COMMERCIAL - IN CONFIDENCE

CONTRACT REPORT NO: CR/637/95/1297

FINAL REPORT 1994 (Year 4)

PROJECT NO:	FV92a
PROJECT TITLE:	Carrots: Disposal of straw after field storage - chopping straw off the carrot bed. Methods and commercialisation of equipment.
PROJECT LEADER:	R. E. Cope
PROJECT COORDINATOR:	Dr Andrew Prestt
DATE PROJECT COMMENCED:	October 1993
DATE PROJECT DUE:	June 1994
KEYWORDS:	Carrots, Field storage, Chopping, Straw, New machinery, Novel ideas, Cost saving

REPORT TO:	Horticultural Development Council 18 Lavant Street Petersfield Hants. GU32 3EW
SRI COMMERCIAL OFFICER:	M. D. P. Matthews
PERIOD OF INVESTIGATION:	October 1993 to June 1994
PRINCIPAL WORKER AND AUTHOR OF REPORT:	Richard E. Cope, Research Engineer/ Cultivation Specialist

---

CONTENTS

COMMERCIAL - IN CONFIDENCE

Summary

The effects of incorporating up to 40 t/ha of straw have been investigated under project FV92. Different degrees of straw and soil pre-mixing were examined in relation to subsequent plough and crop performance.

Results from two seasons work showed that pre-mixing cultivations beyond those required to achieve complete inversion with the plough were no advantage in subsequent crop performance.

Straw which had been partially chopped required two to three pre-mixing passes, each followed by a pressing (1 ton/m), to enable a mouldboard plough fitted with trashboards to achieve optimum workrates and inversion. A further two pre-mixing treatments were often required for a plough fitted with skim coulters to operate successfully. The interbody and underbeam clearance was 39" (990 mm) and 27" (686 mm) in both cases.

Pre-mixing operations are not agronomically beneficial. In order to minimise or eliminate them, a complete chop of the straw residue will be necessary. The only practical way to achieve this is to chop the straw as it is removed from the bed.

Two alternative designs of machine capable of chopping the straw as it is removed from the bed were examined; one has now become a commercial reality after successfully undergoing field evaluation.

This technique is likely to save contractors and growers between £50 and £80/ha when preparing the soil for the following crop. (Contract Report No. 93/21, Project FV92.)

1. Introduction

Growers field store at least one third of their main crop carrots to ensure that there is a continuity of supply during winter. Some 3,000 ha are stored on mineral soil types which offer little insulation from frost. This means that a very thick layer of straw is required if the roots are to be adequately protected and growers now use at least 40 t/ha of straw.

At the end of the storage period the straw must be removed prior to harvesting. Straw can be burnt after removal from the carrot bed, but it is subject to legislation on pollution, the environment and worker safety. In practice, burning of wet straw is very difficult and can cause a serious nuisance to neighbours. Most growers therefore choose to dispose of the straw by incorporation.

Present straw removal systems lift the unchopped straw from the bed and spread it sideways onto a very rutted uneven surface. Further wheeling pushes more of the residue below the soil surface. In this situation it is impossible for a conventional tractor three point linkage mounted chopper to pick up and chop all of the straw without considerable blade damage through contact with the soil. The result is that only 50-60% of the straw can be chopped and in very severe conditions only 25-30%.

2. Objectives

(a) To identify techniques to chop the straw from the carrot bed at speeds equivalent to the harvesting operation.

(b) To remove straw from the surface of polythene membranes while keeping the membrane intact.

(c) To chop straw from the bed wheelways, without lifting soil and stones.

(d) To spread the chopped straw away from the bed to be harvested, taking account of the effect of high winds.

(e) To lift the polythene membrane if present in the same operation after having first removed the straw. (Ideal but not absolutely necessary for successful harvesting.)

3. Methods and materials

The results of field trials carried out under project FV92 identified possible ideas which could be further developed to achieve some, if not all, of the objectives.

A tractor mounted straw chopper being a relatively low cost machine had shown

potential in dealing with these residues which could often be very wet, frozen or covered in snow.

A number of field trials were carried out using two different mechanisms:

The first mechanism to be evaluated was a modified Hesston metered chop forage harvester. The fan and side delivery chute were removed and replaced with two deflector plates, to prevent the chopped residue being lifted too high in windy conditions, reduce power requirement and deflect the residue sideways.

The transport wheels were modified by introducing spacers between the axle and the chassis frame so that the machine could be lifted clear of the carrot bed. The pick- up reel mechanism was hinged at the front with a hydraulic ram to adjust its operating height and depth. The main feed rollers and chopping cylinder were as per the standard machine. The angle of the drawbar was adjusted to allow the tractor to run at the side of the bed being processed.

Trials were carried out over the carrot bed and also after the straw had been tipped off the polythene membrane and placed immediately at the side of the bed to be harvested.

The second mechanism to be evaluated was a standard three-point linkage mounted Kverneland FX 255 straw chopper fitted with two straight blades and one fan blade per location, with a maximum rotor speed of 2000 rev/min. Fixed blades were mounted on the chassis frame in the three o'clock position and the action between the fixed and rotating blades chopped the straw.

Trials were carried out with the machine mounted behind a high clearance tractor which could run over the top of the bed of carrots with 300 mm depth of straw without picking up the straw underneath the tractor. This allowed the chopper to straddle the bed and pick up the straw directly from the top of the bed. The depth wheels were positioned to run in the bed wheelways and also moved towards the centre of the chopper and run in-between the rows of carrots on top of the bed.

This mechanism was also used to chop some of the straw after it had been removed from the bed, but because the straw had fallen into wheel ruts from the harvesting machinery and further wheeled into the soil by transport trailers only 50-60% of the straw could be picked up by the chopping mechanism.

4. Results and discussion

4.1 Hesston metered chop forage harvester

This mechanism straddled the bed, the pick-up reel lifted the straw into the metering

rollers for delivery to the chopping cylinder. An adequate chop length of 100 mm or less was achieved at a forward speed of 1.8 km/h. Power requirement was well within the capabilities of the 75 kW tractor used.

The forward speed was limited by the ability of the pick-up mechanism to deal with the large volumes of wet straw. At speeds above 2.0 km/h the sheer bolt in the reel drive kept breaking.

The feed rollers became clogged up with particles of soil and wet straw which in turn caused that sheer bolt to break. Further problems were also encountered with the pick-up reel height control mechanism, especially with a polythene membrane present. Sensors would need to be fitted to detect the top of the carrots and then adjust the height of the pick-up mechanism accordingly. It is impossible for the operator to control the height without sensors, as the top of the bed cannot be seen beneath the straw layer.

4.2 Kverneland FX 255 straw chopper

This mechanism straddled the bed behind a high clearance tractor. The depth wheels were adjusted to run in the bed wheelways and lift the rotor clear of the bed. Further height adjustment of the rotor was achieved by raising and lowering the tractor lift arms without a top link being fitted.

This mechanism was able to chop 75-80% of the residue without damaging the membrane, but the straw in the bed wheelways remained unchopped. Depth control was not easy with the wheels of the chopper following the tractor wheelings on an uneven straw surface. Moving the depth wheels of the chopper on top of the bed, in-between the rows of carrots gave more accurate depth control. Further trials were carried out and this showed a major improvement in controlling the height of the rotor above the top of the carrot bed.

With 40 t/ha of straw it was evident that the throat of the mechanism would need to accept a 300 mm depth of straw swath which was just possible with this standard chopper. Forward speeds of between 1.5 and 3.0 km/h were tried at a rotor speed of 2000 rev/min. Power requirement was well within the capacity of a 65 kW tractor.

After a few hours operation, wet straw started to build up on the fixed knives which caused the overall power requirement to increase. This could possibly be overcome by adjusting the angle of the fixed blade to allow the residue to slide off, but the chop length could be compromised. It is also possible that using "L" shaped chopper blades in conjunction with "V" shaped serrated fixed knives would prevent build up of straw.

This technique showed considerable promise and could be a very cost effective way forward to save the grower/contractor £50-£80/ha on incorporation costs.

5. Discussion with potential manufacturers and results of trials with prototype machines

During these preliminary field trials, the interest of two manufacturers was sought to produce machines capable of chopping and removing straw from the top of the carrot bed, with and without a polythene membrane being present. These were:-

Reed and Upton Ltd - Colin Reed
Bay Quarry Works
Barton Mills
Bury St Edmunds
Suffolk
IP28 6BS

Everett Bros. Eng. Ltd. - Brian Everett
Cowles Drove
Hockwold
Thetford
Norfolk
IP26 4JQ

Discussion first took place with Colin Reed and he was able to see the results of some of our field trials. He could see the enormous potential for a chopping mechanism to work over the carrot bed. His company already produced a straw removing machine which lifted the straw off the bed and moved it sideways to be spread over the already harvested beds. This machine had accurate means of depth control above the bed of carrots and star wheels lifted the straw from the bed wheelways onto the adjoining bed or onto the harvested area.

Although he could see potential for a cheaper machine based around a tractor mounted straw chopper, he felt that the easiest way forward for him was to include a chopping mechanism behind the main lifting rotor of his present straw removing machine which could chop the straw before being dropped onto the transverse horizontal conveyor. Some concern was expressed about the additional power requirement and the cost of providing a belt drive so remote from the main power source, but after further investigation it was felt that economic solutions could be found.

Colin pursued these ideas and a prototype machine was produced. A Kverneland FX 255 rotor with fixed knives was introduced between main lifting rotor and horizontal conveyor of his present straw removing machine. Initial field trials showed potential and the machine was capable of chopping up to 80% of the straw even with a polythene membrane present. Improved automatic height sensing of the front rotor was introduced

by increasing the number of sensing wheels from two to four and modifying the control mechanism. Further details of this machine with results of field trials are given in Appendix I. Details of the machine concept are shown in Figure 1.

Discussion also took place with Brian Everett using the tractor mounted Kverneland FX 255 straw chopper as the basis of a straw removing machine. This was seen as a cheaper option to the system already described.

Further field trials were carried out with the chopper mounted across the bed behind a high clearance tractor. The depth wheels were positioned in-between the rows of carrots on top of the polythene and further height adjustment was facilitated by lifting or lowering the tractor lift arms. The 600 mm dia rotor was fitted with two straight blades per location for cutting and one fan blade to increase the suction provided by the rotor. Two sets of fixed knives were originally used, but it was found that only one set was necessary to achieve a chop length of 100 mm or less.

These trials showed that the mechanism had further potential, and two carrot growers were impressed by the machine's capabilities. A machine specification was prepared by Silsoe Research Institute and this is shown in Figures 2 and 3. Further details of this specification are given in Appendix II, together with results of further field trials. A copy of the specification was sent to Everett Bros. Eng. Ltd. to assist in the design of a prototype machine.

Fig. 1. Reed and Upton straw chopper/remover.

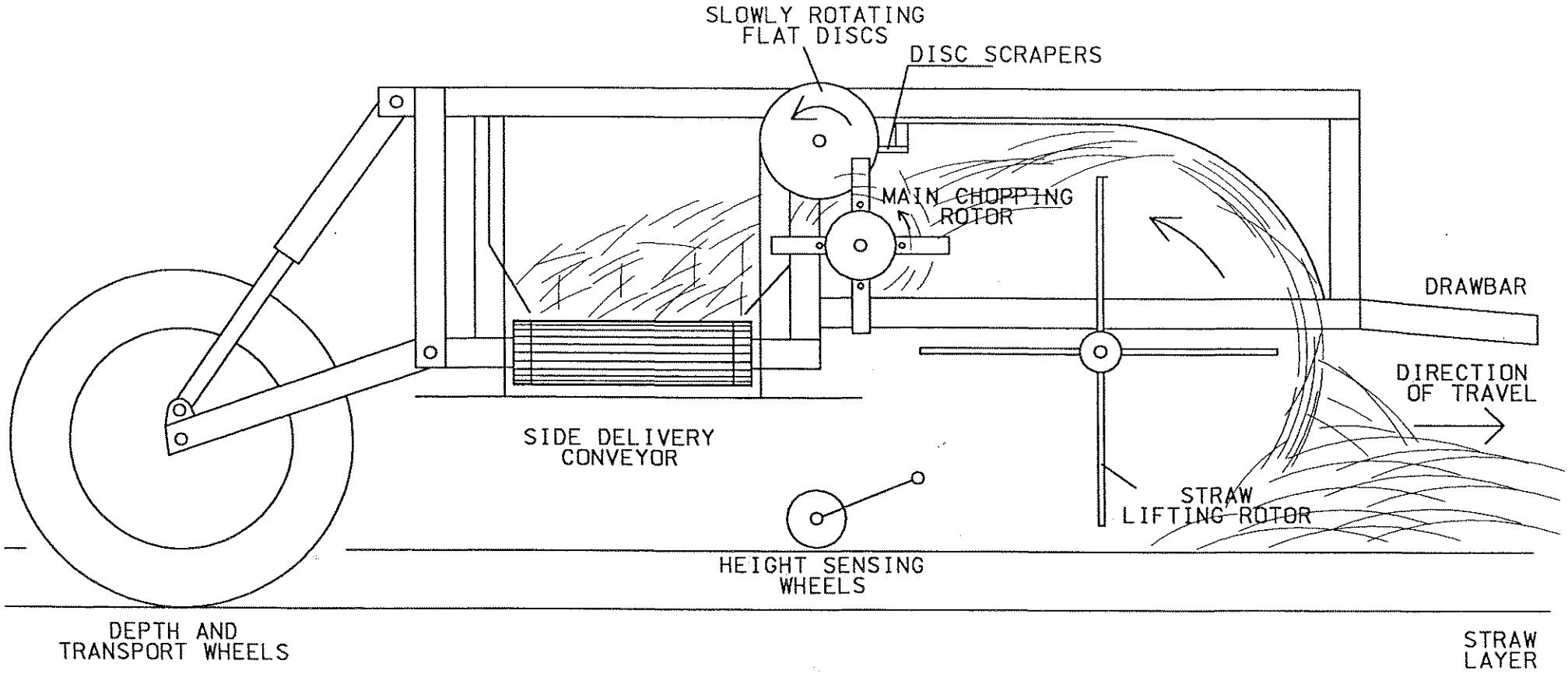


Fig. 2. Rear view of proposed straw chopper/remover.

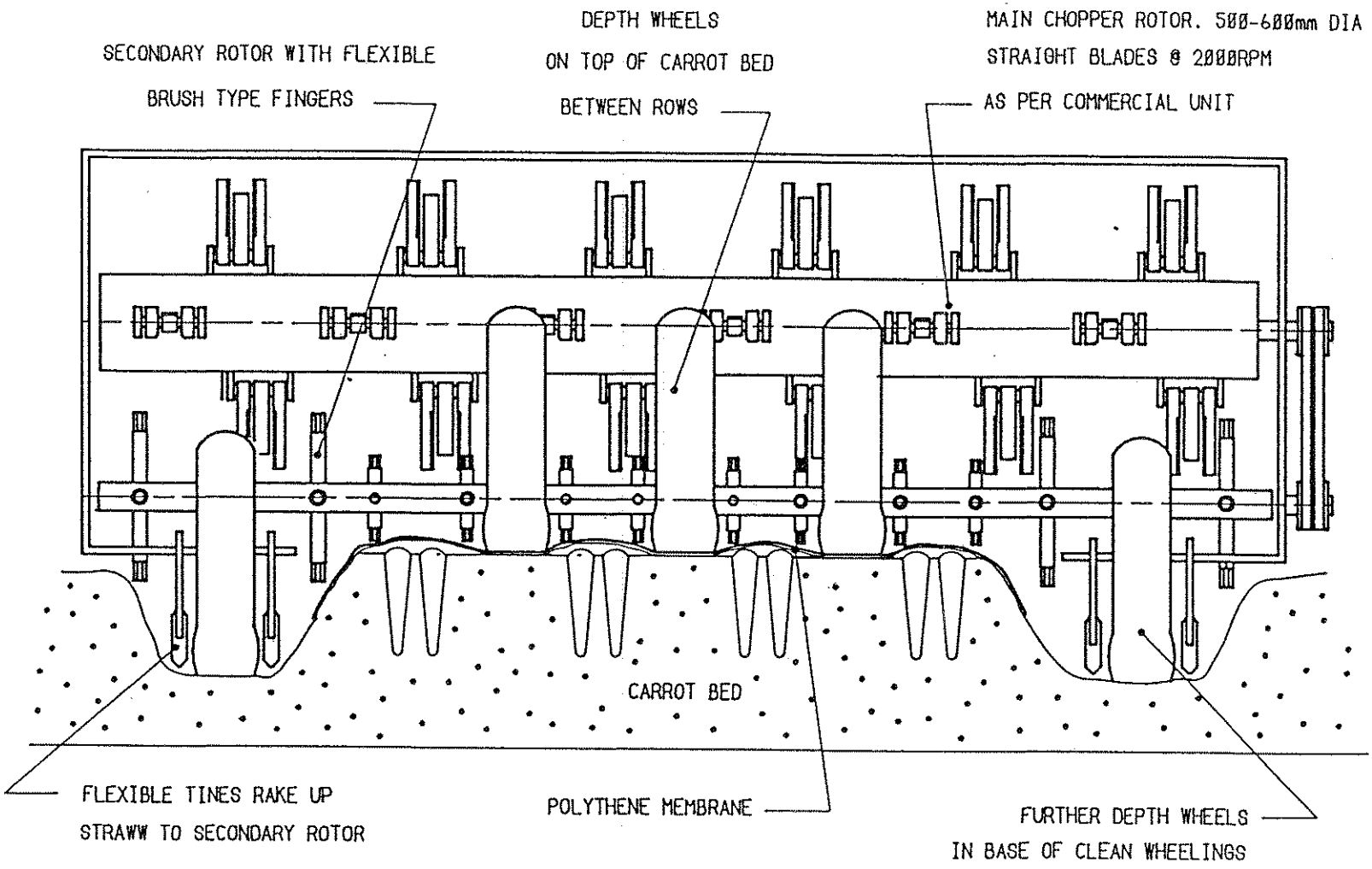
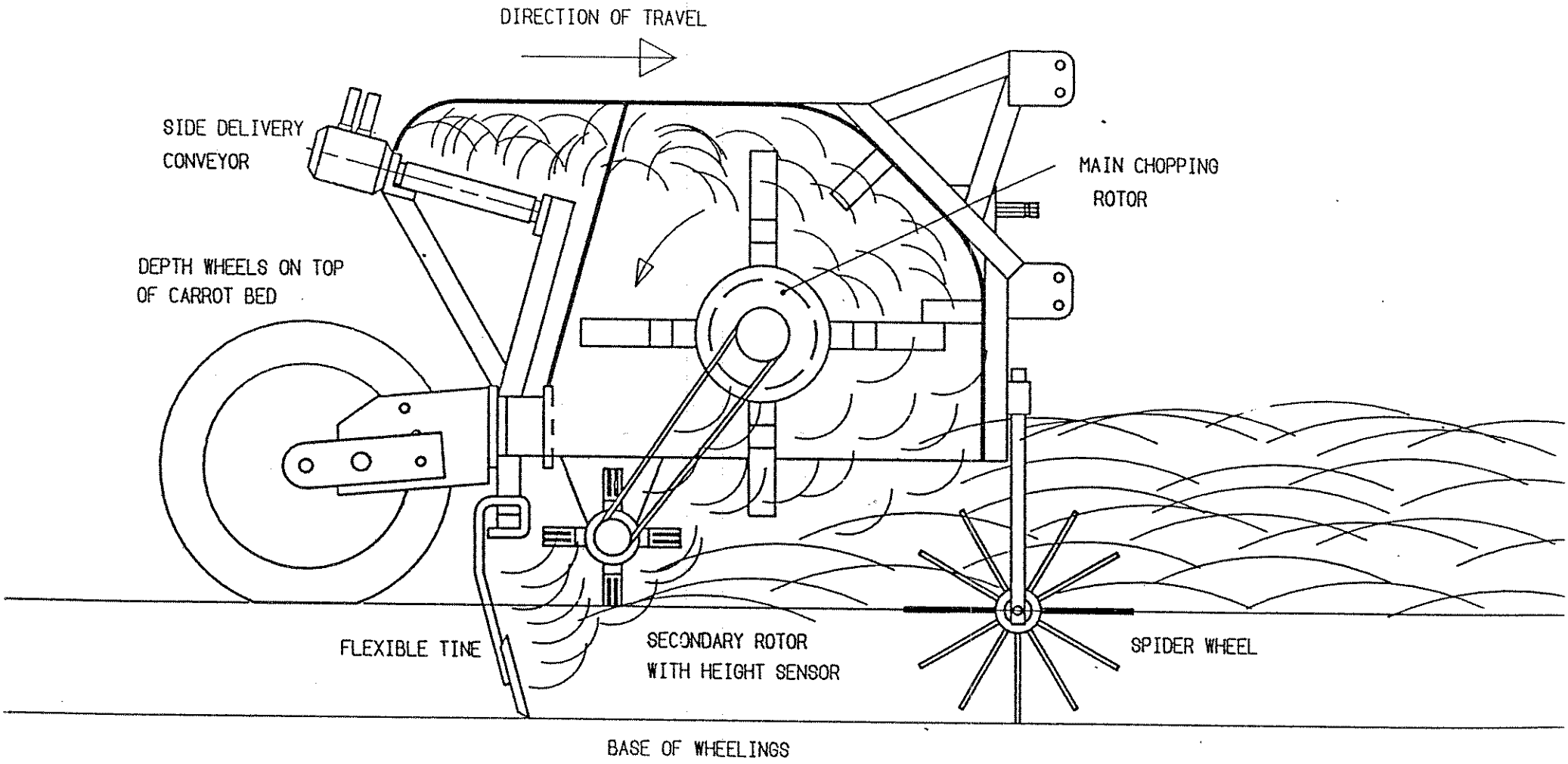


Fig. 3. Side view of proposed straw chopper/remover.



6. Conclusions

1. Incorporation costs of at least 40 t/ha of straw can be considerably reduced when using a purpose built straw chopper (remover). It is likely that savings of between £50 and £80/ha can be achieved. (Contract Report No. 93/21, Project FV92.)

2. Increased mixing of the straw residue does not increase crop yield (Project FV92), therefore if total chop of the residue can be achieved mixing cultivations can be eliminated. (Contract Report No. 93/21, Project FV92.)

3. A mouldboard plough with 30" (760 mm) underbeam and 44" (1.12 m) point to point clearance, fitted with large wrap-round skim tops can give total burial of fully chopped residue.

4. Reed and Upton Ltd have marketed a machine based around their original straw remover. A chopper mechanism has been positioned behind the main lifting rotor and a novel series of flat rotating vertical discs have been introduced to replace the fixed knives. This eliminates straw build up and helps to reduce the overall power requirement.

5. Some five new machines have been sold and another six existing straw removal machines have, to date, been converted to allow chopping to take place during the process of removal. None of these machines completely clean the polythene membrane (about 3-5% left) or remove straw from the bed wheelways. It appears that growers are well satisfied with their overall performance and accept removal of the polythene as a separate operation as an interim measure.

6. Everett Bros. were initially very interested in the alternative simpler design of machine put forward by Silsoe Research Institute and carried out some preliminary design work on the concept. I believe a very efficient machine could be produced at a significantly lower cost which could also be front mounted. However, because of the limited market for any type of machine, it is likely that no further work will be done on this concept unless some of the growers express further interest and are willing to pay for a prototype to be manufactured.

7. It is likely that as contractors and growers become familiar with using the new concept that some refinements could be introduced to achieve total chop of all the residue and removal of the polythene membrane in one operation.

Appendix I - Reed and Upton prototype straw chopper/remover

Details of field trials and machine modifications

Transfer of straw off the pick-up rotor to the chopping mechanism was initially a problem but plates bolted between the rows of spikes stopped retention of the straw and a power driven roller mounted behind the chopping rotor assisted flow of chopped residue onto the horizontal conveyor. One set of fixed knives plus fan blades created an adequate chop length of 75-100 mm at 1800 rev/min.

Speed of transfer of chopped straw along the horizontal conveyor was variable and sometimes caused bunching which prevented continuous flow of residue between the vertical shafts of the spreaders so blockages occurred. The distance between the vertical shafts of the spinners was increased by 300 mm to overcome this problem and the speed of the horizontal conveyor increased.

The slatted cross conveyor allowed a little chopped straw to fall through it onto the polythene or bare bed when the membrane is not used. Modern harvesters with blower systems are able to remove some straw from the harvested crop, so a problem is not envisaged in washing plant filters.

On present straw removing machines, spider wheels are used to lift straw from the bed wheelways. It was shown that these can still be used where a membrane is not present, but care must be taken not to lift soil and stones onto the bed which could damage the chopper knives. It was almost impossible to use spider wheels with a polythene membrane as the edge of the sheet was lifted up and torn. It is possible that rubber fingers could be advantageous in creating less damage to the polythene and not lifting stones onto the bed of straw but these have not been tried to date. Greater care will also be needed when laying the membrane to ensure each join is well anchored.

The front pick-up rotor sometimes pushed straw from the edge of the bed into the wheelways which will never be chopped unless spider wheels put it back onto the bed.

Further field trials using a modified machine showed that it was possible to pick up at least 95% of the straw from the bed, with or without, a polythene membrane present. Depth control was now adequate and in future, modified methods of laying the membrane together with bed wheelway cleaners/straw lifters could improve the 95% pick-up rate to virtually 100%.

The fixed knives used in the first prototype machine became built up with wet, partially chopped straw after a few hours operation; this grew around the leading edge and caused power requirement to rise considerably. Changing the angle of the contact edge helped

the straw to be pushed off, but it caused a small increase in the chop length. The fixed knives were eventually replaced with a series of (hydraulically driven) rotating discs. These were spaced across the rotor so that each rotating knife passed between them. Cleaning bars were fitted between each disc to prevent straw residue from being trapped between them. This mechanism prevented build up of straw and therefore kept the total power requirement at 75 kW or less depending on straw conditions. Some slight increase in chop length was again evident but the reduction in power requirement was more beneficial.

A device was later added to the rear of the straw remover to wind up the polythene membrane at the same time as removing the straw. It was felt that this would have the benefit of tightening the membrane underneath the main rotor. Initial trials showed that it was probably too much for one operator to control at one time, although the potential was evident. Removal of the membrane as a separate operation is still accepted, although in the future automatic sensing could considerably help to make the two operations more compatible.

Appendix II - Silsoe Research Institute's specification for a simplified chopper/straw remover

1. Front mounting the machine would ensure that the straw in the bed wheelways could be chopped prior to being wheeled. At the moment this could restrict its uptake because not all contractors and growers have front linkages so further details are centred around a rear mounted machine.

2. The primary chopping rotor would be 600 mm dia with two straight blades per location making 64 for a 2.55 m wide rotor. Fan blades should be mounted in-between the straight blades to suck straw into the rotor; this would allow the distance between the blades and the polythene membrane to be increased to 50 mm. The basic machine frame would be similar to the Kverneland FX 255 but it is likely that a double end drive would be needed to transmit the power to the main rotor.

3. Power driven rubber fingered spider wheels may be needed to lift straw from the wheelways, but these may still pick up stones and soil which could damage the chopper blades. Alternatively, the straw should be directed into the main rotor by a secondary sweeping type rotor, in conjunction with a flexible tine running in the base of the wheelways to lift the straw. Increasing the diameter of the secondary rotor over the bed wheelways would also assist lifting straw from the wheelways into the main rotor.

4. The accurate depth control of both rotors is crucial. Depth wheels should be mounted between each row of carrots and height sensors positioned above the carrots. These wheels would also help to hold down the polythene against the suction of the main rotor.

5. Straw left on the membrane by the main rotor could also be lifted by the secondary brush type rotor. This rotor would need to be in the 8 o'clock position behind the main rotor and driven from it. The brush type components would need to be flexible to protect the carrot crowns which protrude through the soil surface and prevent tearing of the polythene membrane. They could also be positioned to sweep between the rows of carrots and intermeshed with the main rotor to maintain continuous feed. The suction created by the fan blades would help to pull the straw into the chopping rotor once it has been lifted from the membrane. The secondary rotor weight could be counteracted using tension springs with adjustable stops and its height adjustment would need to be controlled automatically by sensors over the crowns of the carrots.

6. Sideways movement of the chopped straw should be facilitated using a

mechanically or hydraulically driven rubber belt or slatted conveyor, tipped towards the flow of residue from the chopper hood. A spreader on the end would make sure that the chopped straw is spread back over a 2.5 m width.

7. Additional caster type depth wheels should be fitted at the rear of the machine to run in the bed wheelways. Height adjustment using hydraulic rams will give coarse depth control to the whole machine.

8. The overall shape of the skirt and hood will need to be determined by the amount of suction required to lift the straw from the bed surface, in conjunction with the sweeping type rotor. The position of the fixed knives may need further investigation, especially the angle of the leading edge, so that build up of chopped residue may be prevented. It is unlikely that two rows of fixed knives will be required, the finer chop appears to be unnecessary agronomically and the plough with greater clearances can achieve 100% burial at the longer chop length of 75-100 mm.

Everett Bros. have taken on board much of this design and further field trials indicated that further improvements in the design may be possible and these are as follows:-

1. A short full width elevator similar to the SIMON straw lifter feeding into a full width chopper mechanism could be advantageous and should reduce overall power requirement.

2. An additional fan mechanism could be used to blow the chopped straw sideways instead of a horizontal conveyor.

3. At least 80% of the straw can be dealt with by the main chopping rotor fitted with straight and fan blades. It may be possible to increase the suction capabilities of the main rotor and introduce soft material flails instead of the metal fan blades within the main rotor. These could sweep the top of the bed or polythene and may eliminate the need for a secondary brush type rotor.

4. A full width polythene removal device could be mounted behind the machine to wind up the membrane at the same time as straw removal, providing all the straw is cleaned from the polythene. This will assist straw pick-up from the polythene by holding it tight underneath the main rotor.