Present Status and Future Requirement of Farm Equipment for Crop Production

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Abstract

Farm equipment are used in farming operations including immediate post-harvest activities with a view to increase productivity of land and labour through timeliness of operations, for efficient use of inputs, improvement in quality of produce and safety and comfort of farmers, and reduction in loss of produce and drudgery of farmer.

Tractor mounted implements such as mouldboard ploughs, disc ploughs, cultivators and other crop- specific equipment are widely being used for seed bed preparation. Seed drills and planters, both animal drawn and tractor mounted, have become popular. Mechanical transplanters for rice and vegetable crops are catching up with farmers. Long handle tools and power weeders for weeding and interculture and manual and power operated sprayers and dusters for application of chemicals have been commercialized. Cereal crop harvesters including various designs of vertical conveyor reaper windrowers and combine harvesters are being used on large scale. Tractor mounted digger- elevators for groundnut and tuber crops are being used. Spike-tooth and rasp-bar type threshers for cereal crops and crop specific threshers for major crops such as soybean, groundnut, sunflower have been developed and commercialized.

Future requirement for farm equipment and technologies include rota- tiller for seed bed preparation, till planter, strip till drill, pneumatic precision planter, sugarcane sett cutter planter, vegetable transplanter and check-row planter, for sowing and planting. Power weeders and equipment for chemico-mechanical weed management, electro-static spraying and tall tree spraying are required. Harvesting equipment for sugarcane and cotton are required to be developed.

1. INTRODUCTION

The early agricultural mechanization in India was greatly influenced by the technological developments in England. Horse drawn and steam-tractor-operated equipments were imported during the later part of the nineteenth century. The horse-drawn equipments imported from England were not suitable for bullocks and he-buffaloes being used in India. These were suitably modified to suit Indian draught animals. With the production of indigenous tractors and irrigation pumps, the use of mechanical power in agriculture, has been showing an increasing trend.

As a result of Green Revolution in the sixties, the total food grain production increased from a mere 50.8 million tonnes during 1950-51 to 211 million tonnes in 2001-02, and productivity increased from 522 kg/ha to more than 1,500 kg/ha. The increase in production of food grains was possible as a result of adoption of quality seeds, higher dose of fertilizer and plant protection chemicals. Irrigation played a major role in increasing the productivity. The improved seeds have been the catalyst for making other inputs cost effective. The use of certified/quality seeds by the farmers has increased to 650,000 tonnes in 1994-98 from 200,000 tonnes during 1970-71. Fertilizer consumption has increased to 12.37 million tonnes (about 75 kg/ha) in 1994-95 from 0.29 million tonnes in 1960-61. It increased at annual growth rate of 11.7%. The use of technical grade plant protection chemicals has increased to 80.684 tonnes in 1994-95 (0.44 kg/ha) from a meagre of 8.62 tonnes in 1960-61. Increased cropping intensity and higher quantity of inputs could no longer be effectively managed by animate power alone and, therefore, farmers

adopted tractors, irrigation pumps, harvesters and power threshers extensively.

2. DEVELOPMENT OF IMPROVED FARM MACHINERY

It is misconceived that benefits of mechanization could be reaped only by farmers having large acreage. The Indian farmer, however orthodox he/she may be, has only to be convinced of the relevance of techniques and machinery to induce him to accept them. Equipments for tillage, sowing, irrigation, plant protection and threshing have widely been accepted by them. Even farmers with small holdings utilize selected improved farm equipment through custom hiring to increase productivity and reduce cost of production. The small plot size might have been an impediment for use of large tractors but not for adoption of small tractors, power tillers and improved machinery. The improved hand tools, animal drawn and tractor operated implements have been adopted more in those states where productivity per unit area has increased. The ICAR with the cooperation of agricultural universities and local industries has developed many simple, low cost hand tools and animal drawn region specific improved machinery to suit to crops commodities and cultural practices. The State Agro Industries Development Corporations of Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Rajasthan, Uttar Pradesh, West Bengal, Assam, Orissa and Kerala are already manufacturing improved implements besides local small scale industries.

3. ADOPTION OF AGRICULTURAL MACHINERY

3.1 Tillage and planting machinery

The traditional animal drawn country plough has low output (30-40 h/ha) and high unit cost of operation. It also requires 3-4 passes to get desired seed bed. In vertisols, bakhar or *guntaka* (straight or curved blade harrow) is used. Cultivator and disc harrow cover 2-3 times more area than a plough and the quality of tillage is also better. Their annual use has grown from 3% to 8%. The mould board plough, puddler, disc harrow-cum-puddler, peg tooth harrow, spring-tine harrow and patela harrow operated by animal, power tiller and tractor are better machinery. It is estimated that more than 11.79 million steel ploughs, 5.79 million cultivators, 3.86 million disc harrows and 4.67 million animal drawn puddlers were in use during 1991-92. Custom hiring of tractor drawn tillage and puddling is quite prevalent. For land development, bullock drawn implements like scoop, buck scraper, U-leveler and float leveler have also been developed and are available commercially.

Line sowing not only saves seed but also allows post-sowing operations conveniently and efficiently. Besides, it helps control of weeds through use of mechanical weeders. The local seeding tube made of bamboo pipe and wooden funnel have been replaced by steel and plastic materials and by seed drills. The animal-drawn *Dufan* (2-row), *Tifan* (3-row), *Enatigoru* and FESPO plough (all local sowing devices) have been adopted as these cover more area and unit cost is less. These, however, require skilled operator to regulate the seed rate and are being replaced by seed drills and planters. Mechanically metered seed drill and seed-cum-fertilizer-drill operated by animal, power tiller and tractor have been developed and are being manufactured suiting to specific crops and regions for sowing/planting of wheat, rice, coarse cereals, pulses, oilseeds and maize. A multi-purpose animal-drawn tool frame has been developed that can prepare seedbed, do sowing/planting and interculture.

For paddy transplanting manual, power tiller and engine-operated rice transplanters are now available. Sugarcane planting is not only arduous but also time consuming. Tractor-operated semi-automatic sugarcane planter and sugarcane sett cutter-cum-planter are available. For potato, semi-automatic and automatic planters are gaining popularity especially in Uttar Pradesh and Punjab.

3.2 Interculture and plant protection equipment

Weed control in irrigated and rainfed agriculture during rainy season (kharif) is a serious problem. The yield is affected to the extent of 20-60%, if weeds are not controlled. The *khurpi* is the most versatile and traditional hand hoe for removal of weeds but it takes 300-700 man-h/ha. Use of long handle weeders, developed through the efforts of the ICAR network (wheel hoe and peg type weeders), reduce this weeding time to 25-110 h. Bullock and tractor operated and cultivators are also used for control of weeds. Pre-emergence weedicide followed by mechanical weed control technology are the economical methods of weed control.

The crops need protection not only from weeds but also from pests and diseases. Different designs of low cost hand-operated sprayers and dusters are commercially available for application of plant protection chemicals. Low volume and ultra low volume (ULV) sprayers, which require comparatively smaller quantity of water, are also in use. Spraying in cotton, rice, sugarcane, fruits and vegetables, oilseeds and pulses has become popular.

Traditionally, earthing operation in potato, sugarcane

and in other crops is performed using *khurpi*, *karaha*, spade or country plough. Now bullock operated cultivator, furrower, bund former and ridger are available which are effective and cover more area in a shorter interval.

3.3 Harvesting and threshing

The sickle, spade and *khurpi* are the major tools for harvesting and digging. These are easily available at low cost in the villages. Their output is low and effort required in cutting operation is high. Self sharpening serrated sickle has been developed with better material and design. It also requires less frequent sharpening and output is also more.

Delayed harvesting during *kharif* hampers seed bed preparation and sowing of winter season (*rabi*) crop. Reapers operated by engine, power tiller and tractor have been developed and introduced for harvesting wheat, rice, soybean, *ragi* and mustard. The cost of reaper varies from Rs 45,000 for walk-behind type to Rs 95,000 for riding type. Combine harvesting of wheat, rice and soybean has been accepted by the farmers in regions having labour shortage during the period and to reduce turn around time for planting at next crop. These are more suitable for custom hire service. Combine harvesting costs Rs 800/ha in northern India for wheat and soybean to Rs 1,500/ha for rice in the south. Straw combines have been developed to facilitate straw retrieval after combining. More than 60% rice and 50% wheat in Punjab is estimated to be harvested by combines.

Traditionally, threshing of wheat and barley was done by bullock treading which is arduous and time consuming. It results in considerable loss and poor quality grain. This has been gradually replaced by power threshers operated by 5-15 HP engine or electric motor. More than 200,000 power threshers are introduced every year. The farmers use them on individual ownership basis or on custom hiring. About 70-80% wheat, barley, gram, soybean, sorghum and pearl millet crops are estimated to be threshed by mechanical power thresher. To avoid accidents during operation of thresher, safety devices have been developed, which helped in enactment of Dangerous Machinery (Regulation) Act. Multicrop threshers are suitable for threshing major cereals, oilseeds and pulses. These threshers have provision to control concave clearance and threshing drum and blower speed independently so as to reduce grain breakage and improve cleaning. These are preferred for threshing oilseeds, soybean, peas, pigeon pea and sunflower.

Rice crop is easy to thresh by beating but losses are quite high. Pedal operated rice threshers reduce drudgery. These have become popular in Eastern India. Raspbar type rice thresher causes less breakage to rice stem and, thus, straw can be put to better use. These threshers have become very popular in Andhra Pradesh, Tamil Nadu, Karnataka and Kerala.

The low cost hand-maize sheller, costing about Rs. 15, is a simple device for shelling maize cobs. It can remove 16-24 kg grains from the cobs in one hr. Women can also handle this with equal ease. Similarly, rocking type manual groundnut decorticator is very effective for decorticating groundnut pods. About 60 kg groundnut can be decorticator in one hour compared to 5-6 kg by hand. Manually operated cleaner, grader and winnower are effective equipments for cleaning of grains and even small farmers have adopted these.

4. SOME SELECTED TRADITIONAL AND IMPROVED CROP PRODUCTION EQUIPMENT

4.1 Tillage and seedbed preparation

Optimum tillage to achieve maximum crop yields with minimum energy consumption should be the aim of seedbed preparation. A good seedbed preparation shows finer particles and greater firmness in the vicinity of the seeds. Depending upon the depth up to which tillage operations disturb the soil, we can classify the operations as shallow, medium or deep. The depth of tillage depends on the crop and soil characteristics and also on the source of power available.

Animal Drawn Indigenous (*Desi*) Plough

The traditional seedbed preparation equipment of India is *desi hal* (country plough) which continues to be used in many parts of the country. These are wedge ploughs with apex on the top or bottom with triangular steel share and operate with a draft of 80-100 kg. Their designs vary from region to region and sometimes craftsman to craftsman. These ploughs cause low inversion of soil.

Animal Drawn Maco Soil Stirring Plough

Pulled by a pair of animals, this plough opens the soil to aid aeration. Its working width is 175 mm and depth of cut is 110 mm.

Animal Drawn Sudan Type Plough

This plough is made from high grade steel. The handle and beam are adjustable and the landside is fitted with a heel for better control.

Animal Drawn Plough Sets

Twin Furrow: Fabricated from angle iron and

designed to be used with either the Raja ordinary type, deluxe type or master type plough shares. These are available from Baby to Giant size. These ploughs are of very simple construction.

Animal Drawn General Purpose Mould-board Ploughs

These ploughs are manufactured and used in many parts of the world. The important feature of this type of plough is that a slice of soil is cut from the ground and inverted, so that weeds and surface trash are buried and the soil is exposed to weathering agents and further cultivation.

Animal Drawn Light Ridger Plough

It consists of double mouldboard with reversible share. It is a light duty, type plough suitable for ploughing and making ridges in light soils and hilly terrain. The implement was developed at ICAR Research Complex for NEH Region, Barapani during 1980-82. Compared to conventional method of using spade for making ridges, this animal drawn implement has high capacity. It was found superior over local plough, Mandi plough, *Parvatiya* plough.

Birsa Animal Drawn Ridger Plough

It is a ridger type plough to perform all functions of country plough with added efficiency and advantages. It is suitable for hilly region of Chota Nagpur. This implement was developed at BAU, Ranchi during 1981-82. It costs Rs 150/- and its cost of operation is Rs 145/ha compared to Rs 158/ha by country plough. The effective field capacity, field efficiency and labour requirement were 0.022 ha/h, 63% and 46 man-h/ha, respectively. The draft of plough was 450 N.

Animal Drawn Bose Plough

It is a mould board plough suitable for upland paddy and dryland cultivation. This implement was developed by a Karnataka Farmer Mr. Bose. It was extensively evaluated, improved and adopted by IIT, Kharagpur during 1984-89. The equipment is commercially available and accepted by the farmers of Karnataka region due to better quality of work. The effective field capacity, field efficiency and labour requirement were 0.01 ha/h, 58%, and 98 man-h/ha, respectively. The draft of the plough was 410 N.

Animal Drawn Disc Harrow

Pulverizes soil, provides surface mulch and compacts sub surface. Notched discs provide more effective pulverization of soil than plain discs. It is a single acting double gang type disc harrow suitable for secondary tillage operation. This implement was adopted by IIT, Kharagpur during 1983-89. This implement costs Rs.3200/- and its cost of operation is Rs 95/ha compared to Rs 468/ha by conventional method. The effective field capacity, field efficiency, draft and labour requirement were 0.13 ha/h, 75%, 430 N and 8 man-h/ha, respectively.

Animal Drawn Spike Tooth Harrow

Breaks clods, stirs the soil, uproots the early weeds, levels the ground, and breaks soil crust. This harrow also covers the seeds. Usually it operates at shallow depths upto 5 cm.

Animal Drawn Spring type Harrow

Penetrates deeper than spike tooth harrow and is suitable for soils where obstructions like stones, roots and weeds are buried just below the soil surface. It requires three to five times the draft of a spike tooth harrow of similar size.

Animal Drawn Blade Harrow

Blade harrow, popularly known as *Bakhar*, is an implement of Indian origin. It is one of the agricultural implement of the Buddhist period (the others being plough shares, sickles and trowels) preserved in the Archaeological Museum at Sanchi (Madhya Pradesh). It is used mainly for secondary tillage operations like breaking clods and land smoothening in seed bed preparation. It is also used for breaking surface soil crust, controlling weeds, removing old stubble from the field and for soil mulching after the rains. It works like a sweep skimming under the soil surface without inverting it. In some parts of the country it is used for covering the seeds broadcasted and for harvesting groundnut crop. In the deep black vertisol regions of the country, the implement is used even for primary tillage.

Animal Drawn Spring-tine Harrow

Spring-tine harrows are versatile secondary tillage tools. By adjusting the depth of work (usually with a simple lever mechanism) the curved spring tines present a different angle of attack to the soil. Thus at shallow settings the tines are almost vertical while at full depth the tips are nearly horizontal.

Animal Drawn Spring Tooth Harrow

The spring tooth harrow is an implement for deep tillage. It works up to a depth of 150 mm. It is suitable for work in ground filled with stones and roots. A hand lever adjusts the depth of the harrow. Weight: five-tine, 35 kg, seven-tine, 57 kg.

Animal Drawn Triangular Harrow

This all-steel triangular harrow has thirty five tines made from 16 mm square section steel and held in place with standard fasteners. Its weight is 34 kg.

Animal Drawn Triangular Tine Harrow

This harrow consists of a triangular fabricated frame from which seven tines (200 mm) protrude on each side. Its width of coverage is 1500 mm.

Animal Drawn Diamond Harrow

With a diamond pattern frame of twenty tines, this harrow can be used for pulling out weeds and grass from light ploughed land. It is available in light, medium and heavy sections.

Animal Drawn Zig-zag Harrow

The Zig-zag pattern of tines allows each tine to cut a separate track. There are twenty tines in total. The harrow is available in light, medium and heavy sections.

Animal Drawn Peg Tooth Level Harrow

The rake angle of the tines is adjustable (by means of a lever) in order to vary the amount of penetration. There are thirty tines on each section of harrow. The harrow can be pulled by a pair of bullocks. Working width is 1200 mm.

Animal Drawn Five-tine Lever Adjustable Cultivator

This all steel cultivator has five tines and can be adjusted for width from 300 to 625 mm by means of a lever. Mould-board shares are available for earthing up ridges and making irrigation channels.

Animal Drawn Screw Adjustable Seven-tine Cultivator

The implement is designed for preparing seedbeds or inter-row cultivation of crops such as sugarcane, cotton, maize, tobacco and potato. The seven points made in steel are reversible. Right/left mouldboards are available as extra fitments. Working width varies 300 to 625 mm.

Animal Drawn Three-tine Cultivator

This three-tine cultivator has reversible carbon steel tines and the width can be adjusted across the beam. The depth of work can also be altered by changing the angle of the drawbar. Various attachments can be mounted as per requirement.

Animal Drawn Clod Crushers

Clod crushers are used after ploughing or harrowing for a fine tilth. They can work on an unevenly ploughed soil to produce a well packed seedbed and they also help in minimizing evaporation losses from the land surface. Of the several types in use, clod crushers of the Norwegian harrow type have been found to be quite efficient in crushing clods. They consist of a rectangular frame mounted on wheels. On the rear side of the frame, two square axles are fixed one behind the other. At each axle, cast iron stars with tapering spikes are fixed. The number of stars varies from 12 to 20 in each gang. The stars are fixed in such a way that there is continuous rolling action without jerks.

Animal Drawn Chisel Ploughs and Subsoilers

The chisel plough is a tool having a rigid curved or straight shank with a relatively narrow shovel point. It may also be termed as a heavy duty deep cultivator. Chisel plough and sub-soiler are similar in their actions, but differ mainly in their working depths. Because the chisel plough does not work as deep as a sub soiler, its draft is lower. The chisel plough works primarily in the top soil and hard pan at shallow depths and is therefore suitable to work with animal power, with a heavy pair or with two pairs of bullocks. The subsoiler is usually operated with a tractor, as the power required to rip open the hard pan at deeper depths is high. It costs Rs 1000 and its cost of operation is Rs 90/ha. The effective field capacity and labour requirement were 0.02 ha/h and 5 man-h/ha, respectively. The draft of the implement was 1200 N.

Animal Drawn Scraper

This scraper is suitable for use in tropical conditions and can be pulled by two draught animals. The capacity is between 0.1 and 0.15 cubic meters.

Animal Drawn Wooden Leveler

The leveler consists of two wooden planks hinged together. A steel handle is provided to control scraping and dumping. The working width is 1225 mm.

Animal Drawn Bund Former

It is a simple labour saving implement for forming bunds (ridges). It helps in the preparation of fields for irrigation and can be used in dry farming areas to preserve moisture. On steep slopes, bunds are made along the contour to prevent soil erosion during heavy rains.

Animal Drawn Channel cum Bund Former

It is a bullock drawn implement suitable for making field channels to manage the irrigation water effectively and making small bunds across the slope for inter-plot

rain water harvesting under rainfed areas. It works under well prepared and pulverised soil condition and can be used under all types of soil and crop conditions.

Animal Drawn Cossul Bund Former

The main parts are a pair of collecting mould boards made of steel. They are fitted so as to collect soil and throw it in the centre to make a bund. The size of bund and soil-collecting capacity can be increased or decreased by adjusting the mould boards. The weight of implement is 16.5 kg.

Animal Drawn Broad Bed Formers

These are various types of bed formers based on iron or wooden T-bars, to which standard ridger bodies are attached at either end, the distance between them determining the bed width. A drag chain is, sometime hitched between the bodies to smooth the surface of the bed and help to retain moisture.

Animal Drawn *Kapas* (Emcot) Ridger

This ridger is supplied with depth control wheel, mould board and handles all made of steel. Breasts with tailpieces can be fitted to the mould boards to extend the furrow width. Its weight is 44 kg.

Animal Drawn Engine operated Rotary Tiller

A bullock drawn, engine operated rotary tiller was developed under the ICAR Ad-hoc scheme of intermediate power sources for agricultural implements and machinery, at JNKVV, Jabalpur during seventies. It was fitted with 10 hp diesel engine which powered only the soil working tool namely, tiller, while the forward motion for the unit was provided by a pair of bullocks. As most of the two wheel tractors (power tillers) possessed low drawbar pull, much of the engine power being used up in providing traction, this arrangement of bullocks hauling the machine and the engine power being used for operating the soil working tool is an effective way of utilizing power with the minimum loss. The animals gradually experienced to the engine noise and performed their work normally.

CIAE Animal Drawn Multipurpose Tool Frame

It is a multipurpose frame with screw jacks to adjust the depth of operation. It is suitable for tillage, sowing, weeding and interculture operations under irrigated farming. This implement was developed at CIAE, Bhopal during 1983-84. The cost of the equipment with all attachments for tillage, sowing, weeding and interculture operations is Rs 10,000/-. For ploughing operation with MB plough, the effective field capacity, field efficiency and labour requirement were 0.06 ha/h, 83% and 20 man-h/ha, respectively. The draft of the equipment was 1060 N. For sweep operation the tool frame gave effective field capacity, field efficiency and labour requirement were 0.12 ha/h, 60% and 10 man-h/ha, respectively. The draft of the implement during this operation was 1100 N.

Puddlers

Puddling of soil is one of the common operations in paddy growing areas. Puddling is done after initial ploughing and allowing about 5 to 10 cm of standing water in the field. The main purpose of puddling is to reduce deep percolation of water, to kill weeds by decomposing them and to facilitate transplanting of paddy seedlings by making the soil softer.

Cage Wheels

Cage wheels are attached to tractors and power tillers during puddling operation. They are made of a lattice of reinforced steel angles, flats or bars and are approximately three times the width of the normal steel or pneumatic tyre wheel in a power tiller or tractor. The wide cage wheels provide good floatation and traction for the power units pressing organic materials down into the puddle and the wheels themselves have a considerable puddling effect.

Cossul Puddler

The Cossul puddler has three axle mounted cast iron hubs. The each hub is provided with four blades which act on the soil to break up clods and stir the surface layer. The draught power of one animal is sufficient to pull the implement. Its weight and work rate are 39 kg and 1.15 ha/day (8 hrs), respectively.

Animal Drawn Cono Puddlers

The design uses the concept of conical shaped rotors for wetland preparation. The blades on the rotors puddle the top 100 mm by a differential soil displacing motion which also buries weeds and trash with a rolling action. There are six rotors individually clamped to a toolbar for easy removal and spacing adjustment. Two wooden beams are rigidly fixed to the tool bar for hitching to the yoke. A removable seat is provided for the driver, whose additional weight will assist in penetration on harder soils. Its weight and draft requirement are 40 kg and 30-80 kg, respectively. For 1600 mm working width work rate of the puddler is 0.8 ha/day.

Animal Drawn Harrow cum Puddler

It is a disc type modified harrow used for puddling as well as dry seedbed preparation for raising wheat, cotton, *bajra*, *raya* and paddy. This implement was

developed at PAU, Ludhiana during 1983-84. It costs Rs 2500/- and cost of puddling is Rs 175/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.2 ha/h, 75-85%, 700-800 N and 5 man-h/ha, respectively.

Animal Drawn Puddler

It is a rectangular blade type puddler suitable for puddling operation under wet land condition. This implement was developed at ANGRAU, Hyderabad. It costs Rs 1500/- and cost of operation is Rs 260/ha. The implement is very popular among the farmers of Andhra Pradesh. The effective field capacity, field efficiency, draft and labour requirement were 0.07 ha/h, 60%, 600 N and 15 man-h/ha, respectively.

Animal drawn Lugged Wheel Puddler

It is an animal drawn equipment to break the soil clods near saturation level into soil particles in order to prepare homogenized puddled tilth for mechanized paddy transplanting. The equipment is suitable for shallow puddling with higher mechanical dispersion of soil. The unit consists of main frame, hitch, operator seat, angle lugs, roller wheel. It costs Rs 3000/- and its cost of operation is Rs 240/ha. The effective field capacity, field efficiency and labour requirement were 0.10 ha/h, 65% and 10 man-h/ha, respectively.

Animal Drawn Helical Blade Puddler

It is a helical blade type puddler suitable for puddling wetland and also for cutting and mixing of green manure crops. This implement was developed at TNAU, Coimbatore during 1983-84. It costs Rs 1200/- and its cost of operation is Rs 850/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.12 ha/h, 75%, 520-600 N and 8.5 man-h/ha, respectively.

Power Tiller Mounted Cono-puddler

Similar in design and use to the animal drawn unit, the tool bar can be fitted to a walking tractor by means of a special hitch adaptor. The mounting has a free side swinging arrangement to aid turning. For 1600 mm working width, the work rate is 1.5 ha/day.

Self propelled Hydrotiller

It is a self propelled, walk behind type equipment with power operated cage wheels suitable for puddling in light and medium soils. The field is required to be ploughed once with MB plough before using the machine. Four to five passes are required to achieve desired quality of puddling. This implement was developed at APAU, Hyderabad during 1990-93. It costs Rs 32,000/- (including engine) and its cost of operation is Rs 280/ ha. The effective field capacity, field efficiency, and labour requirement were 0.15 ha/h, 75% and 20 man-h/ha, respectively.

Power Tiller operated Leveller

It is used for back blading, vee draining, and so on. It can be offset to left or right. The angle and tilt adjustment is provided as it has a reversible cutting edge. It is suitable for dry land leveling.

Power Tiller operated Ridger

This implement can form 900 mm wide ridges and furrows.

Tractor Mounted Ridgers

This implement comprises of a row of three ridger bodies mounted on a tool bar coupled to a tractor using a Category I three point hitch. This is capable of producing three parallel ridges in one pass.

Tractor Mounted Pipe Harrow

The tractor operated pipe harrow is used for mixing seeds with soil in rangelands. It is reported to be specially suitable for areas infested with boulders and rocky outcrops.

Tractor Mounted Wetland Puddler cum Leveller

It has been developed at GBPUAT, Pantnagar which is useful for carrying out both puddling and levelling operations simultaneously.

Tractor Mounted Mouldboard Plough

The mouldboard plough is attached to the tractor with 3 point linkage system and controlled by hydraulic system. The plough share is fabricated from high carbon steel and parts from cast iron and steel. The coulters and skimmers are also provided for the operation of the plough. These can be used as basic tillage implement for opening of the soil, to bury the trash in the field by inversion, for the destruction of weeds and for the aeration of soil. Two to three bottom plough is operated with tractor of 35-50 hp and its effective field capacity varies 0.25-0.35 ha/h.

Tractor Mounted Disc Ploughs

Disc ploughs differ considerably from mould board ploughs. In this the coulter, share and mouldboard are replaced by a large concave disc fabricated of cross-rolled steel which is free to rotate. Owing to the form of construction, the implements weight can be substantial, and so all the ploughs described are of the tractor mounted type. The disc is set at an angle to the direction

of travel and turns a slice of soil to one side. The lateral force generated by the plough is counteracted by both the wheels of the tractor and a furrow wheel attached to the frame. Disc ploughs are well suited to work in hard and stony soils and can operate in trashy conditions where a mouldboard plough may not perform well. Two-four bottom ploughs are operated with 35-50 hp tractor and their effective field capacity varies 0.3-0.4 ha/h.

Tractor Mounted Five Tine Cultivators

Five tine cultivator consists of replaceable shares and adjustable depth wheels. It is mounted using a standard Category 1, three point hitch. Its working width is 1400 mm.

Spring Loaded Tine Cultivator

It is a tractor mounted equipment which can be fitted using Category I or II three-point hitch. It is available in three models with seven, nine or eleven 920 mm tines respectively. The tine spacing is adjustable for inter-row cultivation and the high carbon steel tips are reversible. The weight and working width of 7, 9 and 11 tynes units are 180, 220, 260 kg and 1650, 2160 and 2670 mm, respectively.

Duck Foot Cultivator

The duck foot cultivator consists of a steel frame, rigid tines to which sweeps (resembling duck foot) are attached. It is attached to the tractor with three point hitch system and controlled by the tractor hydraulic system. The sweeps are fabricated from high carbon steel. The implement is mostly used for shallow ploughing. Number of sweeps can be varied according to usage. It can be used for primary tillage, destruction of weeds and retention of moisture.

Tractor Driven Disc Harrow (Trailing Type)

The front gang of discs is notched enabling the implement to dig better. This implement can often replace the ploughing operation in soft irrigated soil. It is available in gangs of five, six, seven and nine disc. The disc diameter of harrow is 610 mm.

Tractor Driven Disc Harrows (Mounted Type)

These harrows can be mounted offset from the centre line of the tractor to enable cultivation to take place beneath the overhanging branches in an orchard. In order to counteract the side thrust caused by such a set-up, the second gang of discs can be set at a greater angle to the line of draught than the first. A range of disc sizes available are two gangs of four 560 mm diameter, two gangs of five 560 mm diameter, two gangs of five 610 mm diameter, and two gangs of six 610 mm diameter.

Offset Disc Harrow

It is available in three models with ten, twelve and fourteen discs respectively. It is fitted with self-lubricating, sealed, deep-groove ball bearings. The offset disc harrows are tractor mounted requiring a Category I or Category II hitch. The cutting widths are, 900, 1120 and 1340 mm, for 10, 12 and 14 discs models. The weight of 10, 12 and 14 discs models are 280, 300 and 340 kg, respectively. The harrow can be offset either to the left or right. In addition to field discing, it is used for operation in orchards, plantations and vine yards where operation is required under the branches of the trees.

Tractor Drawn Basin Lister

It is an attachment fitted behind 9-tine tractor mounted cultivator. It is used for water harvesting and conservation of soil and moisture. This implement was developed at TNAU, Coimbatore during 1986-87. It conserves 18% more moisture as compared to ploughing with country plough or tractor drawn cultivator. It costs Rs 7000/- and its cost of operation is Rs 400/ha. The effective field capacity, field efficiency, and labour requirement were 0.60 ha/h, 80% and 2 man-h/ha, respectively.

Tractor Drawn Bed-Furrow Former

The tractor drawn bed-furrow former is capable of forming alternate beds and channels. The beds are suitable for planting crops like sorghum, maize and cotton. This bed and furrow system is ideal for efficient irrigation management. This implement was developed at TNAU, Coimbatore. This implement cost Rs 10,000/- and its cost of operation is Rs 500/ha compared to Rs 1600/ha with conventional method. The effective field capacity, field efficiency, and labour requirement were 0.75-1.00 ha/h, 75% and 8 man-h/ha, respectively.

Tractor Drawn Channel cum Bund Former

It is a tractor mounted implement suitable for making field channels to manage the irrigation water effectively and making small bunds across the slope for interplot rain water harvesting under rainfed areas. It is operated under well prepared and pulverised soil condition and can be used under all types of soil and crop conditions. This implement was developed at IGFRI, Jhansi. This implement costs Rs 1700/- and its cost of operation is Rs 30/ha compared to Rs 300/ha by conventional method. The effective field capacity, field efficiency, and labour requirement were 4 ha/h, 70%, and 0.25 man-h/ha, respectively.

Tractor Drawn Pulverising Roller Attachment

It is an attachment to commercially available tractor operated tyned cultivator. It is suitable for puddling as well as dry seedbed preparation. This implement was developed at PAU, Ludhiana during 1983-84. It costs Rs 3500/- and the cost of operation is Rs 290/ha. The effective field capacity, field efficiency, and labour requirement were 0.62-75 ha/h, 70-90% and 1.5 man-h/ha, respectively.

Tractor Drawn Spiked Clod Crusher

It is used as a combination tillage tool with tractor drawn harrow or cultivator. It is suitable for breaking and segregation of clods for seedbed preparation after paddy harvest. This implement was developed at GBPUAT, Pantnagar during 1988-93. It saves 22% time of operation and 2-3 h/ha of tractor compared to conventional method of using harrow and wooden patela in two operations. It costs Rs 6,500/-. The effective field capacity, draft and labour requirement were 0.4 ha/h, 750 N and 2.5 man-h/ha, respectively.

Tractor Drawn Combine Tillage Tool

It is a tillage tool having cutting blade with rotary slicer making it suitable for seedbed preparation in one pass under irrigated soil conditions. It has a blade in front which loosens the soil. The rotary slicer operated with tractor pto pulverises the soil. This implement was developed at TNAU, Coimbatore during 1990-93. This implement costs Rs 20,000/- and its cost of operation is Rs 770/ha compared to Rs 1740/ha by conventional method. The effective field capacity, field efficiency, field consumption and labour requirement were 0.22 ha/h, 71 per cent, 2.3 l/h, and 9 man-h/ha, respectively.

4.2 Sowing and Planting Equipment

The basic objective of sowing operation is to put the seed and fertilizer in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed. The recommended row to row spacing, seed rate, seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields.

Depending upon climatic and soil conditions, seeds are sown on well-prepared and leveled fields, on ridges, in furrows or on beds. Flat seeding and planting refer to operation when the field being sown/planted is leveled and smooth. Seeds and tubers are planted on ridges either to improve soil drainage due to high rainfall or it may be a cropping requirement. Potatoes are usually sown on ridges. Seeding in furrows is done in arid regions to conserve soil moisture and improve plant growth. Bed planting helps in conserving soil moisture, avoids soil compaction and promotes plant growth.

Hand Seed Drills

It is a simple single row seed drill which can be operated by two persons. It is used to sow small plots or for gap filling in the rows which have been incorrectly sown by a larger drill. A two-row version of the drill is also available which requires two people to pull the implement while a third guides the tool and feeds the seed into the seed tubes.

Manually Operated Mustard Drill

It is a manually operated implement suitable for sowing rapeseed and mustard. By changing the fluted roller, other crops like wheat and green gram can also be sown. It is also suitable for inter-row sowing. This implement was developed at PAU, Ludhiana during 1989-91. It results in 5% increase in yield compared to conventional method of sowing behind country plough. It costs Rs 650/- and its cost of operation is Rs 200/ha. The machine has been accepted by the farmers especially for inter row sowing. The implement can also be used in hilly areas provided the hilly land is terraced and row marker is used prior to sowing operation. The effective field capacity, field efficiency, and labour requirement were 0.10ha/h, 85-90% and 20 man-h/ha, respectively.

Manually Operated Naveen Dibbler

It can be used in all type of soils with good land preparation. It is suitable for sowing pea, soybean, sorghum and maize in small plots or hilly terrain. It can also be used for gap filling. The planting operation is accomplished by pushing the jaws penetrate into the soil at desired depth and by forward movement of the dibbler jaws to release metered seeds into the soil. This implement was developed at CIAE, Bhopal during 1981-83 and adopted by BAU, Ranchi. It costs Rs 200/- and its cost of operation is Rs 150/ha. The field capacity, missing seed and labour requirement were as 0.03 ha/h, 6%, and 39 man-h/ha, respectively.

Manually Operated Rotary Dibbler

The dibbler is operated by pushing it manually into the soil in the direction of travel. The jaws enter into soil and automatic dropping of seed takes place. Well prepared seed bed is required for its operation. It is suitable for dibbling of maize, soyabean, sorghum, pigeonpea and Bengal gram crops. This implement was developed at CIAE, Bhopal during 1981-83 and adopted by BAU, Ranchi. This implement costs Rs 500/- and

its cost of operation is Rs100/ha compared to Rs 234/ha by conventional method. The effective field capacity, and labour requirement were 0.042 ha/h and 27 man-h/ha, respectively.

Low Land Manual Rice Seeder

It is a manual pull type implement useful for sowing pre-germinated paddy in puddled fields. The seeder is capable of sowing 8-rows at 200 mm row-to-row spacing. It has a lugged ground wheel and two skids. The pregerminated paddy seeds are kept in four drums which have peripheral openings at two ends for seed discharge. Perfect levelling and proper maintenance of water level (10 mm) are necessary. The soils should be allowed to settle for 2-3 days prior to sowing. Use of this device results in 16% increase in yield compared to conventional method. This implement costs Rs 1200/- and its cost of operation is Rs 370/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.12 ha/h, 65% and 17 man-h/ha, respectively. The seeder gave number of hills 76/m^2, number of seedlings 2.8/ hill and hill to hill spacings 4.4 mm during test trials.

Manually Operated Single Row Garlic Planter

A manually operated single row garlic planter was developed at PAU, Ludhiana to improve the quality of planting in addition to removal of human drudgery during planting. The machine is simple in design and weighs only 12.0 kg. In this machine, the planting mechanism is attached over the existing design of PAU wheel hand hoe which is used for interculture operation and is already commercialized. The machine with a hopper capacity of about 3.0 kg is operated by two persons. One person pulls the machine from the front through a rope attached to the hook on the machine and the other person steers the machine by holding it from the handle. Machine is also provided with markers for maintaining the specific row to row distance. Plant to plant spacing can be varied by varying the number of spoons on the periphery of vertical plate. It can plant 0.3-0.4 ha/day with the help of 3 persons. Two persons are required for machine operation and the third for seed transport and feeding into the hopper. The approximate cost of this machine is Rs 1,000/- and this cost can be recovered by the use of this machine on an area of only 0.4 ha.

Animal drawn *Nari* Plough

It is a single row animal drawn manually metered sowing equipment which consists of a seed bowl or funnel. A vertical seed tube is fitted to the indigenous plough. The seed tube is either fitted into the shoe of the plough or tied with the body such that seeds from funnel fall through it in furrow behind the plough. Two persons are required to use this equipment.

Animal drawn *Duphan*

It is an animal drawn equipment and has an arrangement for sowing two rows at a time. This is fitted with two seed tubes and a seed funnel to drop seeds in furrows made by two furrow openers. Sometimes, an extra arrangements, similar to that for seed sowing, is provided for fertilizer drilling. In this equipment, the furrow openers are attached to the frame called head piece. Furrow openers have holes to which seed and fertilizer tubes are fitted. A beam fitted to the head piece facilitates hitching of the equipment. In *Duphan*, all parts except beam are metallic but some times wood is also used for head piece. It is generally used for sowing small and medium size seeds.

Animal drawn Tifan

The design of this equipment is similar to *Duphan* excepting that it has an arrangement for sowing three rows at a time. Seeds in three furrows are dropped through a single seed bowl and distributed through three seed-tubes. This is also used for sowing small and medium size seeds.

Seeding attachment to Wheel Hoe

The seed-cum-fertilizer drill has been developed by providing suitable furrow opener, power transmission mechanism, seed and fertilizer hoppers and metering mechanism to a wheel hoe. Both the hoppers are made of mild steel sheet. Seed rate can be varied by changing the axial length of fluted roller. Fertilizer rate can be adjusted upto 568 kg/ha. One person is required to push the unit for its operation in the field. This unit can also be used as a wheel hoe.

Animal drawn Seed/Fertilizer Drill

This is a four-row animal drawn implement which is similar in principle to the simple hand seed drills. It requires two operators. The frame is made of steel and plastic seed tubes are used between the bowls and the coulters.

Animal Drawn Jyoti Multicrop Planter

It is an animal drawn implement suitable for planting groundnut, sunflower, safflower, soybean, pigeon pea, bengal gram, sorghum, wheat and maize. The equipment can also be used for inter-cropping. This implement was developed at MPKV, Pune during 1975-78 and adopted by KAU, Tavanur. This implement costs Rs 7100/- and its cost of operation is Rs 250/ha compared to Rs 900/ ha by conventional method. The effective field capacity,

field efficiency, draft and labour requirement were 0.10 ha/h, 70%, 450-500 N and 10 man-h/ha, respectively.

Automatic Seed Drill

Both three and five row versions of this animal drawn seed drill are available. It is provided with single hopper, disc coulters and a fluted roller seed metering system. Row spacing is adjustable between 150 and 250 mm. The drill is also available with a fertilizer distribution attachment. The weight of the machine for 3 and 5 rows units are 94 kg and 110 kg, respectively.

CIAE 3-row Seed-cum-Fertilizer Drill

It is an animal drawn simple, light weight and compact machine to sow crops like wheat, gram, sorghum, soybean, lentil, pea, sunflower, safflower etc. and drill fertilizer in black soil under rainfed condition. The fluted roller metering mechanism, fitted in the unit, gets the drive from ground drive wheel of 300 mm diameter through chain and sprocket. The shoe type furrow opener with non clogging boot place the seed at desired depth. It costs Rs 3000/- and cost of operation is Rs 120-375/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.10-0.28 ha/h, 65-75%, 450 N and 5-15 man-h/ha, respectively.

CIAE 2-row Rapeseed-mustard Seed-cum-Fertilizer Drill

This machine consists of two seed boxes with vertical rotor with cells type seed metering mechanism. Fertilizer box is provided with fluted roller metering. The pointed shoe type furrow openers are used for furrow opening and a small compaction wheel serves the purpose of covering the seeds and compacting of soil.

Birsa Animal Drawn Seed Drill

It is a bullock drawn implement suitable for sowing paddy, *ragi*, wheat, linseed, gram, safflower and other small sized seeds. This equipment was developed at BAU, Ranchi during 1979-82. It saves 56% labour and operating time and 25% on cost of operation compared to conventional method of sowing behind country plough. It also results in 14 to 27% increase in yield compared to sowing by conventional method. This implement costs Rs 650/- and its cost of operation is Rs 150/ha compared to Rs 200/ha by conventional method. For rice crop the effective field capacity, draft, seed damage and labour requirement were 0.04 ha/h, 376 N, 4% and 29 man-h/ha, respectively. For ragi crop the effective field capacity, draft and seed damage were 0.03 ha/h, 369 N and 7%, respectively.

HAU Animal Drawn Seed-cum-Fertilizer Drill

It is a bullock drawn implement suitable for sowing wheat, gram, *raya*, pigeon pea, green gram and inter-cropping wheat, gram and cotton-*bajra*. This implement was developed at HAU, Hisar centre. It costs Rs 3000 and cost of operation is Rs 120/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.10-0.20 ha/h, 65-70%, 500-600 N and 5-10 man-h/ha, respectively.

HAU Animal Drawn Mustard Drill

It is an animal drawn implement suitable for sowing rapeseed mustard, wheat and pearl- millet. This implement was developed at HAU, Hisar during 1988-92. It results in 15-20 per cent increase in yield compared to conventional method of sowing behind country plough. It costs Rs 1350/- and cost of operation is Rs 120/ha.. The effective field capacity, field efficiency, draft and labour requirement were 0.2 ha/h, 65-70%, 320 N and 5 man-h/ha, respectively.

Camel Operated Seed-cum-Fertilizer Drill

It is similar to HAU bullock drawn seed-cum-fertilizer drill. Only the hitching system is modified to suit camel. It is suitable for sowing cotton, wheat, *guar*, *bajra*, gram and *methi*. This implement was developed at HAU, Hisar centre during 1984-87. It results in 15-20% more yield compared to conventional method of sowing behind country plough. It costs Rs 3000/- and cost of operation is Rs 120 per ha. The effective field capacity, plant population and labour requirement were 0.22-0.25 ha/h, 30-35 plants/m^2, and 8-9 man-h/ha, respectively.

ANGRAU Animal Drawn Seed-cum-Fertilizer Drill

It is an animal drawn implement suitable for planting groundnut, castor and sunflower. This implement was developed at ANGRAU, Rajendranagar during 1994-96. Use of this machine also results in 20 per cent increase in yield. It costs Rs 4500/- and its cost of operation is Rs 165/ha. The effective field capacity, field efficiency and labour requirement were 0.18-0.24 ha/h, 66%, and 5-6 man-h/ha, respectively for groundnut, sunflower and castor crops.

TNAU Animal Drawn Planter

Three row planter consists of a simple frame, seed box, hitch bracket, handle, clutch and furrow openers (pointed shovel type). The unit is mounted on two wheels and is provided with cup feed type metering mechanism.

It is an animal drawn implement suitable for sowing groundnut, cotton, maize, sorghum and Bengal gram. This implement was developed at TNAU, Coimbatore during 1977-79. It saves 97.5% labour and operating

time and 73% on cost of operation compared to conventional method of sowing behind the country plough. This implement costs Rs 10000/- and the cost of operation is Rs 425/ha compared to Rs 1600/ha by conventional method. The effective field capacity, field efficiency, draft and labour requirement were 0.19 ha/h, 74%, 600 N and 29 man-h/ha, respectively.

CIAE 3-row Animal Drawn Groundnut Planter

This planter was developed at CIAE during 1990-95 for sowing groundnut and other crops, like, maize, pigeonpea, sorghum, other oilseeds and pulses. The inclined plates with cells (edge drop type) are provided for metering of seeds and fluted rollers for fertilizer. The drive to metering systems is given through chain and sprocket and bevel gears from a spiked ground drive wheel. Individual seed metering units with separate boxes, provided in the planter, can be used for sowing inter-crops. The seed plates can be changed for sowing different crops. It costs Rs 5000/- and cost of operation is Rs 90/ha. The effective field capacity, field efficiency, draft and labour requirement were 0.12-0.15 ha/h, 60-65%, 800-900 N and 7-8 man-h/ha, respectively.

Animal Drawn Sugarcane Planter

This equipment plants pre-cut sugarcane setts that are manually metered. It has a three wheeled fore-carriage and a trailed implement attached behind it. The fore-carriage has a seat for operator and two wooden seed hoppers on either side of seat. As the implement moves forward the share point opens out a furrow. The operator riding on fore-carriage picks up setts from the sett- hoppers and drops them down the chute one after the other. Gamma BHC is sprinkled over the planted setts and soil surface under gravity. Fertilizer is applied and the setts are covered with soil by the ridger bottom.

Tractor Drawn Seed-cum-Fertilizer Drill

Tractor mounted seed-cum-fertilizer drill with inter-row spacing adjustable from 180 mm to 800 mm is capable of meering seed and fertilizer separately. Depth control wheels are provided but the drill is fully mounted on a standard three-point hitch. The machine has to be lifted out of work for transportation using the tractor's hydraulic system.

TNAU Tractor Mounted Cultivator - Planter

It is a planter attachment to tractor mounted nine tine cultivator frame. A ground drive wheel provides power to cup feed type seed metering mechanism through a clutch. A square bar is provided at the rear of the unit for covering the seeds. Seed to seed spacing is adjusted by changing the sprockets on drive shaft. Different size of cups are required for different crops.

Tractor Operated Seed-cum-Fertilizer Drill cum Planter

It consists of a seed-cum-fertilizer drill with fluted roller type metering for seeds and adjustable orifice type metering for fertilizer. A planter attachment with cast iron inclined plate metering mechanism can be fitted for sowing of bold seeds. This seed drill is suitable for medium size seeds whereas the planter attachment is used for bold seeds like groundnut, cotton, castor, etc.

Tractor Mounted Strip Till Drill

It is a tractor mounted machine, a combination of rotavator and seed -cum-fertilizer drill with fluted metering rollers. The rotavator is operated with tractor pto. The machine prepares 75 mm strips for each row and places seed and fertilizer in the centre of the strip. It does not need field preparation before sowing and wheat can be sown immediately after the harvest of rice. This results in the saving of irrigation and ploughing expenses apart from timeliness in wheat sowing. Rotary tillage controls the weeds in the immediate vicinity of crop rows.

CIAE Tractor Drawn Pneumatic Precision Planter

A six row (option 2 and 4) tractor drawn pneumatic precision planter is suited for exact planting of single seeds at predetermined seed/row spacings. The machine works on suction principle. Air is sucked through a rotating plate having various holes radially. Any seed coming in contact gets stuck to the holes on the plate and falls immediately when suction is cut off at the lowest position, and hence no mechanical seed damage occurs. The fall of seed is synchronized with the predetermined seed spacings. The effective field capacity of the machine with a 2 m tool bar is 0.5 to 0.6 ha/h. Lot of seed can be saved by using this planter.

Power Tiller Operated Seed-cum-Fertilizer Drill

The power tiller operated seed-cum-fertilizer drill is suitable for sowing 5 rows of wheat and paddy, 4 rows of bengal gram, black gram, 3 rows of soybean, safflower, sunflower and sorghum and 2 rows of pigeonpea crop. The seed-cum-fertilizer drill has provision to adjust row to row spacing and to adjust depth of seed placement. Granular fertilizer can also be drilled by this machine simultaneously. It can be successfully operated in moderately prepared seedbed. The effective field capacity of this machine ranges from 0.185 to 0.250 ha/h.

Animal drawn Mechanical Planter

This is a bullock-drawn, four-row planter consisting of a single seed hopper with four outlets, each with

metering plates. The metering shaft is rotated through chain and sprocket from ground drive wheel. The ground wheel is lifted for transport. Coulters and furrow press wheels are fitted and a chain type seed coverer can be attached for use in dry soil. An optional fertilizer applicator with a hand metering device is available.

Animal Drawn Potato Planter

It is a rotating sector type planter suitable for making ridges and planting potato on the ridges. This implement was developed at IISR, Lucknow. This implement costs Rs 8000/- and cost of operation is Rs 400/ha compared to Rs 1000/ha by conventional method. The effective field capacity, field efficiency and labour requirement were 0.1 ha/h, 70%, and 40 man-h/ha, respectively.

TNAU Tractor Mounted Cultivator Seed Planter

It is an attachment to the commercially available tractor drawn cultivator suitable for planting groundnut, gram, soybean etc. This implement was developed at TNAU, Coimbatore during 1985-87. It resulted in 20% increase in yield. It costs Rs 9000/- and cost of operation is Rs 350/ha. The effective field capacity, field efficiency and labour requirement were 0.63 ha/h, 78% and 4.1 man-h/ha, respectively.

ANGRAU Tractor Mounted Cultivator Seed Planter

It is an attachment to commercially available tractor mounted cultivator suitable for planting castor, maize, red-gram, wheat, dry paddy, groundnut etc. It was developed at ANGRAU, Hyderabad during 1985-86. It costs Rs 8000/- and cost of its operation is Rs 410/ha. The effective field capacity, field efficiency and labour requirement were 0.4 ha/h, 60%, and 5 man-h/ha, respectively.

Tractor Mounted Seed Fertilizer Drill-cum-Planter

It is a planting attachment to the commercially available tractor operated seed-cum-fertilizer drills suitable for sowing maize, soybean, groundnut, cotton etc. This implement was developed at PAU, Ludhiana. It resulted in 5 to 10% increase in yield compared to conventional method of sowing. This implement costs Rs 5000/- and cost of operation is Rs 450/ha compared to Rs 550/ha by conventional method. The effective field capacity, field efficiency and labour requirement were 0.30 ha/h, 60% and 7 man-h/ha, respectively.

PAU Tractor Mounted Seed-cum-fertilizer Drill for Oilseeds

It is a tractor mounted implement provided with two fluted rollers instead of single in the existing drills and is suitable for sowing rapeseed and mustard in addition to wheat. This implement was developed at PAU, Ludhiana during 1986-89. Use of this machine resulted in 5 to 6 per cent increase in yield compared to conventional method of broadcasting. It costs Rs 7000/- and its cost of operation is Rs 300/ha. The effective field capacity, field efficiency, fuel consumption and labour requirement were 0.3-0.4 ha/h, 75-80%, 3 l/h, and 5.0 man-h/ha, respectively.

Tractor Mounted Ridge Planter for Winter Maize

It is a tractor operated implement suitable for planting crops like maize on one side of ridges. In this, a planting unit is mounted on the commercially available ridger. The furrow opener is moved to sow seeds only on left side of a ridge. This implement was developed at PAU, Ludhiana during 1984-85. It resulted in 10% increase in yield compared to conventional method of making ridges by tractor operated ridger and planting manually. It costs Rs 8000/- and cost of operation is Rs 420/ha. The effective field capacity, field efficiency, fuel consumption and labour requirement were 0.20-0.25 ha/h, 60-70%, 3 l/h and 10 man-h/ha, respectively.

Tractor Mounted Broad Bed Former-cum-Seed Planter

It is a tractor mounted implement which forms raised bed of 1.5 m width with trenches at both ends and sows seeds. It is suitable for sowing maize, cotton, groundnut etc. This implement was developed at TNAU, Coimbatore during 1988-89. It costs Rs 12000/- and the cost of its operation is Rs 320/ha. The effective field capacity, field efficiency, and labour requirement were 0.43 ha/h, 82%, 5 man-h/ha.

Tractor Mounted Ridger Seeder

It is a tractor drawn implement which forms ridges and furrows and carries out sowing either on the ridge, a side of the ridge or in the furrows as desired. For *kharif* crops seeding is done on the ridge in paired row system and for *Rabi* crops seeding is done in deep furrows. It is suitable for planting *raya*, gram and *bajra* seeds. This implement was developed at HAU, Hisar during 1988-89. It resulted in 15% increase in yield compared to conventional method of flat furrow planting by country plough. It costs Rs.10000/- and its cost of operation is Rs 250/ha. The effective field capacity and labour requirement were 0.75-1.00 ha/h, and 2-3 man-h/ha, respectively.

Tractor Mounted Direct Rice Seeder

It is an attachment to the commercially available tractor mounted cultivator for direct sowing of paddy

in dry land conditions. This implement was developed at TNAU, Coimbatore during 1989-90. It also resulted in 16 per cent increase of yield. It costs Rs 4500/- and cost of its operation is Rs 250/ha. The effective field capacity, field efficiency, fuel consumption and labour requirement were 0.68 ha/h, 75%, 4.5 l/h and 14.5 man-h/ha, respectively.

Tractor Drawn Mustard Drill Attachment to Semi-automatic Sugarcane Planter

It is an attachment to tractor mounted IISR semi-automatic sugarcane planter for sowing mustard. This implement was developed at IISR, Lucknow. This implement costs Rs 8500/- and its cost of operation is Rs 600/ha compared to Rs 750/ha by conventional method. The effective field capacity, field efficiency and labour requirement were 0.30 ha/h, 80% and 3-4 man-h/ha for mustard crop, respectively.

Power Operated Sugarcane Sett Cutting Machine

It is a power operated machine suitable for cutting sugarcane setts for planting. This implement was developed at IISR, Lucknow. This implement costs Rs 7000/- and cost of its operation is Rs 400/ha compared to Rs 500/ha by conventional method. The effective field capacity, bud damage and labour requirement were 0.04 ha/h, 2-4% and 8 man-h/ha, respectively.

Tractor Drawn Semi-Automatic Sugarcane Planter

It is a tractor mounted implement suitable for planting sugarcane setts and application of granular fertilizer. This implement was developed at IISR, Lucknow. It costs Rs 10000/- and its cost of operation is Rs 950/ha compared to Rs 1800/ha by conventional method. This implement was extensively evaluated at IISR, Lucknow. The effective field capacity, field efficiency, missings and labour requirement were 0.18 ha/h, 60%, 3% and 40 man-h/ha, respectively.

Tractor Drawn Sugarcane Cutter Planter with Discs

It is a tractor mounted implement suitable for cutting and planting sugarcane setts and application of granular fertilizer in single operation. The machine accepts whole cane for planting. This implement was developed at IISR, Lucknow. This implement costs Rs 40000/- and its cost of operation is Rs 700/ha compared to Rs 1800/ha by conventional method. The effective field capacity, field efficiency and labour requirement were 0.20 ha/h, 65% and 20-30 man-h/ha, respectively.

Tractor Mounted Ridger Type Sugarcane Cutter Planter

It is a tractor mounted implement suitable for cutting and planting sugarcane setts and application of granular fertilizer in single operation. The machine accepts whole cane. This implement was developed at IISR, Lucknow. This implement costs Rs 30000/- and the cost of operation is Rs 700/ha compared to Rs 1,800/ha by conventional method. The effective field capacity, field efficiency and labour requirement were 0.20 ha/h, 65% and 20-30 man-h/ha, respectively.

Tractor Mounted Seed Drill for Rapeseed-Mustard

It is a tractor drawn implement suitable for sowing of small seed such as rapeseed, mustard and millets. This implement was developed at GBPUAT, Pantnagar during 1988-92. It results in 20-25 per cent increase in yield compared to conventional method of hand broadcasting. It costs Rs 10000/- and its cost of operation is Rs 200/ha. The effective field capacity, field efficiency, number of plants and labour requirement were 0.18 ha/h, 62%, 37/m^2 and 3.3 man-h/ha for rapeseed crop, respectively.

CIAE Tractor Mounted Inclined Plate Type Planter

A tractor mounted inclined plate type planter was developed at CIAE, Bhopal during 1997-98. The planter unit consists of a frame with tool bar, seed boxes, furrow openers and ground drive wheel system. The planter is provided with six seed boxes of modular design with independent inclined plate type seed metering mechanism. The shoe type furrow openers are mounted on tool bar of main frame through clamps. The seed boxes are bolted to furrow openers and seed box-furrow opener assemblies are adjustable for row to row spacing and work as a modular unit for sowing of each row. The drive to seed metering mechanism is transmitted from ground drive wheel through chain and sprockets. The ground drive wheel and power transmission system are fixed on the main frame. The cost of the implement is Rs.12000 and its cost of operation is Rs.400/ha. The effective field capacity and field efficiency were 0.50-0.65 ha/h and 70-75%, respectively.

Tractor Mounted No-Till Ferti. Seed Drill

It is a seed-cum-fertilizer drill developed for sowing wheat after the harvest of rice, without preparing any seedbed. It was developed at GBPUAT, Pantnagar during 1997-98. The machine is found very successful under the condition when the rice harvesting gets delayed and soil moisture is too high to facilitate seed bed preparation for wheat. It is a nine row unit consisting of fluted rollers for seed metering and gravity metering for fertilizer. The ground drive wheel imparts motion to metering device through sprocket and chain drive. Use of zero-till drill for direct sowing of wheat after rice was found to be advantageous in terms of 52.5% saving in time and 41%

in cost of sowing as compared to the conventional practice of seedbed preparation (two operations of duck-foot cultivator) and sowing with seed cum fertilizer drill. It costs Rs 12,000/- and its cost of operation is Rs 560/- per ha - a saving of about Rs. 200/ha in the cost of production. The effective field capacity and field efficiency were 0.46 ha/h and 72% for wheat crop, respectively.

Power Tiller Operated Till Plant Machine

It is a specially designed as a matching equipment for 10-12 hp power tiller to prepare seedbed and drilling seed and fertilizer simultaneously. It is suitable for wheat, bengal gram, soybean etc., under medium and heavy soil. It consists of main frame with standard hitch, seed/fertilizer boxes, transport wheel, drive wheel etc. It costs Rs.6000/- and its cost of operation is Rs.750/ha, 200/ha. Its field capacity and field efficiency were 0.18 ha/h and 62%, respectively.

Raised Bed Planter

The Furrow Irrigated Ridge-till Bed-planting System (FIRBS) is a method where cultivation of crops is done on raised beds. This system is suitable for the wheat crop. In the crop sequences where wheat follows soybean, maize or cotton, a system of reduced tillage can also be followed whereby sowing can be done directly on the same beds without field preparation. If wheat follows rice then it requires a fine seed bed preparation followed by sowing of wheat on raised beds. The sowing on raised beds is done with the help of the raised bed planter. The machine has adjustable blades for making raised beds of different widths and heights that can be adjusted by the shifting of blades on the frame and roller on the rear. It has seed-cum-fertilizer drilling mechanism for sowing one, two or three rows on each bed. The planter makes two beds at a time. The width of beds can also be adjusted from 65-70 cm. The planter is fitted with knife type tines so that it can also be used for sowing of other crops. The benefits of the machine are saving of cost of operation, seed (25%) fertilizer (25%), irrigation water (35%) and low *Phalaris* minor weed problem. The cost of the machine is Rs 18,000/- and its effective field capacity was 0.2 ha/h.

Rice Transplanters

The transplanters can be classified on the basis of power source as, manual, animal drawn, power tiller mounted, tractor mounted and self-propelled. Transplanters can also be classified on the basis of the type of nursery required by them e.g. root washed seedlings type and soil bearing seedlings type. In the root washed seedlings type transplanter, the nursery is raised in the conventional way on moist or puddled soil. At the time of transplanting the nursery is manually uprooted and the roots are washed and/or shaken by hand to remove the soil sticking to the roots. Then the seedlings are fed to the trays of the transplanter.

The root washed seedling based mechanical rice transplanter have not been found viable because of high labour requirement with this machine and no net labour saving over the manual transplanting. Only mat-type nursery based transplanters have scope for adoption. For the soil bearing, mat type, seedlings type transplanters, the nursery is raised in trays on soil-and-manure bed of uniform thickness. After the seedlings grow for about 22 days the roots form a mat which can be lifted out of the trays by hand and placed on the transplanter trays.

The transplanters can also be classified on the basis of the type of planting fingers as, fixed fork type, tweezer type, fixed fork and knock out lever type, pair of moving fingers type, and rotating pincet type. In the fixed fork type transplanters the seedlings are held in the fork. When the fork enters the puddled soil the seedlings are held by the soil while the fork is withdrawn. In the tweezer type transplanters two more or less flat plates open like a pair of tongs, hold the seedlings in between, get closed and then enter the soil. When in soil they open again, and are withdrawn leaving the seedlings behind.

Fixed fork and knock out lever type transplanters have a fixed fork which takes the seedlings from the seedling mat and brings them near the soil/water surface. At this position a lever hits the soil near the seedlings roots and the root portion of seedlings enters the puddled soil due to its momentum. Thus, the planting mechanism always remains out of puddled soil. The cleaning action of the knock out lever also helps in improving the picking of seedlings by the fork.

In the moving finger type mechanism two round fingers come closer when they enter the seedling mat. Due to this, seedlings are held in between them. Then the pair of fingers enter the puddled soil, get themselves separated and come out leaving the seedlings planted on puddled soil.

Rotating pincet type transplanting mechanism has two flat plates which can be brought nearer or separated by rotating them around an axis by rotation of two coaxial tubes on which they are mounted. The pincets are closed after seedlings enter the space between them when the coaxial tube enters the seedling box. The pincets open when the coaxial tube enters the puddled soil leaving the seedlings planted on the soil.

Efforts have been made to mechanise the process of transplanting right from the fifties both for manual, self propelled and tractor drawn type of transplanters.

Different designs have been tested and modified for adoption using the mat type nursery. Earliest trials of the mat type nursery were made in the Cauvery delta with the sole purpose of reducing the area required for nursery.

Significant results were visible only during the eighties which saw the development of many types of mechanical transplanters. These are as follows:

Manually operated 6-row Rice Transplanter

It is a manually operated rice transplanter suitable for transplanting of mat type rice seedlings in puddled soils in rows. This implement was developed at PAU, Ludhiana, based on IRRI design during 1993-95. It resulted in 5 to 10 per cent increase in yield compared to conventional method of hand transplanting. It costs Rs 2500/- and its cost of operation is Rs 450/ha as compared to Rs 850/ha with manual method. The effective field capacity and field efficiency were 0.04-0.05 ha/h and 55-60%, respectively.

Self Propelled Riding Type Rice Transplanter

It is a self propelled riding type rice transplanter suitable for transplanting mat type seedlings. This machine was developed at PAU, Ludhiana during 1984-90. It resulted in 5 to 10 per cent increase in yields compared to conventional method of manual transplanting. It costs Rs 40000/- and cost of its operation is Rs 550/ha. The effective field capacity and field efficiency were 0.15-0.20 ha/h and 55-60%, respectively.

Riding Type - Self Propelled Rice Transplanter (8-Row)

This is a commercial unit and adopted by CIAE, Bhopal. The unit is single wheel driven and fitted with a 2.4 kW diesel engine. The transplanting system consists of fixed fork and knock out lever type planting fingers. The machine covers 8-rows with 238 mm row spacing per pass. It is suitable for transplanting rice seedlings in puddled soils in rows with uniform depth of standing water of 50 mm and weed free plot. The seedling mat of size 210 mm x 500 mm x 25 mm with 20-22 days old seedlings is suitable for transplanting. It costs Rs 1,20,000/- and its cost of operation is Rs 975/- per ha. The effective field capacity and field efficiency were 1200 m^2/h and 76%, respectively.

4.3 Weeding, Hoeing and Interculture Equipment

Virtually most of the hand tools used for seedbed preparation can be used for weeding, some of the important hand tools continuing to be used in the country. Most of the animal drawn equipment has provision for inter - row weeding. The spring tyne duck foot points enable breaking of clods and uprooting of weeds. Ridge tyne with full or half sweeps removes the top portion of the weeds. Reversible shovels can penetrate deeper. Rotary tyned cultivator is useful in ridges. Some of the more popular equipments in the order of their development are described below:

V-Blade Hand Hoe

It is a manual weeding tool used for weeding in row crops. The V-shaped blade cuts a thin layer of soil and the repeated use of the tool causes earthing-up effect. The hoe is suitable for weeding operations when the weeds are small.

Karjat Hoe

This weeder/cultivator consists of three arrow-headed, inclined tines and a wedge-fitted handle. The operator walks backwards, pulling the tool along in a single-pass operation, rather than using it as a push-pull tool.

Wheeled Hand Hoes

These implements are widely used for the weeding of row crops using a push-pull operation. The frame and handle assembly is mounted on a single ground wheel and a range of interchangeable tools can be fitted. These include a V-blade hoe, a furrower, a narrow tine and a set of three spade tines. Handle height and working depth are both adjustable.

Hand Pushed Rice Weeder

This simple weeder is used for weeding low land rice planted in rows. Two spiked wheels rotate in a supporting frame, the front of which forms a skid; it also provides depth control for the wheels. When the implement is pushed between rows, the spikes press the weeds under the soil. The two wheels and the skid are made of light sheet metal and the handle is made of wood. The assembly can be dismantled for cleaning and repair.

CIAE Three Tyned Grubber

It is a manual, pull type implement suitable for weeding and interculture of upland row crops in black soil regions. This implement was developed at CIAE, Bhopal during 1979-80 and adopted by BAU, Ranchi. It costs Rs 100/- and its cost of operation is Rs 575/ha compared to Rs 750/- by conventional method. The effective field capacity and weeding efficiency were 0.005 ha/h and 59%, respectively.

CIAE Peg Type Dryland Weeder

It is a manual push-pull type weeder suitable for weeding and mulching in row crops with 225-450 mm

row-to-row spacing like groundnut, sunflower, safflower, soybean, and sorghum. This implement was developed at CIAE, Bhopal during 1979-85 and adopted by MPKV, Pune and BAU, Ranchi. This implement costs Rs 250/- and its cost of operation is Rs 333/ha compared to Rs 750/ha by conventional method. The effective field capacity and weeding efficiency were 0.009 ha/h and 72%, respectively.

CIAE Single Wheel Hoe

It is a manual push-pull type single wheel weeder. It uproots and cuts weeds in upland row crops. It is suitable for weeding crops having row spacing of 300 mm or more such as sorghum, soybean, maize and pigeon pea. This implement was developed at CIAE, Bhopal during 1979-85. The implement costs Rs 300/- and its cost of operation is Rs 333/ha compared to Rs 750/ha by conventional method. The implement has been adopted by BAU, Ranchi. The effective field capacity and weeding efficiency were 0.009 ha/h and 83%, respectively.

PAU Wheel Hand Hoe

It is manually operated implement suitable for weeding and interculture in upland row crops except paddy. This implement was developed at PAU, Ludhiana during 1985-86. It costs Rs 270/- and its cost of operation is Rs 250-400/ha. The effective field capacity and weeding efficiency were 0.03-0.05 ha/h and 75%, respectively.

TNAU Star Weeder

It is a manual push-pull type weeder suitable for weeding in row crops in rainfed as well as garden lands. It performs well in plain fields where the weeds are shallow rooted and the land is not very thickly infested with weeds. This implement was developed at TNAU, Coimbatore and adopted by BAU, Ranchi Centre. This implement costs Rs 300/- and its cost of operation is Rs 740/ha compared to Rs 1050/ha by conventional method. The effective field capacity and weeding efficiency were 0.007 ha/h and 79%, respectively.

Animal Drawn Multipurpose Hoe

It is an animal drawn implement suitable for weeding and interculture operation in groundnut, sunflower, safflower, sorghum, soybean and other row crops. This implement was developed at MPKV, Pune during 1987-89. It costs Rs 835/- and its cost of operation is Rs 190 to 260/ha. For the depth of tilling of 35-75mm, draft of the implement varied 280-320 N. The effective field capacity, weeding efficiency and labour requirement were 0.15-0.25 ha/h 68-86%, 75-89%, and 6 man-h/ha, respectively.

Animal Drawn Sugarcane Earthing Hoe

It is an animal drawn implement suitable for earthing operation of sugarcane crop having row spacing of 900 to 1200 mm. It consists of three iron bars for loosening of soil and scraper with adjustable wings for earthing. This implement was developed at MPKV, Pune during 1987-95. It costs Rs 2000/- and its cost of operation is Rs 330/ha. The effective field capacity and field efficiency were 0.14 ha/h and 77%, respectively.

Animal Drawn Sweeps

It is used as an intercultural implement in row crops. It consists of duck-foot type sweeps clamped on a common tool bar and a pair of wheels for depth adjustment. It removes the shallow rooted weeds and provides a soil mulch so as to conserve the soil moisture from evaporation loss. This implement was developed by TNAU, Coimbatore. This implement costs Rs 2500/- and its cost of operation is Rs 250/ha compared to Rs 1050/ha by conventional method. The effective field capacity and weeding efficiency were 0.2 ha/h and 91%, respectively.

Tractor Mounted Earthing-cum-Interculture Equipment

It is a disc type tractor mounted implement suitable for earthing and interculture operation in sugarcane where planting is done at row spacing of 700 mm or more. The equipment is useful for areas where lodging of crop is pronounced. This implement was developed at GBPUAT, Pantnagar during 1990-94. It costs Rs 8500/- and its cost of operation is about Rs 260/ha. The effective field capacity and field efficiency were 0.39 ha/h and 65%, respectively.

Tractor Mounted 2-row Sugarcane Stubble Shaver

This implement was developed by IISR, Lucknow. The stubble shaver consists of a rotary blade operated by tractor pto. Use of this equipment results in 15 per cent increase in yield compared to conventional method of harrowing between the rows of sugarcane. This implement costs Rs 15000/- and cost of its operation is Rs 300/ha. The effective field capacity and field efficiency were 0.35 ha/h and 80%, respectively.

TNAU Power Weeder with Rotary and Tined Attachments

A power weeder was developed at TNAU, Coimbatore. The equipment consists of a 5.4 hp, 34 kg light weight diesel engine mounted on the frame. From the engine, the power is transmitted to the transmission gear box and then to the ground wheels and rotary weeder. The machine is suitable for wide spaced crops

such as cotton, tapioca, sugarcane, grapes, coconut, arecanut and other orchard and plantation crops. The row mounted hoe and sweep type weeders have three staggered tynes with provision for adjusting row-to-row spacing. The engine is mounted in front of the drive wheels for balancing of the machine. The cost of the machine is Rs 50,000/- and its cost of operation is Rs 380/ha. The effective field capacity and field efficiency were 0.09-0.11 ha/h and 85%, respectively.

CIAE Self Propelled Weeder

A self-propelled interculture equipment (power weeder) was developed utilizing the chassis of self propelled walking type reaper windrower. The machine was powered by a light weight petrol-start kerosene-run 1.1 kW engine having rated engine speed of 1500 rpm (at the camshaft) (Greaves make model MK 12/2). The machine is light in weight and can be operated with three sweeps of 150 mm for weeding operation in crops sown at 30-35 cm spacing. If the spacing is 40 cm or more, only two sweeps of 150-200 mm can be used. A set of narrow wheel of 110 mm width was also developed to facilitate operation of machine during weeding operation. For weeding operation in soybean crop (sown at 30 cm spacing) with two 150 mm size sweeps, the mean values of forward speed, effective field capacity, fuel (kerosene) consumption and weeding efficiency were 2.12 km/h, 0.149 ha/h, 0.64 l/h and 55.5%, respectively.

4.4 Plant Protection Equipment

Most of the plant protection equipment are designed to apply the desired chemicals in the form of spray, dust or mist. Different types of duster and sprayers have been developed for operation by hand, a small engine and also by using the tractor power. Except for the ultra low volume and the electro static sprayers, all other equipment have been in existence for the last 40-50 years.

Sprayers

Spraying is employed for a variety of purposes such as application of:

- Herbicides in order to reduce competition from weeds,
- Protective fungicides to minimise the effects of fungus diseases,
- Insecticides to control various kinds of insect pests,
- Micro-nutrients such as manganese or boron on cereal crops.

The main function of a sprayer is to break the liquid into droplets of effective size and distribute them uniformly over the surface or space to be protected. Another function is to regulate the amount of insecticide to avoid excessive application that might prove harmful or wasteful. A sprayer that delivers droplets large enough to wet the surface readily should be used for proper application. Extremely fine droplets less than 100 micron size tend to be diverted by air currents and get wasted. Crops should, as far as possible, be treated in regular swaths. By use of a boom, uniform application can be obtained with constant output of the machine and uniform forward travel. There are basically two types of sprayers.

Hand/foot operated sprayers: These may be compression or knapsack type. The pressure used in these sprayers ranges from 1 to 7 kg/cm^2.

Engine operated sprayers: Power sprayers may be knapsack type or trolley mounted. Pressure in these units ranges from 20 to 56 kg/cm^2.

Lever operated sprayers (Rocker Sprayer): This sprayer is mounted on a small platform on which the operator stands while rocking a long hand lever in a 'push-pull' action. The suction hose is placed in the spray container (not provided) and an eight metre discharge hose connects to the spraying lance.

Trigger Operated and Hand Compression Sprayers: These small, hand held sprayers are suitable for the treatment of individual plants or very small plots. They are usually made of plastic or brass, with a calibrated reservoir of 1-1.5 litres capacity. The spray can be gradually adjusted from a fine mist to a continuous jet, by twisting the nozzle. In the simplest type, the liquid is pumped out directly, by trigger action. In other types, the reservoir is first pressurized using a plunger.

Atomizers: These piston-action hand sprayers are available with either intermittent or continuous action. They are suitable for agricultural use and also common for the disinfestation of buildings. Brass, copper and plastic atomizers of 0.5 to 1.0 litre capacity are available.

Pedal Operated Sprayer: The cylinder of this sprayer is pumped by a double spring, foot pedal in the manner of a tyre pressure pump. It is easier to use if one person operates the foot pedal while another holds and directs the spray lance. The sprayer is supplied with hoses, lance and nozzle but without the spray container.

Lever operated sprayers (Rocker Sprayer): This sprayer is mounted on a small platform on which the operator stands while rocking a long hand lever in a 'push-pull' action. The suction hose is placed in the spray container (not provided) and an eight metre discharge hose connects to the spraying lance.

Booms and Nozzles: The large variety of booms and nozzles supplied by many manufacturers of knapsack sprayers reflects the range of chemicals used and the

crops to which they are applied. An eight nozzle boom of 400 cm length and a five nozzle boom of 150 cm are available.

Power Knapsack Combined Dusters and Mist Blowers (Spraymist): Although primarily designed as a sprayer this knapsack type unit is supplied with dusting accessories as standard. Optional attachments are also available for ULV spraying. The unit has a 10 litre (10 kg) tank and is powered by a 35 cc two stroke, air-cooled engine with rope start. The discharge capacity is 0.5-2.0 lt/min for liquid sprays and 0.7-2.0 kg/min for dusts.

ASPEE Tractor-mount Sprayer: The sprayer carries 400 lt of chemical in a glass fibre tank or in two steel drums mounted on a steel frame fitted with a standard which can also be used to fill the tank. The version illustrated is fitted with an overhead spray boom for treating tall crops grown in rows. The spray can cover two swaths of 9 m to either side. A 2.5 m wide path must be provided in the crop after every 18 m interval to allow the tractor to pass.

Power Sprayer: The Sigma power sprayer comprises of a horizontal piston pump and a petrol engine or electric motor mounted on a steel frame. The frame can be provided with wheels or carrying handles. The pumps available include single, double or triple cylinder versions and engines of appropriate power are provided to drive them. The pumps are fitted with a 3 m suction hose and a 15 m delivery hose which can be coupled to a lance or spray gun.

Motorized Knapsack Mist Blower-cum-Duster: These are suitable for low volume pesticide spraying and dust application on foliage of crop for control of insects, pests, etc. It consists of blower, tank for chemical, and a high speed petrol engine (5000-7000 rpm). The air blast from blower at a very high velocity strikes and carries the liquid chemical in mist form. The spray jet strikes at a long distance upto 10 m. It is useful for low volume spraying because it creates very fine spray droplets. The machine can be adapted for ULV spraying with the use of very fine aperture dosage tube.

Hand Held ULV Sprayer: It can spray at low volume (LV) and ultra low volume (ULV) rates with water and oil based chemicals, respectively. These sprayers produce very fine spray suitable for foliar application. The light weight hand held ULV sprayers have a plastic spinning disc with small DC motor, which drives the disc at 7000-9000 rpm. Because of high speed of disc, liquid chemical gets disintegrated into fine droplets. Wind transports the spray droplets. For accurate spraying wind should be neither too gentle (less than 3 kmph) nor too strong (more than 22 kmph).

CDA Crop Sprayer: This sprayer has been developed using Controlled Droplet Atomizers (CDA) and is suitable for spraying all types of chemicals at desired application rates with optimum spray droplet size. The sprayer can be used either as a push type unit or tractor rear mounted. It is suitable for spraying crops upto 1 metre height. The Micromax-III, CD atomizer has three rotational speed of 2000, 3500 and 5000 rpm to produce droplets of 250, 130 and 70 micron sizes, suitable for application of herbicides, insecticides and fungicides. The unit can apply chemicals at application rates varying from 5 to 64 l/ha. The field capacity of the sprayer, with tractor operation, was 0.76 ha/h with effective swath of 5.5 metres.

Recent advances of plant protection equipment developed are as follows:

Wide Swath Spray boom for Tall Crop

It was developed at IISR, Lucknow. The boom consists of two aluminium square sections of 1.8 and 2.7 meter lengths, joined together to make "T" shape. The top members are kept at an angle of 20o to horizontal. The two swiveled nozzles are fixed at both ends and connected with two foot pump. For regulating flow of liquid two stop cocks are provided in the hose. The nozzles make a spray trajectory of 10.4 m swath. It costs Rs 650/- excluding pump assembly and its cost of operation is Rs 35-40/ha. The effective field capacity and the application rate were 0.05 ha/h and 100-150%, respectively.

Self Propelled High Clearance Sprayer

It is a self propelled unit suitable for spraying on tall crops like cotton. The machine consists of two rear steered wheels and two front lugged wheels which is powered with a 20 hp diesel engine through a gear box, tank, hydraulic pump and boom fitted with 15 nozzles. It costs Rs 1,80,000/- and its cost of operation is Rs 35/ha. The effective field capacity and field efficiency were 1.6-2.0 ha/h and 70-80%, respectively.

Self Propelled Boom Sprayer

To meet the requirement of a high capacity effective sprayer, a self propelled boom sprayer with 14 nozzles was developed at ANGRAU, Hyderabad center of AICRP on FIM. It was mounted on a frame of self propelled vertical conveyor reaper. The spacing of nozzles can be varied from 300 to 600 mm. The height of boom can be varied from 400 to 1200 mm. The effective field capacity and field efficiency were 0.06 ha/h and 61%, respectively.

Dusters

Bellow type dusters: This lightweight duster uses a hand operated bellows to disperse the powder. It is carried on a shoulder strap.

Hand rotary dusters: These spinning disc dust applicators are worn at the operator's waist and supported by a neck strap. They are hand cranked and the flexible discharge hose is hand held.

Shoulder carried hand operated rotary dusters: This type of hand cranked duster can be used for all kinds of powders and dusts. The hopper is separated from the cranking mechanism and carried behind the elbow. This is to improve the balance of the duster when carried on the shoulder strap.

Sigma duster: It consists of a galvanized steel with 7 litre hopper and lance. The fan casing and impeller are made of mild steel of 7 kg weight.

Aerated steam therapy

Sugarcane crop often becomes susceptible to sett borne diseases. If it is protected from this kind of disease the crop can grow healthy. Two methods were developed to treat the sugarcane by which it could be protected. They were:

1. Hot water treatment of sugarcane in which the cane is treated with hot water at 50°C for 2 hours, and
2. Hot air treatment in which the cane is treated with hot air at 54°C for 8 hours.

4.5 Harvesting Equipment

Crops are harvested after normal maturity with the objective to take out grain, straw, tubers etc. without much loss. It involves cutting/digging/picking, laying, gathering, curing, transport and stacking of the crop. In case of cereals like wheat and paddy the plants are straight and smooth and ears containing grains are at the top whereas most of oilseed and pulse crops have branches which create problems in harvesting by manual or mechanical means. As per Bureau of Indian Standards the cutting and conveying losses should not be more than 2 per cent.

Traditional method of harvesting

The harvesting of crops is traditionally done by manual methods. Harvesting of major cereals, pulse and oilseed crops are done by using sickle whereas tuber crops are harvested by country plough or spade. All these traditional methods involve drudgery and consume long time.

Mechanical harvesting equipment

Timeliness of harvest is of prime importance. During harvesting season, often rains and storms occur causing considerable damage to standing crops. Rapid harvest facilitates extra days for land preparation and earlier planting of the next crop. The use of machines can help to harvest at proper stage of crop maturity and reduce drudgery and operation time. Considering these, improved harvesting tools, equipment, combines are being accepted by the farmers.

Wheat & Rice: Harvesting of these crops is traditionally done by using local sickle. Improved serrated blade sickles are also in use. The following machines are available for efficient harvesting of these crops.

i. Self propelled walking type reaper
ii. Reaper binders
iii. Tractor front and rear mounted reapers
iv. Combine harvesters

Sorghum: Harvesting by local sickle is the traditional practice followed by farmers. Suitable machines are not available for harvesting this crop. However, combine harvesters are in use in advanced countries.

Maize: The traditional practice is to collect the matured cobs manually. Grain combines equipped with corn-head snapping unit are being used in developed countries.

Bengal gram: Harvesting by local sickle is the traditional practice. Improved serrated blade sickles are also in use. The performance of narrow pitch cutter bar with horizontal conveyor is better than other types of available reapers. Combines with floating cutter-bar are in use in advanced countries.

Pigeon pea: This crop is traditionally harvested at ground level by using a manual chopper or local sickle. No suitable machine for harvesting this crop is available in the country. Crop stems are being used by farmers for domestic use.

***Urad, Moong* & Cowpea:** These crops are traditionally harvested by using local sickle. Improved serrated blade sickles are also in use.

Groundnut: Digging of crop with country plough and blade hoe at proper soil moisture level and manual pulling and gathering of pods using hand hoe is common practice. Animal drawn and tractor operated diggers and digger windrowers are improved implements developed for groundnut harvesting. The blade harrow is widely used for digging of groundnut crop in Gujarat. TNAU, CIAE and CTAE, designs are some of the improved animal drawn groundnut diggers. Tractor operated groundnut diggers have wide blade, which cover 1.25 to 2 metre width and operate at 10 to 15 cm depth. PAU, ANGAU and GAU diggers are some of the designs developed.

Rapeseed and Mustard: The traditional practice is to harvest manually using sickles. In tall varieties, farmers cut the plants above ground level and leave long stubbles in field, which are subsequently ploughed in.

In some areas, where plants are used as fuel or thatch material, harvesting with serrated blade sickles close to ground level, is practiced by farmers.

Mechanical harvesting of rapeseed/mustard can be carried out by

i. Self propelled walk behind type vertical conveyor reaper,
ii. Tractor front or rear mounted pto operated reaper, and
iii. Combine harvester with some modification

Soybean: Harvesting by local sickle is the traditional practice followed by farmers. However, modified serrated blade sickles is recommended as plant stem is 8 to 12 mm thick. Methods used for mechanical harvesting of rapeseed and mustard can be used for soybean too.

Sunflower and Castor: The traditional practice is to manually harvest the flower heads of sunflower and castor plants. These are stacked and sun dried for threshing. Suitable machines are not available for harvesting of sunflower and castor crops.

The combine harvesters are used in advanced countries for harvesting of above crops using specially designed header. These are in use in advanced countries.

Safflower: The traditional practice is to manually harvest the crop using sickles. Because of thorny and spiny nature of crop, harvesting and handling of safflower plants is a problem. Use of hand gloves and covers on legs and arms is recommended during harvesting. Hay forks are used for gathering and stacking the plants in field or on trailers. Vertical conveyer reapers and combine harvesters can be used for safflower harvesting.

Sesamum and Linseed: Traditional practice is to harvest and gather the crop manually using sickles. Tractor rear and side mounted reaper can be used for harvesting the broadcast crop. Vertical conveyor reapers have been used for harvesting crop, raised in rows and at optimum moisture level, i.e. 15-20 per cent, to avoid shattering of pods.

Different type of harvesting tools/equipment

Serrated blade sickle

It has a serrated curved blade and a wooden handle. The handle of improved sickle has a bend at the rear for better grip and to avoid hand injury during operation. Serrated blade sickles cut the crop by principle of friction cutting like in saw blade. The crop is held in one hand and the sickle is pulled along an arc for cutting. Cutting of crop close to the ground is possible with modified handle. The labour requirement is 80-110 man-h/ha. It can be used effectively for harvesting of wheat, rice and grasses. There are several serrated sickles commercially available like, Naveen sickle, Punjab sickle and Vaibhav sickle.

Reapers

Reapers are used for harvesting of crops mostly at ground level. It consists of crop-row-divider, cutter bar assembly, feeding and conveying devices. Reapers are classified on the basis of conveying of crops as given below:

Vertical conveying reaper windrower: It consists of crop row divider, star wheel, cutter bar, and a pair of lugged canvas conveyor belts. These machines cut the crops and convey vertically to one end and windrow the crops on the ground uniformly. Collection of crop for making bundles is easy and it is done manually. Self propelled walking type, self propelled riding type and tractor mounted type reaper-windrowers are available. These types of reapers are suitable for crops like wheat and rice. The effective field capacities of such machines vary 0.20-0.40 ha/h.

Self Propelled Vertical Conveyor Reaper: The first prototype was developed under CIAE-IRRI Industrial Extension Project at Coimbatore for rice and further development for other crops was done at CIAE, Bhopal during 1988-91. It is an engine operated, walking type harvester suitable for harvesting and windrowing cereals & oilseed crops. The engine power is transmitted to cutterbar and conveyor belts through belt-pulleys. This implement costs Rs 40000/- and its cost of operation is Rs 665/ha compared to Rs 1400/ha by conventional method. The effective field capacity and field efficiency were 0.20-0.23 ha/h and 65%, respectively.

Self Propelled Rice Harvester: It is an engine operated walking type implement suitable for harvesting rice crop. It is provided with engine, clutch & gear box, narrow lugged wheels, crop row dividers, star wheels, crop conveyor belt and cutter bar. The engine provides power to wheels, cutter bar and conveyor belts. This machine was modified at ANGRAU, Hyderabad during 1995. It costs Rs 60000/- and its cost of operation is Rs 320/ha under dry land condition. The effective field capacity and field efficiency were 0.175 ha/h and 68.5%, respectively.

Power Tiller Operated Vertical Conveyor Reaper Windrower: It is a power tiller front mounted, walking type reaper windrower developed by suitably modifying IRRI self propelled reaper to suit commercially available power tiller. It is suitable for harvesting and windrowing of erect rice crop. This implement was developed by TNAU, Coimbatore during 1983-85. This attachment costs Rs 20000/- and its cost of operation is Rs 600/ha compared to Rs 1911/ha by conventional method. The

effective field capacity and labour requirement were 0.25 ha/h and 4 man-h/ha, respectively.

CIAE Tractor Front Mounted Vertical Conveying Reaper Windrower: It is a tractor front mounted reaper suitable for harvesting and windrowing of rice and wheat crops. The reaper consists of cutter bar, crop conveyor belts, crop dividers, and star wheels. Lifting and lowering is done by tractor hydraulic. This vertical conveyor reaper is run with power from tractor pto through a shaft beneath the tractor chassis. This implement was developed at CIAE, Bhopal during 1981-84. This attachment costs Rs 30000/- and its cost of operation is Rs 400/ha compared to Rs 700/ha by conventional method. The effective field capacity and field efficiency were 0.31 ha/h and 74%, respectively.

PAU Tractor Front Mounted Vertical Conveyor Reaper Windrower: It is a tractor front mounted reaper similar to CIAE machine. This machine was developed at PAU, Ludhiana during 1982-84. The machine cost is Rs 30,000/- with attachments and the cost of operation is Rs 400/ha compared to Rs 750/ha by conventional method. The effective field capacity and field efficiency were 0.3-0.38 ha/h and 55-70%, respectively.

Self Propelled Riding Type Reaper

A Self propelled riding type reaper developed by CIAE, Bhopal in collaboration with a Private Manufacturer. The front two wheels of the machine get drive from a 6.5 hp diesel engine through a gear box. The two rear wheels are for steering. The harvesting unit consisting of 1.6 m long cutter bar, crop row dividers and crop conveying system is mounted on hydraulically operated front hitch. The effective field capacity and machine losses were 0.26-0.29 ha/h and 0.472 (wheat) - 5.89% (soybean), respectively.

Horizontal conveying reapers

Such reapers are provided with crop dividers at the end, crop gathering reel, cutter bar and horizontal conveyor belt. They cut the crop, convey the crop horizontally to one end and drop it to the ground in head-tail fashion. Collection of crop for making bundles is difficult. These are tractor mounted and suitable for wheat, rice, soybean, and gram. Performance of reapers with narrow-pitch cutter bar is better for soybean and gram crops.

Bunch conveying reapers

This type of reapers are similar to horizontal conveying reapers except that the cut crop is collected on a platform and is released occasionally to the ground in the form of a bunch by actuating a hand lever. Here, collection of crops for making bundles is difficult. Bullock drawn and tractor operated models are available and they are suitable for harvesting wheat, rice and soybean crops.

Animal Drawn Reaper

The animal drawn reaper was developed during 1966 at Punjab Agricultural University, Ludhiana. It has a cutter bar, a gear box, crank and pitman drive. The pitman imparts reciprocating motion to the blade. The crop cut by the cutter bar falls behind on the platform and is removed by manual raking in bunches of approximately 10 kg weight. This is achieved by tilting the platform downward. The bunches are manually shifted to side to clear the passage for the next run of the machine. The output of machine ranges from 0.15 to 0.30 ha/hr. Two pairs of bullocks may be required to operate machine smoothly. Six to eight persons are required to collect the crop and for tying of the bundles.

Tractor Rear Mounted Reaper Windrower

It is a tractor rear mounted pto driven reaper for harvesting of crop and dropping it in field in bunches. The machine consists of standard cutterbar, crop board, reel and power transmission system. The rotary motion of pto shaft is converted into reciprocating mode by crank and pitman shaft arrangement. The cutterbar is 2.07 metre long. A bat type reel is used to push the crop towards cutter bar and help in dropping the cut crop on the platform behind the cutter bar. As soon as the harvested crop of 3 to 5 metre row length is gathered, the reel pushes the crop on the field, in bunches. The harvested crop is collected and bundled outside to clear the swath for subsequent movement of tractor. It is suitable for wheat, rice and soybean. Its cost is Rs 35,000/- and cost of operation is Rs 650/ha. The effective field capacity and field efficiency were 0.40 ha/h and 66%, respectively.

Reaper binders

The cutting unit of this type of reapers may be disc or cutter bar type. After cutting, the crop is conveyed vertically to the binding mechanism and released to the ground in the form of bundles. Self propelled walking type models are available but these are not popular due to high cost of twine. Reaper binders are suitable for rice and wheat.

Strippers

The tractor front mounted stripper collects matured grass seeds from the seed crops. It consists of a reel having helical rubber bats which beat the grass over a sweeping surface. The ripened seeds get detached and the seeds are collected in the seed box.

Self Propelled Flail-type Bush Cutter

It is an attachment to prime mover of self propelled paddy reaper for cutting bushy crops like parthenium. The cutting units consist of swinging chain with round cutters at the tips. This implement was developed by TNAU, Coimbatore during 1989-91. This implement costs Rs 35000/- with prime mover and its cost of operation is Rs 200/ha compared to Rs 450/ha by conventional method. The effective field capacity and cutting efficiency were 0.20 ha/h and 95%, respectively.

Tractor Front Mounted Grass Seed Collector

It is a tractor front mounted machine which has been designed to harvest matured grass seeds from the seed crop. It consists of a frame, seed sweeping assembly, height adjustment unit and seed collection box. The seed sweeping assembly comprises of a helical rubber bat reel and a curved iron sheet called sweeping surface. The reel is driven by tractor rear wheel. The helical rubber bats beat the grasses over the sweeping surface where the ripened seeds get detached and the seeds are collected in the seed box. This implement was developed at IGFRI, Jhansi. This implement costs Rs 7000/- and its cost of operation is Rs 200/ha compared to Rs 2000/- by manual method. The effective field capacity and field efficiency were 0.3 ha/h and 57%, respectively.

Diggers

The design of groundnut and potato diggers of animal drawn and tractor operated types are available. The digging units consist of V-shaped or straight blade and lifter rods are attached behind the share. These lifter rods are spaced to allow the clods and residual material to drop while operating the implement. The plant along with pods/tubers are collected manually.

TNAU Animal Drawn Groundnut Digger: It is an animal drawn implement suitable for harvesting groundnut and also potato. It is provided with a crescent shaped blade attached to a common square shank and fitted to a frame. It is provided with two steel wheels and a hand lever for depth control. This implement was developed at TNAU, Coimbatore during 1989-90. It costs Rs 3000/- and its cost of operation is Rs 300/ha. The field capacity and digging efficiency were 0.10 ha/h and 98.6%, respectively.

Udaipur Animal Drawn Groundnut Digger: It is an animal drawn single row implement suitable for digging out groundnut. It has a V-shaped ridger type share with lifter rods attached behind the share. These lifter rods are spaced to allow the clods and residual material to drop while operating the implement. The plant along with pods are then collected manually. It costs Rs 855/- and its cost of operation is Rs 425/ha. This implement was developed at CTAE, Udaipur during 1984-88. This implement has got wide acceptance among the groundnut growers due to its efficient operation. The field capacity and field efficiency were 0.16 ha/h and 61%, respectively.

Birsa Animal Drawn Potato Digger: This digger consists of a ridger shaped bottom with welded extension rods on the wings. These rods help in separation of soil and dirt from the potato tubers. It is suitable for digging potato tubers after removal of vines from the field. This implement was developed at BAU, Ranchi during 1979-83. It resulted in reduction of 11.3% losses compared to conventional method of digging with spade. It costs Rs 850/- and its cost of operation is Rs 475/ha compared to Rs 580/ha by conventional method. The field capacity and damage of potato were 0.030-0.035 ha/h and 3.8%, respectively.

PAU Animal Drawn Single Row Potato Digger: It is provided with a V-shaped blade with round bars at the rear. These rods help in separation of soil from potato tubers. It is suitable for digging and exposing tubers from one row. This implement was developed by PAU, Ludhiana during 1973-75. Its results in 3-4% increase in yield. This implement costs Rs 800/- and its cost of operation is Rs 1500/ha compared to Rs 2400/ha by conventional method. The effective field capacity and field efficiency were 0.12 ha/h and 80%, respectively.

Tractor Mounted Groundnut Digger Shaker Windrower: It is a tractor mounted unit consisting of digging blade and an elevator shaker suitable for digging groundnut vines below pod zone, and exposing them to sun for drying in the form of a windrow. It is also provided with depth wheels. The elevator shaker is operated by tractor pto through universal shaft, gear box and belt-pulleys. This machine was developed at PAU, Ludhiana during 1966-68. This implement costs Rs 18000/- and its cost of operation is Rs 600/ha compared to Rs 1000/ha by conventional method. The effective field capacity and field efficiency were 0.25 ha/h and 70-80%, respectively.

Tractor Mounted Groundnut Digger: It is a tractor mounted unit consisting of V-shaped blade and depth wheels, suitable for digging out groundnut vines after softening of soil through irrigation. This implement was developed at ANGRAU, Hyderabad during 1988-90. It costs Rs 10000/- and its cost of operation is Rs 620/ha. The effective field capacity and field efficiency were 0.266 ha/h and 74.8%, respectively.

Tractor Mounted 2-row Potato Digger: It is a tractor mounted equipment suitable for digging and exposing tubers from two rows. Two V-shaped blades with round bars at the rear are mounted on cultivator frame with provision for adjustment of row to row distance. The

lifter rods help in separation of soil and potato tubers. This implement was developed at PAU, Ludhiana. It resulted in 3-4% reduction in harvesting losses compared to conventional method. This implement costs Rs 5000/- and its cost of operation is Rs 1600/ha compared to Rs 2400/ha by conventional method. The effective field capacity and field efficiency were 0.3 ha/h and 70%, respectively.

Tractor Mounted Potato Digger Elevator: It is a tractor rear mounted single row unit consisting of digging blade, endless rod chain conveyor and gauge wheels. The elevator is driven by tractor pto. It is suitable for digging and exposing tubers. This implement was developed at PAU, Ludhiana. Its results in 4-5% reduction in harvesting losses compared to conventional method. This implement costs Rs 25000/- and its cost of operation is Rs 1200/ha compared to Rs 2400/ha by conventional method. The effective field capacity and field efficiency were 0.14 ha/h and 60-65%, respectively.

Combines

Various designs of combine harvester having 2 to 6 m long cutter bar are commercially available. The need of a small whole crop combine harvester is felt. The function of a combine harvester is to cut, thresh, winnow and clean grain/seed. It consists of header unit, threshing unit, separation unit, cleaning unit and grain collection unit. The function of the header is to cut and gather the crop and deliver it to the threshing cylinder. The reel pushes the straw back on to the platform while it is cut by the cutter bar. The crops are threshed between cylinder and concave due to impact and rubbing action. The threshed material is shaken and forced back by the straw rack so that the grain moves and falls through the openings in the rack onto the cleaning shoe while the straw is discharged at the rear. The cleaning mechanism consists of two sieves and a fan. The grain is conveyed with a conveyor and collected in a grain tank.

4.6 Threshing Equipment

Traditional threshing methods

Trampling of paddy under feet, beating shelves of rice or wheat crop on hard slant surface, beating crop with a flail, treading a layer of 15 to 20 cm thick harvested crop by a team of animals are traditional methods followed by farmers depending upon capacity, lot size and situation. Threshing by bullock treading is practised on large scale in the country but it is also time consuming and involves drudgery. Tractor in many places is now used in place of animals for treading. Introduction of animal drawn olpad thresher reduced the drudgery of the operator and gave comparatively higher output per unit time. In all above methods the threshed materials are subjected to winnowing either in natural wind or blast from winnowing fan for separation of grain from straw. Threshing wheat by traditional method involves drudgery and takes more time to obtain required quality of *bhusa*. Due to these, mechanical threshers are widely accepted by the farmers.

Pedal Operated Thresher

It consists of wire-loop type threshing cylinder operated by foot pedal. It is suitable for threshing rice. This machine is based on IRRI design and was adopted by IIT Kharagpur during 1984-90. It costs Rs 2100/- and its cost of operation is Rs 28/q. It was extensively evaluated and adopted by the farmers of West Bengal State for threshing rice. The output capacity, threshing efficiency and labour requirement were 44 kg/h, 98.8% and 5.0 man-h/q, respectively.

Phule Sunflower Thresher

It is a pedal operated hold on type sunflower thresher suitable for separating seeds from sunflower heads. It consists of a threshing wheel having spokes and a blower fan operated by foot pedal through chain and sprocket. Four holes are provided on the cover for holding sunflower heads to the threshing wheel by upto four persons. This implement was developed at MPKV, Pune, during 1987-90. It costs Rs 5700/- and its cost of operation is Rs 0.40/kg compared to Rs 0.60/kg with conventional method. The output capacity, threshing efficiency and labour requirement were 40 kg/h, 100% and 10 man-h/q, respectively.

TNAU Groundnut Decorticator

It is a manually operated oscillating type beater having cast iron shoes with triangular projections suitable for decorticating groundnut pods to separate kernels. Decortication is done by putting 4-5 kg pods into the hopper and swinging the lever forward and backward manually. This device was developed at TNAU, Coimbatore during 1975-77. It costs Rs 1000/- and its cost of operation is Rs 0.20/kg of pods. The decorticating efficiency, decorticating capacity and labour requirement were 98%, 100 kg/h and 1 man-h/q, respectively.

Comb Type Stripper

The stripper of 15 kg has a square frame with four legs and a metallic strip in the form of a comb is fixed on each side. Stripping of pods is accomplished by drawing a handful of crop vines across comb. Four labourers can work simultaneously around frame. Output capacity is 10 kg pods/man-h.

Drum Type Stripper

It consists of a hollow stripping drum formed by two end discs connected by five mild steel rods. The rods are covered with a thick rubber tubing. The drum is fixed horizontally on an angle iron frame. The root portion of plants is beaten over drum to separate pods. Pod output is 20 kg/man-h. The weight of stripper is 23 kg.

CIAE Groundnut-cum-Castor Decorticator

It is a manually operated oscillating type device having cast iron shoes with triangular projections for decortication of groundnut and castor pods to separate kernels. Separate concaves are provided for decorticating groundnut and castor. It is not provided with cleaning device. This device was developed at CIAE, Bhopal. It costs Rs 600/- and its cost of operation is Rs 0.56/kg. The equipment was evaluated and adopted by Pune centre. The shelling capacity, shelling efficiency and labour requirement were 68 kg/h, 98.8% and 1.60 man-h/q for groundnut. Similarly for castor, the decorticator gave shelling capacity 40 kg/h, shelling efficiency 93%. The labour requirement was 1.60 man-h/q for castor test trials.

Lac Sheller (Peg Type)

The hand operated sheller is provided with two discs mounted on an axles. One disc is kept stationary and the other disc having pegs fixed on the inner face is movable. It is suitable for removing resine from all type of lac sticks. This device was developed at BAU, Ranchi during 1986-89. It costs Rs 500/- and its cost of operation is Rs 35/q. A comparative study of peg type, blade type lac shellers and local dabia indicated best performance of peg type lac sheller. The scrapping efficiency, output capacity, labour requirement and resin losses were 98.8%, 4.78 kg/h, 21 man-h/q and 6.26%, respectively.

Treadle Peg-Drum Threshers

Treadle operated drum threshers are widely available and are used primarily for rice but also for other crops. The threshing drum is covered in pegs, spikes or wire loops and is supported, in bearings and on a horizontal axis, by a free-standing framework. Sheaves or bundles of the crop are held against the pegs as the drum is rotated by a foot-operated treadle mechanism. Output capacity varies 70-100 kg/h.

Hand and Power Maize Sheller

This free standing sheller is a single hole machine, suitable for feed or seed maize. It is of all steel construction with a built in cleaning fan and a ratchet type hand crank. A belt pulley can be supplied for use with an external power drive; a 0.75 kW motor is recommended for optimum performance.

Tubular Maize Sheller

The tubular maize sheller is made from MS Pipe on which 4 tapered fins are rivetted. For operation the sheller is held in one hand and cob in the other. After inserting the cob in the sheller both are rotated in the opposite direction. The action separates the grains from the cob.

Maize Sheller (Manually Operated)

The manually operated maize shellers are available in different shapes and dimensions. The unit consists of 3 discs having projections, either in the forms of pegs or helical gear teeth forming a conical passage through which a cob moves during shelling. The grains are removed by rubbing action.

CIAE Manual Groundnut Decorticator

A light weight and low cost groundnut decorticator. The design is based on principle of separation by rubbing action. Size and weight of machine and therefore, cost were reduced to suit small farmers. Decorticator consists of an oscillating sector with three cast iron shoes and a perforated screen. Decorticated pods fall through screen and kernels are separated manually. Clearance between shoe and screen is adjustable. The screen can be replaced to suit different size of kernels. The breakage of kernels was 1 to 3 per cent and decortication efficiency was 98 to 99 per cent with seed germination of 93 to 96 per cent. This machine can be used for castor shelling also by changing the screen and adjusting the clearance.

Animal-powered threshing

Animal trampling remains the standard method of threshing grain crops in many parts of the world. While slow, and often resulting in impurities and damage to the grain, it makes threshing less arduous and can be cheap if oxen or buffaloes are readily available. Productivity, at 30-50 person-hours per tonne, is about the same as for manual methods. The animals may pull a heavy object or implement behind them, such as a stone roller, sledge or disc harrows, to increase the rate of work.

Olpad Thresher

It is a bullock trailed equipment used for threshing. The notched discs are arranged on three gangs mounted on wooden bushings. The top cover is of wood and has a provision for the operator to sit. It simply chops the material and cleaning has to be done separately.

Tractor treading

One method of threshing which has become widespread for rice, wheat, barley and sorghum is driving a tractor round and round on the crop spread over the threshing floor. If tyre pressure is kept low to minimize grain damage, excellent results are possible, and no added investment in machinery is required. In some areas, near roads, threshing is carried out by spreading the crop on the road and allowing passing traffic to do the threshing. Whilst convenient and cheap, this method relies on the existence of sufficient traffic, and normally leads to dirty and damaged grain. There are also the obvious dangers associated with road traffic.

Mechanical Threshing

Drummy type, hammer mill type and syndicator type threshers are suitable for threshing wheat crops only and they can produce fine quality of 'bhusa', rasp-bar type, wire-loop type and axial flow type threshers are suitable for paddy and they do not make fine straw. Rasp-bar type threshers can be used for threshing other crops but farmers do not prefer, this machine because it does not make fine 'bhusa'; and cost is very high due to its bulky size. Though the hammer mill type threshers can produce fine quality 'bhusa' its use is decreasing day by day due to high power requirement. Portable wire loop type paddle operated threshers are widely used by farmers in paddy growing areas. Spike tooth type thresher can thresh wheat crop and can produce fine quality of 'bhusa'. This thresher can be used for threshing other crops if the blower is mounted on a separate shaft so that the cylinder speed can be varied independently. Majority of farmers prefer spike tooth type threshers because of their simplicity in design, low cost and their ability to make fine 'bhusa'.

Beans are more susceptible to damage due to impact and the variety of grain has much influence on grain loss during threshing. Damage of large beans is more than smaller beans at same impact velocity and orientation. The amount of damage increases rapidly below ambient temperature of 10ºC. So, handling of dry beans at low temperature should be avoided. Moisture content of grains is a major factor in controlling grain damage. Decrease in moisture content greatly increases the brittleness of grains. Unthreshed grains are more at high pod moisture content whereas grain damage decreases with increase in grain moisture content. More threshing effort is required for threshing high moisture crop which causes more internal grain damage and thus affects viability. Soybean moisture content between 8 and 12 per cent (wb) is optimum for low mechanical damage.

The base angle of feeding chute affects the feed rate. It should be tangential to cylinder drum for maximum feed rate and minimum physical effort. The threshing cylinder requires power as high as 60-75 per cent of total power input. Hammer mill type threshers bruise the straw very fine but the specific energy requirement is the highest among all types of threshers. Rasp-bar cylinder design can thresh most of the crop except groundnut but these machines do not provide bruised straw. The concept of a straw bruising attachment to rasp-bar thresher is not economically viable. Spike tooth type threshers having independent drive to cylinder and blower can thresh major crops effectively but the cylinder speed is to be adjusted according to the crop conditions. Larger cylinder diameter has lower power requirements than smaller ones at higher feed rates. Higher rib spacing in upper concave increases unthreshed grain but reduces power consumption. The performance with flat spikes is better than round and square spikes. Larger spike spacing in a row reduces power consumption and broken grains whereas power increases and broken grains reduce with the increase in number of rows of spikes. However, uniformity of spike distribution over cylinder periphery is more important for better performance. Power consumption and grain damage increases with the increase in spike length and thickness. The grain damage decreases and unthreshed grains increase with the increase in concave gap. Higher concave clearance reduces power consumption whereas straw bruising is more at low concave clearance.

The effect of cylinder speed on threshing performance is highly significant at all machine settings. Power consumption and broken grains increase and unthreshed grains decrease with the increase in cylinder speed. Though the unthreshed grain losses decrease but the total grain losses increase with the increase in cylinder speed. Quality of bhusa is better at higher cylinder speeds, low concave clearance and concave gap. Higher feed rate increases power consumption, reduces broken grains and unthreshed losses and to some extent helps in straw bruising. In general, feed input capacity is considerably affected by machine settings. Lower rib spacing in upper concave, concave bar spacing, concave clearance and non-uniform spike distribution over cylinder periphery reduces the capacity. Low feed rate, high labour rate, high energy consumption, high percentage of broken grain and poor quality of straw all contribute to high qualitative cost of operation.

Hold-on threshers

In areas where whole, undamaged straw is valued, some machines thresh rice by stripping grain from the panicles without damaging the straw. The simplest of these are mechanized versions of the treadle thresher in

which the drum is rotated by a 1-3hp engine. Double drum threshers contain two-wire looped cylinders. Most threshing is done in the slower, first cylinder which strips the grain on the panicles from the straw. The second, faster, cylinder is designed to thresh the broken panicles. Double drum threshers are used for wheat and sorghum as well as paddy. Some have a self-feeding mechanism, which continuously feeds the bundles into the machine, thus reducing the labour requirement. Hold-on threshers require that the crop be formed up into even bundles, and this can be laborious if the crop was badly lodged or if even bundles were not harvested in the first place. Their main advantage is that they solve the major problem of all other threshers-how to separate the grain from the straw.

Through flow threshers

The entire harvested crop is fed into this type of thresher, thus increasing the bulk which has to pass through the machine. Faster feeding is possible but higher power requirements are inevitable. There are two main types:

- tangential flow machines in which the crop passes directly through the threshing cylinder, around the circumference of the drum;
- axial flow machines which have spirally positioned fins on the upper concave so that material fed in at one end of the drum passes along the drum as it is rotated, and is ejected at the other end.

Flow-through Rice Thresher

It is a portable, straight flow type thresher having rasp bar cylinder, special concave, double sieves, blower and three straw walkers suitable for threshing green and moist paddy crop. This implement is commercially available. The concave is modified and the thresher was adopted by KAU, Tavanur centre during 1994-95. It costs Rs 37000/- and its cost of operation is Rs 16/q. The output capacity was 1620 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 99.0%, 97.3% and 0.3 man-h/q, respectively.

Maize Sheller/Thresher

This is a static sheller, supported on a pair of two legged metal stands. It is fitted with a drive-belt pulley, to be powered by any type of motor or engine.

Powered Maize Shellers

This is a powered sheller with a winnowing fan. The cobs are discharged at the top of the machine and the cleaned grain through a bottom chute. Four models are available, ranging from 1.5 to 4 kW in power.

CIAE Multicrop Thresher

This thresher incorporates the desirable features of wheat thresher and IRRI axial flow thresher for paddy. It consists of a feed tray, spike tooth cylinder, straw thrower, blower and cleaning sieves. Three concave grates are provided for threshing different crops. A semi-hexagonal top cover with spiral louvers is provided for threshing paddy. It is used when fine chaff is not required. Spiral louvers on top cover move the material axially from feed end to discharge end. Long straw is ejected from machine by thrower paddles, provided at discharge outlet. For threshing other crops, top cover is replaced by a semi-circular cover and a semi-circular disc is inserted in between cylinder and straw thrower, to achieve better threshing. It is suitable for threshing wheat, maize, sorghum, rice, gram, pigeon pea, soybean, mustard, sunflower, safflower and linseed crops. This implement was developed at CIAE, Bhopal during 1981-85. It costs Rs 20000/- and its cost of operation is Rs 25/q. Output capacity was 200-1635 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 98-99%, 93-99% and 0.24-1.00 man-h/q, respectively.

ANGRAU Multicrop Thresher

It consists of rasp bar cylinder, blower and a set of reciprocating sieves. It is suitable for threshing crops like rice, wheat, sorghum, pearl millet and safflower. This implement was developed at ANGRAU, Hyderabad during 1984-85. It costs Rs 35000/-(without prime mover) and its cost of operation is Rs 9/q compared to Rs 20/q by manual beating. The output capacity, cleaning efficiency and labour requirement were 35 kg/h, 98% and 9 man-h/q for safflower.

Single Ear Head Thresher

It is a batch type thresher suitable for threshing samples of wheat, gram, lentil, soyabean, rice in the form of single ear or bunch of ears. The machine consists of feed inlet, beater type threshing cylinder, aspirator column, light seed gathering chamber and aspirator blower. This is useful for field experiments. It is 2-3 times faster over manual threshing. The unit is also helpful for cleaning of grain sample during threshing experiment. This unit was developed at CIAE, Bhopal, during 1988-89. It costs Rs 15000/- with motor. The crop sample of 30 to 60 g in batch for 7 to 10 sec were fed. The seed recovery, threshing efficiency and cleaning efficiency were 99-100%, 99-100% and 95-100%, respectively.

Axial Flow All Crop Thresher

This all-steel, throw-in type thresher requires a 3.7 kW external power source. It is a mobile unit, mounted

on four cast iron wheels, and is suitable for threshing wheat, rice and sorghum. Minor adjustments and some change of parts enable it to handle a range of other crops. Oscillating screens and two winnowing fans are fitted for cleaning the threshed grain.

Standard Axial-Flow Thresher

The standard axial flow thresher has a power requirement of 7.5 kW. It is suitable for a variety of crops and can be converted for use as a maize sheller. The output capacity ranges from 800 kg/hour for rice to 2500 kg/h for sorghum.

Semi-Axial Flow Multicrop Thresher

It consists of spike-tooth cylinder, aspirator blower and sieve shaker. It works on axial flow principle but crop flow is restricted by inserting a semi-circular plate between cylinder and thrower. It is suitable for threshing wheat, soyabean, sorghum, maize, pigeonpea, rice, sunflower and safflower crops. This machine was developed at CIAE, Bhopal during 1984-87. It costs Rs 26,000/- and its cost of operation is Rs 26/q. The output capacity, threshing efficiency, cleaning efficiency and labour requirement were 350-1350 kg/h, 99%, 99% and 0.30-1.00 man-h/q, respectively.

PAU Axial Flow Rice Thresher

The thresher consists of a spike tooth cylinder, straw thrower, concave, sieve shaker and aspirator blowers. The thresher works on axial flow principle. It is suitable for threshing rice. This equipment was developed at PAU, Ludhiana, during 1986-87. It costs Rs 24000/- and its cost of operation is Rs 22/q. The output capacity was 1300 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 100%, 99% and 4 man-h/q, respectively.

Automatic Feed Wheat Thresher

This is a hopper fed, mobile thresher of 1250 kg weight, with a bagging-off spout for the threshed grain. It is suitable for a range of grains, including wheat and sorghum. The thresher can be powered by a 15 kW electric motor or through the power take-off of a 25-35 kW tractor. The grain cleaning efficiency was 99%. The threshing drum speeds 750 rev/min for wheat and 650-700 rev/min for sorghum/pearl millet were observed. The output capacity of the thresher varies 800-1000 kg/h.

Multi Purpose Rotary Thresher: A range of heavy-duty drum threshers which can be adjusted to handle a variety of crops including grains, pulses, grams and sunflower seeds. There are numerous optional fittings, including fans and cleaners and the threshing drum can be fitted with different types of pegs or teeth as required. The thresher can be powered by a motor, engine or tractor; a pulley belt or tractor power take-off drive option is offered. All units are mounted on wheeled frames and have safety guards fitted on the intake chutes.

Madho Wheat Thresher: This thresher can be powered by either a 3.7 kW electric motor or a 4-6 kW diesel engine or alternatively from a tractor engine. It is a portable unit, mounted on four cast iron wheels and it has a winnower and a bagging system for the threshed grain.

SBI Grain Thresher: This mobile thresher is suitable for most grain types, including rice, wheat, maize, sunflower, sorghum and millet. The threshing unit primarily comprises of a threshing drum, winnower and straw walkers. This assembly is mounted on a two-wheeled trailer with pneumatic tyres. A drawbar with a yoke is provided for transportation by a pair of bullocks or the thresher can be drawn by a tractor. An electric motor or small engine is required to power the machine.

Portable Rice Thresher

The thresher based on IRRI, Philippines, design was adopted by NEH, Barapani during 1980-83. It consists of a peg tooth cylinder with straw throwing paddles on one end enclosed by a cover with spiral lowers, wire mesh concave at the bottom and a blower. It can be shifted from one field to another by two persons. It is suitable for threshing rice. The machine costs Rs 10000/- and its cost of operation is Rs 18/q. The output capacity, threshing efficiency, cleaning efficiency and labour requirement were 100 kg/h, 98%, 90% and 2 man-h/q, respectively.

Multicrop Plot Thresher

It consists of a spike tooth cylinder, concave, aspirator blower and sieve shaker. It is suitable for threshing samples of wheat, gram, sorghum, soybean, safflower, pigeonpea and pearlmillet. It is useful for precision threshing of samples in field experiments. The handling capacity of this equipment is 3-4 times faster over manual method of threshing crop samples. This machine was developed at CIAE, Bhopal during 1984-87. It costs Rs 16000/- with motor and its cost of operation is Rs 66-110/q. The grain recovery, threshing efficiency and cleaning efficiency were 98%, 98-99% and 88-97%, respectively. Crop samples in 8-10kg batch were fed/h/person.

CIAE High Capacity Multicrop Thresher

It consists of a spike-tooth cylinder, three aspirator blowers, cleaning sieves and automatic feeding and bagging systems. The thresher is provided with

accessories such as extra pulleys, concaves and sieves for threshing different crops. It is suitable for threshing wheat, maize, sorghum, gram, pigeon pea, soybean and sunflower crops. This machine was developed at CIAE, Bhopal during 1989-94. It costs Rs 55000/- and its cost of operation is Rs 5/q. Output capacity was 533-2890 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 99-100%, 93-99% and 0.2-0.6 man-h/q, respectively.

Groundnut Pod Stripper

It consists of a wire loop type cylinder powered with 2 hp electric motor. The stripping is done by holding the pod portion of a bunch manually over spiked cylinder. Three persons can work at a time. It is suitable for stripping of groundnut pod from freshly harvested crop. It resulted in 10% reduction in losses compared to conventional method of manual stripping. This machine was developed at ANGRAU, Hyderabad, during 1990-93. It costs Rs 12000/- (with 2 HP electric motor) and its cost of operation is Rs 43/q compared to Rs 65/q with manual stripping. The output capacity, stripping efficiency, cleaning efficiency and labour requirement were 120 kg/h, 100%, 98% and 3 man-h/q, respectively.

PAU Axial Flow Groundnut Thresher

It consists of spike tooth cylinder, straw thrower, concave sieve shaker and a blower. The top cover is provided with helical louvers and works on axial flow principle. It is suitable for threshing groundnut. This machine was developed at PAU, Ludhiana, during 1986-90. It costs Rs 24000/- and its cost of operation is Rs 50/q. The output capacity, threshing efficiency, cleaning efficiency and labour requirement were 170-220 kg/h, 99.0-99.5%, 92-98% and 1.5 man-h/q, respectively.

Pantnagar Axial-flow Multicrop Thresher

It is a modified version of IRRI axial flow paddy thresher. It consists of peg type cylinder, aspirator and sieve shaker. The top cover is provided with louvers for axial movement of crop while threshing. The louvers are covered with a ribbed casing. This machine was developed at GBPUAT, Pantnagar during 1981-84. It costs Rs 25000/- and its cost of operation is Rs 10/q for rice and Rs 35/q for wheat. The output capacity was 425 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 99-99.8%, 98.0-99.2% and 0.25-1.00 man-h/q, respectively.

TNAU Groundnut Thresher

It consists of a cylinder, concave, two sieves, a blower and threshing cylinder provided with curved edge pegs. It is suitable for separation of groundnut pods from freshly harvested crop. This machine was developed at TNAU, Coimbatore, during 1988-90. It costs Rs 25000/- and its cost of operation is Rs 40/q. The output capacity, threshing efficiency, cleaning efficiency and labour requirement were 146-168 kg/h, 99%, 93-96% and 2 man-h/q, respectively.

CIAE Groundnut Stripper

The stripper consists of feeding tray, spike tooth threshing cylinder, concave grate, stripping bars, straw thrower, blower and collecting pan. Groundnut crop is fed through feed inlet and pods are stripped from plants by action of threshing cylinder and stripping bars. The louvers on cylinder top cover retain the crop for long duration, in threshing cylinder, and help in separation of pods from plant material. While threshing moist or freshly harvested crop, unbroken plant stems/vines are axially moved, with the help of louvres, and are ejected through thrower outlet. This helps in achieving high crop feed rate and thus high pod output capacity. Pods alongwith some light chaff, vines, etc. fall through concave grate and are subjected to air stream produced by blower. The light material gets blown off and pods fall in collecting pan.

For threshing JL-24 variety of crop concave of 50x70 mm opening and threshing cylinder speed of 11.75 m/s (340 rpm) gave good results. The output capacity was 216 to 320 kg pods/h at pod moisture content varying from 48 to 73 per cent (db). It costs Rs 15,000/- and its cost of operation is Rs 25/q. The stripping efficiency and labour requirement were 99.6% and 2 man-h/q, respectively.

ANGRAU Sunflower Thresher

It consists of a peg tooth cylinder, feed hopper, sieve shaker and a blower. It is suitable for threshing sunflower heads. This machine was developed at ANGRAU, Hyderabad, during 1993-95. It costs Rs 15000/- (without prime mover) and cost of operation is Rs 19/q. The output capacity was 200 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 99%, 98% and 1.5 man-h/q, respectively.

PAU Axial Flow Sunflower Thresher

The thresher consists of a feed hopper, bar type cylinder, thrower, double sieves, concave and a blower. It works on axial flow principle and is suitable for threshing sunflower heads. This machine was developed at PAU, Ludhiana, during 1988-90. It costs Rs 20000/- and its cost of operation is Rs 25/q. The output capacity was 600-900 kg/h. The threshing efficiency, cleaning efficiency and labour requirement were 100%, 90% and 0.6 man-h/q, respectively.

ANGRAU Power Operated Castor Thresher

It consists of a wooden roller, feed hopper, blower and sieves. It is suitable for shelling and winnowing of dried castor pods. The sheller was developed at ANGRAU, Hyderabad during 1992-94. It costs Rs 16000/- (without motor) and its cost of operation is Rs 22/q. The output capacity, shelling efficiency and labour requirement were 200 kg/h, 76% and 1.2 man-h/q, respectively.

TNAU Power Operated Castor Sheller

It consists of feeding hopper, rubber coated disc type shelling unit and a blower. Castor is fed to the shelling unit through feed hopper. It is suitable for shelling and winnowing of dried castor pods. The unit can be operated manually or with a 0.5 hp electric motor. This machine was developed at TNAU, Coimbatore, during 1986-87. It costs Rs 7000/- and its cost of operation is Rs 24/q. The shelling capacity, shelling efficiency, cleaning efficiency and labour requirement were 163 kg/h, 97%, 91% and 0.6 man-h/q, respectively.

Sunflower Seed Sheller

It consists of a rotor, elevator, blower and two sieves. The rotor consists of two wooden discs with hard rubber of which one is stationary and other one is revolving. The seeds fed into the hopper get graded initially and shelled at rotor assembly. It is used for shelling of sunflower seeds. This machine was developed at TNAU, Coimbatore. Use of this machine results in generation of 23 per cent additional income through superior quality oil and oil cake. It costs Rs 15000/- and its cost of operation is Rs 20/q. The output capacity was 100 kg/h. The shelling efficiency and labour requirement were 90% and 1.4 man-h/q, respectively.

4.7 Horticultural Equipment

The expansion of cultivation of horticultural crops and the increase in their production require the backing of appropriate research. Such research is being taken up at the Indian Institute of Horticultural Research, Bangalore and its sub-station at Lucknow, now CISH, Central Plantation Crops Research Institute, Kasaragod, Central Food Technological Research Institute, Mysore as well as the various agricultural universities in the country. Packages of practices from preparatory tillage to harvesting have been developed for different regions for fruit crops like banana and mango, and for plantation crops like coconut, arecanut, cacao etc. at these Institutes. Similar tillage and irrigation studies are needed for other important orchard and plantation crops. Some tools and implements required for field operations in the orchards and plantations and techniques for processing their products have also been evolved by the above Institutions.

The need for special types of power units or cultivation equipment arises when it is necessary to work between fruit trees in orchards, where the tree crop already exists and the equipment has to conform to it. Narrow rows and low branching of fruit trees sometimes necessitate the use of small power tillers and small implements. One such equipment developed at the TNAU, Coimbatore is a trencher operated by a power tiller for use in cashew plantations where the trees have low lying branches. The implement can work on the periphery of the canopy of such trees to form circular trenches around them for applying manures and for irrigation.

Another type of special purpose implement is needed for rather wider rows, where it is desired to work as close to one side as possible. For this type of operation offset ploughs which will work right up to the outside edge of a power tiller wheel-mark are available. Rotary type of lawn mower attachment for a power tiller is another development made at TNAU, Coimbatore. Fruit picking devices such as a mango nipper and cocoa pod harvester have been developed at KKV, Dapoli and CPCRI, Kasaragod respectively. The latter has also developed a coconut bunch support to be fixed on the trunk of the coconut tree to prevent the buckling of coconut bunches, and a coconut dehusking machine operated manually for reducing the drudgery and fatigue of traditional dehusking operation. A simple weld mesh attachment welded to a pair of shears made at Dr PDKV, Akola helps in cutting and gathering leafy vegetables and greens (Amaranthus polygamus)

Pruning of plants, chopping branches and picking fruits are all labour intensive operations which involve time and drudgery. Size/weight grading of fruits and washing vegetables are a few other operations of similar nature. In some areas in India where people think that labour is available cheaply and in plenty, it is a paradox that farmers sometimes allow the ripe tomatoes, chillies, potatoes etc. to rot in the field for want of adequate labour at reasonable cost to harvest the crop. Even if we cannot afford to have sophisticated mechanical harvesters used in the highly mechanized countries, a time has come to take up research studies on developing simple labour saving tools and implements needed for these operations, particularly those suitable for selective harvesting. Here, as in all other operations, the approach should be not to displace labour altogether, but to develop equipment which will increase the output of each farm worker and minimise his drudgery and save time and cost to the farmer. Research on improving the shelf life of fresh fruits and vegetables, on evolving

simple methods and tools for extraction of papain from papaya fruits is also needed.

5. MECHANIZATION TRENDS AND FACTORS AFFECTING MECHANIZATION

5.1 Mechanization indicators

Mechanization is viewed as facilitator to (i) ensure timely field operations to increase productivity, reduce crop losses and improve quality of agro-produce, (ii) increase productivity of land and other inputs more effectively, and (iii) increase labour productivity using labour saving and drudgery reducing devices. The mechanization technology is thus, dynamic and location specific. It is subject to change with techno-economic advancement and socio-cultural upliftment. Different stages of agricultural development and level of mechanization are (i) manual, (ii) using manual tools, (iii) animal traction and initial motorization using combination of animal and mechanical power, (iv) motorization stage using principally mechanical power, and (v) finally automation stage.

The availability of farm power per unit area (kW/ha) has been considered as one of the parameters for expressing level of mechanization. One of the methods of defining mechanization is through an index which represents ratio of mechanical power and sum of animate and mechanical power. Mechanical power input is also an indicator of progressive attitude of the farmer for modernization of agriculture.

5.2 State-wise Mechanization Scenario

The level of mechanization in the country has shown an increasing progressive trend, however there has been contrasting disparity in its spread. Whereas, the Northern States such as Punjab, Haryana, Uttar Pradesh (particularly Western and Tarai belt) have achieved a faster growth in mechanization over various Plans, the pace of mechanization in the other states is far from satisfactory. A case in point is, during 1997-98, out of the total sale of 2.51 lakh tractors, 83% of them were sold in the states of Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. Of these units, half were sold in the first three states. However, the sale of other implements and machines like combine harvesters, threshers and other power operated equipment have been increasing almost throughout the country. The sale of power tillers in the last three years have shown an increasing trend in a few states, however, it is yet to attain popularity of the level it enjoys in other rice growing countries of the world. The pace of mechanization in North-Eastern States has not been satisfactory due to constraints such as hilly topography, socio-economic conditions, high cost of transport, lack of institutional financing and lack of farm machinery manufacturing industries. The mechanization in Western and Southern states of the country viz., Gujarat, Maharashtra, Rajasthan and certain areas of Tamil Nadu, Andhra Pradesh etc., has increased with the increase in area under irrigation and also with the growing awareness among farmers.

The farmers are using modern agricultural technology, such as sprinkler, drip, micro-irrigation and green house to increase the productivity and quality of produce. All these technological inputs have helped the farmers to mechanize their agriculture. The advantages of adoption of modern technology for modernization of agriculture are given in (Table 5.1 and Table 5.2).

Table 5.1. Economic advantage of mechanization

1	Increase in productivity upto,%	12-34
2	Seed cum fertilizer drill facilitates:	
	Saving in seeds,%	20
	Saving in fertilizer,%	15-20
3	Enhancement in cropping intensity,%	5-22
4	Increase in gross income and return of the farmers,%	29-49

Note: *Report of the Sub-Group on Agricultural Implements and Machinery for Formulation of 9th Five Year Plan, Government of India.*

Table 5.2. Level of mechanization (1996)

Sl. No.	Operation	Percentage
1	Tillage	40.2
	Tractor	15.6
	Animal	24.7
2	Sowing with seed drill/seed-ferti-drill	28.9
	Tractor	8.3
	Animal	20.6
3	Irrigation	37
4	Thresher wheat	47.8
	Paddy & others	4.4
5	Harvesting:	
	Reaper	0.56
	Combine	0.37
6	Plant protection	34.2

Note: Report of the sub-group on Agricultural Implements and Machinery for Formulation of 9th Five Year.

The pace of mechanization can further be accelerated by diversified use of tractors and making available matching and new equipment for specialized operations for vegetable, floriculture, sugarcane, cotton cultivation, etc. The increase in productivity was 12-34%. The seed cum fertilizer drill facilitates 20%, saving in seeds 20% and 15-20% saving in fertilizer. The enhancement in cropping intensity, gross income and return of the farmers were 5-22% and 29-49%, respectively.

5.3 Adaptation of machinery by size of holdings

It is generally believed that only farmers having large acreage have adopted mechanization inputs. It is observed that bullock and power operated machines equally have been adopted by the farmers. The analysis is based on data from Input Survey 1981-82, 1986-87 and 1992 of Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. It revealed that even tractors have been adapted by small and marginal farmers.

5.4 Indices of Mechanization

Mechanization is viewed as package of technology to (i) ensure timely field operations to increase productivity, reduce crop losses and improve quality of agro-produce (ii) increase productivity of land and other inputs more effectively and (iii) increase labour productivity using labour saving and drudgery reducing devices. The mechanization technology is thus, dynamic and location specific. It is subject to change with techno-economic advancement and socio-cultural upliftment. The measure of mechanization here is defined as total available power/energy input per hectare and ratio of mechanical power/energy over total farm power/energy (human, animal and mechanical).

5.4.1 Farm power per unit area

One of the ways of viewing mechanization is by the availability of unit farm power in agriculture. It is observed that the unit farm power available from all sources (animate and mechanical power) increased from 0.18 to 0.74 kW/ha (on the basis of gross cropped area). The draught animal power expressed per unit gross cropped area basis reduced from 0.14 to 0.09 kW/ha, but mechanical power increased from 0.005 to 0.59 kW/ha.

5.4.2 Ratio of mechanical power over total farm power

The mechanization indicator has also been expressed as ratio of mechanical power over total farm power. The ratio of mechanical power to total farm power, has increased from 3.6 to 80% during 1950-51 to 1995-96. In 1995-96, 80% farm power comprised of electro-mechanical power sources in crop production. The share of irrigation was more than 64%.

It is estimated that 39.53 MkW tractive farm power was available from mechanical sources and 16.80 MkW from draught animals in 1995-96. The use of mechanical tractive power in crop production increased from a meagre 0.82 to 28.9% of the total farm power during 1950-51 to 1995-96 but the tractive power is still very low.

5.4.3 Energy ratio as mechanization indicator

In many developing countries, a wide gap exists between infrastructure created and actual utilization. The potential of the country to meet the petroleum demand through local resources is limited to the extent of 40%. The remaining is met through importation. Actual estimate of use of HSD in agriculture was difficult to make but on an average about 9-10% of the total diesel is estimated to be used in agricultural sector, based on the rural outlet created for distribution of POL. The farmers have access to urban POL outlet as well. The availability of electricity in the villages is also limited. During 1970-71 only 18.5% of the total villages were electrified which increased to 85.3% by 1993-94. The growth in electrification increased by 6.9% annually. The energy generation increased by 8% annually but consumption in rural areas increased by 8.6%. In many states electricity is available only for limited duration during the day.

Growth of energy used per hectare in crop production and human energy use increased from 1331 to 1434 MJ/ha during 1970-71 to 1992-93. The animal energy use however, decreased from 1606 to 1059 MJ/ha. It reduced by 1.87% per annum. Maximum growth occurred in the use of diesel and electrical energy. The total energy for crop production increased from 3283 to 6872 MJ/ha growth of (3.4% per annum). The share of mechanical energy over total energy used in crop production has increased from 10.2% to 69%.

5.5 Region-wise variation of farm machinery development

The region-wise distribution of farm implements and machinery is shown in Table 5.3. Development of manually operated implements has been dominant in the eastern region. Maximum number (42) of animal drawn implements have been developed in the central region comprising of Madhya Pradesh and Uttar Pradesh. In the northern region, there has been very low emphasis on the development of power operated (stationary as well as walk behind) implements, while it was high for tractor mounted implements. Thirty-seven tractor mounted implements have been developed in northern region alone as compared to a total of 44 in the remaining parts of the country. The emphasis on tractor mounted implements in northern region may be attributed to farm holdings being large, higher purchasing power of farmers and shortage of labour during peak seasons. Increase in cropping intensity through assured irrigation has also contributed to increased adoption of tractor mounted equipment with higher capacity.

Table 5.3. Region-wise Development of Farm Equipment

Type of machine	Eastern	Western	Northern	Southern	Central	Total
Manually operated	24	15	17	18	19	93
Animal drawn	21	27	31	30	46	155
Power operated stationery	6	3	11	20	10	50
Power operated walk behind	4	-	4	13	6	27
Tractor mounted/riding type	6	3	36	13	18	76
Total	61	48	99	94	99	401

5.6 Reliability of agricultural machinery and after sales service

Manufacturing of agricultural machinery in India is reserved for small scale sector. These units have limited fabrication facility and usually produce machines on contract basis with least regards to quality and standards. Availability of quality parts is constrained and after sales services is limited. The investment in machinery becomes uneconomical due to unreliable functioning of the machine.

Limited demand

Limited yearly demand and lower use of mechanical power sources in a year results in uneconomical investment in machinery. Adequate fuel and electricity to rural sector will enhance yearly use of mechanical farm power and thus reduce the cost of operation.

Absence of long term mechanization policy

There is no long term farm mechanization policy in the country like in Japan or South Korea. Farm machinery promotion programmes are planned on yearly basis subject to the availability of credit and financial incentives. As a result, long term planning for manufacture of agricultural machinery by the manufacturers is not feasible and thus lower results investments being made in plant and machinery.

6. EFFORTS REQUIRED TO BOOST FARM MECHANIZATION

India is a large country with wide agro-ecological diversity having predominance of rainfed agriculture; gross cropped irrigated agriculture is limited to 41% only. Farm holdings are small due to high population density and land fragmentation will continue due to 'Laws of Inheritance' and 'Hindu Succession Act'. Majority of the farmers have limited surplus money to modernize farms or invest in improved inputs. Draught animals and agricultural workers may remain the chief source of farm power for soil manipulation and for crop handling. Mechanical power for tillage, irrigation, harvesting and threshing will be preferred, including custom hiring by those farmers who cannot afford to own machines. As a result of the GATT agreement, prospects of agro-export are likely to increase and product quality standards stipulated under WTO may compel many farmers to adopt modern agricultural production technology. The future agricultural mechanization technology package may have to:

- be eco-friendly utilizing land, water and bio-resource catering to the varied group of farm holders
- facilitate farming operations which are arduous and hazardous.
- increase productivity and conserve resources through effective utilization of chemical, biological and mechanical inputs.
- facilitate contract farming/custom hiring to modernize agriculture and to ensure timely field operations.

The present trend in agricultural mechanization is for high capacity machine to be used on custom hiring and for contractual field operations. The mechanization of rice, sugarcane, cotton, potato and horticulture crops, green house and covered cultivation are new emerging areas which need greater attention. Water is a scarce commodity and in future with increasing demand for more irrigation water, concerted efforts will be needed for controlled application of water through drip, sprinkler and micro-sprinkler systems to economize use of water and improving water use efficiency. With the shift in agriculture towards diversification and agri-business, substantial areas will come under fruits, vegetable, plantation, floriculture etc. This will also help to export good quality high value crops/materials to different countries to earn more foreign exchange. Design of green houses, handling of products and environmental control including mechanized cultivation, will assume greater importance.

Potential exists for export of mechanization equipment to other developing countries. The quality therefore needs to be ensured. In order to enforce quality, reliability and safety in the manufacture of agricultural implements, manufacturing of critical components need to be standardized and encouraged for mass production

by medium and large scale manufacturers.

Presently, almost no efforts have been made to mechanize hill agriculture, where there is tremendous potential of growing fruits, vegetables, flowers etc. This calls for developing appropriate technologies for mechanizing hill agriculture.

The agricultural mechanization in the country is at a very low level. The availability of farm power from the total of 136.79 mkW is estimated as 0.15 kW/ha of which 8% is from manual labour, 12% from animal power, 30% from tractors and power tillers, and about 50% from diesel engines and electric motors. The annual increase in availability of farm power is estimated as 0.03 kW/year/ha. Future increase in farm power will come from mechanical power sources only and, therefore, energy conservation equipment will have to be developed. The reserve of fossil fuel is limited and this is likely to affect the availability of diesel and lubricants for agricultural use. More emphasis need to be given to develop agricultural tractors and engines to run on vegetable oil, alcohol and other oils of plant origins.

The Indian farmers have adopted mechanization inputs for modernization of agriculture. By and large, India is self sufficient in mechanization inputs. The annual introduction of tractors has increased to more than 2.5 lacs and that of irrigation pumps to 700,000. Custom hiring of tractors and combines has increased. Drip and micro irrigation are gradually being adopted. These technologies are being introduced with joint co-operation of foreign industries. The Indian Council of Agricultural Research with the co-operation of States Agricultural Universities has developed a large number of agricultural machinery suitable for Indian farmers. More than 200 equipments have been developed, of which about 80 have been commercialized by the industries. The Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India has already released 35 improved implements for popularization amongst farmers. The State Agro Industrial Development Corporations of Madhya Pradesh, Maharashtra, Gujarat, Rajasthan, Andhra Pradesh, Uttar Pradesh, Orissa and West Bengal, besides small scale industries, have adopted the technology developed by the ICAR research system. These equipments have helped the farmers in removing drudgery in farm operations, reducing cost of operation and increasing agricultural inputs effectiveness.

Present farm mechanization thrust

Objectives

- To increase yields and cropping intensity
- To increase income of agricultural workers to reduce inequality reduction.
- To mechanize the farms of all categories.
- To reduce health hazards and increase safety in operation of farm machinery.
- To conserve and properly utilize natural resources such as land and water.
- To improve utilization efficiency of inputs such as seeds, chemicals, fertilizers and energy.
- To reduce cost of production.
- To impart dignity to farm work.

The targets to achieve the above objectives are:

- Increase of power input to 2 kW/ha by the year 2020.
- To develop high capacity farm machines for timeliness of operation where turn around time is low.
- To improve management of farm machinery
- To mechanize hill agriculture
- To mechanize sugarcane, cotton, fruits and vegetable crops and covered cultivation
- To improve quality of manufacture of farm machinery
- To strengthen R&D - manufacturer linkages for speedy commercialization.

6.1 Mechanization Strategy

Resources like land and water are limited and shrinking as population increases. Keeping pace with the present growth of population and consumption pattern, the food requirement by the year 2007 AD is estimated as 238 million tonnes. This would mean an annual growth of 4-5% to be achieved. Agricultural development to provide adequate food to every person in the country besides, employment and alleviation of poverty, will be the major challenges in agriculture. Sustaining agriculture to meet the growing domestic demand and export through modernization will be the guiding factors for any future developmental planning in relation to population growth.

6.2 Integrated land use planning and water management

There is an urgent need for micro level planning due to competing demands on land for agriculture, forestry, grass lands etc., on one side and urban and industrial development on the other. This should also be seen in the light of gradual reduction in the average size of farm holdings due to ever increasing population. Land use planning has also to be considered along with watershed management as our water resources are depleting at an alarming rate. This demands evolving economically viable and environmentally sound water conservation and management techniques.

The country has limited ground water resources. Due attention has to be given to minimize and/or control surface run off through insitu water conservation measures and development of micro-watersheds to ensure adequate moisture for crop production. The total irrigated gross cropped area is about 42 per cent (79.9 mha). Precision controlled irrigation through micro and drip system, especially in horticulture and high value crops may save water and thereby more area can be brought under irrigation.

6.3 Enhancing agricultural production and productivity

There are considerable gaps between the actual and potential yields which have to be reduced by further boosting the productivity per unit area or per unit time. The scientists will have to develop and promote technology for sustainable agriculture through conservation and efficient utilization of natural resources keeping the constraints/limitations of land resources, biotic pressure on land, natural precipitation, availability of solar energy, social and economic diversity of the farmers.

This poses a challenge to scientists of genetic engineering, biotechnology and cognate sciences. Concerted efforts are required to provide good quality certified seeds, chemicals and other inputs to the farmers at reasonable price. Micro processor based green house and covered cultivation, micro sprinkler, fertigation, organic farming, hybrid seeds, plants propagated through tissue culture and biotech may have to be introduced in a big way which would require different approach for infrastructure and human resource development. Development of technology for dryland/ rainfed areas will be another challenge for increasing production and productivity.

6.4 Achieving rapid mechanization

The level of mechanization in the country, as a whole, is still at a very low level. The main reasons are small and scattered holdings, poor investing capacities of the farmers and non-availability of good quality of implements/machinery in the vicinity of the farmers. The investment in agricultural machinery vis-a-vis their utilization on small farms is quite high because of which farmers give comparatively low priority to purchase of agricultural machinery in comparison to other inputs viz., seeds, fertilizer, chemicals etc. However, in the present circumstances when labour wages are increasing at a high rate and their availability at peak times of sowing, harvesting and threshing is decreasing, the farmers are now getting more inclined towards use of agricultural machinery. This demands good quality machines and better sales and service facilities. Farm machinery industry will have to modernize their products not only in terms of performance characteristics but also for comfort, safety and energy conservation. The industry has also to develop new machines for mechanization of horticulture, plantation and agro-forestry.

6.5 Encouragement to contract and commercial farming

Need of higher energy inputs to ensure timely field operations, on one hand and fear of increasing cost of farm labour, coupled with drudgery involved in farm operations may drive away agricultural labourers to other less arduous sectors like industry and services sectors. Appropriate farm machines may have to be introduced to ensure timely farm operations. Custom hiring of tractors for tillage, material handling, irrigation and combine harvesting is already in vogue in many parts of the country. Contract farming and franchise cultivation by the industries with progressive farmers not only will ensure quality produce for processing but will also help the producer to modernize agriculture for producing high value crops. Diversification of agriculture for growing high value crops and horticulture, floriculture, industrial crops, mushroom cultivation, agro forestry and energy plantation would again require higher investment which may not be feasible for individual farmers due to financial and technological limitations. The group farming could be encouraged by industries under contract farming or franchise cultivation arrangement.

India is blessed with climatological diversity and this coupled with modern environment control green houses can provide a steady regular supply of agro produce especially for export and also to the hotel industries for domestic and foreign tourists. This will further increase productivity as farmers will be able to invest more for modernizing agriculture especially for growing high value and industrial crops such as sugarcanes, cotton, tobacco, exotic fruits, vegetables, cut flower etc.

6.6 Encouragement to diversification

India is the largest producer and exporter of spices. The farmers continue to practice traditional techniques for their cultivation. Industry has to come forward to provide better methods of collection, curing, cleaning, grading, packaging etc., for quality products. In the field of medicinal and aromatic plants also, there is lot of challenge with respect to export of intermediary phyto-chemicals, perfumery, food flavour, cosmetics and toiletry goods.

The plantation crops have not been modernized as yet. Oil palm cultivation is another example in this

reference. Malaysia, due to cultivation and processing of palm oil, has become one of the progressive countries in this region. Immense economic potential exists for introducing oil palm cultivation in India. Farmers and industrialists both will have to join hands together to promote oil palm cultivation which may also help in solving shortage of edible oil.

6.7 Agro-processing and other agro-based industries in rural areas

Agro-processing technology helps in conservation and elimination of avoidable losses and improves quality of agro-produce and low grade raw materials and by-products by value addition. This also helps in generating more employment opportunities. Primary processing facilities need to be developed in rural areas for on farm processing of cereals, pulses, oilseeds and fruits/ vegetables. This will render:

(a) enhanced availability of raw materials for processing in the catchment areas at reduced cost.
(b) reduction in cost of processing as a result of reduced cost of handling, transport and availability of labour.
(c) more employment to rural people which will arrest the rural migration and reduce social problems in cities (mitigation of congestion in cities).
(d) overall development of rural areas with the creation of other infrastructure to serve these units in terms of education, health, communication etc.
(e) utilization of by-products after value addition as animal feed, compost, biogas feed etc. They will help in reducing in the cities also.

6.8 Marketing, processing and transport of horticultural produce

Non-availability of appropriate processing and handling technology cause excessive losses in horticultural produce. Simple techniques to increase shelf life like wax coating, polythene/cellophane packaging etc. will reduce the losses considerably which should be adopted at farm level. There is a need to develop and provide specialized containers for packaging and transport to promote export. The priorities in the horticultural sector are:

(a) Minimise post-harvest handling, transport and storage
(b) providing right quality of raw materials to processing industry,
(c) raising productivity to obtain them at economic levels.
(d) establishing large cooperative farms with processing and preservation facilities.
(e) improving packaging quality with decreased cost of packaging.
(f) increasing shelf life, and
(g) improve distribution system through cold storage, freezers etc., at retail and consumer level.

6.9 Livestock improvement and their management

The livestock not only have economic importance but symbiotic relationship with the Indian rural folks. Due to existence of large number of poor quality livestock in the country, serious attention has to be given for their improvement through better management, health, feed and breeding. The industries will have to contribute not only for processing of the animal products but also for providing services like cattle feed and fodder, poultry and animal shelter, milk handling and processing plants.

6.10 Aquaculture development

There is immense potential in fisheries sector. Construction of ponds, aerators, hatcheries, fishing gear, cold containers, processing, packaging, transport etc. require specialized technology for domestic and export market. India will have to take lead in this sector by following the technology adopted in Japan, Thailand and Philippines. As of today, a large percentage of fish and other marine products disintegrate before reaching processing factories/market. Refrigerated container for handling and transport would help in increasing their shelf life besides more economic returns to producers.

6.11 Enhancing rural employment

Value addition of agro produce (food, feed and fibre) through joint ventures is a welcome step to strengthen physical infrastructure especially for export and this should be encouraged. The Indian industries will ultimately adopt the technology, may be at a reduced scale. The introduction of highly advanced technology in traditional/cottage industry in food sector such as rice and dal milling, oil extraction, flour milling, processed instant foods etc., which were earlier processed at rural level, are however, likely to reduce the rural employment opportunities. It will be in the overall interest of the country to establish primary processing units in rural areas only. Besides, providing employment to rural people, it will have all round rural development and will increase additional employment avenues. The cottage/tiny sector has also to be encouraged, which have no parallel in employment generation.

6.12 Enhancing export of value added processed foods and farm machinery

The agricultural sector will not only have to meet the domestic requirement of feeding the growing

population (growth being more than 2 per cent per annum) but also has to earn valuable foreign exchange through export of various agro-produce and processed products. As a result of GATT agreement and the quality standards stipulated under the agreement of WTO, the Indian agriculture and industry will have to play a major role in producing quality agro-produce and also internationally acceptable value added food products. Export of oil meals, cereals, (rice, durum wheat), fish and marine products, fruits and vegetables, cut flowers, tea, coffee, spices, textiles, etc., have to be increased. This will generate more income or revenue to the exporters, middle men, allied service industries in addition to the producers who would equally get benefit of producing quality products. The export of agro products would also increase employment in other service sectors engaged in packaging, handling, transport (road, rail, ship and air) directly or indirectly.

The country is yet to be internationally recognised as exporter of processed foods. The trend, so far, has been to export raw and semi-processed agro produce, as a result, middle men and exporter only get the maximum advantage. This is one big challenge before the country and the opportunities are immense. Better packaging technology is needed for raw as well as processed products which will help in maintaining original quality of produce in terms of appearance, colour, texture, flavour and taste. Moreover, increased export of agro-produce would also require better quality products, storage facilities, controlled temperature containers/controlled atmospheric and aseptic packaging, modern material handling equipment and services.

7. FUTURE REQUIREMENT OF FARM EQUIPMENT AND TECHNOLOGIES

The farm equipment which have been introduced in recent past to overcome specific agro-economic constraints are as follows:

7.1 Equipment for seedbed preparation and sowing and planting

Roto tillage

The roto-tilling is done by rotavator which combines primary and secondary tillage in one operation. The rotavator is powered by the tractor PTO. When the rotavator works it exerts a forward push on the tractor and thus facilitates the traction. The advantage of rotary cultivation has been found to be more significant in seed bed preparation during the turn-around time between the kharif harvest and rabi sowing. Saving of 60-70 per cent in operational time and 55-65 per cent in fuel consumption with single rotavation compared to the conventional method of seed bed preparation with separate ploughing and harrowing operations have been observed, besides conservation of moisture due to destruction of capillaries.

Till plant machine

The till plant machine is a minimum tillage equipment capable of sowing and applying fertilizer without prior preparation of seed bed. The soil engaging components (sweep/shovel or rotavator) are mounted on a frame in front of the furrow openers to remove weeds and open passage for the seeds to be placed in the soil in one operation.

Strip till drill

In strip till drilling, seeds are drilled directly in a narrow tilled striped in single pass. Strip tillage technology has the distinct advantage where the soil is loosen in a band to allow effective crop root development besides, being energy efficient. It avoids undesirable compaction of the soil in the crop rows. It is more suitable for subsequent crops after rice/soybean for timely planting in a single operation. The system comprises of a seed-cum-fertilizer drill with a rotary attachment fixed ahead of the furrow openers for soil manipulation in strips. The rotary attachment consists of a rotor with flanges in which tines (blades) are mounted. The spacing between the flanges is the same as the row spacings of the crops to be planted. Power to the rotor is provided from the tractor PTO with required speed reduction.

No Till or Zero Till Drill

Zero-till drilling is referred when seeds are drilled directly into uncultivated (zero-till or no-till) seed beds. The zero-till drill is similar to that of the conventional seed cum fertilizer drill except that the furrow openers are of specially designed inverted 'T' type which create furrow grooves with reduced surface exposure and thereby helps to maintain the in-groove humidity in a reasonably wet soil for better germination of seeds and emergence of seedlings. The system offers the apparent advantage of timely planting, at reduced time, fuel and labour costs and, therefore, helps reducing the cost of production besides reducing the drudgery of the task. Investigations have revealed that compared to conventional sowing of wheat, zero-till-drilling saved 70 per cent sowing time and 64 per cent cost of seeding operation with overall increase in benefit of 20-25% in black soil. The system is more effective in situations where late harvesting of rice compels delay in planting of wheat. The first irrigation is given within a week

which helps in providing better seed-soil contact besides moisture.

Inclined plate planter

Inclined plate planter facilitates uniform placement of single seed in soil and therefore helps saving of costly seeds. It avoids the problem of thinning of over plant population and helps to improve crop yield as the individual plant get the required nutrient, water and sunlight. The unit consists of individual seed boxes, furrow openers and transmission system with ground drive wheel. The seed boxes are of modular design with independent inclined plate type seed metering mechanism. The seed boxes are bolted to furrow openers. The furrow opener assemblies are adjustable for crop row spacings and work as a modular unit for sowing in each row. The planter is suitable for small and bold size seeds such as maize, pigeon pea, soybean, chick pea, rape seed-mustard, sorghum etc., by use of different seed metering plates. For a six row tractor mounted unit the field capacity vary from 0.50 to 0.65 ha/h at overall field efficiency of 70-75 per cent.

Pneumatic Precision Planter

Precision planting is practiced to save seeds and place them in proper soil environment for better seed distribution and uniformity at pre-determined seed and row spacings. It has also provision for drilling fertilizer simultaneously with seed. It consists of pneumatic disk and suction type seed metering mechanism. It can be used for different crops by changing the disk. The planter is suitable for small to bold seeds and also for inter-cropping since each row has separate planting mechanism.

Sugarcane Sett Cutter Planter

The equipment consists of a carriage having an operator seat, sett cutter, two seed boxes, a rectangular box for fertilizer, a chute for seed dropping and a pesticide tank. It is operated by a 45 hp tractor. As the equipment moves forward the share point opens the furrow, the operator drops the setts through chute, pesticide is sprinkled and the fertilizer is applied. The machine plants setts end to end. In semi-automatic design it uses a rotating drum for each furrow with vertical compartments in it for feeding the setts. The sett is carried along by the rotating drum till it aligns with the opening provided in the stationary bottom plate underneath the drum. The work capacity of the machine is around 0.2 ha/h.

Rice Seeder

Direct seeding of rice in puddled soil offers the advantage of faster and easier planting, reduced labour and hence less drudgery, 7 to 10 days earlier crop maturity, more efficient water use and higher tolerance to water deficits and often higher profit in areas with assured water supply. Pre-germinated seeds (24 h soaking + 12-24 h incubation) are sown on to a puddled soil 1-2 days after puddling. A shorter incubation time (12 h) is critical for easy flow of sprouted seeds from the perforated drums. The water should be drained before seeding and the puddle bed should be firm enough to support the seeder and to make shallow furrows for sowing. The seed rate depends on the rate of revolution of drums and normally 50-70 kg/ha. The rice seeds could also be drilled with a cup type seed metering mechanism in a well prepared soil provided weeds and water are properly managed.

Potato Planter

The potato planters facilitate furrow opening, tuber placement and cover the soil simultaneously. Belt with cup type and picker type tuber metering systems are available for seeding. The picker has 12 notches spread uniformly on its periphery for holding an equal number of grab for picker arms. The picker arms open out approaching picking chamber and picks up a seed potato for subsequent release. The field capacity of the machine with two ridges varies from 0.2 to 0.4 ha/h with tuber distance of 200-450 mm, row spacing of 600 mm and depth of planting of 100-200 mm. The automatic unit saves 50-60% labour, 80-85 per cent operation time and 50-60 per cent of cost of operation compared to the conventional method of placement of seeds in rows by making ridges manually.

Vegetable Transplanter

Vegetable transplanting is normally carried out manually all over the country. The labour requirements for transplanting varies from 10-30 man-days per hectare for various vegetable crops except onion. For onion, the labour requirements vary from 50-100 man-days/ha. Semi-automatic vegetable transplanter in which feeding of seedlings is done manually by operator, and furrow opening and placing the seedlings in the furrows by the machine automatically. Bare root nursery and cup type nursery could be used. The bare root nursery is at present adopted in India. Mechanical transplanters are generally tractor operated multi-row models or self propelled one row model. Feasibility analysis show that adoption of these transplanters is economically feasible where labour wage rate is more than Rs 60-80/day.

Mechanized Cultivation of Nursery

Mechanized cultivation of nursery is generally required for raising and supplying seedling for large

scale transplanting. The unit operations such as preparation of soil, seed and trays/mats, spreading of soil, water application, sowing of seeds, covering the mats, handling/conveying of trays etc., are mechanized to ensure uniformity and quality operations. Seedling management is done under controlled conditions of light, temperature and humidity. The system essentially consists of soil crusher, soil manure mixer, soil sieve, soil acidity detector, conveyor belt, sprout promoting machine, water pump, dehydrator, sowing plant, automatic seedling box, supplier, automatic seed supplier, seeding conveyor (with watering function), germination units, automatic seedling box stacker and growing chamber. These gadgets, however, needs to be installed/laid out matching to the nursery area/shed ensuring minimum time loss for handling.

Rice Transplanter

Transplanting of rice by hand is mostly practiced in India. It is time and labour consuming besides being an arduous operation. Nearly25-30 labour days are required for transplanting one hectare of rice by hand using root wash nursery. Mechanical rice transplanters have been introduced to mechanize the transplanting operation. The self propelled rice transplanter (8 rows, single wheel driven, 3 hp diesel engine) with three persons transplants nearly one hectare a day using mat-type seedlings. It saves 75-80% labour hour and 40-45% cost of transplanting per hectare compared to the hand transplanting.

7.2 Irrigation Equipment

Sprinkler Irrigation System

In sprinkler irrigation, water is sprayed into the air and allowed to fall on the ground surface simulating rainfall. It is versatile means of applying water to any crop, soil and topographic conditions where surface irrigation may be inefficient or expensive or where erosion may be hazardous. Low rates of water may be applied as required for seed germination, frost protection, delay of fruit budding and cooling of crops in hot weather. The overall irrigation efficiency of this method is as high as 75-80% compared to 25-30% of surface method of irrigation. Sprinkling has been successful for protecting small plants from wind damage, soil from blowing and for reducing high air and soil temperatures. Fertilizer, soil amendments and pesticides may be injected into the sprinkler lines as a convenient means of applying these materials to the soil or crops. The water and fertilizer saving applied through the system is found to be around 30 per cent.

Micro Irrigation - Drip Irrigation

Micro-irrigation is the method of delivering slow and frequent application of water to the soil using a low pressure distribution and spatial flow control outlets. Micro-irrigation is also referred as drip, sub-surface, bubbler and trickle irrigation. The system delivers water to individual plants or rows of plants. The outlets are generally placed at short intervals along the small tubing, and unlike surface and sprinkler only the soil near the plants is watered. The outlet includes emitters, orifices, bubblers and sprayers or micro-sprinkler with flow ranging from 2 to over 200 l/h. With micro-irrigation only the root zone of the plants is supplied with water and with proper system management deep percolation losses are minimal. The water evaporation from soil may be lower because a portion of the surface area is wet. Labour requirements are lower and the system can be readily automated. Reduced percolation and evaporation losses result in a greater economy of water use. Weeds are more easily controlled, specially for the soil area that is not irrigated. Bacteria, fungi and other pests and diseases that depends on a moist environment are reduced as the plant parts above ground are completely dry. Field edge losses and spray evaporation losses as occur with sprinklers, are reduced with these systems. The yield increase varies from 10-60%. The fertilizer saving is about 30% as compared to the surface irrigation methods. The water saving is about 60-70%. The irrigation efficiency varies between 80-90%. The quality of the produce is also better. Advantages increase further by incorporating plastic mulching in appropriate cases.

Surge Flow Irrigation

The surge flow irrigation is improved surface irrigation method where water is applied intermittently (in cyclic form of on and off periods). The water continues to advance and recede simultaneously along the furrows during the off time. After suitable off time water is again introduced in the furrow. This cyclic process of on and off is repeated until the completion of irrigation. It has been found that under surge flow irrigation infiltration rates decrease, advance of water down furrows becomes faster, uniformity of surface irrigation increases, deep percolation reduces, time and total volume of water required to complete the irrigation reduces and thus the reduction in cost of required quantity of water and pumping per unit irrigated area as compared with the continuous water application. This method saves irrigation time (50%), water (32.5%) and human labour (15 man-h/ha) over conventional furrow irrigation methods. The efficiency is also higher than conventional furrow irrigation.

7.3 Interculture and Plant Protection Equipment

Power Weeder

The equipment consists of a 5 hp light weight diesel engine mounted on the frame. The engine power is transmitted to the ground wheels and rotary through gear reduction unit. The wheel setting is done as per crop row spacing. The rotary unit can be engaged/disengaged through the actuating clutch. The rotary weeder consists of discs mounted with curved blades in opposite directions alternatively in each disc. The rotating blades enable cutting of weeds and integrating into the soil. The width of coverage of the rotary weeder is 350 mm and the depth of operation can be adjusted.

Chemico-Mechanical Weed Management

The loss of grain yield due to unchecked weed growth is always higher. In many crops the weed competition is so intense that failure to control weeds may result in no yield. Mechanical weeding alone is not feasible in some situations and is costly and time consuming. To overcome the problem of weeds, combination of mechanical weeding by use of improved weeders and herbicide application has been proved to be advantageous in terms of reduced labour-hour requirement and increased yield and net income. The schedule of mechanical-chemical weed control practices has also been evolved based on the growth characteristics of crops and weeds.

Plastic Mulching

Plastic mulching is used to conserve soil temperature and moisture under adverse conditions. For plastic mulching, usually bed is prepared and plastic is laid by a machine (tractor or power tiller operated). At present, mulch layers are commercially available in several countries. Several planters and vegetable transplanters are designed to operate through plastic mulches.

Electro-static Spraying

Agricultural sprays are charged by applying induction potential up to 10 kV. These charged droplets experience an electrostatic force in addition to the normal gravitation and air drag forces which tend to attract the drops to the target plant and result in greater deposition of sprays even underneath the surface of the leaves where insects population is higher. Application of the technique makes possible to achieve pest control at a lower overall application rate. But the requirement of specialized pesticides which do not chemically disintegrate at such higher voltage has limited its large scale application.

Orchard Sprayer

Spraying of chemical at heights in orchard crops pose problems in respect of uniformity of application. The tractor mounted orchard sprayer with air assisted rotary atomizer has been found suitable for spraying of fungicides on small berries and mango trees upto 6 m height. The sprayer consists of a fluid tank, atomizer with hydraulic motor and a flow control valve. The atomizer blows the chemical up to the maximum swath providing uniform and efficient spraying pattern. The flow control valve adjust from low to high volume applications. The equipment operated by a 35 hp tractor can cover 0.20-0.50 ha/h with 3 m penetration of droplets inside the plant canopy.

Self Propelled High Clearance Sprayer

It is a self propelled unit suitable for spraying on tall crops like cotton. The machine consists of two rear steered wheels and two front lugged wheels which is powered with a 20 hp diesel engine through a gear box, tank, hydraulic pump and boom fitted with 15 nozzles. It costs Rs 1,80,000/- and its cost of operation is Rs 35/ ha. The effective field capacity and field efficiency were 1.6-2.0 ha/h and 70-80%, respectively.

7.4 Harvesting and Threshing

Grain Combine Harvester

Combine harvesting of field crops offers the advantage of timely harvesting with reduced grain losses and drudgery and makes available the field for immediate sowing of subsequent crops. The machine being a self propelled unit has the provision of cutting/reaping, conveying, threshing, cleaning and delivering the grain to tank/bags. It is generally suitable for harvesting rice, wheat, soybean, chick pea and similar crops and covers wide area depending on the size of cutter bar and conditions of field. Combine harvesters with pneumatic wheels are suitable for wheat and other upland crops whereas for rice in wet/water logged field condition, rubberized under-carriage system are available featuring minimum ground pressure. Provision for harvesting of completely lodged crop with crop divider attachment and provision for chopped/stripped straw as per requirements are available in many combines. A medium size combine attached with 35 hp engine and having reaping width of 1.4 m can give field coverage of 0.25-0.30 ha/h with good quality grains and chopped/stripped straw. The combines are generally attached with high power engine and automatic hydrostatic transmission/controls to obtain desired threshing speeds, concave clearance and grain movement.

High Capacity Multicrop Thresher

The high capacity multicrop thresher consists of a spike tooth cylinder, three number of aspirator blowers, cleaning sieves and automatic feeding and bagging system. The thresher is provided with accessories for threshing of different crops. It is operated by 20 hp electric motor or 35 hp tractor. It is suitable for threshing of wheat, maize, sorghum, chickpea, pigeon pea, soybean and sunflower crops. It saves 50% labour and operating time and 54% cost of operation compared to the conventional spike tooth thresher.

High Capacity Pigeon Pea Thresher

Farmers need threshed stalk of pigeon pea for various domestic uses. Presently, pigeon pea is threshed by manual beating or threshing by hold-on-method. These methods are time consuming, tiresome and provide low output. A high capacity pigeon pea thresher has been designed which consists of automatic chain conveyor type feeding mechanism. Only pod portions of plant bundles are fed continuously to the cylinder one after another through chain conveyor and the threshed bundles are discharged through other end after stripping and threshing of pods. Thus, intact bundles with long stem are obtained with increased capacity. The cleaning and separating systems are as per the conventional design of threshers having aspirator blower.

Strip Harvester cum Reaper Windrower

The strip harvester cum reaper windrower is an engine operated stripper and thresher for cereals crops followed by cutting and windrowing the stripped crop simultaneously. The system has the advantage of higher capacity, low grain breakage and better straw recovery from the field for other uses.

Sugarcane Harvester

Sugarcane Harvesting is highly labour intensive requiring around 1200 labour-hour per hectare. Due to non-availability of labourers in time, the harvesting operations get delayed. For timely harvesting of sugarcane. Austoft and Class Billet type sugarcane harvesters are being adapted under Indian conditions. The field efficiency of these harvesters have been found to be 44-53% with the harvesting speed of 2.2-4.5 km/h. Average billet length is observed as 258 mm with 33.5% damaged and mutilated billets. Average sugarcane output was found to be 21.8 tonnes per hour. The cost of mechanized harvesting was found to be Rs 178/- per tonne against the manual harvesting of Rs 102/- per tonne. Considering the non-availability of sufficient labourers and increased wages in near future, the mechanized harvesting holds a lot of promise.

Mechanical Cotton Picker

Hand picking of cotton requires around 465 labour-hour per hectare. Due to non-availability of labourers in time the cotton pickings get delayed causing around 15 per cent field losses and affecting the overall quality of cotton balls. To overcome the problems associated with the manual pickings, mechanical cotton pickers are being adapted under Indian conditions. The mechanical cotton picker is a self propelled two row unit provided with spindle type picking mechanism. The average field capacity of the machine is 0.7 ha/h with output of 1000 kg/ha of seed cotton. The cost of operation of the cotton picker have been found to be Rs 6000/ha giving cost of harvesting per kg of seed cotton as Rs 6.00 against the cost of manual picking of Rs 5/- per kg of seed cotton. However, considering the constraint of availability of labourers for manual pickings during peak season, the adoption of mechanical cotton picking is promising.

Tractor Mounted Potato Digger Elevator

The potato digger elevator consists of digging blade, endless rod chain conveyor and gauge wheels. The elevator is driven by tractor PTO. It is suitable for digging and exposing the tubers. With 600 mm width of cut (one row) the field capacity of the machine is 0.14 ha/h at field efficiency of 60-65%. It saves 75% labour and operation time and 50 per cent on cost of operation compared to conventional method of manual digging with spades. It also results in 4-5% reduction in harvesting losses compared to the conventional method.

Greenhouse and low tunnel cultivation

Green house and low tunnel structures permit enhancement of crop productivity in all seasons by controlling the micro-climates in respect of light, temperature and air composition within the covered structure. For maintaining the green house environment, polyethylene/polyvinyl chloride film/acrylic polycarbonate sheet or UV stabilized plastic films are generally preferred over glass to cover the green house structure because of their lightness, flexibility, mobility and being more resistant to hail and wind loads besides requiring simple framework for the structure. These coverings act like a selective radiation filter which allows solar radiation to pass through but traps the thermal radiation emitted by the objects within, thus contributing to the Green house Effect.

Different shapes/sizes of green house structure have been developed to create/maintain the green house effect for growing of crops particularly vegetables, fruits and flowers. Green house cultivation has been found

advantageous compared to the open field as it ensures uniform production conditions and gives consistent quality of produce with 10-15 times higher yield.

7.5 Precision Agriculture

Crop Modeling and Crop Planning - GIS and GPS Applications

Geographical Information Systems (GIS) being an integrated multi-disciplinary science from application point of view is increasingly recognized as an appropriate and cost-effective management and planning tool for modeling and optimization of the essential components of natural resources (e.g. soil, water and plants/vegetation) required for sustainable development of any production system. GIS having the potentiality to store, manage, retrieve, analyse and integrate different spatial and non-spatial data of enormous quantity is also useful in aiding decision making processes. The advent of satellite technology has provided a new system known as the Global Positioning System (GPS). The GPS provides the position of a point on earth surface with reference to a mapping reference system such as Universe Transverse Marketer (UTM). The GPS is utilized now a days as a modern technique in the fields of surveying, mapping and pre-processing of satellite data/imagery for geometric corrections.

The major applications of GIS integrated with satellite remote sensing and GPS in the field of crop modeling and crop planning include identification of water resources and assessment of water availability; water distribution and irrigation scheduling; study of agricultural cropping pattern; land use allocation and land suitability, evaluation of crops; assessment of soil moisture and water requirement through evapo-transpiration estimation; monitoring of crop growth stages for crop growth simulation models; crop stress and crops influenced with diseases; and crop acreage and production estimation. At present GIS in integration with satellite remote sensing and GPS is being used for planning and monitoring of major agricultural crops such as wheat, rice, cotton, sugarcane in the country under Crop Area and Production Estimation (CAPE) programme of Department of Space, Government of India.

7.6 Mechanized Sugarcane Cultivation

Sugarcane harvesting has become a critical problem in tropical zones due to high wages and non-availability of labourers. Sugarcane harvesting includes base cutting, detrashing, detopping and windrowing. IISR, Lucknow has developed a tractor mounted harvester which cuts the cane and windrows it below the tractor in between the wheels. MERADO, Ludhiana and Pune have developed harvester for paired row crops. Provision has been made for detopping also. These two harvesters windrow the cut cane in row. VSI, Sangli and KCP Sugar Mills, Vyuur have imported sugarcane harvesters. All the harvesters are whole cane type. CAMECO harvesters have given promising test results. Since the crop requirement of the harvester is 150 cm spacing, large scale trial could not be conducted.

Sugarcane is a labour intensive crop. It is cultivated in over million ha area. It is used as a sweetening agent for production of sugar, gur and khandsari and for chewing purposes. About 20 kg per annum per capita gur, khandsari and sugar is available in the country. In order to increase sugar availability and also for export as foreign exchange earner, production of sugarcane as well as recovery of sugar has to be increased by strengthening research and developmental activities. Sugarcane production can be increased through mechanization of the cultivation practices by way of application of efficient input like seed, fertilizer, etc., reducing dependence on labour, ensuring timeliness, increasing operator's comfort, and improving overall economics of sugarcane production.

Labour shortage is experienced during sugarcane planting, earthing, interculture and harvesting seasons. Plant protection in sugarcane cultivation is a very difficult job particularly during rainy season when the crop attains growth. Harvesting has become acute problem in tropical India. It is well established fact that stubble shaving and fertilizer placement near the root zone are important operations of ratoon cultivation. IISR, Lucknow has developed a two row tractor operated stubble shaver with off baring and fertilizer application attachment for 90 cm row to row spacing. Many com-mercial firms have also developed shrubber which can also perform stubble shaving with little modifications.

Various types of tractor drawn and bullock drawn planters (viz. Semi automatic and automatic sett planters and cutter planter) have been developed at IISR and rotodrum sett planter at PAU, Ludhiana. Out of all these designs sugarcane cutter planter has been found promising. Presently there is variation from one prototype to another one. Few shortcomings have been noticed in the designs being commercially produced by few firms. A suitable design has to be recommended for a particular area from efficiency and reliability point of view. Interculture, earthing, fertilizer application are again important operations of planted sugarcane as well as ratoon crop. Presently traditional country plough and bullock operated cultivator are largely being used for

intercultural operation. Country plough has to be run 2-3 times to cover the area between rows. Sweep shovels are better than reversible shovels. Efforts to develop self propelled interculture equipment was initiated but could not be pursued to bring them to farmers field. Presently light weight power tillers with cultivators and rotary tillers are available which can be tried and recommended for their use in cane cultivation. Power weeders can also be tried for their suitability in sugarcane production for interculture, weed control and also for earthing up operation with suitable soil working components.

7.7 Mechanization of Dryland Agriculture

Dryland agriculture constitutes about 67% of total cultivated area in India and contributes only 42% to food production. Drylands are spread over to about 118 million ha of gross cropped area in India with average productivity of 0.7 to 0.8 t/ha. One of the major causes of the poor productivity in drylands is lack of mechanized operations and rainwater harvesting for protective irrigation. Faster field operations assist directly or indirectly in conserving rain water and its effective use.

Timeliness and precision in field operations are key factors governed by available power and status of mechanization in dryland ecosystem. The resource poor farmers with small and marginal holdings dominate these areas. Human and animal resources in these area are continuously dwindling leading to time consuming operations and unusual increase in cost of operation. Conventional tools and equipments are no longer adequate to meet the needs of precision in dry land agriculture, besides timeliness being the first casualty. Power and mechanization constraints are leading conventional dryland agriculture into a non-profit and risk prone enterprise. Introduction of powered mechanization systems thus has become absolutely necessary for sustainable dryland agriculture.

The productivity of the crops in dryland is still low which require greater attention. Selection of crops and efficient use of inputs in rainfed areas is more important due to high risk in agriculture. The farmers in dryland areas hardly use fertilizer to supplement the nutrient due to high risk of crop establishment. Where applied, farmers broadcast fertilizer in smaller quantities in the field. Fertilizer placed in the furrows results in higher yields as demonstrated in different regions of the country. Timeliness is more important in rainfed farming to utilize the available moisture for crop establishment. Decreasing availability of draught animal power is affecting dryland agriculture.

In drylands, most of the land holdings are small and scattered. Poor investment capacity of dryland farmers, non availability of quality implements and lack of adequate extension link are some of the constraints in adoption of improved technology to farmers. The investment in farm machinery vis-a-vis their utilization on small farms works out to be high and therefore majority of farmers give comparatively lower priority on purchase of agricultural machinery compared to purchase of other inputs. The mechanization is predominately taking place for operations where traditional practices have limitations to achieve timeliness of operation.

The detailed studies carried out at various Dry Farming Centres have revealed that soils in north although poor in fertility have low wilting point and thus even small amount of rainfall is adequate to wet the root zone of the area. Large tracks of Deccan plateau are clayey soil with low depth due to undulating terrain and have high moisture at wilting. These soils require high rainfall to wet the root zone. Soils in western regions are prone to erosion due to high intensity of rainfall. The soils in south particularly in Karnataka and Tamil Nadu have high proportion of alkalinity and, therefore, have better penetration of rain water. The studies on dry farming in these regions developed the following package which is relevant even today.

8. THE NEED FOR IMPROVED FARM IMPLEMENTS FOR RAINFED AGRICULTURE INCLUDES:

(a) bunding to conserve soil moisture,
(b) deep ploughing and summer ploughing for better intake and storage of rain water,
(c) contour cultivation to reduce runoff and soil loss,
(d) use of low seed rates and contour sowing,
(e) interculturing for control of weed and to check evaporation of soil moisture.
(f) Farm ponds and waterlifting and application devices draught-proofing

Tillage equipments and their impact on moisture conservation and yield increase have been established from various studies. The low cost seeding devices matching to available power source has been one of the success stories in dryland mechanization research. Efficient interculture, harvesting, threshing, post harvest and processing equipment are also available for different crops. However there is a need to commercialize and popularize these equipments for viable dryland farming system.

9. CONCLUSION

The efficacy of agricultural inputs and natural resources -seed, fertilizers, chemicals, land and water

has been increased through adoption of appropriate agricultural equipment. Energy is the key input for agricultural, industrial and socio-economical development of a nation. The energy in agriculture is required for field operations which facilitate crop production and processing besides indirect energy in terms of seeds, fertilizer, irrigation, and chemicals. Human, animal, electrical and mechanical energy sources are extensively used in agriculture. Today, more than 2,70,000 tractors and over ten lakhs irrigation pumps are introduced every year. The farm mechanization facilitates use of inputs effectively and in reducing the drudgery in farm operations besides ensuring timeliness. The Indian farmers have adopted improved farm machinery irrespective of land holding size. Equipment for tillage, sowing, irrigation, plant protection and threshing have widely been accepted by them. Farmers with small holdings utilize selected improved farm equipment through custom hiring to increase productivity and reduce cost of production.

About 250 improved agricultural equipment and technologies have been designed and developed for various pre and post-harvest operations operated by human, animal, mechanical and electrical power for timely field operation, facilitating timeliness, removal of farm drudgery, reducing post harvest losses and addition of value to the agro-produce. Increased productivity does not mean additional income to the growers unless it is matched with appropriate post-harvest technologies that minimize post-harvest losses and add value to the produce and by-products. Simple equipment and processing technologies have been developed for agro-processing at rural level.

Drying is major operation before the grains are stored. Majority of the farmers use sun drying which depends upon availability of clear weather. Mechanical dryers have been used by few industries only. Major equipment which have been developed for farm level processing include cleaners, graders, dryers, shellers, decorticators, storage structures etc. Cottage and industrial level secondary processing include, rice mills, grain mills, dal mills, oil mills, preservation and processing of animals, fruits and vegetables etc. to increase shelf life and their quality.

The use of soybean in Indian diet is still very low and, therefore, efforts have been made to enrich the Indian food by blending traditional food items with soybean such as soymilk, tofu, bakery products, soy-sattu, idly and dosa mix, barfi, gulab jamun, tempeh, soy-sauce, shrikhand, soya icecream, soya doughnuts etc.

Model Agro-Processing Centres and cottage level soypaneer plants have been established for feasibility evaluation, entrepreneurship development and training. Agro-processing in horticultural produce has equally increased to provide quality products for domestic and export markets.

Adaption of technology depends upon infrastructure created for technology verification, training, and demonstration, besides system developed for technology transfer. The equipment and technologies that are meant for commercialization by small scale industries and on-farm post-harvest technology, agro-processing rural enterprises are transferred through publicity, demonstration, training and in-plant-advisement/ consultancy by R&D institutions and development department. The equipment are initially being multiplied institutionally through Revolving Fund scheme of the ICAR and supplied at no-profit no-loss or nominal profit. Private sector has drawn good response in commercial manufacture and marketing of new equipment. Sometimes they innovate on the designs adapted. New products are test marketed exhibited and techno-economic feasibility information shared with the customers. Technologies that relate to improvement in existing process or equipment are transferred through consultancy/contract research. Prototype production centers, pilot plants and agro-processing centers have been established by ICAR Institutes for pilot introduction and intensive evaluation until it is commercialized. The existing mechanism/strategy, by and large has worked. However, some of these technologies could not reach the farmers or remained un-commercialized at a scale desired. The reasons include cost effectiveness and the scale of these technologies. It is well known that, for mass production and transfer, commercial manufacturing may be necessary. This situation needs to be improved by playing a proactive role and following strategies where involvement of private sector is very much needed. Such a strategy will not only ensure competition among technology providers cost effectivity, but also quick dissemination of the technologies.

Introspection has been made in this document to assess the status of development and adoption of mechanization and agro-processing technologies in the country with a view to identify futuristic requirement. Precision agriculture using GIS/GPS techniques for region specific crop planning, controlled precision application of water through drip and micro-sprinkler, multi-functional farm equipment to conserve energy and to reduce turn around time, integrated energy management, application of bio-fuels and plant oil for motive and tractive power in internal combustion engines, occupational health hazards and safety on the farms, application of micro-processor and computer in

agriculture are some of the areas that need more attention in future. Majority of agro-based enterprises will continue to depend upon indigenous technology and, therefore, R&D through public sector has to be strengthened to become globally competitive and serve small scale food processing sector of the country.

The increased export of agriculture commodities would require internationally acceptable quality products, storage facilities, temperature controlled containers, controlled atmospheric packaging, modern material handling equipment and services. The major issues involved in post-production agriculture will be need based and market driven refinement and adoption of available technology for loss prevention and value addition, and entrepreneurship development. More thrust will be required to food processing and agro-based industries in an endeavor to promote agri-business, and foster rural industrialization, create employment opportunities, and thus increase income of the farmers.

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