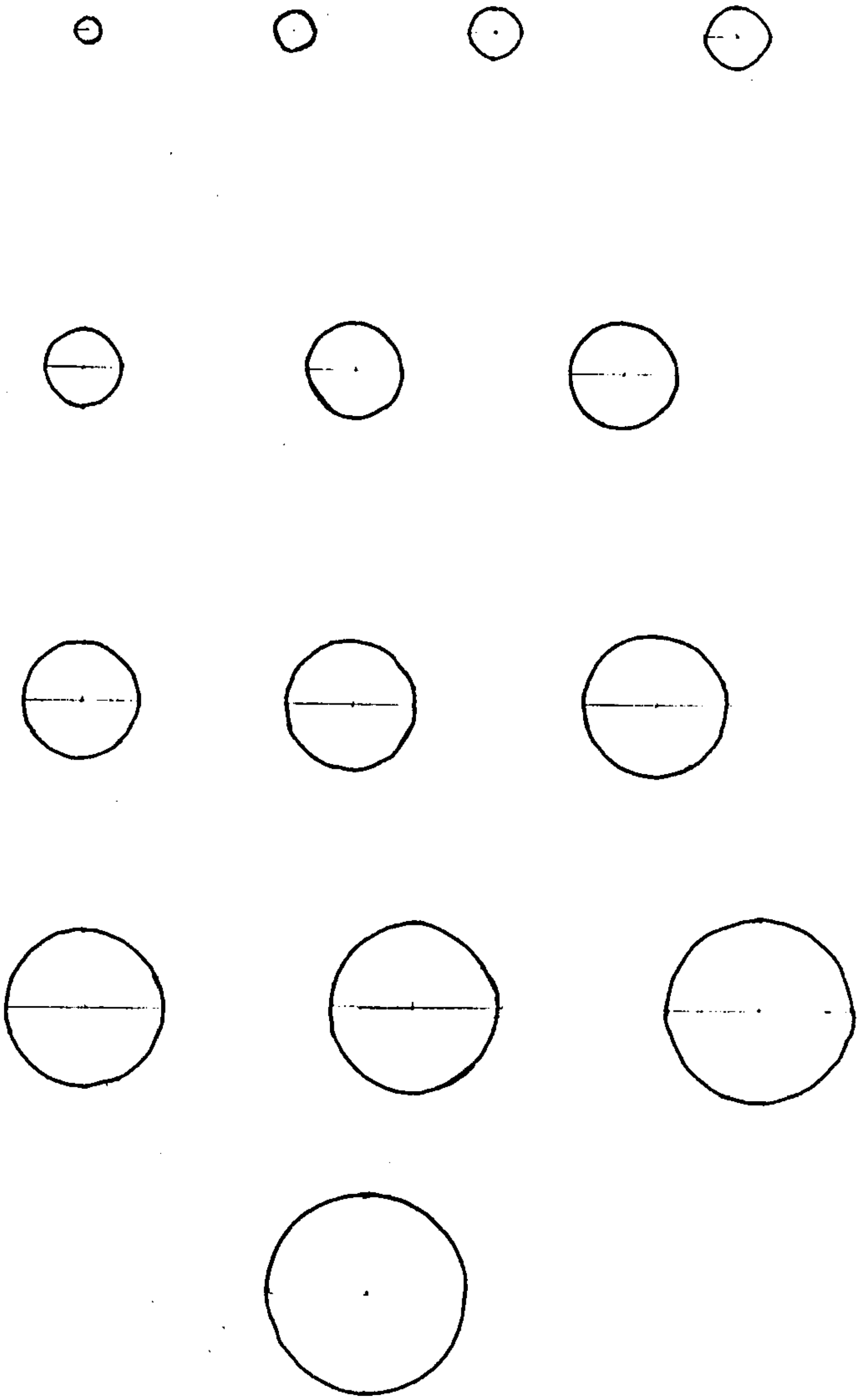


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TABLE 3.6 Basic anthropometric data for examiners at the 7 commercial packhouses. Note that all examiners were female, and that all measurements include winter apparel.

FARM	AGE	HEIGHT (mm)	EYE HEIGHT (mm)	RIGHT ARM LENGTH (mm)	WEIGHT (kg)
1	22	1650	1580	750	57
	24	1700	1580	720	62
	48	1680	1540	750	630
	60	1640	1570	770	790
	33	1530	1430	690	550
	57	1650	1520	690	670
2	37	1630	1560	600	57
	56	1620	1540	620	55
	49	1680	1500	690	66
	36	1610	1490	730	56
	50	1740	1660	780	80
	30	1640	1540	710	60
	46	1700	1590	820	60
	47	1680	1560	740	60
	37	1570	1460	640	54
3	22	1620	1520	-	49
	34	1550	1440	640	55
	45	1680	1580	720	65
	51	1610	1500	600	57
	43	1680	1510	700	67
	59	1510	1410	730	70
4	36	1620	1520	840	-
	32	-	-	-	-
	51	1640	1540	760	-
	60	-	-	-	-
	59	1550	1450	710	-
	34	1600	-	740	-
	47	1620	1500	730	-
5	39	1680	1540	720	64
	27	1660	1540	710	45
	52	1660	1530	730	56
	38	1610	1490	690	75
	26	1640	1520	700	66
	44	1640	1520	680	55

FARM	AGE	HEIGHT (mm)	EYE HEIGHT (mm)	RIGHT ARM LENGTH (mm)	WEIGHT (kg)
6	32	1600	1500	680	-
	56	-	-	-	-
	35	1630	1540	740	-
	34	1580	1480	740	-
	33	1580	1480	670	-
	57	1580	1480	670	-
	36	1630	1530	-	79
	59	1630	1500	720	-
7	52	1620	1500	680	-
	39	-	-	-	-
	53	1700	1590	870	-
	30	1630	1530	720	-
	42	-	-	-	-
	37	1650	1550	700	-
Mean	40.3	1632	1522	714	62
S.D.	13.9	48	48	56	8.8
N	48	42	41	41	28

Normal population values

Mean	-	1626	1520	698	59.8
S.D.	-	66	60	48	8.5

APPENDIX 1.3 - ANALYSIS OF EFFECTS OF IMPROVING GRADING PERFORMANCE

ASSUMPTIONS

(a) Apples arriving at the grading table are downgradable by bruising alone.

(b) The amount of bruise damage on the apples is as given in Fig. 1.1, immediately after grading.

(c) The optimum strategy is being pursued; Class II apples are moved to a separate lane, Rejects are removed.

(d) Damage occurring to the apples after grading is negligible.

(e) It is appropriate to use market prices for 1983.

Class I Cox apples 34p per kg.

Class II Cox apples 25.5p per kg.

(f) Throughput of apples per examiner is 60/min.

(g) Performance of examiners without training is as given in Table 5.8. It is assumed that misgrades are by one class only. This underestimates slightly the true extent of misgrading.

(h) Performance of examiners with training is assumed to be 50% successful. A criterion given in Section 1.4.7 is that good examiners may reach 75% correct decisions; 50% success is taken to mean that examiners will move from 60% correct decisions (Table 5.8) to 67.5% correct decisions.

(i) Training given to examiners continues for six months at the rate of one day in the first week, supplemented by 30 mins once every subsequent week, as suggested in Section 1.4.9.

(j) Trained examiners are rotated every 90 minutes for 90 minutes. Effectively, this means that twice as many examiners need to be trained as in current circumstances, where examiners are at the grading table for the full 8 hours of the working day.

(k) The probability that a batch will be returned from the market for regrading is proportional to one half the percentage by which that batch fails to meet the Class requirements (to allow for grading errors by the wholesaler). For example, if a Class I batch has 15% Class II apples, and the allowance for out-of-grade fruit is 5%, then the probability that the batch will be rejected is 0.05

(i.e. 10% x 1/2). This assumption is introduced in view of the absence of any public information on the rejection of market fruit, or of the sensitivity of price to the quality of produce.

(1) Class I fruit rejected at market is sold as Class II fruit, instead of being regraded. Class II fruit is regraded and then sold. It is assumed for simplicity that regraded fruit has all rejects removed.

ANALYSIS

Throughput of apples per examiner per 8-hour day = 28800,
= 4800 kg

Marginal cost of training examiners =
(1.0/(1.0 - (AVTR x 2) x PAY)/THRUPUT

where AVTR = average training time per day
= ((25 weeks x 15 mins) + (1 week x 8 hrs))/(26 weeks x 5 days)
= ((25 x .25) + (1 x 8))/(26 x 5 x 8)
= 0.014 hrs.

PAY = average daily rate of pay excluding overheads
= £20.00

THRUPUT = daily throughput per examiner
= 4800 kg.

= (1.0/(1.0 - (0.014 x 2)) x 20.00)/4800
= 0.043 p per kg.

Apple quality arriving at the grading table:	Class I	66%
	Class II	23%
	Rejects	11%

Apple quality after examining (adjusted for misgrades from Table 5.8):
Examining by untrained examiners:

		Absolute	Relative
Class I lane:	Class I apples	57.8%	74.7%
	Class II apples	19.6%	25.3%
	Rejects	-	-
	Total	77.4%	100.0%
Class II lane:	Class I apples	8.2%	45.3%
	Class II apples	0.5%	2.8%
	Rejects	9.4%	51.9%
	Total	18.1%	100.0%
Rejects:	Class I apples	-	-
	Class II apples	2.9%	64.4%
	Rejects	1.6%	35.6%
	Total	4.5%	100.0%

Apple quality after examining by trained examiners:

		Absolute	Relative
Class I lane:	Class I apples	59.4%	78.8%
	Class II apples	16.0%	21.2%
	Rejects	-	-
	Total	75.4%	100.0%
Class II lane:	Class I apples	6.6%	34.9%
	Class II apples	4.7%	24.9%
	Rejects	7.6%	40.2%
	Total	18.9%	100.0%
Rejects:	Class I apples	-	-
	Class II apples	2.3%	40.4%
	Rejects	3.4%	59.6%
	Total	5.7%	100.0%

It therefore seems reasonable to draw the conclusion that it pays to misgrade, as long as upgrades are more probable than downgrades. This in turn assumes that all apples in Classes I and II will be sold on the market at normal prices. Introducing the rather arbitrary assumptions given above regarding the probability of batches being rejected gives the following.

	Probability of rejection	
	Class I	Class II
Fruit examined by untrained examiners	0.10	0.23
Fruit examined by trained examiners	0.08	0.17

Hence,

Value of crop per kg =

(PRI x %CI x PROPACCI) + (PRII x %CI x PROPREJI) +
(PRII x %CII x PROPACCII) + (PRII x (%CII x ACCII) x PROPREJII)
- (COGRAD x %CII x PROPREJII) - COGRAD

where PRI = price of Class I fruit = 34 p per kg
PRII = price of Class II fruit = 25.5 p per kg
%CI = % of Class I batches
%CII = % of Class II batches
PROPACCI = proportion of Class I batches accepted
PROPACCII = proportion of Class II batches accepted
PROPREJI = (1 - PROPACCI)
PROPREJII = (1 - PROPACCII)
ACCII = (proportion of acceptable apples in Class II)
COGRAD = cost of grading crop = 15.3 p per kg.

Value of crop graded by untrained examiners =

(34 x 0.774 x 0.90) + (25.5 x 0.774 x 0.10) +
(25.5 x 0.181 x 0.77) + (25.5 x (0.181 x 0.48) x 0.23)
- (15.3 x 0.181 x 0.23) - 15.3

= 13.8 p per kg (less other costs)

Value of crop graded by trained examiners =

$$(34 \times 0.754 \times 0.92) + (25.5 \times 0.754 \times 0.08) + (25.5 \times 0.189 \times 0.17) + (25.5 \times (0.189 \times 0.60) \times 0.17) - (15.3 \times 0.189 \times 0.17) - 15.3 - \text{Marginal training cost}$$

$$= 9.9 \text{ p per kilo (less other costs)}$$

This still indicates an advantage in misgrading, provided most misgrades are upgrades, and emphasises the importance of a proper study of the relationship between the marketing of fruit and its quality.

It should be noted that the equation above is relatively insensitive to changes in the proportion of genuine Class I fruit, and to the changes that could be realised in grading performance, but is sensitive to price differences and the probability of poor batches being rejected.