

HARVESTERS

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Keywords: Harvesters, harvesting machines, combine harvesters, robotics, image analysis, seed harvesters, root harvesters, leaf harvesters, fruit harvesters, fiber crop harvesters, timber harvesters.

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Summary

A wide range of seeds and plants are gathered by humans as food for themselves and their animals, also as the raw materials for many life support systems. This article categorises many of the plants grown specifically and some that are indigenous, listing whether they produce seed, root or tuber, green material, fruit, fuel or fiber. Having established the plant categories, the appropriate machines to harvest the desired part are listed and then described in greater detail. Combine harvesters account for most of the seed crops harvested throughout the world, but a few specialist harvesters may be used, such as green seed viners. Root crops are more diverse so a range of machines which lift and separate them from the soil are available. Green crops cover the widest range from grass and forage crops through to vegetables, and herbs used for culinary and pharmaceutical purposes. Mowers, conditioners, forage harvesters, specialist vegetable harvesters, and strippers for herbs are all discussed. Fruit harvesting is more manually orientated but machines are being developed to automate some of the processes. Image analysis by computer is enabling robotics to be used to select and pick individual fruit at economic speeds.

Fiber crops present some different challenges to the engineer but machines to pick the cotton fibers from the boll or pull the flax plants complete with the root and lay them in neat rows to dry are all available. Whole trees are also harvested and cut into logs with bark and branches removed by a machine controlled by a single operator.

1. Introduction

For the purpose of this article 'harvester' will be defined as - a means of gathering in ripe grains or other parts of a plant, for subsequent use by humans or their animals - and a second definition 'crops' are plants grown specifically for subsequent gathering or naturally growing plants that can be gathered by humans.

The most basic means of gathering crops is the human hand, but through necessity tools and mechanisms have been invented and developed to assist or replace the human hand and in some situations completely automate the gathering operation.

The end use and the part or parts of the plant being gathered will determine which machine or principle is most suited to harvest the crop. For example wheat is usually grown for the grain, to be harvested by a combine harvester when it is ripe and dry, and the straw may be collected for feed, bedding or as industrial raw material. Alternatively if the straw is the prime component for 'reed thatching' and the grain a by-product, a different harvesting process will be needed. A further use, requiring another set of machines, would be to gather the whole crop green and ensile it for animal fodder.

A machine that has been exclusively developed for one crop can be suitable for harvesting a crop for quite a different purpose. e.g. a sugar cane harvester will gather coppice wood for use as fuel.

In order to focus on how machines are related to many of the crops that are grown throughout the world including many of the specialist crops; Tables are presented, to describe the different types of plant or parts of the plant that are gathered, to list common crop names into categories related to their end use, and to associate types of machine with the harvesting needs of a crop.

Although in much of the world for economic reasons crop harvesting is done manually this article will concentrate on the state of the art mechanised harvesting.

The types of machines listed will be discussed in terms of how they gather the crop and the mechanisms involved, for some crops there is more than one machine appropriate to the gathering operation, where possible the range of options will be discussed.

Crop gathering like any other mechanized process is continually developing, so techniques described in this article will not necessarily be the current state of the art but in most cases developments are relatively minor and principles rarely change drastically.

2. Classification of Crops

The main components and characteristics of the wide range of plants used by humans and their animals have been categorised and are set out in Table 1. Two further tables are included to enable the reader to identify the needs of a particular crop so that the machines that have been developed to harvest them can be studied in more detail.

Types of crop	Part of plant	Detail
Seed	seed holder	ear, panicle, pod, cob.
Root	below ground storage organ	tuber, swollen root rhizome, bulb,
Leaf	leaf type	linear veins, branched veins, leaf stalk,
Fruit	edible seed carrying organ	top fruit, growing on trees. soft fruit, growing on bushes, canes, vines or ground plants.
Nut	hard woody seed carrier	edible kernel or seed within a hard shell
Flower	inflorescence prior to seed formation	decorative or source of flavourings and chemicals
Fiber	stems	plants where the fibers within the stems are of commercial value.
	leaves	linear veined leaves containing strong fibers
	seed pod or seed carrier	fibers either internal or external to the seed carrier
Timber	stem structure	mature plant stems more than 1 year old

Table 1. Plant Categories

In Table 2. a comprehensive list of common crop names are presented in relation to the parts of the plant that are used as a food or raw material, some crops may fall into more than one of these categories. This is by no means a complete list of crops grown throughout the world but will, it is hoped, include examples of most types.

Crop Type	Common name
Seed crops, often referred to as combinable crops	wheat, barley, oats, rye, triticale, rice, lentils, sorghum, millet, dry peas, beans(various), linseed, mustard, oil seed rape, buckwheat, maize, grasses and clovers.
Vegetables	potatoes, carrots, parsnips, beet, turnips, yams, onions, Jerusalem artichoke, globe artichoke, cassava, cabbage, cauliflower, lettuce, Brussels sprouts,

	leek, celery, rhubarb
Processed crops	sugar beet, sugar cane, rubber, tobacco
Fruit	apples, pears, plums, citrus, olives, banana, dates, figs, tomato, pepper, courgette, marrow, pumpkin, melon, strawberry, raspberry, blackberry, loganberry, mulberry, gooseberry, currants, grape, pineapple, cocoa, coffee
Beverages	tea
Herbs and pharmaceuticals	mint, parsley, fennel, borage, evening primrose
Nuts	groundnut, almond, walnut, hazelnut, sweet chestnut,
Fungi	mushroom
Fodder crops	grass, alfalfa (lucerne), mangel, fodderbeet, maize, wholecrop cereals, clover
Flowers	hops, lavender, and many others
Fiber	cotton, kapok, flax, hemp, jute, sisal, coir, cereal straw, timber,

Table 2. Common Names of Plants

Having described the wide range of plant parts that are harvested and some of the common names by which they are recognised, the picture is completed by listing in Table 3. the types of mechanisms and principles of operation most appropriate for harvesting each crop type.

Crop type	Harvesting principle	Operational detail
Seeds	reaper binder	cuts and bundles crop for subsequent drying, storage and threshing.
	combine harvester	gathers, threshes and separates seeds from crop residues.
	two stage harvesting	crop is cut into windrows to dry then threshed and separated with a combine.
	green crop vining	unripe seeds are shed from their pods and separated from the crop residues.
	specialist harvesters	e.g. ripe seed shaken from standing or cut crop.
Roots	lift with shares or blade	roots are lifted to the surface for subsequent hand or machine operations.

	lift and clean for later collection	roots are lifted and passed through a cleaning mechanism and on to the ground.
	complete harvester	a. remove foliage well before lifting and separating from soil. b. defoliate, lift and clean in one operation c. loosen plant and lift out by foliage then separate root from foliage.
Leaves and green plants	cutting with a mowing mechanism	a. finger bar, cuts by scissor action b. disk or drum, cuts with horizontally rotating knives c. flail, blades attached to a rotating horizontal cylinder, cut and convey. Crop conditioning may be included with a.and b.

Table 3. Details of Harvester Mechanisms

The very wide range of harvesting principles and machines listed will be described in sufficient detail for the layperson to understand the way in which they are used and a more detailed discription of some of the mechanisms for the more technical reader.

3. Seed Harvesting Machines

3.1 The Reaper Binder

From before the advent of the ‘combine harvester’ and still in use today, the reaper binder is a machine which cuts a standing crop and collects it into bundles (sheaves) and ties them with twine. The sheaves then dry in the field before being stored in a stack or barn prior to threshing. Reaper binders work well in low density crops and cereals that are not lodged or flat. High density crops in developed countries would overload such machines and there would be huge volumes to be transported and stacked.

First developed as a horse drawn machine the principle has changed little. Along the front of a gathering platform a reciprocating knife of triangular blades passing between static fingers cuts the stems of the crop by a scissoring action. To insure the crop falls smoothly on to the gathering platform four or more ‘bats’ the same width as the knife rotate as a cylinder and interleave with the crop to guide it on to the platform. This cylinder is called the ‘reel’ or ‘sails’.

The gathering platform will be one of two types, either wide flat canvas belts that carry the crop at 90° to the forward travel across the platform and up to the tying mechanism, or narrower conveyors that carry the crop leaning at about 45° to the center of the platform where secondary conveyors take it to the bundling and tying mechanism. In the bundling device, the crop is packed together by reciprocating fingers until sufficient is accumulated to trip the knotting cycle. The needle then carries the second end of the tying twine round the bundle and into the knotter. In the knotter, the two twines are

twisted and gripped by the bills and the knot completed by being pulled from the bills as the bundle is ejected from the machine. A new twine is left in the twine holder for the next bundle.

When reaper binders were horse drawn the rotary motion for the various mechanisms was taken from a single wheel of 1 meter or more diameter. With the advent of the tractor 'Power Take Off' this became the drive source making the machine much more versatile.

3.2 Combine Harvester

The combine harvester is most likely the first harvesting machine considered by most people, probably because, more crops are harvested by combine harvester than any other type of machine.

The name 'combine harvester' comes from the fact that three operations are combined in one machine, the crop is cut, threshed and the grains separated from the MOG (material other than grain). Although the combine (Figure 1), has developed over more than 100 years this section will describe the various mechanisms in use in today's machines.



Figure 1. A combine harvester for the 21st century.

Early versions had 2 to 3m cutting width and handled less than 0.5 tonnes per hour of threshed grain; today 8 to 10m cut and 20 tonnes per hour are not uncommon. The overwhelming majority of machines are self propelled and include operator's cab, engine, transmission and pneumatic tyres. Special tracked versions may be used in some situations. Although power transmission to the component parts is often by belt or shaft, hydrostatic drives are increasingly being used, especially where the physical size

of modern machines need many kW of power in remote positions.

3.3 Crop Gathering

Five different types of gathering mechanism may be found on the front of a combine harvester and all have been developed to satisfy the needs of a range of crops. These crops can vary from a few centimeters to two or more meters in height so what ever header is used its operating height must be adjustable manually by the operator, or automatically in response to sensors.

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Biographical Sketch

Michael A. Neale: One of three sons of an East Anglian arable farmer, and grandson of a former M.D. of the International Harvester Company UK. The farm was 700 acres of chalk soil growing cereals and sugar beet. From the age of 10 years I spent much of my available time driving tractors and working with machines on the farm. I chose to persue a career in agricultural engineering, securing an Honours Diploma and Intermediate NDAgE from the College of Aeronautical, Automobile & Agricultural Engineering Chelsea, followed by the National Diploma in Agricultural Engineering at Writtle Institute of Agriculture.

Two years of National Service was spent in the Royal Signals where I was trained as a radio technician, then worked on a wide range of activities with a Territorial Unit.

I then joined a local firm of Agricultural Engineers, as a technician working on grain storage and farm yard machinery projects, turning customers ideas into working schemes then supervising the instalation and commissioning of the project. After five years I moved to The National Institute of Agricultural Engineering at Silsoe, Beds.(now Silsoe Research Institute).

Here I joined the Farm Buildings department and worked on a range of projects related to the storage of crops, ventilated bulk vegetable stores, ice bank cooling, silage stores and other related projects. In 1983 I moved to the Machine Engineering department to work on the development of a hydraulic high density baling machine and assembled the first prototype 'grain stripper'. At this point I chose to stay with the compaction projects and took over a 'straw wafering' project when the leader retired.

In 1992 I returned to the now commercially successful 'grain stripper' project to complete comparisons with conventional headers in varying conditions. In 1994 I accepted early retirement to pursue my own interests.

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