

FARM MACHINERY

Ninth Edition

CLAUDE CULPIN,

79.2
C968

Preface
To The Ninth Edition

FARM MACHINERY

Ninth Edition

CLAUDE CULPIN,
OBE, MA, DipAgric(Cantab), FIAGrE

CROSBY LOCKWOOD STAPLES LONDON

#077

By the same author

Profitable Farm Mechanization
(third edition 1975)

Granada Publishing Limited
First published in Great Britain 1938
by Crosby Lockwood & Son Ltd

Second edition 1944
Reprinted 1945 and 1946

Third edition 1947
Reprinted 1949

Fourth edition 1952
Fifth edition 1957
Sixth edition 1960
Seventh edition 1963
Eighth edition 1969

Ninth edition published 1976 by Crosby Lockwood Staples
Frogmore St Albans Hertfordshire AL2 2NF and
3 Upper James Street London W1R 4BP

Copyright © 1976 by Claude Culpin

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

ISBN 0 258 97048 0

Filmset in Photon Times 11 on 12 pt by
Richard Clay (The Chaucer Press), Ltd, Bungay, Suffolk
and printed in Great Britain by
Fletcher & Son Ltd, Norwich

Preface

To The Ninth Edition

This edition, like its predecessors, is written for farmers and those who advise them; for students of farm mechanization and agricultural engineering; and for those concerned with technical aspects of the supply of power and machinery for agriculture. The scope remains broadly the same as that of the eighth edition, but to save space and cost the chapter on Development and Economic Aspects of Mechanization has been omitted, since this subject is dealt with more fully in the companion volume *Profitable Farm Mechanization*. The revision is the most comprehensive ever undertaken.

As in earlier editions, the objective has been to deal with principles and this will ensure that most of the information provided will remain valid long after machines illustrated have been superseded.

With the impending use of metric units in agriculture, metric units or equivalents are used where appropriate, usually in addition to Imperial. Most of the

figures used are purely illustrative, so equivalents where given are generally only approximations. In the case of heat units it is particularly clumsy and laborious to give both metric and Imperial units, so Chapter 23, which deals with environment control, has been converted fully to metric units. A table in Appendix 8 gives some useful conversion factors.

Where several firms make the same type of machine, illustration of a particular make does not indicate any expression of opinion concerning the relative merits of the products of different manufacturers.

Facts and opinions concerning farm machinery can change rapidly, and no one person can be familiar with developments in all branches of the subject. I shall be glad to receive advice concerning any inaccuracies.

Claude Culpin
Silsoe, Bedfordshire
1976

Preface To The Ninth Edition

Acknowledgements

The author wishes to acknowledge valuable assistance kindly given by many individuals and firms in the preparation of the illustrations and in supplying information. Where possible the names of manufacturing firms or suppliers of copyright photographs are indicated beneath the respective illustrations.

D. I. Bartlett and B. R. Smith have helped me with revision of Chapter 23 (Environmental Control), and J. M. Beeny and Professor B. A. May with some aspects of metrication in the Appendices.

Figures 7.2, 9.2, 9.3, 9.4, 19.13, 19.15, 23.1, 23.2, 23.3, 23.5 and 23.13, reproduced by permission of the Controller of Her Majesty's Stationery Office, are from Mechanization Leaflets of the Ministry of Agriculture, Fisheries and Food.

The frontispiece shows the Hunter sugar-beet harvester (*Ransomes Sims & Jeffries Limited*).

Contents

Preface to the Ninth Edition v

Acknowledgements vi

1 Tractors: Use in Farming 1

Development of modern tractors Use in British farming
Cost of tractor work Choice of a tractor: type, size,
engine, wheels, etc. Tractor power or capacity Tractor
tests Economic operation: loading, wheel slip, operating
speeds, engine speed Maintenance Safety precautions
and regulations

2 Tractors: Constructional Features 16

Principal types All-purpose Steering Transmission
Hydraulics Belt pulley and power take-off Drawbar and
hitch Wheels Pneumatic tyres Engines Air cleaner, oil
filter, governor Hydraulic lifts Implement control
systems Power-lift linkage Tracklayers Half-track
equipment Four-wheel drive Motor hoes and two-wheel
tractors Self-propelled tool-bars

3 Tillage 45

Objects and principles of tillage Soil structure, moisture,
temperature, aeration Destruction of weeds and pests
Changing views on tillage Influence of mechanization

4 Ploughs: Components and Operation 50

Plough components Share, coulter, skimmer,
mouldboard Principles of hitching trailed ploughs
Setting tractor-mounted ploughs Draught of ploughs
Methods of tractor ploughing Styles of ploughing
Essentials of good ploughing

5 Ploughs: Principal Types 64

Mounted and semi-mounted ploughs Reversible ploughs
Shallow ploughs Subsoilers Disc ploughs

6 Implements for Seed-beds and Inter-cultivation 71

Tined implements Cultivators Harrows: zig-zag,
wooden-framed and spring-tined Spring-toothed
weeders Rotary weeders Chain harrows Power-driven
harrows Disc harrows Rolls and presses Land levellers
Rotary cultivators Ridgers Hoeing tool-bars Gapping or
thinning machines

7 Equipment for Sowing and Planting 87

Feed mechanisms Coulters Gearing Tractor drills
Equipment for direct drilling Operation Unit drills
Single-seed drills Maize drills Electronic monitors Grass
seed drills Broadcasting machines Potato planting
Fertilizer and insecticide placement for potatoes
Transplanting machines

8 Equipment for Distributing Manures 102

Distribution of fertilizers Mechanical handling of solid
fertilizers Bulk handling Handling liquid and gaseous
fertilizers Fertilizer distributors Feed mechanisms
Pneumatic distributors Lime spreaders Combined
grain and fertilizer drills Farmyard manure handling
machinery: loaders, gutter-cleaners and spreaders
Manure-handling systems Distribution of liquid manure
Distribution of slurry Equipment for slurry treatment

Contents

9 Equipment for Crop Protection 121

Crop spraying Spray materials Spraying machinery Pumps Nozzles Vibrated jet distribution Types of field-crop sprayers: high volume, low volume, 'Universal', pneumatic and air-carrier Spray booms Self-propelled sprayers Band sprayers Operation of ground-crop sprayers Adjustment Operation Maintenance Safety precautions Orchard sprayers Choice of fruit sprayer Dusting machines Granular insecticide and herbicide application Aircraft spraying Chemical seed dressers

10 Pumps and Irrigation Equipment 135

Farm water supply Types of pump: plunger, piston, centrifugal, propeller, rotary, semi-rotary and diaphragm Capacities and efficiencies Choice of pump Irrigation Choice of equipment Management of pumps Distribution systems Mobile equipment Automatic irrigation Frost protection Equipment for pipe line distribution of liquid manure

11 Forage Harvesting: Cutting and Swath Treatment 146

Mowers, construction and adjustments Mounting and drive Developments in mowers Rotary grass cutters Orchard mowers Gang mowers Flail mowers Machines for swath treatment Swath treatment by flails, roller crushers, crimpers Tined machines for swath treatment Tedders Combined haymaking machines: cylindrical reel, rake-bar, rotating head, finger-wheel, endless chain or belt Combined mowing and swath treatment

12 Silage Making and Feeding 157

Making silage Machines for collecting green crops Flail type harvesters Double-chop Metered chop Maize harvesting Systems of operating forage harvesters Making wilted silage Making high dry-matter silage in tower silos Loader wagons Forage blowers Spreading in the silo Silo unloaders Mechanical feeding

13 Haymaking, Balers and Bale Handling 173

Field baling Pick-up balers, types and operation Collecting the bales Loading direct from baler Loading single bales from the ground Bale sledges and wheeled collectors Bale group accumulators Bale packers

Loaders and carriers for groups of bales Stacking Big balers Stacking machines for loose hay Handling chopped hay Hay wafering

14 Combine Harvesters 188

Methods of harvesting by combine Windrowing Main types of combine Cutting and threshing mechanisms Operation and adjustments Capacity Grain handling Grain loss monitors Handling of the straw Crop varieties

15 Root Harvesting Machinery 199

Potato lifting Ploughs, spinners, elevator diggers Use of bulk boxes for handling to store Complete potato harvesters Stone and clod separation Handling systems Comparison of harvesting methods Developments in harvesters Haulm destroyers Equipment for storage, ventilation and unloading in bulk potato stores Potato sorters Sugar-beet harvesters Topper-windrowers Topping mechanisms Beet cleaner-loaders Turnip harvesters Carrot harvesters Multi-purpose root and vegetable harvesters

16 Horticultural Machinery 218

Special power units and cultivation implements Cutter bars for market garden tractors Hand type hedge trimmers Flame weeders Soil sterilizing equipment Compost shredders and mixers Soil block making machines Orchard equipment Mechanical harvesting of fruit Fruit grading machinery Vegetable washing Hydro-cooling Hop-picking machines Bulb-lifting machines Vegetable harvesting Green pea harvesting Mobile viners Bean harvesters Brussels sprouts harvesters Spinach harvester

17 Seed Cleaning and Food Preparation 233

Grain cleaning and grading machinery Sieve cleaners Endless woven wire pre-cleaners Winnowers Aspirating machines Combined aspirating and sieving machines Indented cylinders Pneumatic separators Specific gravity table separators Grinding, kibbling and crushing machines Plate mills, crushers, hammer mills Meal bins Choice of mill 'Mix milling' Food mixing machines Liquid feed mixing Planning food preparation installations Cubers Chaff and root cutters Mobile root feeders

18 Crop Drying Equipment 248

Principles of crop drying Grass drying Drier capacities and efficiencies Fuels Types of grass driers: tray, conveyor and high-temperature driers Mobile grass driers Operation of grass driers Barn hay drying Grain drying Continuous driers Operation of continuous driers Automatic moisture content controllers Batch type grain driers Platform driers Ventilated bins On-floor driers Cooling bulk grain Grain chilling Choice of a grain drier Grain drier layouts Grain conveying equipment Automatic weighers Airtight storage of high-moisture grain Handling moist grain Chemical grain preservatives Drying poultry manure

19 Equipment for Livestock**Husbandry 275**

Equipment for mechanized stock feeding Bulk delivery vehicles Auger and endless chain concentrate feed conveyors Feed dispensers for milking parlours Central pre-setting of dispensers Automatic liquid feeding Automatic calf feeders Feed meters for addition of concentrate supplement Mechanical pig-feeding equipment Liquid pig-feeding equipment Poultry feeders Sheep-shearing machines Electric fences Sheep's foot trimmers Livestock weighers

20 Equipment for Milk Production 288

Essentials of milking machines Types of milking plant: bucket, direct-to-churn, pipe-line and parlour General design of installations Pipe-line installations Types of parlour Rotary parlours Automatic cluster removal 'Duovac' system Milking bails Operation of milking machines Cleaning and sterilizing equipment Milk cooling Refrigerated coolers Bulk milk tanks Hot water for milking Cream separators

21 Farm Transport and Materials**Handling 300**

Importance of transport in agriculture Draught of vehicles Pneumatic tyres Two-wheeled tractor trailers High-lift tipping trailers Trailer hitches and brakes Vertical jack-knifing Four-wheeled trailers P.t.o.-driven trailers Self-emptying trailers Tractor and implement transporters Self-propelled transport vehicles Motor lorries and four-wheel-drive trucks Hoists and lorry loaders Universal elevators Slewing loaders Potato bulk-loading elevators Stillage handling Fork lifts and stackers Self-loading vehicles Tractor cranes Bulk handling feedingstuffs Pneumatic conveyors Transport in the farmyard

22 Machinery for Land Drainage, Reclamation and Estate Maintenance 313

Drainage excavators Ditching equipment Trench-cutting machines Trenchless drainage machines Mole drainage: methods of draining and types of mole ploughs Machinery for land reclamation Bull-dozers, angle-dozers, earth scoops and graders Tractor winches Tree extractors Stone disposal Bracken-cutting machines Hedge-cutting machines Post hole diggers Post drivers Road sweepers and slurry scrapers

23 Environment Control in Crop and Stock Buildings 328

Environment control in commercial greenhouses Oil firing equipment Solid fuel firing equipment Boilers Boiler feed water treatment Low temperature corrosion Heat distribution Types of heating system Glasshouse ventilation Control of heating and ventilation in greenhouses Carbon dioxide enrichment Calculation of heat losses from buildings Control of environment in horticultural stores Heating and ventilation of livestock buildings Controlled lighting for laying hens Ventilation systems for stock buildings Control of ventilation

24 Care and Maintenance of Farm Machinery 344

Housing Care, repair and adjustment Farm workshops Oxyacetylene and electric welding Washing and steam cleaning equipment High pressure greasing equipment Fuel and spares trailer

Appendix 1**Fundamental Mechanical Principles and Simple Machines 347**

Forces Composition and resolution of forces Moments Work power Horse-power Energy Mechanical advantage velocity ratio and efficiency of machines Simple machines: the lever, wheel and axle, inclined plane, screw, wedge and pulleys The hydraulic press or jack Fluid power

Appendix 2**The Transmission of Power 355**

Belting and pulleys Chain drives Friction drives Toothed gears Shafting, couplings and bearings Positive and friction clutches Pawl and ratchet drive Cams and eccentrics Brakes

Contents

Appendix 3

Friction, Lubrication and Bearings 365

Sliding and rolling friction Lubrication Requirements of a lubricant Effect of temperature on viscosity Tractor lubrication The application of lubricants High-speed bearings Slow-speed bearings

Appendix 4

The Measurement of Power 369

Dynamometers Measurement of drawbar and brake powers Transmission dynamometers Belt and p.t.o. power Engine torque-speed and power-speed characteristics Tractor drawbar performance curves Indicated power

Appendix 5

Materials used in the Construction of Farm Machinery 374

Stresses Strength of materials and yield point Factor of safety Hardness The ferrous metals: cast-iron, chilled cast-iron, malleable iron, wrought-iron and steels Heat treatment of steels: hardening, tempering and annealing Case hardening Non-ferrous metals and alloys Cement and concrete Timber Thermal insulation materials Paints

Appendix 6

Internal-combustion Engines 381

Heat engines The 4-stroke and 2-stroke cycles Constructional features of engines: cylinder, cooling system, piston and connecting rod, crankshaft, flywheel and valve gear Carburettors and ignition of the charge Diesel engines Working principle, fuel injection and starting of diesel engines Maintenance and adjustment of internal-combustion engines

Appendix 7

Electricity on the Farm 394

Electrical terms and principles Voltage, current, power and resistance Alternating current Applications of electricity including lighting, heating and power Single and three-phase supply Cost of power Sizes of motors Load characteristics Wiring

Appendix 8

Definitions and Useful Data 402

Index 407

Chapter 1

Tractors: Use in Farming

The history of tractor development is too long to relate in this book. Landmarks along the road include the first use of an internal combustion engine in a tractor in the United States in 1890; the 'Ivel' tractor of 1901; the American Ford of 1917, and the International 'Farmall' of 1923. During the 1930s, the use of low-pressure pneumatic tyres soon became popular, and the first Ferguson system tractors incorporating three-point linkage with hydraulic draught control were introduced.

In more recent years diesel engines have rapidly become the accepted power unit for all British tractors apart from small motor hoes. The most important development, one which is continuing, is the upsurge of engine power. Wheeled tractors in the 100 horse-power class have been introduced by most of the British tractor manufacturers, and are increasingly used. Most tractors employ two large driving wheels at the rear and small steering wheels at the front; but with the increase in engine power, four-wheel-drive has become common. The most usual form has a rigid frame, a pivoting front axle and power-assisted Ackermann-type steering; but a general arrangement favoured for some of the largest tractors involves hydraulic power steering by means of a two-section articulated chassis. Large tractors tend to be used for a limited range of operations, the chief being tillage, combined tillage and sowing and forage harvesting. Safety regulations designed for the protection of tractor drivers and considered more fully later require most new tractors to be fitted with safety cabs; and other regulations are leading to the necessity for cabs which reduce the intensity of noise at the tractor driver's ear. Drivers' seats are also being improved to reduce spinal and intestinal injuries caused by excessive vibration, and controls designed to improve ergonomic aspects of tractor driving. Most modern tractors are truly 'all purpose'. They can operate a vast range of mounted, semi-mounted and trailed implements and

machines, and have hydraulic devices to provide easy and accurate control of the equipment from the tractor driver's seat. It has now become normal practice to provide electric starting, lights and light-signalling; other developments that have rapidly become commonplace include such items as multi-speed gear-boxes, live power take-off, differential lock, power steering and various devices for transferring weight from mounted implements to the tractor's drive wheels. The live power take-off ('live drive') is an asset with many p.t.o.-driven machines such as mowers, forage harvesters and pick-up balers. It enables the driver to check the tractor's forward motion while the machine clears itself. A 'constant-running' drive to the hydraulic pump is a great advantage with many implements that are operated by the tractor's hydraulic system. For example, 'live hydraulics', as it is sometimes called, enables the tractor driver to continue to raise a loaded manure fork as he backs away from the heap and manoeuvres his tractor towards the spreader or trailer.

The differential lock now standard on nearly all tractors on sale in Britain is mainly used in ploughing, where the land wheel almost always tends to slip before the furrow wheel — partly because of the difference in ground surfaces, and partly because the furrow wheel inevitably carries more of the tractor's weight.

Power steering is fitted as standard on several of the higher horse-power tractors, and it is a necessity on all the large four-wheel-drive tractors. Some developments have not caught on quite so rapidly as was at first anticipated. These include ground speed power take-off and hydraulic transmission.

The hydraulic transmission systems that have been successfully applied to farm tractors are mainly of the hydro-static type, as opposed to the hydro-kinetic type used on some expensive cars.

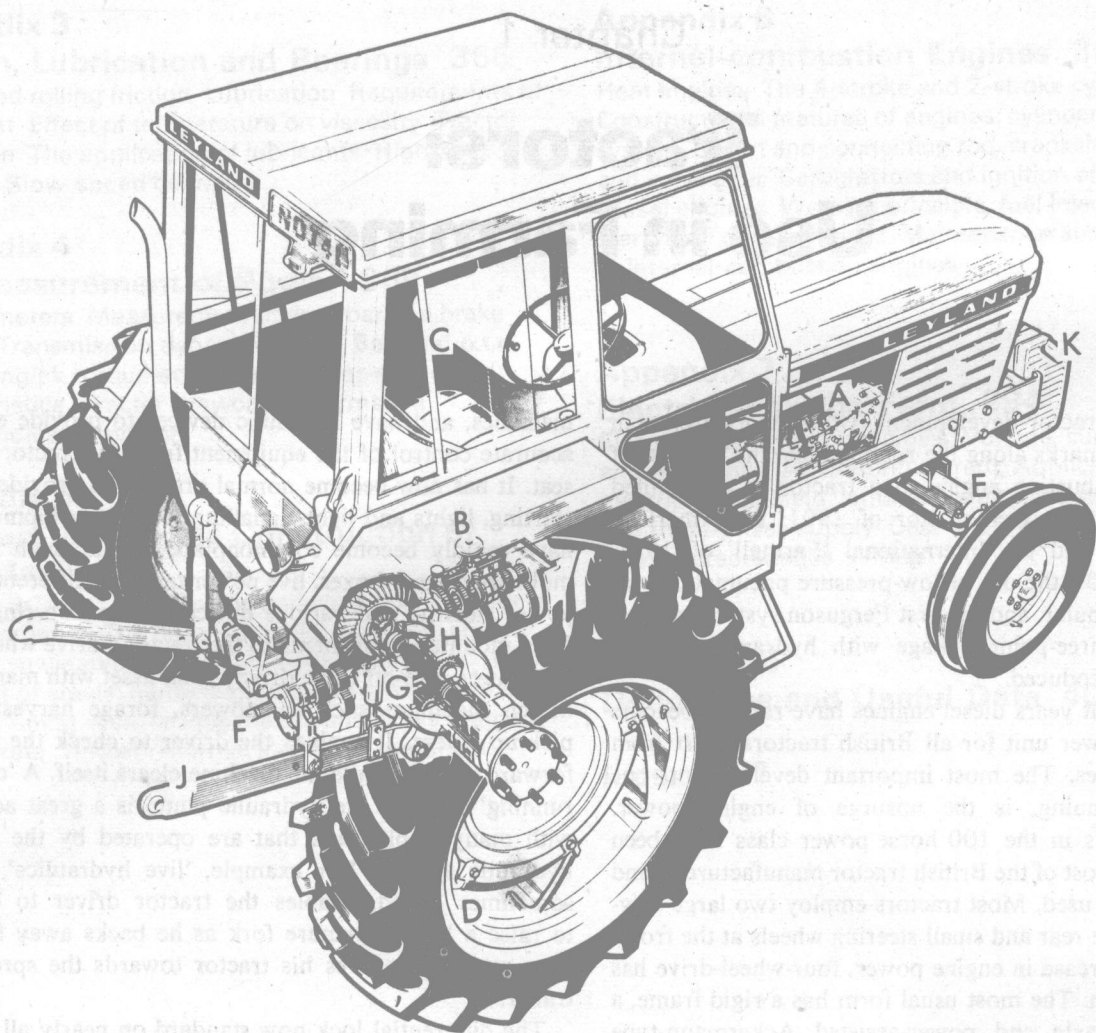


Fig. 1.1 Characteristics of high-power rear-wheel-drive tractor (Leyland)

- A High-torque engine
- B 10-speed gear-box
- C Safety cab
- D Power-adjusted variable-track drive wheels
- E Power steering
- F Independent two-speed p.t.o.
- G Multiple wet plate disc brakes
- H Epicyclic final drive
- J Category Two linkage with assister rams for heavy implements
- K Front weights

The step-less speed change provided by a hydraulic transmission system is clearly advantageous for many purposes; but since some modern tractors provide up to 12 forward speeds by mechanical transmission, the advantages of the hydrostatic transmission are less than they would have been in the past. This is particularly so when a finger-

tip controlled power-shift system is installed to make it easy to change gear on the move.

There are obvious advantages in a high p.t.o. speed where high powers have to be transmitted and the principal mechanisms run at a high speed, as in flail type forage harvesters. The 1000 rev/min p.t.o. speed is an ISO

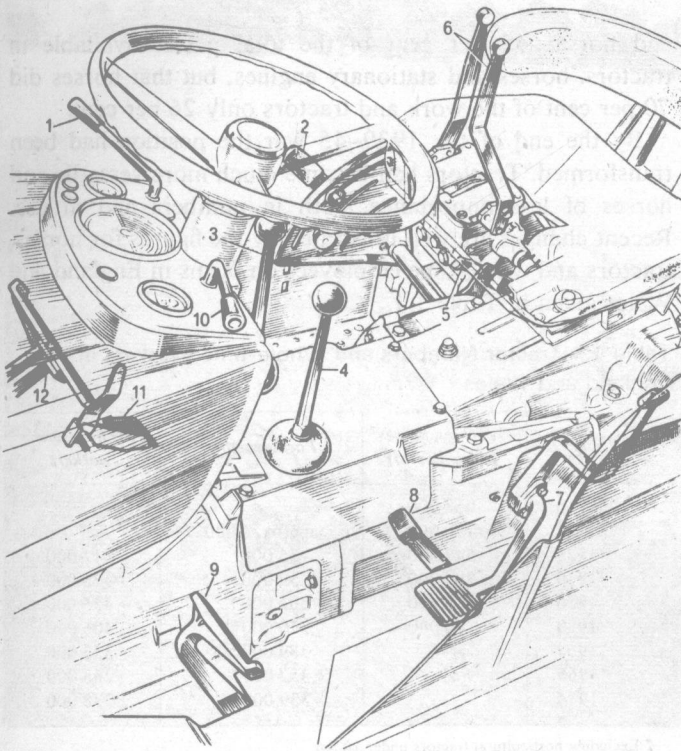


Fig. 1.2 Controls of all-purpose tractor (*John Deere*)
 1 Hand throttle 2 Hydraulic lift/lower lever 3 Gear shift lever with four positions 4 Gear range lever (high, low or reverse) 5 Hydraulic selector lever (provides for load control, depth control, or combined load and depth control) 6 Hydraulic external cylinder controls 7 Hand/foot control for differential lock 8 P.t.o.-engagement lever 9 Clutch 10 Hi-Lo transmission lever (gives immediate ground-speed reduction of 26 per cent without declutching) 11 Foot throttle 12 Brake pedals (latched) (Reproduced from *Farm Mechanization and Buildings*)

Standard. It is available in addition to 540 r.p.m. either as standard or as an optional extra on most British tractors. The 1000 rev/min p.t.o. shaft speed allows shafts and universal joints to be kept small, but the vibration of a high-speed shaft with two Hooke's joints is acute under some conditions.

Use of a single constant velocity joint, so that no cyclical speed variation (which causes the vibration) occurs, unfortunately limits the angle of articulation between the tractor and the implement to 40°, which is insufficient for field work. Arrangements to increase this angle to 75° are likely to be costly and to make use of such mechanisms somewhat unattractive to implement manufacturers.

Few makes of tractor have ground speed p.t.o., and specifications are sometimes widely different from the British Standard of 1 revolution for every $7 \pm \frac{1}{2}$ in of forward travel. Technically, ground-speed p.t.o. drive would appear to offer advantages for drills and fertilizer distributors. Because so few tractors are equipped with ground-speed p.t.o., few implement manufacturers have so far attempted to make use of this fitting.

As tractor size progressively increases and implements become heavier, there is more and more to be said for a device like a pick-up hitch which allows the implement to be coupled up to the tractor without the driver having to leave his seat. Quick hitches of various types were developed in America and one of these, which was introduced by John Deere in 1960, was designed to be used between the standard three-point linkage and slightly modified implements. After a study of this hitch by other American manufacturers, an American Standard Quick Hitch, applicable in different sizes to all three categories of three-point free-link hitches, was agreed and published.

In the meantime, developments with the same objective had been pursued in other countries, notably Germany. Among the designs favoured were some with a matching triangular framework on both tractor linkage and implement headstock, as opposed to three hooks used in the ASAE Standard. It is claimed for the American Standard that it does not require any alteration of the standard tractor three-point linkage, and that the small design changes required on implement headstocks do not prevent easy conversion for conventional three-point hitch operation. These are important considerations. The American hitch is not quite as good as some designs incorporating matching 'A' frames in ability to pick up implements which are out of line with the tractor. There is also a small displacement of the implement rearwards in order to accommodate the hitch.

With an eye to the future, several research organizations both in Britain and abroad are actively engaged in the development of driverless tractors, using a variety of methods, none of which seems likely to be widely used in the near future. The only system in commercial use is one based on the use of a 'leader-cable' laid under the ground. A sensor carried on the front of the tractor is connected to the steering controls. This allows the tractor to follow a cable which has been laid out in an orchard in the pattern required for automatic mowing or spraying.

In the USSR experiments have been made with a tractor (a tracklayer) which guides itself on a straight line by follow-

Tractors: Use in Farming

ing a leader cable anchored at opposite ends of a rectangular field. The cable is automatically transferred to the next path at the end of each traverse by the tractor's self-winding arrangement. The system appears suitable only for large rectangular fields.

Though 'all-purpose' tractors represent by far the most important group, there are also many useful specialized types which are only designed to deal with a limited range of jobs. For example, there are tracklayers for heavy cultivations in difficult conditions, and power-frame tractors which are particularly suitable for accurate row-crop work. Though the small self-propelled tool frame is very little used in Britain, this type is more widely used in some European countries where the power range includes models of 30 h.p. (22 kW) and 50 h.p. (37 kW) in addition to those of 20 h.p. (15 kW) or less.

A few machines are self-propelled, and incorporate a power unit and transmission system that does nothing but operate the one specialized machine. This has obvious drawbacks in the case of seasonal machines such as combine harvesters, and many efforts have been made to develop traction units suitable for operating a range of mounted harvesting machines at different seasons. Examples include an American unit which powers a forage harvester, combine harvester or pick-up baler. In Czechoslovakia, somewhat similar three-wheeled units have been developed for powering a range of machines that includes potato and sugar-beet harvesters as well as machines for the hay and corn harvest. In Russia, a four-wheeled chassis can be used as a general-purpose truck when not needed for harvesting.

A four-wheeled Dutch self-propelled power unit of 170 h.p. (127 kW) has a hydrostatic transmission giving infinitely variable speeds in any one of three gear ranges. Reversible controls facilitate driving with the smaller steering wheels either at front or rear. Two high-speed p.t.o.s are provided at both front and rear. The machine is designed primarily for the operation of mowers, conditioners and forage harvesters for either grass or maize.

Use of Tractors in British Farming

In the period between the first and second world wars the use of tractors in Britain increased steadily, but by 1939 the total number in use in England and Wales was still no more than 55 000, as compared with 549 000 working horses. A survey of tractor use in the Eastern Counties during the middle 1930s showed that tractors represented 42 per cent

and horses 45 per cent of the total power available in tractors, horses and stationary engines, but that horses did 70 per cent of the work and tractors only 26 per cent.

By the end of the 1939-45 war the position had been transformed. Tractors had become much more versatile and horses of less importance, both in numbers and in use. Recent changes are well illustrated by the figures for horses, tractors and whole-time employees on farms in England and Wales given in Table 1.1.

Table 1.1 Tractor Numbers and Whole-time Workers in England and Wales

Period	Working horses (agricultural)	Farm tractors	Whole-time workers
1906-10	968 000	—	—
1921-25	796 000	approx. 2 000	—
1939	549 000	55 000	511 000
1950	289 000	259 000	575 000
1956	105 000	364 000*	455 000
1960	46 000	370 000*	406 000
1964	—	389 000*†	333 000
1968	—	352 000*	263 000
1974	—	339 000*‡	238 000

* Excluding horticultural tractors under 10 h.p.
† Note decline in tractor numbers after this date.
‡ December 1973.

The change from animal to mechanical power in farming is certain to continue. The steady increase in wages, and the need to obtain increased output from a restricted labour force, make it essential for farm workers to utilize mechanical power on an ever-increasing scale.

It is generally agreed that a man is capable of developing approximately $\frac{1}{8}$ h.p. (0.17 kW). The cost of this power, with wages at 80p an hour, is over £6 per h.p. hour (£8/kW hr). No farmer can afford to rely much on the unaided power of human muscles. The worker who is equipped with a tractor developing only 30 drawbar h.p. (22 kW) can provide power at the drawbar at less than 6p per drawbar h.p. hour (8p/kW hr). Agricultural progress depends largely on the extent to which mechanical power and machinery can be employed to render labour more productive.

Little research has been carried out on economic aspects of tractor utilization. Average annual use per tractor is about 700 hours.

Farms with low total tractor use requirements tend to have more tractors in proportion to the amount of work to be done. The number of tractors required for a particular farm depends not only on the annual amount of work to be

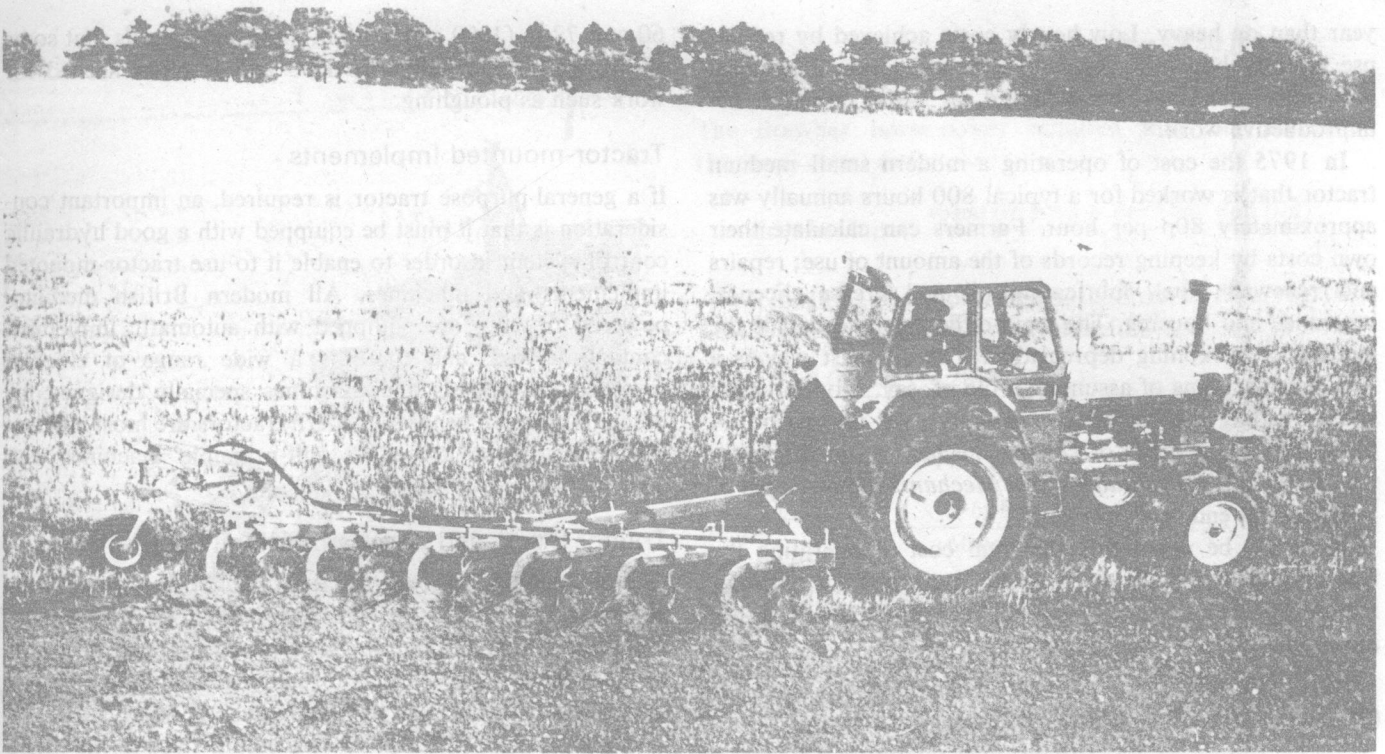


Fig. 1.3 The long semi-mounted plough operated by a high-powered tractor is depth-regulated at both front and rear by a torque-sensing ('Load Monitor') system (Ford/Ransomes)

done, but also on such factors as the time of year by which the work must be completed, and the speed at which particular types and sizes of tractors and equipment can work. Increases in the power of tractors and in working capacities of machines are drastically reducing the total hours of tractor use needed for particular farming systems.

When tractor needs are being assessed, hours of use in the peak month is likely to be a more reliable guide than annual use. Investigations in Scotland and in South-Western England have shown that on large farms tractors may work over 140 hours per month, while on medium-sized farms 100 hours per month is rarely exceeded. On arable farms the peak month is usually at the time of spring sowing, in March–April. On grass farms it comes later, during the silage or hay harvest.

In considering the influence of the use of tractors on farming organization the whole farming business must be studied. Tractors have attained their present important posi-

tion in British agriculture not merely on account of lower working costs, but also because of the benefits that arise from ability to do cultivations more thoroughly and in better season, with the production of more or better crops. Extra tractor work is frequently justified by a more intensive system of farming and a greater output.

Cost of Tractor Work

The cost of operating tractors varies from farm to farm and from district to district. Factors influencing costs, apart from the size and type of machine, include the number of days worked annually, the types of work performed, the care the tractor receives, and several other items. One of the most important factors influencing cost per tractor hour is the amount of use. Low hourly costs are achieved on some farms by using tractors nearly every day of the year and doing all kinds of work with them. On light land it is generally possible to work tractors many more days in the

Tractors: Use in Farming

year than on heavy. Low hourly costs achieved by regular use are not, however, necessarily an indication of efficient use, since this may be achieved by using tractors for unproductive work.

In 1975 the cost of operating a modern small-medium tractor that is worked for a typical 800 hours annually was approximately 80p per hour. Farmers can calculate their own costs by keeping records of the amount of use; repairs and renewals; fuel, lubricating oil and grease; licence, insurance and housing. The main difficulty is to decide the method of reckoning depreciation. The simplest way is a very arbitrary one of assuming a life of, say, 8 or 10 years and spreading the capital cost equally over the period. A discussion of methods of costing mechanization processes may be found in *Profitable Farm Mechanization* (see list of references at end of chapter).

It should be noted that the total cost of operating the tractor considered above must be increased by approximately 80p per hour (1975 rate), since the driver's wages are not included in the calculation.

Choice of a Tractor

The best basis for choosing suitable tractors is experience, and practical trial in the conditions in which the machines are to work. Nevertheless, it is helpful to consider some of the principles involved in choice and to mention factors that need to be studied.

Type of Tractor

In most instances the tractor will need to be an 'all-purpose' machine which can be applied to almost any kind of farm work, including ploughing, cultivations, sowing, row-crop work, harvesting, transport and stationary p.t.o.-work. This will apply particularly to small farms where one or two tractors are required to do everything. On larger farms there may be sufficient of particular kinds of work to warrant using special types of tractors, e.g. large four-wheel-drive tractors to cope with the autumn cultivation in good time, or light tractors of the self-propelled tool-bar type for drilling and inter-cultivation of root crops. Market gardeners may require tractors specially adapted for work in vegetable crops, and such special needs are briefly considered in Chapter 2, where the principal types of tractor available are described. Most modern medium-powered tractors incorporate such features as make them suitable for work in all common farm row crops. Standard wheel-track widths of

60 and 72 in (1.50 and 1.80 m) meet most needs, but some adjustment is normally provided and is often needed for work such as ploughing.

Tractor-mounted Implements

If a general-purpose tractor is required, an important consideration is that it must be equipped with a good hydraulic control system in order to enable it to use tractor-mounted implements and machines. All modern British medium-powered tractors are equipped with automatic implement control devices, and there is a wide range of efficient mounted implements and machines specially designed for use with them. In general, modern tractors are most efficient and economic when used as 'unit-principle' machines with their mounted equipment.

Tractor Sizes, and Standardization

One of the most difficult problems in choosing tractors for general farm work is to decide whether all the tractors should be of one make and size, or whether a range of makes or sizes should be selected to suit the various jobs. This needs consideration on any farm where more than one tractor is used, and especially on medium-sized farms where three or four tractors are used. The current (1976) range of ISO three-point linkage standards (R 730) includes Category 1, recommended for tractors up to 35 kW, Cat. 2 for 30–70 kW and Cat. 3 for over 70 kW. It is likely that Cat. 0 will apply to lawn and garden tractors up to 15 kW and Cat. 4 to 110–180 kW. Category 2 is most widely used, but Category 1 is used for many implements designed for use with small-medium tractors. Fortunately, many mounted implements and machines are now designed for use with either Category 1 or 2 tractors, and this is a point to note in selecting equipment. There is, however, much to be said for sticking to one make and size of tractor on small farms, and in these circumstances choice will frequently depend as much on the range of mounted equipment that is available to go with the tractor as on the size or other features of the tractor itself.

On larger farms, there is considerable advantage in having more than one type and size of tractor, since this arrangement allows the matching of the tractor with the job in hand, and permits choosing the best equipment from more than one manufacturer. Operating more than one type of tractor necessitates keeping more spare parts on the farm, and requires the man responsible for maintenance to have a wider knowledge; but these are minor disadvantages com-

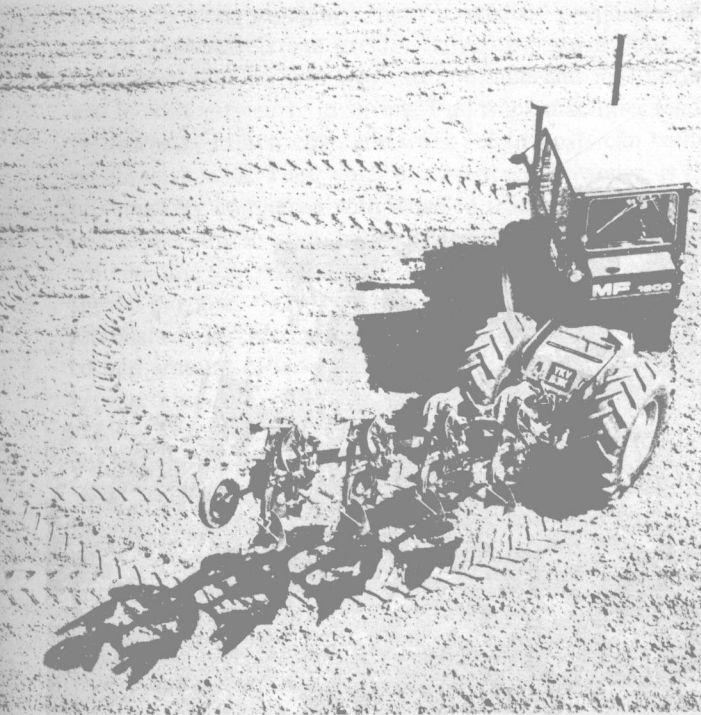


Fig. 1.4 The high-powered four-wheel-drive tractor with articulated chassis has a noise-insulated safety cab on the forward part. All implement controls are operated hydraulically (Massey-Ferguson)

pared with the greater operating efficiency where both tractor and equipment really suit the job.

Where it is decided to stick to one make and size of tractor, the decision as to which is most suitable must embrace a study of all the operations that will need to be carried out. Among the most important are ploughing and the basic cultivations, which must be done thoroughly and in good season, and will serve to illustrate the problems. The power needed for ploughing and other cultivations varies greatly according to the nature and condition of the land. The 'ploughing resistance' of various types of soil may be indicated by a figure which, when multiplied by the total sectional area of the furrow slices, gives the drawbar pull needed. Ploughing resistances range from about 5 lbf/in² (34.5 kN/m²) for very light blowing sand to over 15 lbf/in² (103.4 kN/m²) for heavy clay, an average figure for medium loam being about 10 lbf/in² (68.95 kN/m²) of furrow section. Thus, in average conditions, the drawbar pull needed to operate a three-furrow plough with furrows 12 in (305 mm) wide and 8 in (203 mm) deep would be

$$12 \times 8 \times 3 \times 10 = 2880 \text{ lbf}$$

$$(0.305 \times 0.203 \times 3 \times 68.95 = 12.8 \text{ kN})$$

The drawbar horse-power required may be calculated (Imperial units) as follows:

$$\text{drawbar h.p.} = \frac{\text{speed (m.p.h.)} \times \text{drawbar pull (lbf)}}{375}$$

At a ploughing speed of 4 m.p.h. the drawbar h.p. required for the above conditions would therefore be

$$\frac{4 \text{ (m.p.h.)} \times 2880 \text{ (lbf)}}{375} = 30 \text{ h.p. approx.}$$

In SI units, power = Nm/s (watts)

$$= 12.8 \times 10^3 \times \frac{4 \times 1.609 \times 10^3}{60 \times 60} \text{ watts} = 23 \text{ kW approx.}$$

Such a performance is just within the capabilities of a small-medium tractor of about 40 engine h.p. (30 kW), provided that conditions for traction are ideal. For heavier land, however, especially if the tractor is to operate on pneumatic tyres, it would be necessary to consider either a two-furrow plough or a more powerful tractor.

Cultivation performance is not the only factor determining the choice of tractor power, especially on the larger farm. Several specialized implements, especially those dealing with the harvesting of forage, require considerable power at the p.t.o. Their output is, in fact, often directly related to the tractor power available. With the need for greater output per man, high power at the p.t.o. is becoming an increasingly important criterion in deciding the size or type of tractor to be bought. Where a large tractor can be given a full load there may be a considerable saving of labour cost by using it – a fact which may often be taken advantage of on large farms and by contractors.

Type of Engine

Before the 1939–45 war practically all tractors were powered by petrol or paraffin (vaporizing oil) engines. Because of the tax on petrol in Britain most tractor engines were, in fact, paraffin models. It was not until the early 1950s that diesel-engined tractors became popular, but by the later part of that decade diesel tractors were predominant. The reasons for this are not hard to find. The first cost of the diesel engine was at first higher, but this was more than balanced by the saving on fuel. (The higher efficiency of the diesel (see Appendix 6) results in appreciably lower fuel

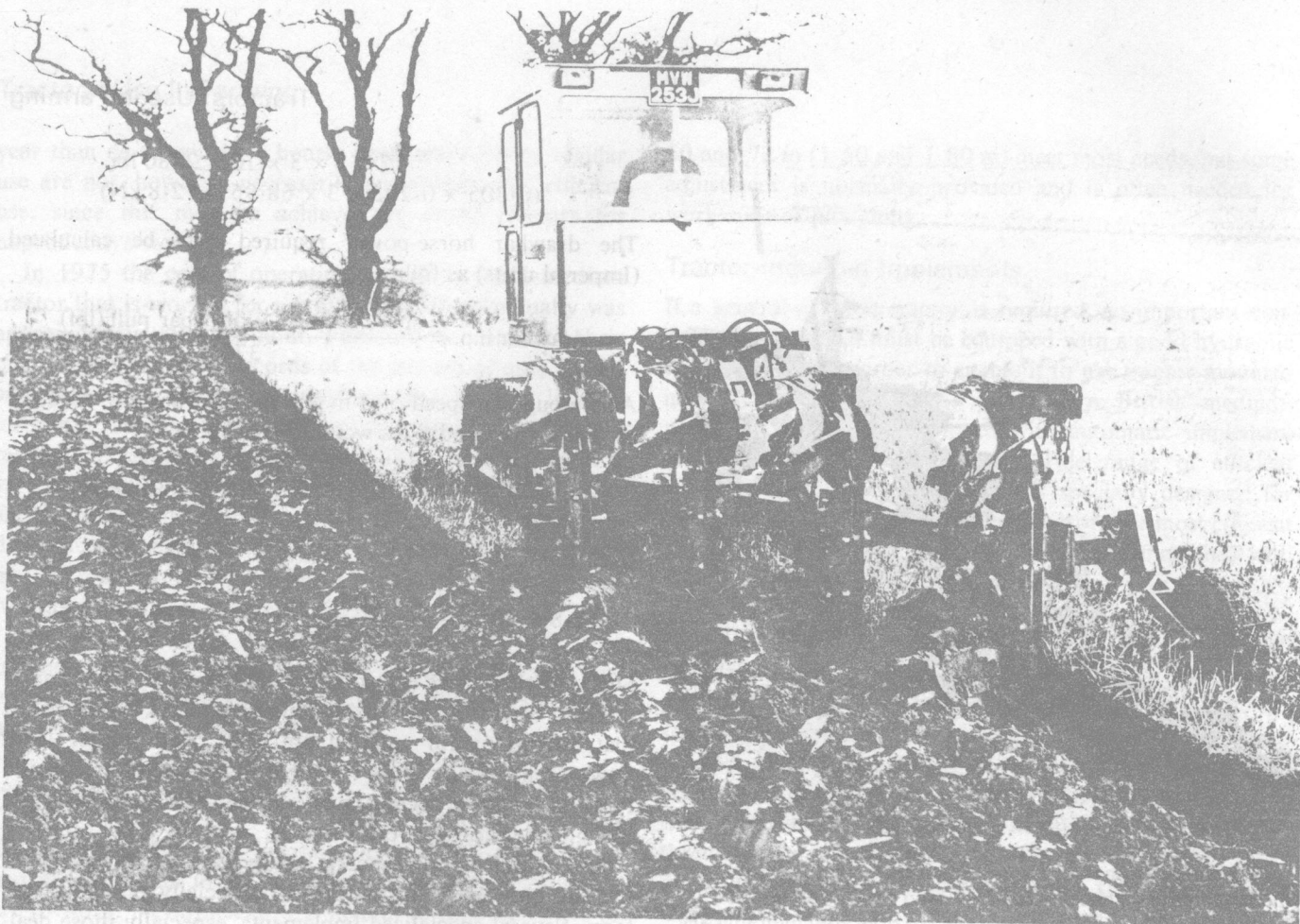


Fig. 1.5 The tracklayer, running out of the furrow and fitted with three-point-linkage implements, can work effectively in soil conditions that are too wet for some wheeled tractors (Track-Marshall/Ransomes)

consumption.) The modern diesel engine has every advantage as regards convenience of operation, being a reliable starter and immediately ready for hard work. Its good torque characteristics are widely appreciated. Though it may cost rather more to repair when an overhaul is needed, chiefly because of the fuel injection equipment, these repairs are generally less frequently required. The diesel is standard equipment in all modern British tractors other than small market garden machines; and with large scale production, capital cost has become very little higher than that of the vaporizing oil engines which have been displaced.

Wheel and Track Equipment

For general farm work, where the medium-powered tractor is to be regularly used for transport as well as for all kinds of field work, pneumatic-tyred wheels are now an automatic choice.

Many types of four-wheel-drive unit are available. They have advantages over rear-wheel-drive for heavy cultivations or transport in difficult conditions, but do not necessarily give a better performance on medium-powered tractors where conditions for adhesion are good. The extra cost of four-wheel-drive is more easily justified on powerful tractors, where the unit replaces a tracklayer.

For heavy tillage operations the choice lies between the large wheeled tractor and the tracklayer. Both have their advantages. Wheeled tractors are able, when conditions are good, to work at higher forward speeds than crawlers; but when conditions are difficult their weight and excessive wheel slip may cause physical damage to certain soils. When ploughing in wet conditions the tracklayer may do less damage to soil structure because it runs out of the furrow. Large wheeled tractors sometimes create deep ruts with